

# CHEMICAL SAFETY REPORT

## Non-confidential version

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**Submitted by:** Brenntag UK Ltd

**Substances:** Sodium dichromate (SD)                      EC 234-190-3                      CAS 10588-01-9

**Uses applied for:** Use 1: Passivation of stainless steel using sodium dichromate in aerospace and defence industry and its supply chains

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### **Preliminary Remark**

This Chemical Safety Report (CSR) has been prepared on behalf of the applicants by the Aerospace and Defence Chromates Reauthorisation (ADCR) Consortium.

Photos are for illustrative purposes only. PPE shown in the photos might be also driven by site-specific considerations and by exposures other than to chromates. PPE requirements are laid down in the Condition of Use tables.

## **Part A**

### **1. SUMMARY OF RISK MANAGEMENT MEASURES**

The risk management measures implemented for the use applied for are documented in detail in the exposure scenario in Chapter 9 of this CSR.

A succinct summary table of the risk management measures and operational conditions is submitted with this review report.

### **2. DECLARATION THAT RISK MANAGEMENT MEASURES ARE IMPLEMENTED**

Not applicable - as the applicants are not using the substance for this use (upstream application).

### **3. DECLARATION THAT RISK MANAGEMENT MEASURES ARE COMMUNICATED**

We declare that the risk management measures described in the exposure scenarios in Chapter 9 of this CSR are communicated via safety data sheets in the supply chain.

## **Part B**

This review report uses the dose-response relationship established by RAC (see below). In this case, Chapters 1-8 of the CSR do not need to be provided as described in the ECHA document 'How to apply for authorisation' (ECHA, 2021). Relevant physico-chemical and environmental fate data used for modelling are taken from the literature as documented in section 9.1.2.

## 9 EXPOSURE ASSESSMENT (AND RELATED RISK CHARACTERISATION)

### 9.1 Introduction

#### 9.1.1 Structure of this dossier “Passivation of stainless steel” and uses covered in this dossier

The Aerospace and Defence Chromates Reauthorisation (ADCR) Consortium on behalf of the applicants has developed several review reports. These applications cover all uses of soluble chromates considered to be relevant by the ADCR consortium members. Although formally they are upstream applications submitted by manufacturers, importers or formulators of chromate-containing chemical products, the applications are based on sector-specific data and detailed information obtained from actors throughout the supply chain.

The ADCR consortium developed the following dossiers with one use each:

- Formulation
- Pre-treatments: deoxidising, pickling, etching and/or desmutting
- Passivation of stainless steel
- Electroplating
- Anodising
- Chemical conversion coating
- Passivation of (non-Al) metallic coatings
- Inorganic finish stripping
- Anodise sealing
- Slurry coating
- Chromate rinsing after phosphating

This dossier “Passivation of stainless steel” contains a single use: “Passivation of stainless steel using chromium trioxide or sodium dichromate in the aerospace and defence industry and its supply chains”.

#### 9.1.2 Introduction to the assessment

##### 9.1.2.1 Grouping approach for Cr(VI) compounds

The chromates shown in Table 9-1 have been included into Annex XIV of Regulation (EC) No 1907/2006 due to their intrinsic properties (mutagenic, carcinogenic, toxic for reproduction; depending on the chromate). According to Article 62 (4)(d) of this Regulation, the chemical safety report (CSR) supporting an Application for Authorisation (AFA) needs to cover only those risks arising from the intrinsic properties specified in Annex XIV. Therefore, only the human health risks related to the classification of the respective chromate(s) as mutagenic, carcinogenic and/or reproductive toxic substance(s) are addressed in this CSR. This requires investigating the potential exposure of workers as well as exposure of humans via the environment.

Chromium trioxide (CT) has been included in Annex XIV of REACH (Entry No. 16) due to its carcinogenic and mutagenic properties as it is classified as carcinogenic (Cat. 1A) and mutagenic (Cat. 1B). As CT is

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mainly used as aqueous solution in the processes described below, this Application for Authorisation also covers Entry No. 17 of Annex XIV of REACH, which refers to acids generated from CT and their oligomers. **In the following, when referring to CT, this always also implies acids generated from CT and their oligomers.**

Sodium dichromate (SD; Entry No. 18) has been included in Annex XIV of REACH due to its CMR properties as it is all classified as carcinogenic (Cat. 1B), mutagenic (Cat. 1B) and reproductive toxicant (Cat. 1B).

For CT and its acids, only carcinogenic and mutagenic properties must be considered for risk characterisation. Reproductive toxicity has also to be taken into account for Cr(VI) exposure related to SD as this chromate affects both fertility and development.

**Table 9-1: Substances considered for the assessment**

Substance name	CAS No.	EC No.	Annex XIV Entry No.	Intrinsic properties referred to in Art. 57	Formula	Mol. weight [g/mol]	Cr(VI) mol. weight fraction
Cr(VI)	-	-	-		Cr <sup>6+</sup>	52.00	1
Chromium trioxide <sup>a</sup> (CT)	1333-82-0	215-607-8	16	Muta. 1B Carc. 1A	CrO <sub>3</sub>	99.99	0.52
Acids generated from chromium trioxide and their oligomers <sup>a,b</sup>	-	-	17	Carc. 1A			
Sodium dichromate <sup>c</sup> (SD)	10588-01-9	234-190-3	18	Muta. 1B Carc. 1B Repr. 1B	Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	261.97	0.40

<sup>a</sup> Chromium trioxide, when encountering water forms chromic acid, dichromic acid and oligomers of chromic acid and dichromic acid, which are in the following referred as "Chromic acids and their oligomers". Chromium trioxide has been included in Annex XIV of REACH (Entry No. 16) due to its carcinogenic and mutagenic properties as it is classified as carcinogenic (Cat. 1A) and mutagenic (Cat. 1B). As chromium trioxide is mainly used as aqueous solution in the processes described below, this Application for Authorisation also covers Entry No. 17 of Annex XIV of REACH, which refers to "Acids generated from chromium trioxide and their oligomers". Differences between the substances (e.g., due to different forms: liquid, solid) with relevance to their hazards, exposure, alternatives etc. are considered in the assessment.

<sup>b</sup> Including chromic acid (CAS No.: 7738-94-5 | EC No.: 231-801-5), dichromic acid (CAS No.: 13530-68-2 | EC No.: 236-881-5) and oligomers of chromic acid and dichromic acid.

<sup>c</sup> This entry also covers sodium dichromate dihydrate (Formula: Cr<sub>2</sub>H<sub>4</sub>Na<sub>2</sub>O<sub>9</sub> | CAS No.: 7789-12-0 | EC No.: 616-541-6), which is neither registered nor does it have a harmonised classification. Should it be used, we will treat it as if it were also classified as mutagenic (Muta. 1B), carcinogenic (Carc. 1B) and reprotoxic (Repr. 1B), same as the anhydrous form. In this case, the molecular weight fraction of 0.4, as calculated for sodium dichromate, would be used, which is a conservative approach, because sodium dichromate dihydrate has a higher molecular weight (298 g/mol) with a lower Cr(VI) fraction (0.35) than sodium dichromate.

The carcinogenicity, mutagenicity and reproductive toxicities of CT, its acids, and SD are driven by the chromium VI (Cr(VI)) ion released when the substances solubilise and dissociate. Since Cr(VI) is the relevant and common molecular entity generated from all these substances, all exposure assessments

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are performed for Cr(VI). Also, the exposure-risk relationships and DNELs proposed by the Committee for Risk Assessment (RAC) express exposure as Cr(VI).

A grouping approach is used in this CSR, because

- All substances share this common toxic moiety (Cr(VI)), and are therefore expected to exert effects in an additive manner,
- At many sites various chromates are used in parallel, exposures of which are additive,
- For some uses, different chromates can be used interchangeably, as they provide the same performance properties and functionalities.

Human exposures (as well as environmental emissions) are expressed in units of Cr(VI) (converted by using substance-specific molecular weights) to allow for comparing and summing up of exposures and to support comparison with RAC's exposure-risk relationship and DNELs.

#### **9.1.2.2 Exposure-risk relationships (ERRs) for carcinogenic effects and DNEL values for reproductive toxicity used for the assessment**

The hazard evaluation follows recommendations given by RAC (ECHA, 2015)<sup>1</sup>:

For assessing carcinogenic risk, exposure-risk relationships are used to calculate excess cancer risks.

As mutagenicity is a mode of action expected to contribute to carcinogenicity, the mutagenic risk is included in the assessment of carcinogenic risk, and low risks for mutagenicity are expected for exposures associated with low carcinogenic risks.

With respect to reproductive toxicity, DNELs for effects on fertility proposed by RAC are lower than DNELs derived for effects on developmental toxicity and, therefore, the RAC DNELs are used for the assessment of reproductive toxicity.

Sodium dichromate, sodium chromate and potassium dichromate are included in Annex XIV not only due to their carcinogenic and mutagenic properties but also because of their reproductive toxicities. Although the effects on reproduction only need to be assessed for Cr(VI) derived from these three substances, for reasons of simplification risk characterization ratios were calculated for total Cr(VI), regardless of the source (i.e., total Cr(VI)). Therefore, exposures resulting from all substances mentioned in Table 9-1 will be considered for each applicable exposure scenario relevant for uses of one or more of these three chromates. With respect to a possible risk to fertility, this represents a conservative estimate for sites which use CT and in parallel with SD, because the contribution of CT does not have to be considered for effects on fertility.

A dermal DNEL for long-term systemic effects for workers is used in the risk characterization for dermal occupational exposures, because there is no data to indicate that dermal exposure to Cr(VI) compounds presents a cancer risk in humans (ECHA, 2015).

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<sup>1</sup> ECHA Website: [https://echa.europa.eu/documents/10162/21961120/rac\\_35\\_09\\_1\\_c\\_dnel\\_cr-vi\\_en.pdf/8964d39c-d94e-4abc-8c8e-4e2866041fc6](https://echa.europa.eu/documents/10162/21961120/rac_35_09_1_c_dnel_cr-vi_en.pdf/8964d39c-d94e-4abc-8c8e-4e2866041fc6); assessed in March 2021

### 9.1.2.2.1 Exposure risk relationships (ERRs) for carcinogenic effects

ECHA published on December 4, 2013 the document “*Application for Authorisation: Establishing a reference dose response relationship for carcinogenicity of hexavalent chromium*”<sup>2</sup> (ECHA, 2013), which states the opinion of RAC that hexavalent chromium is a non-threshold carcinogen. Consequently, demonstrating adequate control is not possible and the socioeconomic analysis (SEA) route is applicable. The exposure-risk relationships published in this document from ECHA (2013) are used to calculate excess cancer risks associated with the use(s) of Cr(VI) covered by this application. However, the resulting risk estimates likely overestimate the cancer risk. RAC states in its publication of the ERR (ECHA, 2013): “As the mechanistic evidence is suggestive of non-linearity, it is acknowledged that the excess risks in the low exposure range might be an overestimate”.

The excess cancer risk characterisation for workers is solely based on inhalation exposure and the risk for lung cancer, as no information on the fraction of inhalable, but non-respirable particles is available, which prevents a differentiated consideration of inhalation and oral exposure of workers. This is also the standard procedure proposed by ECHA (2013), as ECHA states: “*In cases where the applicant only provides data for the exposure to the inhalable particulate fraction, as a default, it will be assumed that all particles were in the respirable size range*”.

Therefore, it is assumed that all Cr(VI)-bearing particles are of respirable sizes, and thus no oral exposure routes are considered for worker inhalation. This is a conservative approach, since the potential lung cancer risk is at least an order of magnitude higher compared to the potential cancer risk for the digestive tract.

The following exposure-risk relationships are used for estimating excess lung cancer risks for workers (inhalation):

**Table 9-2: Exposure-risk relationships for inhalation exposure of workers used for calculating cancer risks due to Cr(VI) exposure (from ECHA, 2013)**

TWA Cr(VI) inhalation exposure concentration [ $\mu\text{g}/\text{m}^3$ ]*	Excess lung cancer risk in workers [ $\times 10^{-3}$ ]
25	100
12.5	50
10	40
5	20
2.5	10
1	4
0.5	2
0.25	1

<sup>2</sup> ECHA Website: [https://echa.europa.eu/documents/10162/13579/rac\\_carcinogenicity\\_dose\\_response\\_crvi\\_en.pdf](https://echa.europa.eu/documents/10162/13579/rac_carcinogenicity_dose_response_crvi_en.pdf); assessed in March 2021

TWA Cr(VI) inhalation exposure concentration [ $\mu\text{g}/\text{m}^3$ ]*	Excess lung cancer risk in workers [ $\times 10^{-3}$ ]
0.1	0.4
0.01	0.04

TWA: Time-weighted average, expressed in micrograms of Cr(VI) per cubic meter of air

\* Based on a 40-year working life (8h/day, 5 days/week).

For the general population, oral (via drinking water and food) and inhalation exposure is considered following recommendations of RAC (RAC did not identify cancer risks after dermal exposure for workers or the general population). For inhalation exposure RAC again is presenting an exposure-risk relationship for lung cancer, whereas for oral exposure the focus is on an increased risk for tumours of the small intestine (ECHA, 2013). As with the assessment of worker exposure, for inhalation exposure of the general population, it is assumed that all particles are in the respirable size range.

The following exposure-risk relationships are used to characterise risks of the general population after exposure (over 70 years) of humans via the environment.

**Table 9-3: Exposure-risk relationships for inhalation exposure of general population used for calculating cancer risks due to Cr(VI) exposure (from ECHA, 2013)**

Average Cr(VI) exposure concentration in ambient [ $\mu\text{g}/\text{m}^3$ ]*	Excess lung cancer risk in the general population [ $\times 10^{-3}$ ]
10	290
5	145
2.5	72
1	29
0.5	14
0.25	7
0.1	2.9
0.01	0.29
0.001	0.029
0.0001	0.0029

\* Based on an exposure for 70 years (24h/day, every day).

**Table 9-4: Exposure-risk relationships for oral exposure of general population used for calculating cancer risks due to Cr(VI) exposure of humans via environment (from ECHA, 2013)**

Constant average oral daily dose of Cr(VI) [ $\mu\text{g}/\text{kg bw}/\text{day}$ ]*	Excess small intestine cancer risk in the general population [ $\times 10^{-4}$ ]
10	80
5	40
2.5	20
1	8
0.5	4
0.1	0.8

\* Based on an exposure for 70 years (24h/day, every day)

#### 9.1.2.2.2 Derived no effect levels (DNELs) for the assessment of potential risks to reproduction

For the assessment of the potential risk to reproduction (fertility as the most sensitive endpoint), the risk characterisation ratios for inhalation exposure of **workers** are based on the DNEL inhalation for effects on fertility derived by RAC (ECHA, 2015):

- inhalation DNEL systemic long-term:  $43 \mu\text{g Cr(VI)}/\text{m}^3$

The risk characterisation ratios for dermal exposure of **workers** are based on the DNEL dermal for effects on fertility derived by RAC (ECHA, 2015):

- dermal DNEL systemic long-term:  $43 \mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$

The risk characterisation for oral and inhalation exposure of humans via the environment is based on the DNEL inhalation and the DNEL oral for the **general population** derived by RAC for effects on fertility (ECHA, 2015):

- inhalation DNEL systemic long-term:  $11 \mu\text{g Cr(VI)}/\text{m}^3$
- oral DNEL systemic long-term:  $17 \mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$ .

Dermal exposure of humans via the environment is considered very unlikely (ECHA, 2016a).

#### 9.1.2.3 Environment

##### Scope and type of assessment

The chromates in Table 9-1 are not listed in Annex XIV for endpoints related to concerns for the environment. Therefore, no environmental assessment has been performed.

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#### 9.1.2.4 Exposure of humans via the environment

##### 9.1.2.4.1 Scope and type of assessment

The exposure of humans to Cr(VI) via the environment (HVE) as a result of wastewater and air emissions from the sites of the applicants and downstream users covered by this CSR is considered in section 9.2.3.1. With regard to oral exposure of humans via the environment, it has to be acknowledged that Cr(VI) is rapidly reduced to Cr(III) in many environmental compartments (ECB, 2005). Therefore, exposure to Cr(VI), estimated based on the release of Cr(VI) into environmental compartments may significantly overestimate human exposure via the environment. Moreover, several of the parameters necessary for environmental modelling (in particular the partition coefficients) are based on the log of the octanol-water partition coefficient ( $K_{ow}$ ) of a given substance. This parameter is of no relevance for inorganic substances such as Cr(VI), and therefore the calculated partition coefficients are not applicable.

Apart from that, there is only limited data on the presence of Cr(VI) in food. In most cases, only total chromium was measured. According to a few studies, Cr(VI) generally amounts to less than 10% of total chromium (range 1.31-12.9%) (EFSA, 2014). Furthermore, some studies even indicate that foods of plant origin do not contain Cr(VI) at all and that the Cr(VI) levels measured are analytical artifacts (EFSA, 2014). The same may be the case with foods of animal origin. Based on these data, the EFSA-CONTAM Panel concluded 'that there is a lack of data on the presence of Cr(VI) in food' and 'decided to consider all the reported analytical results in food as Cr(III)' (EFSA, 2014). Furthermore, the CONTAM Panel concluded that it can be assumed 'that all the chromium ingested via food is in the trivalent form (i.e., Cr(III)), in contrast to drinking water where chromium may easily be present in the hexavalent state', primarily due to the use of strong oxidizing agents in the treatment of drinking water (EFSA, 2014). These considerations of the CONTAM Panel support the earlier evaluation of the EU Risk Assessment Report for chromates, in which the indirect oral exposure of humans via the environment was assessed only on the basis of exposure via (drinking) water and the consumption of fish (ECB, 2005). Therefore, same approach is followed here.

This assessment focuses primarily on the carcinogenicity of Cr(VI) released from the chromates as the most relevant endpoint and compares the exposure estimates with the exposure-risk relationship derived by the RAC for the general population, as shown below in Table 9-5.

In addition, risk characterisation ratios (RCRs) based on the DNELs derived by RAC (see also section 9.1.2.2) are calculated to take into account possible effects on reproduction for those chromates, which have been included in Annex XIV of the REACH Regulation due to their reproductive toxicity (in addition to their carcinogenic properties). Although in principle effects on reproduction only have to be evaluated for Cr(VI) originating from SD, RCRs have been calculated for total Cr(VI) exposure, irrespective from which of the chromates covered in this CSR it was released, following a conservative approach.

**Table 9-5: Type of risk characterisation required for humans via the environment**

Route of exposure and type of effects	Endpoint considered and type of risk characterisation	Hazard conclusion DNEL/dose – response relationship
Inhalation: Systemic Long Term	Carcinogenicity Quantitative	RAC dose-response relationship based on excess lung cancer risk (ECHA, 2013)  For general population; based on 70 years of exposure; 24h/day:  Exposure to 1 µg/m <sup>3</sup> Cr(VI) relates to an excess risk of 2.9x10 <sup>-2</sup> *
	Reproductive toxicity Quantitative	RAC DNEL for the general population, derived for effects on fertility (ECHA, 2015)  11 µg Cr(VI)/m <sup>3</sup>
Oral: Systemic Long Term	Carcinogenicity Quantitative	RAC dose-response relationship based on excess cancer risk for tumours of the small intestine (ECHA, 2013)  For general population; based on 70 years of exposure:  Exposure to 1 µg Cr(VI) /kg bw/day relates to an excess risk of 8x10 <sup>-4</sup>
	Reproductive toxicity Quantitative	RAC DNEL for the general population, derived for effects on fertility (ECHA, 2015)  17 µg Cr(VI)/kg bw/d

\* The inhalation cancer risk characterisation for humans via the environment is solely considering risk for lung cancer, as no information on the fraction of inhalable, but non-respirable particles is available, which prevents a differentiated consideration of inhalation and oral exposure of humans via the environment).

#### 9.1.2.4.2 Comments on assessment approach

In this section, we describe the approach to assess human exposure to Cr(VI) via the environment (HvE) resulting from the industrial use of chromates covered in this CSR (see Table 9-1). Exposure via ambient air and oral exposure (through drinking water intake and consumption of fish) has been assessed at local levels. No regional assessment has been carried out as it can be assumed that Cr(VI) from any source will be reduced to Cr(III) in most environmental situations and therefore the effects of Cr(VI) as such are likely to be limited to the area around the source, as described in the EU Risk Assessment Report for chromates (ECB, 2005). The approach to not perform a regional assessment for human Cr(VI) exposure via the environment as part of AfAs for chromate uses was also supported in compiled RAC and SEAC (Socio-economic Analysis Committee) opinions, as described for example in the *Opinion on an Application for Authorisation for Use of Sodium dichromate for surface treatment of metals such as aluminium, steel, zinc, magnesium, titanium, alloys, composites and sealings of anodic films* (ID 0043-02). This states that regional exposure of the general population is not considered relevant by

RAC<sup>3</sup>.

### **EUSES modelling of human exposure via the environment**

The assessment of human Cr(VI) exposure via the environment is based on emission measurements in air and wastewater from representative sites, and distribution and exposure modelling are carried out with the European Union System for the Evaluation of Substances (EUSES) software (v. 2.1.2).

#### Release days

For the considered exposure pathways air, water, and fish, 365 release days are always assumed. This approach is considered justified, because:

- the air concentration (*annual average local "Predicted environmental concentration" (PEC) in air (total)*) and the concentration in fish (calculated from the bioconcentration factor in fish and from the *annual average local PEC in surface water (dissolved)*) are based on annual average PEC values, on which the number of release days has no impact.
- the Cr(VI) concentration in drinking water is based on the higher of the two values "*annual average local PEC in surface water (dissolved)*", which is independent of the number of release days, as described above, and "*local PEC in pore water of agricultural soil*", where fewer release days would lead to an intermittently higher PEC value. If the concentration in drinking water is based on the "*local PEC in pore water of agricultural soil*" and if this value is temporarily increased due to intermittent release (of sewage sludge to agricultural soil with temporarily higher Cr(VI) concentrations), the concentration in drinking water would be temporarily higher than under the assumption of 365 release days. This is a very unrealistic scenario since a spatial and temporal distance between pore water of agricultural soil and drinking water would compensate for variations in Cr(VI) drinking water concentrations due to intermittent release of Cr(VI) to wastewater. Furthermore, the use of an intermittently elevated drinking water concentration for the calculation of a lifelong cancer risk via drinking water consumption would be an overestimation of the realistic risk and therefore, by considering 365 release days, a stable concentration in drinking water is calculated.
- in this latter case, the "*local PEC in pore water of agricultural soil*" is simply equated by EUSES software with the "*local concentration in groundwater*", which is taken as the concentration in drinking water (if the concentration is higher than the one derived from surface water; see above). As noted in the EUSES background report, equating the soil pore water concentration with the groundwater concentration 'is a worst-case assumption, neglecting transformation and dilution in deeper soil layers'. This conservatism would increase the unrealistic nature of intermittent release further and the use of an annual average exposure estimate is considered more adequate in the present context.

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<sup>3</sup> RAC/SEAC "Opinion on an Application for Authorisation for Use of Sodium dichromate for surface treatment of metals such as aluminium, steel, zinc, magnesium, titanium, alloys, composites and sealings of anodic films", consolidated version, 2016; <https://echa.europa.eu/documents/10162/658d42f4-93ac-b472-c721-ad5f0c22823c>

### Sewage treatment plant (STP)

For sites where wastewater is sent to a biological sewage treatment plant (STP), we have adjusted the default distribution of Cr(VI) in the sewage treatment plant (STP) used in EUSES (99.9% in water and 0.1% in sludge) to 50% in water and 50% in sludge. This is based on the description given in the EU Risk Assessment Report (ECB, 2005) that during biological treatment 50% of Cr(VI) are released into the effluent and 50% are absorbed to sewage sludge. The application of sludge on agricultural soil (rate: 5000 kg/ha/year) and grassland (rate: 1000 kg/ha/year) was considered according to the EUSES standard setting unless there was information to the contrary.

### Oral uptake via drinking water and fish

The intake of pollutants via drinking water and fish, as modelled in EUSES, is unreasonably conservative and therefore, specific reduction factors are applied for risk calculations in the environmental contributing scenario (see section 9.2.3.1). The arguments why the EUSES calculations are overly conservative for these pathways, and derivation of reduction factors are described below:

- Drinking water

- a) Local concentration in drinking water based on the local PEC in surface water (*“annual average local PEC in surface water (dissolved)”*):

- The approach chosen is likely to *“overestimate the actual indirect exposure as the conversion of Cr (VI) to Cr (III) is expected to occur under the vast majority of environmental conditions”* (ECB, 2005). This reduction is not considered in the exposure values calculated in EUSES.
- EUSES typically specifies a “purification factor” that accounts for removal processes from surface water in deriving the concentration in drinking water, e.g., by evaporation or adsorption to suspended solids. However, the latter is estimated by log Kow and not by specific distribution coefficients. This approach is not feasible for inorganic substances and therefore the estimate does not account for adsorption to suspended particles as a removal process before and during drinking water purification. Although these effects are difficult to quantify, the value of 50% (i.e. reduction by factor 2) for adsorption to sewage sludge as applied in the EU RAR (ECB, 2005) (as described above) can serve as an indicator of the degree of Cr(VI) adsorption to suspended solids in surface water.
- The local PEC in surface water is calculated for the mixing zone, neglecting the fact that for drinking water preparation additional water sources are added and dilution takes place.

- b) Local concentration in drinking water based on the *“local PEC in pore water of agricultural soil”*:

- The Cr(VI) concentration in groundwater is taken directly from the pore water concentration in the soil, which in turn is modelled from the Cr(VI) concentration in the soil. Cr(VI) reduction in soil is a well-known process and the EU Risk Assessment Report states that *“chromium (VI) is reduced to chromium (III) by organic matter and this process occurs reasonably readily in soils”* and assumes *“chromium present in soil following application is in the form of chromium (III)”* (ECB, 2005). This reduction is not considered in EUSES modelling.

- In addition, EUSES calculates the deposition (the main relevant pathway of groundwater contamination) for a circle around the source with a radius of 1000 m (RIVM, 2004), so that the resulting groundwater concentration only applies to the groundwater below this area.
- EUSES modelling of the concentration in groundwater is based on a simple algorithm that equates the concentration of a substance in groundwater with its concentration in the pore water of the soil (RIVM, 2004). These authors state, that *“this is a worst-case assumption, neglecting transformation and dilution in deeper soil layers”*.
- Like for surface water, any additional dilution with other groundwater or surface water for drinking water preparation is not considered.

Overall, the conservatism of EUSES with respect to exposure to drinking water is classified as “worst case” by the software developers (RIVM, 2004).

Against the background of these substance-specific and model-inherent considerations, the estimate for local exposure via drinking water is regarded as unreasonable. The effects of all these issues are not quantifiable, but a general reduction of the local Cr(VI) concentration in drinking water, calculated in EUSES, by a factor of 5 due to the above factors, seems to be appropriate. Still, this is considered to result in a conservative exposure estimate.

- Fish

- 1) In EUSES, a default consumption of 115 g fish per day is used, which overestimates the realistic human daily intake of fish on a long-term basis. According to the food consumption data for humans in Europe, as accessible in the *PRIMo – Pesticide Residue Intake Model*<sup>4</sup> (v.3.1) of the European Food Safety Authority (EFSA), the maximum of the mean consumption of fish (and fish- and marine-/freshwater-products) is 29.3 g per day<sup>5</sup>. This amount is approximately 4-fold lower (factor 3.9) than the default consumption used in EUSES, most likely due to the fact that it reflects a long-term estimate (i.e., most people do not eat fish every single day).
- 2) It must be noted, that *“(p)eople do not consume 100% of their food products from the immediate vicinity of a point source. Therefore, the local assessment represents a situation which does not exist in reality”* (ECHA, 2016a).

From argument 1) (almost) a reduction factor of 4 can be assumed and although argument 2) is not scientifically verifiable, it certainly makes up more than a factor of 1.25. Thus, combining these two arguments, a **total reduction factor of 5** can be derived, which is assumed to be sufficiently conservative to also cover, for example, that some countries have not indicated long-term

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<sup>4</sup> In the *PRIMo – Pesticide Residue Intake Model* (v.3.1) of the European Food Safety Authority (EFSA) food consumption data for individuals of different age groups in numerous European countries are listed. The model can be accessed via <https://www.efsa.europa.eu/en/applications/pesticides/tools> (accessed in November 2020).

More detailed information on the model is under the following links:  
<https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2018.5147> and  
<https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/sp.efsa.2019.EN-1605>

<sup>5</sup> The value was provided for Germany (general population) based on the daily intake (reported in the PRIMo model in g/kg bw and day), multiplied by the body weight (reported in kg). The value represents the maximum of the mean values reported for different countries and population groups (e.g., children, adults, general population).

consumption quantities to EFSA (and are thus not represented in the PRIMo Model). Adding further to the conservatism, it must be noted that the value derived from the data in the PRIMo model relate to the consumption of '*fish, fish products and other marine and freshwater food product*' and therefore include food items that are unlikely to be sourced from the immediate vicinity of the site assessed.

### Inhalation exposure

The following must be considered for local inhalation risks: The concentration in air and deposition are estimated in EUSES with the Operational Priority Substances (OPS) model that is embedded in EUSES (de Bruin et al., 2010; Toet and de Leeuw, 1992). When EUSES was developed, conservative input values were chosen (e.g., stack height of 10 m, no excess heat of the plume emitted compared to environmental temperature and an ideal point source). For a stack height of 10 m, the maximum concentration is modelled at a distance of 100 m from the source and this distance was set as the default distance for the local PECair in EUSES. The developers of the OPS model at the Dutch RIVM analysed the impact of these conservative default settings on the estimated concentration in air and on the total deposition. For example, they noted that '*[i]ncreasing the stack height from 10 to 50 m lowers the maximum concentration by a factor 40*' and – considering all factors – concluded that '*air concentration and total deposition used for risk assessment purposes are likely to be overestimated due to over-conservative default settings used in the standard scenario in EUSES*' (de Bruin et al., 2010). In the light of these findings, the inhalation risk estimates presented in this report are highly conservative.

### **Site-specific release fractions**

Data for monitoring of Cr(VI) releases to water and air are available from several sites in Europe. Release fractions for Cr(VI) emissions to water, air and soil were derived from the site-specific emission data and tonnages of used chromates. These releases are generally governed by, and comply with, local worker and environmental regulatory requirements.

### Wastewater

Wastewater containing Cr(VI) may occur from bath solutions when treatment baths are renewed, rinsing water from rinsing tanks, and from manual rinsing operations, cleaning water, liquids from secondary containment pits, wash water from wet scrubbers, and liquid waste from the laboratory. At all sites wastewater is collected and then treated by one or more of the following three options:

- Sending it to an external waste management company (licensed contractor) where it is treated as hazardous waste
- Recycling and evaporation in an on-site evaporation system; the residue is discharged as hazardous solid waste or liquid waste
- Discharge into a special treatment facility

The special treatment facility is in most cases located on-site but may also be external where the water is transferred via underground pipes. Typically, bath solutions are either disposed as hazardous waste by an external company or conveyed to the special treatment facility. Wastewater from the other sources listed above is usually either collected and mixed for treatment at the treatment facility or recycled and then sent to the evaporation system.

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In the special treatment facility, the Cr(VI) in wastewater is reduced to Cr(III) by addition of a reducing agent (e.g., sodium metabisulphite, ferrous sulphate, or ferric chloride solutions) in excess of stoichiometry. Usually, reduction efficiency is measured by a redox probe. Following the reduction step, the wastewater pH is neutralized, and Cr(III) is precipitated. After monitoring of the Cr(VI) concentration in the reduced wastewater, the wastewater is usually mixed with other non-Cr(VI) containing waste solutions. The wastewater is then discharged to an external municipal wastewater/sewage treatment plant for further treatment prior to discharge to receiving waters (river, canal or sea).

Air

Air from the Cr(VI) process baths is exhausted and treated through wet scrubbers or air filters prior to external release.

Soil

There is no direct release to soil, based on equipment and procedures in place.

Solid waste containing Cr(VI) may arise in the form of sludge from the treatment and rinsing baths, solid residue from the evaporation system for wastewater (at sites where this technique is performed), sludge from the reduction/neutralization process (at sites where this technique is performed), empty chemical containers, cleaning materials (e.g., rags, wipes), sorbents, contaminated equipment (e.g., heaters, pumps) and disposable PPE. Waste materials containing Cr(VI) are classified and treated as hazardous wastes according to EU and national regulations. Any solid or liquid waste is collected and forwarded to an external waste management company (licensed contractor) for disposal as hazardous waste.

**Substance-specific input values**

We have used the properties of CT for the input of substance-specific physico-chemical properties to model the behaviour of Cr(VI) with EUSES. The parameters of CT were selected because a comparative EUSES assessment with an example scenario, in which only the substance-specific physico-chemical properties of the eight chromates covered by the ADCR consortium were used, yielded the most conservative result with the CT parameters. The exposure of H<sub>v</sub>E via the combined exposure via air, drinking water and fish was slightly higher when using the CT parameters than when using the parameters of the other chromates (the physico-chemical properties of the seven other chromates used for EUSES modelling and the outcome of the comparative EUSES assessment is provided in Annex I of the CSR). Accordingly, we have used the **parameters of CT for EUSES modelling of the environmental behaviour of Cr(VI) released from all source chromates and sites** (irrespective of the chromate used at a particular site) for reasons of conservatism and consistency. However, it must be noted that these physico-chemical properties are only used as a surrogate for those of Cr(VI), as no physical properties exist for the Cr(VI) ion. For the environmental fate properties, in contrast, data are available for Cr(VI). Table 9-6 shows the physico-chemical properties of CT and the environmental fate properties of Cr(VI) required for EUSES modelling, as given in the EU Risk Assessment Report (ECB, 2005).

**Table 9-6: Physico-chemical properties of CT and environmental fate properties of Cr(VI) required for EUSES modelling**

Property	Description of key information	Value selected for EUSES modelling	Comment
Molecular weight	100 g/mol	100 g/mol	Refers to CT, value used in ECB (2005)
Melting /freezing point	196 °C	196 °C at 101.3 kPa	Refers to CT, value used in ECB (2005)
Boiling point	n/a decomposes at ~250 °C to Cr <sub>2</sub> O <sub>3</sub> and O <sub>2</sub> (ECB, 2005)	250 °C	Refers to CT; value used in ECB (2005)
Vapour pressure	n/a: inorganic ionic compound	0.00001 Pa	N/A; dummy value entered
Log Kow	n/a: inorganic ionic compound	0	N/A; dummy value entered
Water solubility	Completely soluble in water, 1667 g/L at 20 °C, a 1% solution has a pH <1.	1667 g/L at 20 °C	Refers to CT; value used in ECB (2005)
<i>K<sub>p</sub> suspended matter</i>		1100 L/kg	Refers to Cr(VI); value for acidic and alkaline conditions given in ECB (2005), mean value is used; see text below for details
<i>K<sub>p</sub> sediment</i>		550 L/kg	Refers to Cr(VI); value for acidic and alkaline conditions given in ECB (2005), mean value is used; see text below for details
<i>K<sub>p</sub> soil</i>		26 L/kg	Refers to Cr(VI); value for acidic and alkaline conditions given in ECB (2005), mean value is used; see text below for details
Bioconcentration factor fish	1 L/kg	1 L/kg	Refers to Cr(VI); value used in ECB (2005)

We derived the partition coefficients for Cr(VI) from Table 9-6 as follows (see Table 9-7). In the EU Risk Assessment Report (ECB, 2005), the Cr(VI) partition coefficients are given for suspended matter, sediment and soil under acidic and alkaline conditions. For EUSES modelling the mean value of the partition coefficients under acidic and alkaline conditions was used for each compartment because (a) it reflects the range of values and (b) the underlying data – especially for K<sub>p</sub> suspended matter and K<sub>p</sub> sediment – are not very well founded, which hinders a more reliable prediction of these parameters.

To assess the impact of the selected partition coefficients (under acidic or alkaline conditions), we conducted a sensitivity analysis with EUSES, where an exemplary exposure scenario (with no biological STP) was carried out using (a) the coefficients for acidic conditions, (b) the coefficients for alkaline conditions or (c) the calculated mean values. The outcome of the assessment was that the selected set of partition coefficients had close to no impact on the modelling result, as the variation of Cr(VI) exposure of HvE via the combined exposure routes air, drinking water and fish was lower than 2% (details are given in Annex II of this report).

**Table 9-7: Partition coefficients for Cr(VI) for suspended matter, sediment and soil under acid and alkaline conditions, as given in ECB (2005)**

Partition coefficient *	Acid conditions (pH ≤5)	Alkaline conditions (pH ≥6)	Mean
K <sub>p</sub> <i>suspended matter</i>	2 000 L/kg	200 L/kg	1 100 L/kg
K <sub>p</sub> <i>sediment</i>	1 000 L/kg	100 L/kg	550 L/kg
K <sub>p</sub> <i>soil</i>	50 L/kg	2 L/kg	26 L/kg

\* All K<sub>p</sub> values refer to partitioning between water and the solid phase indicated.

### 9.1.2.5 Workers

#### 9.1.2.5.1 Scope and type of assessment

No professional or consumer uses are applied for in this application for authorisation, and such uses are therefore not part of this chemical safety report (CSR).

All chromates considered in this CSR have been included in Annex XIV of the REACH Regulation for their carcinogenic properties. As regards this toxicological effect, the assessment is limited to the inhalation exposure pathway: indeed, according to RAC “there are no data to indicate that dermal exposure to Cr(VI) compounds presents a cancer risk to humans” (ECHA, 2013). Therefore, the quantitative occupational exposure estimation and risk characterisation for carcinogenic effects focuses on inhalation exposure of workers. Additionally, a quantitative exposure assessment and risk characterisation with respect to effects on reproduction considers both inhalation and dermal exposures.

For chromates classified as toxic for reproduction (SD, see section 9.1.2.1), dermal exposure must be assessed for possible effects on fertility. As explained above, the exposure assessment of this CSR focuses on total Cr(VI) released from all assessed chromates combined. With respect to a possible risk

on fertility this is a very conservative estimate for sites which use CT in parallel with SD (as the contribution of CT does not have to be considered for effects on fertility). The exposure-risk relationships and DNEL values used for risk characterisation are based on the RAC evaluation (ECHA, 2013; 2015).

**Table 9-8: Type of risk characterisation required for workers**

Route of exposure and type of effects	Endpoint considered and type of risk characterisation	Hazard conclusion DNEL/dose – response relationship
Inhalation: Systemic Long Term	Carcinogenicity Quantitative	RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013)  For workers; based on 40 years of exposure; 8h/day; 5 days/week  Exposure to 1 µg/m <sup>3</sup> Cr(VI) relates to an excess risk of 4x10 <sup>-3</sup> <sup>a</sup>
	Reproductive toxicity Quantitative	RAC DNEL for workers, derived for effects on fertility (ECHA, 2015)  43 µg Cr(VI)/m <sup>3</sup>
Dermal: Systemic Long Term	Reproductive toxicity Quantitative	RAC DNEL for workers, derived for effects on fertility (ECHA, 2015)  43 µg Cr(VI)/kg bw/d <sup>b</sup>

<sup>a</sup> The inhalation cancer risk characterisation for workers is solely based on inhalation exposure and the risk for lung cancer, as no information on the fraction of inhalable, but non-respirable particles is available, which prevents a differentiated consideration of inhalation and oral exposure of workers.

<sup>b</sup> Only worker dermal DNEL long-term systemic fertility effects are applied for the risk characterization of dermal exposure, because there is no data to indicate that dermal exposure to Cr(VI) compounds presents a cancer risk to humans (ECHA, 2015).

A qualitative risk characterisation with respect to the corrosive and skin sensitising properties of chromates such as CT is outside the scope of this CSR, as these chromates have been included in Annex XIV to Regulation (EC) No 1907/2006 (REACH) solely due to their carcinogenic and mutagenic properties, and reproductive toxicity (see section 9.1.2.1). According to REACH, Article 62(4)(d), the CSR supporting an AfA needs to cover only those potential risks arising from the intrinsic properties specified in Annex XIV. The applicants duly apply and communicate risk management measures derived by the registrants of the chromates due to other substance properties related to human health concerns, which they communicated via the Safety Data Sheets (SDS).

### 9.1.2.5.2 Comments on assessment approach

#### General approach

The potential for exposure depends on the specific tasks identified for each use, as described below in the respective sections. Based on the process characteristics and properties of chromates as non-volatile substances, all potential inhalation exposure will be due to aerosols/dusts containing Cr(VI). Potential dermal exposures arise from Cr(VI) dissolved in liquids, or from dusts of solid Cr(VI)-containing products.

**Inhalation exposure** of workers is assessed via reliable and representative workplace air measurements. We have assigned exposed workers to “Similar Exposure Groups” (SEGs), which are defined for each use and comprise groups of workers performing similar tasks and, hence, are assumed to experience similar exposures. Measured data from members of the same SEG are pooled. On several occasions, workers might be engaged in more than one use in parallel (e.g., an operator surveying a line of baths, where several surface treatments are done). The respective chapters on the use-specific exposure assessment explain how measured exposures are assigned to specific uses. Generally, the measured full-shift time-weighted average concentration is assigned to all uses for which tasks were performed at the day of the measurement.

Measurement methods with varying sensitivity are applied. For values below the limit of quantification (LOQ), EN 689:2018 (Workplace exposure – Measurement of exposure by inhalation to chemical agents – Strategy for testing compliance with occupational exposure limit values) recommends statistical approaches to estimate the arithmetic or geometric mean in case of values below LOQ. However, due to the heterogeneity of our datasets (which come from different sites, with measurements performed by different service providers) these approaches are not feasible. Two other methods for treating such values, the use of LOQ/√2 or LOQ/2, are discussed in literature. The use of LOQ/2 is preferred for data sets with a geometric standard deviation >3 and the use of LOQ/√2 is preferred for data sets with a geometric standard deviation <3 (Morton and Lion, 2016; Succop et al., 2004). The resulting values of both methods likely overestimate mean values but are expected to have no influence on the 90<sup>th</sup> percentile of worker measurements considered in this CSR for exposure estimation. Since the use of LOQ/2 is a frequently used practical approach accepted by ECHA for the environmental part, we have used LOQ/2 for values <LOQ in the present exposure assessments (ECHA, 2016a; U.S. EPA, 2019).

**Personal monitoring**, with sampling heads in the worker’s breathing zone and with sampling durations which allow to acquire sufficient analytical mass and interpret measured values as shift-average values are preferred. In limited, specific circumstances, values from **stationary (static) measurements** are helpful: incidentally exposed workers, i.e., workers not directly engaged with Cr(VI) (also called bystanders), but spending 10% or more of their working time in the same work hall as operators handling Cr(VI), might experience inhalation exposure. Such exposures can be estimated from stationary measurements, representing concentrations at some distance from the primary sources.

As the focus of the exposure assessment is on carcinogenic risks over a work life, the long-term average (chronic) exposure would be the most adequate measure. ECHA Guidance on Information Requirements and Chemical Safety Assessment, R.14: Occupational exposure assessment recommends use of the 90<sup>th</sup> percentile, without differentiating between health endpoints (ECHA, 2016b). We have followed the recommendation in the ECHA guidance to use the 90<sup>th</sup> percentile,

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although this is considered very conservative (as the data reflect measurement uncertainty as well as day-to-day (intra-individual) and inter-individual variation of exposure).

**Biological monitoring** data are not used in the assessment. Indeed, as regards biological indicators:

- The measure of chromium in erythrocytes is the only one which is specific to Cr(VI). However, the available literature data on the general population and on workers are insufficient to determine reference values and limit values for this indicator (ANSES, 2017). The German method provides a correlation between biomonitoring in erythrocytes and inhalation exposures but only for CrO<sub>3</sub> concentrations above 30 µg/m<sup>3</sup>, which is above what is expected in these exposures (Greim, 2000). Additionally, it is expected that few sites apply biomonitoring in erythrocytes, as it is an invasive method using blood sampling and is thus difficult to apply to consistently use as a method of estimating exposure.
- Urinary biomonitoring does not allow a differentiation between Cr(III) and Cr(VI) (Drexler and Hartwig, 2009). France established a BLV (biological limit value) by ANSES (French evaluation Authorities) in 2017, which can be used for workers but only under the following conditions: when the use is electroplating AND when the chrome products used are exclusively Cr(VI) compounds. Indeed, in case of mixed exposure to both Cr(VI) and Cr(III) compounds, the urine measurements need to be interpreted considering parallel respective atmosphere measurements of Cr(VI) and Cr(III) compounds (if available). According to ANSES, the literature data available does not allow establishing a dose-response relationship between the urine measurements and the health effects (lung cancer, kidney toxicity, immunotoxicity) (ANSES, 2017). These constraints do not facilitate the implementation of this biomonitoring.
- Finally, chromium levels in biomonitoring studies are influenced by factors other than occupational exposure (geographical region, smoking status, intake from food and drinking water etc.), making the interpretation of the measurements as regards their relation to occupational exposures difficult.

Therefore, inhalation exposure measurements (ideally obtained by personal sampling) are preferred over biomonitoring in this case for exposure assessment.

**Exposure modelling** is applied for specific activities only, which cannot be adequately covered by measurements, such as:

- Activities of very short duration (e.g., laboratory workers handling Cr(VI) for a few minutes) might not allow direct measurements, taking into account the sensitivity of available methods.
- Infrequent activities, such as unscheduled maintenance activities, might not be included in occupational safety measurement programmes with the result that they are not covered by existing data.
- Activities using small amounts of mixtures with low concentrations of Cr(VI), such as use of touch-up pens.

Modelling is performed, where required, with Advanced REACH Tool (ART), version 1.5. Again, we have used the 90<sup>th</sup> percentile of the resulting distribution for risk assessment, according to (ECHA, 2016b).

Machining (e.g., drilling, grinding) of parts or blasting of surfaces, which were Cr(VI)-treated before might lead to Cr(VI) exposure via inhalation of fine dust particles that are generated. Such activities

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are included in the assessment if the surface treatment is expected to leave Cr(VI) on or near the surface.

**Dermal exposure** is considered for all activities related to a possible Cr(VI) exposure from using SD (to assess possible risks for reproductive toxicity). Minimisation of dermal exposure is required due to the corrosive and skin sensitising properties of the chromates. This is achieved by automating processes and, where manual handling cannot completely be avoided, by adequate personal protection equipment (for details on PPE see the respective exposure scenarios).

For processes for which dermal exposure cannot be excluded with certainty (e.g., sampling, cleaning, maintenance, bath preparation), the potential dermal exposure is modelled as the intensity of exposure is often difficult to accurately determine. However, modelling dermal exposure from the use of Cr(VI) substances as covered by this review report is difficult. The substances are mostly used as solids dissolved in a liquid, which is outside the applicability domain of the standard modelling tool ECETOC TRA. The Riskofderm model (v.2.1) does not contain adequate modules (DEO units) for several of the activities relevant here, e.g., handling contaminated objects, or cleaning activities. For all activities, including those outside the applicability domain of Riskofderm, we developed an Excel® spreadsheet-based model to estimate dermal exposure. This modelling approach uses dermal loads and assumption on contact areas depending on the tasks (PROCs) performed as proposed in the ECETOC TRA tool.

The following table lists the activities modelled (performed by various types of workers) and the approach used per activity.

**Table 9-9: Activities with potential dermal exposure to SD**

Task	PROC
Surface treatment by dipping/immersion	PROC 13
Sampling of treatment baths	PROC 9
Bath make-up and addition	PROC 5, PROC 8b
Bath emptying and cleaning	PROC 28
Diverse cleaning activities – cleaning of workplace, equipment, jigs	PROC 28
Waste management – Cleaning of empty chemical containers/bags	PROC 28
Waste management – Handling of solid waste	PROC 8b
Maintenance and cleaning of equipment	PROC 28
Aliquot chemicals – Decanting of liquids	PROC 8b
Aliquot chemicals – Measuring and weighing of solids	PROC 8b

The input data and the results of the modelling for the individual activities listed in Table 9-9 as well as the detailed Riskofderm protocols are given in Annex V. The 90<sup>th</sup> percentile exposure estimate from Riskofderm modelling are used for a plausibility check and are compared with the results of the Excel®

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spreadsheet-based model. The aggregated exposure estimates for the various worker contributing scenarios are also presented in Annex V.

**Comments on assessment approach related to toxicological hazard:**

There are no differences in the hazard profile compared to the initial applications regarding carcinogenic risks. Dose-response relationships for carcinogenic effects as proposed by RAC are used for risk characterisation. Further, in this review report reproductive toxicity is assessed using DNELs as proposed by RAC.

**Comments on assessment approach related to physicochemical hazard:**

Physico-chemical hazards are not in the scope of this document.

**General information on risk management related to toxicological hazard:**

Information on risk management measures implemented and a comparison with obligations from previous applications for authorisation are provided in chapter 9.2.1.

**General information on risk management related to physicochemical hazard:**

Physico-chemical hazards are not in the scope of this document.

**9.1.2.6 Consumers**

Consumer uses are not subject of this review report.

## 9.2 Use 1: “Passivation of stainless steel using chromium trioxide or sodium dichromate in aerospace and defence industry and its supply chains”

### 9.2.1 Introduction

#### 9.2.1.1 Relationship to previous application

This review report is for “Use 1: Passivation of stainless steel using chromium trioxide or sodium dichromate in the aerospace and defence industry and its supply chains”. It was prepared on behalf of the applicants by the Aerospace and Defence Chromates Reauthorisation (ADCR) consortium to cover uses of Chromium VI compounds in their supply chains. The review report is based on sector-specific knowledge provided by companies at various levels of the aerospace and defence industry and its supply chains. Compared to the initial applications (see Table 9-10), we narrowed the scope of this report in terms of the use definition, addressing only *Passivation of stainless steel using chromium trioxide or sodium dichromate in aerospace and defence industry and its supply chains*, to provide a more meaningful and specific description of use than the initial applications, which covered a wide range of surface treatments and substrates.

This chemical safety report covers the use of the two soluble Cr(VI) compounds sodium dichromate (SD) and chromium trioxide (CT) in a grouping approach (see section 9.1.2.1 for the justification). The following table shows the initial applications to which this review report refers.

**Table 9-10: Overview of initial applications**

Application ID/ authorisation number	Substance	CAS #	EC #	Applicants	Use name
<a href="#">0032-04/</a> REACH/20/18/14, REACH/20/18/16, REACH/20/18/18	Chromium trioxide	1333-82-0	215-607-8	Various applicants (CTAC consortium)	Surface treatment for applications in the aeronautics and aerospace industries, unrelated to Functional chrome plating or Functional chrome plating with decorative character
<a href="#">0032-05/</a> REACH/20/18/21, REACH/20/18/23, REACH/20/18/25	Chromium trioxide	1333-82-0	215-607-8	Various applicants (CTAC consortium)	Surface treatment (except passivation of tin-plated steel (ETP)) for applications in various industry sectors namely architectural, automotive, metal manufacturing and finishing, and general engineering (unrelated to Functional chrome plating)

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					or Functional chrome plating with decorative character)
<a href="#">0043-02/</a> REACH/20/5/3, REACH/20/5/5	Sodium dichromate	10588-01-9	234-190-3	Various applicants (CCST consortium)	Use of Sodium dichromate for surface treatment of metals such as aluminium, steel, zinc, magnesium, titanium, alloys, composites and sealings of anodic films

With the initial authorisation the European Commission issued several obligations and RAC/SEAC provided recommendations in their joint opinion on initial applications 0032-04 (REACH/20/18/14, REACH/20/18/16, REACH/20/18/18), 0032-05 (REACH/20/18/21, REACH/20/18/23, REACH/20/18/25), and 0043-02 (REACH/20/5/3, REACH/20/5/5). The table below outlines how the applicants (authorisation holder; AH), together with downstream users (DUs) represented by the ADCR consortium, reacted to these tasks.

Table 9-11 describes the comparison between the initial and the current applications in a concise way, while the individual exposure scenarios describe in more detail the measures already implemented.

**Table 9-11: Obligations in EC Implementing decisions**

Initial application	Current application
AH shall develop specific exposure scenarios for representative processes, operations, and individual tasks, describing risk management measures and operational conditions applied and containing information on the exposure levels. This obligation applies to 0032-04, 0032-05 and 0043-02	The consortium responsible for the initial application developed specific exposure scenarios and made them available to the DUs. Starting from that, we further developed and refined the exposure scenarios provided in section 9.2.3 of this report, together with the risk management measures described there, considering the narrower scope of use.
DUs shall implement best practices to reduce workplace exposure to the substances and its emissions to the environment to as low a level as technically and practically feasible, using closed systems and automation and local exhaust ventilation (LEV) systems that are appropriately designed, dimensioned, located and maintained to capture and remove the substances. This obligation applies only to 0043-02, not to 0032-04 or 0032-05	The exposure scenarios in section 9.2.3 describe the conditions of use including the technical and organisational measures to reduce and control workplace exposure.
Where respiratory protective equipment (RPE) is needed to control exposure, it shall be used in accordance with standard procedures for use and maintenance, including procedures for fit testing of RPE masks, applied in accordance with relevant standards. This obligation applies only to 0043-02, not to 0032-04 or 0032-05	Organisational measures to control and maintain adequate functioning and use of respiratory protective equipment (RPE) are described in 0.

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<p>Appropriate standard operating procedures shall be developed and implemented to minimise release of dust into the air during the preparation, transfer and storage of empty bags, filters, and other process waste, in accordance with the hierarchy of control provisions set out in Article 5 of Directive 2004/37/EC.</p> <p>This obligation applies only to 0043-02, not to 0032-04 or 0032-05</p>	<p>The type of activities and the conditions of use relevant for handling solid waste are given in sections 9.2.3.2 to 9.2.3.3, including a description of how LEV can be used in these situations to reduce exposure.</p>
<p>The AHs and DUs shall implement monitoring programmes for air monitoring of occupational exposure representative for the tasks undertaken and shall implement monitoring programmes for chromium (VI) emissions to wastewater and air from local exhaust ventilation.</p> <p>This obligation applies to 0032-04 and 0032-05 (with the requirement for at least annual monitoring of occupational exposure and of environmental wastewater and air emissions) as well as to 0043-02 (with the requirement for annual monitoring of occupational exposure; monitoring programmes for environmental wastewater and air emissions must be implemented without an indication of frequency)</p>	<p>Monitoring programmes are implemented by the DUs, and data from these programmes were used for developing exposure assessments of workers and of humans via the environment.</p>
<p>The AHs and DUs shall regularly review the effectiveness of the risk management measures and operational conditions in place and to introduce measures to further reduce exposure and emissions.</p> <p>This obligation applies to 0032-04, 0032-05 and 0043-02</p>	<p>Sites regularly review the effectiveness of risk management measures and operational conditions in place.</p>
<p>If an authorisation holder submits a review report, it shall include a detailed guidance on how to select and apply risk management measures and a refined assessment of the exposure to chromium (VI) of humans via the environment (HvE), as well as of the resulting risks. This assessment shall be performed using a higher-tier exposure assessment model going beyond the default assumptions of the Guidance on Information Requirements and Chemical Safety Assessment and of the European Union System for the Evaluation of Substances (EUSES) model and making use of site-specific emission information. All reasonably foreseeable routes of exposure of humans via the environment, including the oral route, shall be included in the assessment.</p> <p>This obligation applies to 0032-04, 0032-05 and 0043-02</p>	<p>Detailed information on the adequate RMMs for each activity are included in the exposure scenarios of this review report. The assessment of exposure of HvE is performed based on measured emission data from various sites. Inhalation exposure from emissions to air and oral exposure from emissions to wastewater is considered.</p>

**Enforcement activities by Member State Enforcement Authorities**

So far, we are not aware of any enforcement activity with relation to the use described here.

### 9.2.1.2 Overview of use and exposure scenarios

#### 9.2.1.2.1 Deviations from the exposure scenarios and contributing scenarios in the original submission

The exposure scenarios (ES) and contributing scenarios of this review report deviate from those included in the original submission in the following ways:

- 1) This review report has a much narrower scope than the initial applications to provide more meaningful use descriptions. The use covered by this review report is limited to *Passivation of stainless steel using chromium trioxide or sodium dichromate in aerospace and defence industry and its supply chains* while the initial applications 0032-04 (REACH/20/18/14, REACH/20/18/16, REACH/20/18/18), 0032-05 (REACH/20/18/21, REACH/20/18/23, REACH/20/18/25), and 0043-02 (REACH/20/5/3, REACH/20/5/5) each cover a multitude of surface treatments and substrates.
- 2) In this review report we have identified similar exposure groups (SEGs) of workers for the uses considered here, and the SEGs are described in separate worker contributing scenarios (to respond adequately to the EC Implementing decision and RAC/SEAC recommendations to *develop specific exposure scenarios for representative processes, operations and individual tasks*, as described in Table 9-12). Each contributing scenario covers the relevant processes and individual tasks performed by the respective group of workers in relation to the use and describes the operating conditions (OCs) and risk management measures (RMMs) for the individual tasks involving Cr(VI) exposure. The Cr(VI) exposure from these activities is quantified by personal air measurements. In this way, Cr(VI) inhalation exposures from all relevant tasks performed by a SEG during its daily work are considered and combined for risk assessment.

In the initial applications, no SEGs were determined. Instead, for a general worker, separate tasks with potential Cr(VI) exposure were described in each individual worker contributing scenario. For this, either Cr(VI) exposure was modelled for each task based on standard assumptions for the conditions of use, or, where available, monitoring data were considered for combinations of worker contributing scenarios.

- 3) In the environmental contributing scenario of this review report the assessment of humans via the environment is considered via the inhalation route and the oral route. Environmental monitoring data for releases to air and wastewater serve as a basis for EUSES modelling of human exposure via several environmental compartments (ambient air, drinking water, fish). In the initial applications, only the inhalation route was considered for EUSES modelling and emissions to wastewater were described as negligible and, thus, not considered.

Due to differences in the structure of the current and initial applications, in especially due to the assignment of tasks to SEGs, a direct comparison is not easy to perform. Table 9-12 provides an overview on major differences between the review report and the initial applications. In the first column, the PROCs assigned to different SEGs are shown. The PROCs from the initial applications corresponding to these tasks are listed in the second column. Deviations between the consideration of PROCs are described as remarks in the third column.

**Table 9-12: Activities and descriptors in current and initial applications**

Current application	Initial applications <sup>b</sup>	Remarks
<u>ECS 1 – Passivation of stainless steel – use at industrial site not leading to inclusion (of Cr(VI) or the reaction products) into/onto article</u>  ERC 6b	ERC 6b – Other surface treatment/ ERC 6b – Surface treatment	
<u>WCS 1 – Line operators <sup>a</sup></u> PROC 5, PROC 9, PROC 10, PROC 13, PROC 28	PROC 2, 13 – Surface treatment by dipping/immersion PROC 5 – Mixing of solids/liquids PROC 8b – Cleaning of equipment PROC 10 – Surface treatment by rolling/brushing/pen stick PROC 13 – Rinsing/drying PROC 15 – Laboratory analysis (sampling, laboratory analysis)	For surface treatment by dipping/immersion only PROC 13 is regarded appropriate in the current application, PROC 2 is not considered adequate  For cleaning PROC 28 is regarded more appropriate in the current application  For sampling PROC 9 is regarded more appropriate in the current application, PROC 15 is not considered adequate  For transfer of small amounts of liquids PROC 9 is considered in the current application
<u>WCS 2 – Storage area workers <sup>a</sup></u> PROC 5, PROC 8b, PROC 28	PROC 5 – Mixing of solids/liquids PROC 8b – Re-filling of baths – solids/liquids PROC 8b – Decanting of liquids PROC 8b – Decanting and weighing of solids PROC 8b – Cleaning of equipment PROC 8b – Waste management	For cleaning PROC 28 is regarded more appropriate in the current application
<u>WCS 3 – Laboratory technicians <sup>a</sup></u> PROC 15	PROC 15 – Laboratory analysis (sampling, laboratory analysis)	
<u>WCS 4 – Maintenance and/or cleaning workers <sup>a</sup></u> PROC 28	PROC 8a – Maintenance of equipment	For maintenance and cleaning PROC 28 is regarded more appropriate in the current application

<u>WCS 5 – Incidentally exposed workers (no Cr(VI)-related activities)</u> <sup>a</sup> PROC 0		Not considered in initial application
Not considered relevant in this review report, as not related to Cr(VI) exposure	PROC 1 – Delivery and storage of raw material PROC 4 – Un-/loading and cleaning of jigs PROC 21, 24 – Machining operations PROC 1 – Storage of articles PROC 8a – End of Life PROC 26 – Drying/curing	No exposure is considered from these processes in the current application; cleaning of jigs is covered in WCS 1 under cleaning of equipment (PROC 28)
Not considered relevant in this review report, as these activities are not part of the use described in this review report (but may be relevant for other surface treatments)	PROC 13 – Chemical pre-/post-treatment PROC 7 – Surface treatment by spraying	Not relevant for the scope of this use

<sup>a</sup> For descriptions of tasks assigned to the individual PROCs see worker contributing scenarios in sections 9.2.3.2 to 9.2.3.3.

<sup>b</sup> Since this application is based on several initial applications and the PROC descriptions sometimes vary between the different applications or are used in several variants in some cases the original PROC description is not given in this table but a summary description of the PROC(s) it is assigned to is.

The exposure scenarios and contributing scenarios of this review report are shown below in Table 9-13.

#### 9.2.1.2.2 Scope of use – supply chain considerations

This CSR covers the use of CT and SD for passivation of stainless steel in the aerospace and defence industry and its supply chains. This use is performed in the European Economic Area (EEA) and in the United Kingdom (UK) in exclusively industrial settings in the following levels of the supply chain:

- Original Equipment Manufacturer (OEM)
- Downstream user – Build-to-print manufacturer (BtP)
- Downstream user – Design-to-build manufacturer (DtB), and
- Maintenance, Repair and Overhaul (MRO) companies and Ministries of Defence (MoDs, undertaking military maintenance, repair and overhaul work)

Due to the different levels in the supply chain, to which the individual companies may be associated, and the variation in the size of the sites, the conditions under which the use is carried out can be variable. The conditions of use cover small sites and repair shops with rare and infrequent applications up to large sites with high throughput, and thus, a low to high level of automation for specific activities. This variability also was observed in extensive consultation processes during the preparation of this review report.

The use of CT and SD for passivation of stainless steel typically involves one environmental contributing scenario for the use of these chromates at an industrial site.

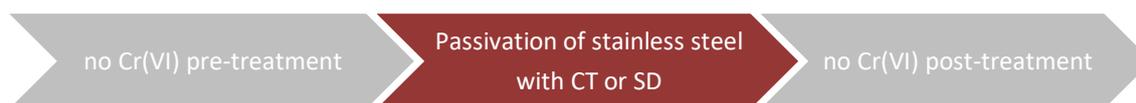
Table 9-13 lists all the exposure scenarios (ES) and contributing scenarios assessed in this chapter.

**Table 9-13: Overview of exposure scenarios and their contributing scenarios**

ES number	ES Title	Environmental release category (ERC)/ Process category (PROC)
ES1-IW1	Passivation of stainless steel – use at industrial site	
Environmental contributing scenario(s)		
ECS 1	Passivation of stainless steel – use at industrial site <b>not</b> leading to inclusion (of Cr(VI) or the reaction products) into/onto article	ERC 6b
Worker contributing scenario(s)		
WCS 1	Line operators	PROC 5, PROC 9, PROC 10, PROC 13, PROC 28
WCS 2	Storage area workers	PROC 5, PROC 8b, PROC 28
WCS 3	Laboratory technicians	PROC 15
WCS 4	Maintenance and/or cleaning workers	PROC 28
WCS 5	Incidentally exposed workers	PROC 0
Exposure scenario for industrial end use at site: ES1-IW1		

### 9.2.1.2.3 Relationship between uses

Passivation of stainless steel with CT or SD is normally not combined with any Cr(VI)-containing pre-treatment or post-treatment (see Figure 9-1). Only Cr(VI)-free pre-treatments (e.g., alkaline cleaning, descaling, etching) or post-treatment (e.g., neutralization) may be applied. For parts with very specific requirements, sometimes two Cr(VI) passivation steps may be carried out in sequence. In case of the sequential passivation the second passivation step is typically applied using SD, with a higher Cr(VI) concentration, a higher temperature and a longer immersion duration than the first passivation step (these parameters are at the upper end of the ranges described in section 9.2.3).

**Figure 9-1: Schematic presentation of treatment steps**

## 9.2.2 Detailed information on use

### 9.2.2.1 Process description

Stainless steel contains chromium as an alloying element and passivates naturally by forming a very thin chromium oxide ( $\text{Cr}_2\text{O}_3$ ) layer on the surface of the stainless steel. The chromium oxide layer is critical for the corrosion resistance of stainless steel. However, this natural film may not be fully

continuous and may exhibit free iron on the surface that can act as corrosion seeds. Therefore natural passivation films are not as strong as when the stainless steel is passivated by surface treatment. The mechanism is dependent in part upon the surface being clean and free from organic or inorganic contamination. Mechanical processing e.g., by machining or forming of stainless steel with steel tools can damage the natural oxide layer and may cause small iron/steel particles to be incorporated into the stainless steel surface, which may initiate rust spots under certain environmental conditions such as elevated humidity or in the presence of salt spray. In the process of passivation of stainless steel these iron/steel particles are chemically removed, and a new thin chromium oxide layer is formed to restore the natural corrosion resistant passive oxide layer. The chromate used in the passivation solution serves to enhance and supplement the formation of the passivating chromium oxide ( $\text{Cr}_2\text{O}_3$ ) layer on the surface of the stainless steel alloy.

**Cr(VI) is reduced in this process and no Cr(VI) is incorporated into or onto the surface layer. As a consequence, subsequent machining activities on treated parts are not further included in this assessment.**

The key functionalities of Cr(VI) for stainless steel passivation are detailed in the Analysis of Alternatives (AoA) report.

Passivation of stainless steel is a chemical, non-electrolytic process which is in most cases carried out by immersion of parts in treatment baths. Typically, the treatment baths for passivation of stainless steel are positioned in a large hall where baths for other immersion processes are also present; some of these baths might also involve the use of Cr(VI) although they may be unrelated to the present use. The immersion tanks can be placed individually or within a line of several immersion tanks. Usually, at least one rinsing tank with water is positioned after an immersion tank, for rinsing off the passivation solution from the part(s).

In some cases, when small components need touching up, passivation of stainless steel is carried out by applying the solution with a brush or pad. This activity is usually performed on a dedicated bench.

#### Substrate(s)

The only substrate to which this use applies is stainless steel.

#### Differences between chromates

Either CT or SD can be used for passivation of stainless steel in the aerospace and defence industry and its supply chains. The two chromates do not differ in terms of functionality for this use. The reason either one or the other is used is, in most cases, due to that particular chromate being defined in the customer specifications for a particular component and/or application; such a customer specification often has a historical or empirical background.

When no specification is given by a client, the choice of the chromate is often based on practical reasons, e. g. because a site prefers to use one of the two chromates for other processes as well, and/or the handling of one of the two products is preferred.

#### **9.2.2.2 Teams and employees involved**

For the present assessment, we have identified the following similar exposure groups (SEGs) for tasks with potential Cr(VI) exposure related to passivation of stainless steel:

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- Line operators
- Storage area workers
- Laboratory technicians
- Maintenance and/or cleaning workers
- Incidentally exposed workers (without direct Cr(VI)-related activities)

### 9.2.2.3 Technical and organisational risk management measures

All sites that perform passivation of stainless steel within the ADCR supply chains are specialised industrial sites being active in the EEA or the UK. They have rigorous internal safety, health, and environment (SHE) organisational plans. The sites adhere to best practices to reduce workplace exposures and environmental emissions to as low as technically and practically feasible and use automated processes to the extent possible. The possibility for and the degree of automation can vary between different sites and depend, among other factors, on the size of the site and the frequency with which the use in question is carried out.

#### 9.2.2.3.1 Workers

At all sites, risk management measures in accordance with Article 5 of Directive 2004/37/EC are implemented as appropriate.

##### 9.2.2.3.1.1 Technical measures

The technical measures implemented at the sites include:

- Requirement for SD: Closed systems and automation are used for tasks involving measuring and weighing of solids, where possible.
- Requirement for SD: Where use of closed systems and automation is not possible, local exhaust ventilation (LEV) systems that are appropriately designed, dimensioned, located and maintained to capture and remove the substances are used. Technical information on the LEV systems used is given for the respective worker contributing scenarios in sections 9.2.3.2 to 9.2.3.3.
- Chemical treatment baths are equipped with LEV, as described in the respective worker contributing scenarios in sections 9.2.3.2 to 9.2.3.3.
- Requirement for SD: When relevant and technically and practically possible, waste management activities are conducted under a LEV. Cases where this is not technically and/or practically possible are described and justified in the respective worker contributing scenarios in sections 9.2.3.2 to 9.2.3.3.

#### Efficiency of LEV

LEV systems are designed and installed for the specific baths to remove contaminants from the workers' breathing zone through exhaust extraction.

The efficiency of the installed LEV system depends on the exhaust air flow rate of the system per time unit. The sites follow the manufacturer requirements as well as recommendations from national guidelines, where applicable, and perform preventative maintenance of equipment to maintain the stated efficiencies of the LEV systems.

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## 9.2.2.3.1.2 Organisational measures

The following organisational measures to reduce workplace exposure are implemented at all sites:

- Annual monitoring programmes are implemented for air monitoring of occupational exposure to Cr(VI), which are representative of the range of tasks undertaken where exposure to Cr(VI) is possible, including tasks involving process and maintenance operations (requirement for CT and SD).
- The effectiveness of the risk management measures and operational conditions in place are regularly reviewed and, as applicable, measures are introduced to further reduce exposure and emissions.
- Requirement for SD: Appropriate standard operating procedures are implemented to minimise release of dust into the air during the preparation, transfer and storage of empty bags, filters, and other process waste, in accordance with the hierarchy of control provisions set out in Article 5 of Directive 2004/37/EC.
- LEV systems are inspected and maintained according to the manufacturer's specification.
- Standard procedures are available for use and maintenance of respiratory protective equipment (RPE) (including procedures for fit testing of RPE masks which are applied in accordance with relevant standards).
- The provision of PPE for the workers is organised by a designated responsible person.
- The conditions of the PPE are checked regularly.
- A program of PPE management is implemented on-site which includes PPE selection, training for correct wear/removal of the PPE, storage of PPE, cleaning or renewal and distribution of the PPE, communication via workplace signage or working instructions at the workplace.
- Training on chemical risks is periodically done for workers handling chemicals. Safety Data Sheets and instructions for hazardous chemicals handling are available.
- Training at the workplace is given periodically and work instructions are available on how to carry out specific tasks through standard operating procedures.
- Cleaning of company supplied uniforms is organised by the site, or contaminated clothes are renewed.
- In the production area reducing chemicals are available, which are suitable to remove Cr(VI) from the skin (e.g., ascorbic acid, formation of Cr(III), which can be washed off easily).
- Small splashes or amounts are taken up with wipes. Wipes are disposed of as solid waste.
- Chemical products are stored in a designated area.
- Effective cleaning practices are implemented to prevent surface contamination in the vicinity of the tanks.
- At some sites, water in rinsing tanks is recirculated and regularly tested for conductivity. When a certain conductivity limit is exceeded, the rinse water is treated as wastewater and renewed in the rinsing tanks. This prevents elevated Cr(VI) concentrations from being present in the rinsing tanks in the working area.

#### 9.2.2.3.1.3 Personal Protective Equipment

For all tasks with potential direct Cr(VI) exposure, standard operating procedures are available at the sites, wherein the appropriate PPE to be worn is specified (selected based on risks and in accordance with the exposure scenarios). The following PPE is applied for activities where exposure to Cr(VI) is possible, in order to control Cr(VI) exposures:

- Chemical protective clothing, where necessary (plus coveralls or aprons for specific tasks)
- Eye protection as per relevant risk assessment
- Chemical resistant gloves
- Respiratory protection, worn during all tasks not performed under an LEV for which industrial hygiene exposure assessment confirms RPE use is required.

#### **Use of Assigned Protection Factors (APFs) throughout this CSR**

The European Standard EN 529 – “Respiratory protective devices. Recommendations for selection, use, care and maintenance” provides guidance on the selection and use of RPE. It also lists “Assigned protection factors” as recommended in various European countries. RPE is described according to the types of device that will be in use rather than APF values to be met. Since APFs vary numerically between countries and no generally accepted factors exist, a conservative approach is taken in this review report, when APFs are used to calculate workers exposure. Where an APF is cited for a type of RPE, this will correspond to the lowest APF value for that type of RPE over all countries listed in the Table to Annex VI.

The specific PPE for each task is described in detail in the worker contributing scenarios in sections 9.2.3.2 to 9.2.3.3.

#### **9.2.2.3.2 Environment**

##### 9.2.2.3.2.1 Emissions to air

The following technical and organisational measures are implemented to reduce environmental air emissions to the maximum extent possible:

- All treatment baths and benches for touch-up applications are equipped with LEV systems. The local exhaust air is collected and released via exhaust stacks.
- The local exhaust air from treatment baths is treated in wet scrubbers or by air filters before it is released to the environment, although due to low temperatures and chromate concentrations in the passivation baths this is not considered essential. Working benches for touch-up applications with a brush or pad are equipped with a wet scrubber.
- Wash water in the wet scrubber is regularly exchanged when a certain threshold value of either conductivity, pH, or Cr(VI) concentration is exceeded. Regular replacement of the wash water helps to ensure that the cleaning performance of the wet scrubber does not decrease.
- Regular monitoring programmes for Cr(VI) emissions to air from LEV systems are implemented and the effectiveness of the risk management measures and operational conditions in place are regularly reviewed.

**Efficiency of air emission abatement technology**

- Wet scrubbers are regularly checked by measuring conductivity, pH, or Cr(VI) concentration ensuring proper function.
- The usual way to check the performance of air filters is to measure pressure loss.
- The efficiency of the wet scrubbers or air filters can also be checked by comparative measurements with and without the use of the wet scrubber/filter or between the duct inlet and outlet. At sites where such measurements are performed, very high efficiencies for air abatement can be demonstrated. As an example, such measured values from one site show a purification of the exhaust air from Cr(VI) concentrations in the range of several mg/m<sup>3</sup> (before the filter) to a concentration below the detection limit of the measurement method used (after the filter).

**9.2.2.3.2.2 Emissions to wastewater**

Cr(VI)-containing wastewater is gathered and either sent to an external waste management company (licensed contractor) or treated on-site in a reduction facility and/or evaporated in an on-site evaporation system (the residue is discharged as hazardous solid waste or liquid waste) and/or recycled or discharged in accordance with regulatory requirements.

For the reduction of environmental emissions to wastewater to the maximum extent possible, the technical and organisational measures implemented at the sites include:

- Wastewater is sent to a reduction facility (typically on-site), where Cr(VI) in wastewater is reduced to Cr(III) by addition of a reducing agent (e.g., sodium bisulfite or ferrous sulfate). After the reduction process, Cr(III) is precipitated and separated from the wastewater by a filter press (the filter cake is disposed as waste), and the treated wastewater is either reused, evaporated or discharged to a wastewater treatment plant (WWTP) or municipal sewage treatment plant (STP) or directly to the receiving water (depending on local regulatory requirements).
- Regular monitoring programmes for Cr(VI) emissions to wastewater are implemented and the effectiveness of the risk management measures (i.e., the efficiency of the wastewater reduction) and operational conditions in place are regularly reviewed.

**9.2.2.3.2.3 Emissions to soil**

The following technical and organisational measures are implemented to prevent environmental emissions to soil:

- The indoor and outdoor surfaces where chemicals are handled are sealed. Chemicals and solid waste containing Cr(VI) are stored in closed containers, either inside or outside
- Treatment baths are surrounded by a secondary containment pit and the solution collected in the containment pit is treated or disposed of as hazardous waste.

**9.2.2.3.3 Solid waste**

Solid waste generated at the sites may include the filter cake from the filter press (only contains Cr(III)), solid residues from the evaporation system for wastewater, and Cr(VI) contaminated waste from activities related to the surface treatment process (e.g., empty chemical containers and bags, brushes

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or pads used for touch-ups, filters, waste from cleaning activities, sorbents, contaminated equipment and PPE).

The filter cake containing Cr(III) is collected and stored in containers and forwarded to an external waste management company (licensed contractor) for disposal as waste.

The solid residues from the evaporation system for wastewater are collected and discharged as hazardous solid waste by an external waste management company (licensed contractor).

The Cr(VI)-contaminated solid waste such as contaminated wipes, rags and PPE (e.g., gloves, overalls, aprons), contaminated equipment or empty chemical containers (canisters, bags, drums) are usually disposed as hazardous waste unless they are cleaned prior to their disposal (if they are cleaned, they are disposed as non-hazardous solid waste). This hazardous solid waste is stored in closed drums and containers and forwarded to an external waste management company (licensed contractor) for disposal.

#### **9.2.2.4 Tonnages and mass balance considerations**

##### **9.2.2.4.1 Tonnages**

Assessed tonnage: 0.1 to 100 kg Cr(VI)/year per site based on:

0 to 120 kg CT used per year and site, thereof up to 62 kg Cr(VI)

0 to 250 kg SD used per year and site, thereof up to 100 kg Cr(VI)

At most sites SD is used for passivation of stainless steel.

##### **9.2.2.4.2 Mass balance considerations**

###### **Consumption during process**

During the bath treatment process, part of the Cr(VI) introduced in the bath is consumed, as it serves as a process aid to build the protective chromium oxide ( $\text{Cr}_2\text{O}_3$ ) layer on the component. Also Cr(VI) contained in the touch-up solution applied by brush or pad is consumed during treatment. Cr(VI) is reduced to Cr(III) in this process. Chromate-containing baths are kept for long periods and consumed chromate is replenished.

###### **Amount of Cr(VI) released to wastewater**

Only a minor share of the total amount of Cr(VI) used at the site goes into wastewater, but the Cr(VI) concentration in wastewater prior to reduction is not measured at the sites. During the reduction step Cr(VI) is converted to Cr(III) and after precipitation collected in a filter press.

As the concentration of Cr(III) in the filter cake is not measured, the amount of chromium leaving the process via the filter cake cannot be assessed.

The residual Cr(VI) in wastewater after reduction, which is released to an STP or WWTP, is between 0 and 0.0114 kg per year (as described in Annex III).

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**Amount of Cr(VI) discharged as waste**

Cr(VI) in solid waste occurs only in the form of solid residues from the wastewater evaporation system (at sites where this technique is performed) and as contaminated objects such as empty chemical containers/bags, brushes or pads used for touch-ups, filters, equipment, sorbents, cleaning materials and PPE; the quantities of Cr(VI) are negligible and not quantifiable. Some sites discharge (part of) their Cr(VI) wastewater as liquid waste by sending it to an external waste management company (licensed contractor). These quantities are highly variable and not consistently quantifiable.

**Amount of Cr(VI) released via fugitive emissions**

No measurement data is available for fugitive emissions. However, due to the low vapour pressure of the chromates and as the baths are usually covered with a lid when not in use, such emissions are expected to be low. When the baths are running, air emissions occur at higher temperatures, which are extracted by the LEV.

**Amount of Cr(VI) released to the atmosphere**

The exhaust air from treatment baths and working benches for touch-up applications released via exhaust stacks is between 0.000157 and 0.084 kg per year (as described in Annex III). The exhaust air is treated in wet scrubbers or by air filters before release. The wash water from wet scrubbers is released to the wastewater reduction plant and thus the Cr(VI) fraction washed off in a wet scrubber contributes to the Cr(VI) fraction released to wastewater.

### 9.2.3 Exposure scenario 1 for Use 1: "Passivation of stainless steel using chromium trioxide or sodium dichromate in the aerospace and defence industry and its supply chains"

**Market sector:** -

**Sector of use:** Other: Aerospace and defence industry and its supply chains

**Article categories:** not relevant

**Environment contributing scenario(s):** ERC 6b

**Worker/Consumer contributing scenario(s):** PROC 0, PROC 5, PROC 8b, PROC 9, PROC 10, PROC 13, PROC 15, PROC 28

**Subsequent service life exposure scenario(s):** not relevant

**Exposure scenario(s) of the uses leading to the inclusion of the substance into the article(s):** not relevant

**Description of the activities and technical processes covered in the exposure scenario:**

Passivation of stainless steel using CT or SD by immersion and touch-up applications with a brush or pad (see detailed use information in section 9.2.2).

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**Explanation on the approach taken for the ES:**

We established the exposure scenario based on sector-specific information provided by sites performing these activities.

**9.2.3.1 Environmental contributing scenario 1**

As CT and SD are not listed in REACH Annex XIV due to environmental effects, no environmental exposure assessment is performed here. However, we assessed the exposure of humans via the environment in the following sections.

**9.2.3.1.1 Conditions of use****Table 9-14: Conditions of use – environmental contributing scenario 1**

<b>Product (article) characteristics</b>
Product A: Solid SD (powder), pure substance (75-100%); max. <b>40% Cr(VI)</b>
Product B: Solid CT (flakes), pure substance (100%); <b>52% Cr(VI)</b>
Product C: Aqueous solution of SD as purchased (50-75.5% SD (w/w)); max. <b>30% (w/w) Cr(VI)</b>
<b>Amount used, frequency and duration of use (or from service life)</b>
Product A: Solid SD (powder), used to prepare aqueous bath solutions <ul style="list-style-type: none"> <li>▪ Daily use at site: up to 0.274 kg/day [as Cr(VI)]</li> <li>▪ Annual use at a site: up to 100 kg/year [as Cr(VI)]</li> <li>▪ Batch process</li> <li>▪ 365 days/year (see section 9.1.2.4.)</li> </ul>
Product B: Solid CT (flakes), used to prepare aqueous bath solutions <ul style="list-style-type: none"> <li>▪ Daily use at site: up to 0.170 kg/day [as Cr(VI)]</li> <li>▪ Annual use at a site: up to 62 kg/year [as Cr(VI)]</li> <li>▪ Batch process</li> <li>▪ 365 days/year (see section 9.1.2.4.)</li> </ul>
Product C: Aqueous solution of SD as purchased, used to prepare aqueous bath solutions <ul style="list-style-type: none"> <li>▪ Daily use at site: up to 0.142 kg/day [as Cr(VI)]</li> <li>▪ Annual use at a site: up to 52 kg/year [as Cr(VI)]</li> <li>▪ Batch process</li> <li>▪ 365 days/year (see section 9.1.2.4.)</li> </ul>
<b>Technical and organisational conditions and measures</b>

All products:

▪ **Technical measures**

- Air
  - Chemical treatment baths are equipped with LEV and
  - exhaust air is treated in wet scrubbers or by air filters before it is released via stack(s)
  - The dedicated bench where touch-up with a brush or pad is performed is equipped with LEV and a wet scrubber
  
- Wastewater
  - Wastewater occurs from bath solutions (depending on the site and the Cr(VI) concentration), rinsing water, cleaning water, liquid from secondary containment pits, water from wet scrubbers, and liquid hazardous waste from the laboratory
  - Cr(VI)-containing wastewater is gathered and either directly sent to an external company certified for disposing of liquid hazardous waste, recycled after evaporation in an on-site evaporation system (the residue is discharged as hazardous solid waste or liquid waste), and/or treated on-site in a reduction facility, where Cr(VI) in wastewater is reduced to Cr(III) by addition of a reduction agent (e.g., sodium bisulfite or ferrous sulfate), followed by neutralisation and precipitation of Cr(III)
  - Reduced wastewater is sent to a wastewater treatment plant (WWTP) or municipal sewage treatment plant (STP) (depending on local regulatory requirements).
  
- Soil
  - The indoor and outdoor surfaces where chemicals are handled are sealed and if chemicals and solid waste containing Cr(VI) are stored outside then it is only in closed containers
  - Tanks are surrounded by tank pits, which collect splashes and wash water and direct it to the wastewater collection tank

▪ **Organisational conditions and measures**

- Air
  - Cr(VI) air emission measurements are performed regularly at identified exhaust stack(s) where the process emissions are released
  
- Wastewater
  - Reduction of Cr(VI) in wastewater is controlled regularly by Cr(VI) measurements
  - Batches of reduced wastewater are discharged only after confirmation of Cr(VI) reduction to a concentration below the permitting limit (in accordance with the local regulatory requirements)

**Conditions and measures related to sewage treatment plant**

All products:

- Biological (municipal) STP: Standard STP or on-site treatment plant (removal rate: 50% to sludge

<p>assumed, see description in section 9.1.2.4.)</p> <ul style="list-style-type: none"> <li>▪ Sludge application to agricultural soil: in most cases not; however, as it is not ascertained in all cases, for a conservative assessment sludge application is assumed</li> <li>▪ Discharge rate STP: 2 000 m<sup>3</sup>/day (by model default if no site-specific data available)</li> <li>▪ Dilution factor for receiving water body: 10 (by model default if no site-specific data available)</li> </ul>
<b>Conditions and measures related to treatment of waste (including article waste)</b>
<p>All products:</p> <ul style="list-style-type: none"> <li>▪ Filter cake from the wastewater reduction plant only contains Cr(III) (since, even if the reduction were incomplete, residual Cr(VI) is readily soluble in water and would be found in the water phase) and is forwarded to an external waste management company (licensed contractor) for disposal as waste.</li> <li>▪ Other solid hazardous waste contaminated with Cr(VI) such as contaminated wipes, brushes or pads used for touch-ups, rags and PPE, contaminated equipment or empty chemical containers (canisters, bags, drums) are usually also disposed as hazardous waste unless they are cleaned prior to their disposal (if they are cleaned, they are disposed as non-hazardous solid waste). This hazardous solid waste is stored in closed drums and containers and forwarded to an external waste management company (licensed contractor) for disposal as hazardous waste.</li> </ul>
<b>Other conditions affecting environmental exposure</b>
<p>All products:</p> <ul style="list-style-type: none"> <li>▪ Process temperature of the treatment baths (20-70°C)</li> </ul>
<b>Additional good practice advice. Obligations according to Article 37(4) of REACH do not apply</b>
<ul style="list-style-type: none"> <li>▪ None</li> </ul>

The use of CT and SD for passivation of stainless steel in the aerospace and defence industry and its supply chains is carried out at small to large sites. The sites operate between 8 and 24h per day, on 5-7 days per week and up to 365 production days per year. Some plants have one or several annual shutdowns (of the whole plant or of individual baths/lines), while other sites are continuously running.

### Air emissions

The passivation process by immersion is carried out in treatment baths at temperatures between 21 and 70°C and with Cr(VI) concentrations of up to 2.2% (a detailed description is given in section 9.2.3.2). Cr(VI) air emissions generated during the treatment process are captured by LEV systems connected to the treatment. The exhaust air is then either treated in a wet scrubber (Figure 9-2 a + b) or by air filters. In stacks receiving exhaust air from baths with higher Cr(VI) concentrations and/or elevated temperatures Cr(VI) emissions to the environment are typically monitored in regular intervals at the sites. However, in stacks receiving only exhaust air from baths with lower Cr(VI) concentrations and/or low temperatures Cr(VI) emissions to the environment are not monitored at some sites.

At sites where a touch-up is performed with a brush or pad, the exhaust air from the dedicated work bench is treated in a wet scrubber. In the stack releasing the exhaust air, the Cr(VI) air concentration is regularly measured.

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Exhaust air from dedicated decanting and weighing stations (e.g., in the storage area), where the raw material is aliquoted, may also contribute to the air emissions of a site. However, due to the low frequency of such aliquoting processes, these emissions are negligible.

It must be noted that, in many cases, the monitored exhaust stack(s) also receive Cr(VI) emissions from other sources, usually from other Cr(VI) containing treatment baths located in the same line or process area as the treatment bath(s) for passivation of stainless steel.



**Figure 9-2: Wet scrubber (a + b)**

**Wastewater emissions**

Cr(VI) containing wastewater can arise from the following sources:

- bath solutions (depending on the site and the Cr(VI) concentration) when they are renewed
- rinsing water from rinsing tanks
- cleaning water (e.g., from bath cleaning, cleaning of empty chemical containers, general/workplace cleaning)
- liquid from secondary containment pits
- water from wet scrubbers
- liquid hazardous waste from samples processed in the laboratory.

At some sites, the bath solutions may also be collected and sent to an external waste management company (licensed contractor) (depending on the site and the Cr(VI) concentration). At sites where wastewater is recycled and evaporated in an on-site evaporation system, the residue is discharged as hazardous solid waste or liquid waste. All other wastewater is sent to an on-site reduction plant, where

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Cr(VI) in wastewater is reduced to Cr(III) by addition of a reduction agent (e.g., sodium bisulfite or ferrous sulfate) in excess, to ensure Cr(VI) reduction to a concentration below the permitting limit. Afterwards the wastewater is neutralised, and Cr(III) is precipitated (Figure 9-3 a). The precipitated Cr(III) is then separated from the wastewater by a filter press (Figure 9-3 b) and the filter cake is disposed by a certified waste handling company. In the reduced wastewater the Cr(VI) content is usually measured with a photometric method to confirm sufficient reduction in accordance with the permitted limit before the wastewater is sent either to a wastewater treatment plant (WWTP) or municipal sewage water treatment plant (STP). In addition to the photometric determination of Cr(VI) in wastewater on-site, the Cr(VI) concentration in reduced wastewater is at many sites also determined in regular intervals by external laboratories, whereby often more sensitive analytical methods are used, allowing the detection of very low Cr(VI) concentrations in wastewater.

For the present assessment, we included both the monitoring data from on-site assessments with the photometric method as well as measurements carried out by external laboratories. Similarly, as described above for the air emissions, also for wastewater, usually diverse sources contribute to the Cr(VI) emissions.



**Figure 9-3:** Water deionisation tanks for wastewater treatment (a) and filter press for separation of the filter cake (b)

### Soil emissions

There is no direct release to soil, based on equipment and procedures in place.

#### 9.2.3.1.2 Releases

The release fractions to water and air are calculated from the annual amount of Cr(VI) used at the sites and the amounts of Cr(VI) emitted to water and air. The site-specific release fractions are used as input for EUSES modelling of the environmental concentrations.

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In case the emissions originated from several Cr(VI) sources (e.g., exhaust air measurement of a stack through which the exhaust air of five Cr(VI) baths for different applications is released, or collected wastewater emissions of ten different Cr(VI) baths), we calculated environmental concentrations based on the share of the emission relevant for passivation of stainless steel. This share was determined by dividing the Cr(VI) amount used for passivation of stainless steel by the total Cr(VI) amount contributing to the measured emission (i.e., used for all uses contributing to the measured emission).

Seven sites performing passivation of stainless steel with CT and/or SD provided site-specific emission data for environmental emission modelling. One additional company provided release data for four sites in one EEA country, but it was not possible to allocate the company's total chromate consumption to the individual sites. Therefore, this company's emission data could not be considered in the present assessment. However, if the total chromate consumption was equally distributed among all four sites, the total risk per site would be lower than the maximum total risk of the seven sites considered for the HvE assessment.

Among these seven sites, five are in four different countries in the EEA and two sites are in the UK. All these sites perform additional surface treatments with Cr(VI) that contribute to environmental emissions.

Table 9-15 shows ranges of release fractions and total emissions from the sites. These release fractions served as input for EUSES modelling of human exposure via the environment. Note that the calculated release fractions to wastewater refer to the emissions after the on-site reduction step.

We point out that **these results represent the overall releases of the sites, among which in each case only a certain share is generated by passivation of stainless steel.** The calculation of the share of exposure from passivation of stainless steel (as described above) is performed after the EUSES calculation. Site-specific information on releases, on wastewater (application of sewage sludge to agricultural soil/grassland, dilution in the treatment plant and in the receiving water) and on the share of passivation of stainless steel of the overall emission are given in Annex III of this CSR.

**Table 9-15 Local releases to the environment**

Release route	Release fraction <sup>a</sup>	Release [kg/year] <sup>a</sup>	Explanation/Justification
<b>Air</b> <sup>b</sup>	3.92E-05 - 1.80E-02 Median = 2.00E-03	0.0205 - 6.57 Median = 0.547	Measured release (site-specific data)
<b>Water</b> <sup>b</sup>	0 - 2.14E-03 Median = 6.32E-05	0 - 1.42 Median = 0.0750	Measured release (site-specific data)
<b>Soil</b> <sup>b</sup>	0	0	No release to soil

<sup>a</sup> The indicated ranges of release fractions to wastewater, air and soil are based on recent release data and tonnages provided by sites that are representative to cover the whole release spectrum relevant for this use.

<sup>b</sup> For values <LOQ a value corresponding to LOQ/2 was used, as described in ECHA's Guidance on Information Requirements and Chemical Safety Assessment. Chapter R.16: Environmental exposure assessment (ECHA, 2016a). For wastewater emissions this is very likely an overestimation, since the upstream redox process leads to the almost complete conversion of Cr(VI) into Cr(III).

Two larger sites (Sites 6 and 7) have higher air emissions (4.48 and 6.57 kg/year) which are one order of magnitude higher than air emissions from other sites while their release fractions to air (2.00E-03 and 5.54E-03) are comparable to those of other sites. Thus, the air releases of these sites are higher

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than the median of the releases from all sites (0.547 kg/year). However, only small fractions of the air emissions of these sites are related to passivation of stainless steel. The total risk from environmental emissions from these sites related to passivation of stainless steel are well within the range respectively at the upper end of the range of risks from all sites (see below).

One out of the seven sites has no Cr(VI) emissions to water as all contaminated water is gathered and sent to an external waste management company (licensed contractor) for disposal (see Annex III). Two sites have water emissions (1.42 and 1.12 kg/year), which are at least one order of magnitude higher than water emissions from other sites while their release fractions to water ( $5.31E-04$  and  $2.14E-03$ ) are at the upper end of the range of release fractions for all sites. Accordingly, the water releases of these sites are higher than those from the other sites. However, total risks from environmental emissions calculated for these sites are well within the range or even at the lower end of emissions from all sites, as their air emissions (which are dominating site-specific total risks) are not in the upper range (see below).

The release to soil is zero for all sites since there are no direct releases to soil.

**Releases to waste**

Solid wastes are disposed of as described above by certified companies specialised in hazardous waste disposal. No emissions from solid wastes are expected.

Release fraction to waste from the process: 0

**9.2.3.1.3 Exposure and risks for the environment and humans via the environment**

The calculated exposure concentrations for humans via the environment (on a local scale) per site are shown in Annex III. The EUSES modelling protocols can be provided upon request. The calculation of the share of exposure and risk specifically for the individual use is performed after the EUSES calculation.

The calculation of the share of exposure and risk from passivation of stainless steel is shown below in Table 9-16. Note that even for sites without emission to wastewater EUSES calculates oral exposure via deposition from air.

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**Table 9-16: Excess cancer risk estimates for humans via the environment (general population, local assessment) attributed to passivation of stainless steel**

Site	Inhalation			Oral			Combined risk
	Local Cr(VI) PEC in air [ $\mu\text{g}/\text{m}^3$ ]	Excess lung cancer risk [ $1/(\mu\text{g}/\text{m}^3)$ ] <sup>a</sup>	Inhalation risk	Oral exposure (water and fish) [ $\mu\text{g Cr(VI)}/\text{kg} \times \text{d}$ ]	Excess cancer risk for tumours of the small intestine [ $1/(\mu\text{g}/\text{kg bw}/\text{day})$ ] <sup>b</sup>	Oral risk	
Site 1	3.33E-06	2.90E-02	9.67E-08	6.49E-05	8.00E-04	5.19E-08	1.49E-07
Site 2	7.37E-07	2.90E-02	2.14E-08	1.85E-08	8.00E-04	1.48E-11	2.14E-08
Site 3	1.65E-05	2.90E-02	4.77E-07	4.25E-07	8.00E-04	3.40E-10	4.78E-07
Site 4	2.28E-06	2.90E-02	6.60E-08	5.64E-08	8.00E-04	4.51E-11	6.60E-08
Site 5	1.19E-07	2.90E-02	3.45E-09	6.88E-09	8.00E-04	5.50E-12	3.46E-09
Site 6	2.13E-05	2.90E-02	6.18E-07	5.29E-07	8.00E-04	4.23E-10	6.18E-07
Site 7	6.41E-05	2.90E-02	1.86E-06	7.07E-06	8.00E-04	5.66E-09	1.86E-06
MIN	1.19E-07		3.45E-09	6.88E-09		5.50E-12	3.46E-09
<b>MAX</b>	<b>6.41E-05</b>		<b>1.86E-06</b>	<b>6.49E-05</b>		<b>5.19E-08</b>	<b>1.86E-06</b>
Median	3.33E-06		9.67E-08	4.25E-07		3.40E-10	1.49E-07
90th percentile	3.84E-05		1.11E-06	3.02E-05		2.42E-08	1.12E-06

<sup>a</sup> RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to  $1 \mu\text{g}/\text{m}^3$  Cr(VI) relates to an excess risk of  $2.9 \times 10^{-2}$  for the general population, based on 70 years of exposure; 24h/day.

<sup>b</sup> RAC dose-response relationship based on excess cancer risk for tumours of the small intestine (ECHA, 2013): Exposure to  $1 \mu\text{g}/\text{kg bw}/\text{day}$  Cr(VI) relates to an excess risk of  $8 \times 10^{-4}$  for the general population, based on 70 years of exposure; daily exposure.

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For the risk assessment of passivation of stainless steel, we conservatively use the maximum environmental concentrations and risks given the small number of sites. The maximum local PEC in air is  $6.41\text{E-}05 \mu\text{g}/\text{m}^3$  and the maximum inhalation risk is  $1.86\text{E-}06$ . The maximum oral exposure is  $6.49\text{E-}05 \mu\text{g Cr(VI)}/\text{kg}$  per day and the maximum oral risk is  $5.19\text{E-}08$ . **The maximum combined risk of humans via inhalation and oral exposure is  $1.86\text{E-}06$ .** Risks span a range of three orders of magnitude, mainly caused by differences in the size of the sites and amounts of substances used. The median for inhalation risk ( $9.67\text{E-}08$ ) and combined risks ( $1.49\text{E-}07$ ) is by approximately factor 10 lower than the maximum values. Risks from oral exposure are consistently lower than risks from inhalation for all sites.

The combined risks of the sites with the higher air emissions (Sites 6 and 7) are with  $6.18\text{E-}07$  and  $1.86\text{E-}06$  at the upper end of the range of calculated risks for all sites.

The overall risks of the sites with high water emissions mentioned above are well within respectively at the lower end of the range of calculated risks, as these sites have comparably low air emissions (combined risks of  $1.49\text{E-}07$  and  $3.46\text{E-}09$ ).

Note that the modelling of local air concentrations with EUSES is generally acknowledged as being overly conservative, as described in detail in section 9.1.2.4.2.

In Table 9-17, the RCRs for reproductive toxicity for humans via the environment are shown, based on the PECs as given in Table 9-16.

**Table 9-17: RCRs for reproductive toxicity for humans via the environment**

Site	Inhalation			Oral		
	Inhalation exposure [ $\mu\text{g}/\text{m}^3$ ]	DNEL inhalation systemic long-term [ $\mu\text{g}/\text{m}^3$ ]	RCR inhalation	Oral exposure [ $\mu\text{g}/\text{kg} \times \text{d}$ ]	DNEL oral systemic long-term [ $\mu\text{g}/\text{kg} \times \text{d}$ ]	RCR oral
Site 1	$3.33\text{E-}06$	11	$3.03\text{E-}07$	$6.49\text{E-}05$	17	$3.82\text{E-}06$
Site 2	$7.37\text{E-}07$	11	$6.70\text{E-}08$	$1.85\text{E-}08$	17	$1.09\text{E-}09$
Site 3	$1.65\text{E-}05$	11	$1.50\text{E-}06$	$4.25\text{E-}07$	17	$2.50\text{E-}08$
Site 4	$2.28\text{E-}06$	11	$2.07\text{E-}07$	$5.64\text{E-}08$	17	$3.32\text{E-}09$
Site 5	$1.19\text{E-}07$	11	$1.08\text{E-}08$	$6.88\text{E-}09$	17	$4.05\text{E-}10$
Site 6	$2.13\text{E-}05$	11	$1.94\text{E-}06$	$5.29\text{E-}07$	17	$3.11\text{E-}08$
Site 7	$6.41\text{E-}05$	11	$5.83\text{E-}06$	$7.07\text{E-}06$	17	$4.16\text{E-}07$
MIN	$1.19\text{E-}07$		$1.08\text{E-}08$	$6.88\text{E-}09$		$4.05\text{E-}10$
<b>MAX</b>	<b><math>6.41\text{E-}05</math></b>		<b><math>5.83\text{E-}06</math></b>	<b><math>6.49\text{E-}05</math></b>		<b><math>3.82\text{E-}06</math></b>
Median	$3.33\text{E-}06$		$3.03\text{E-}07$	$4.25\text{E-}07$		$2.50\text{E-}08$
90th percentile	$3.84\text{E-}05$		$3.49\text{E-}06$	$3.02\text{E-}05$		$1.78\text{E-}06$

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**Conclusion on risk characterisation:**Carcinogenicity

Combined risks of cancer by inhalation and by the oral route from the local assessment result in a maximum excess cancer risk of **1.86E-06 (maximum)**; range from 3.46E-09 to 1.86E-06). These theoretical cancer risks are based on a conservative, linear ERR. Further, due to the overly conservative nature of the predictions of the EUSES model for the local air concentrations the risk level can be considered an overestimation.

Reproductive toxicity

Risks for reproductive toxicity are negligible as RCRs for inhalation and oral exposure are orders of magnitude below 1.

Based on the gathered information and considering the implemented RMMs we conclude that risk of exposure is minimised.

**Comparison of outcome with initial applications**

The assessment of exposure of humans via the environment in this review report is based on measured data for emission to air and wastewater. For this assessment combined exposure of humans via the inhalation (air) and the oral (uptake of water and fish) route is considered.

Total exposure of humans via the environment via inhalation (maximum for local PEC in air = 6.41E-05  $\mu\text{g}/\text{m}^3$ ) and oral exposure (maximum for oral exposure from fish and drinking water = 6.49E-05  $\mu\text{g}/\text{kg}$  per day) results in an estimated excess cancer risk of 1.86E-06 (maximum of combined risks).

In the initial applications only the inhalation route was considered for the assessment of human exposure via the environment. The following exposure was estimated:

Application ID	Chromate	90 <sup>th</sup> percentile of PEC <sub>local air,ann</sub> [ $\mu\text{g}/\text{m}^3$ ]	Excess lung cancer risk
0032-04	CT	0.00325	9.43E-05
0032-05	CT	0.00325	9.43E-05
0043-02	SD	0.00186	5.39E-05

The excess lung cancer risk in the initial applications is 9.43E-05 for CT and 5.39E-05 for SD. These risks are about one order of magnitude higher than the maximum combined risk of 1.86E-06 as estimated for the present assessment, which considers emissions from all substances used at a site.

**9.2.3.2 Worker contributing scenario 1 – Line operators**

Line operators for passivation of stainless steel are usually involved in numerous activities related to the passivation process. Most of their working time they spend in a hall where the passivation tanks are located and where the immersion process takes place, either on activities with direct or indirect Cr(VI) exposure. Typical activities with possible Cr(VI) exposure performed by line operators are:

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Main tasks

- Task 1: Passivation of stainless steel parts via immersion or dipping, followed by rinsing and drying of parts (PROC 13)
- Task 2: Sampling of treatment baths (PROC 9)
- Task 3: Diverse cleaning activities – Cleaning of workplace, equipment, jigs (PROC 28)
- Task 4: Touch-up – preparation of touch-up solution and application with a brush or pad (PROC 5, PROC 9, PROC 10)

Secondary tasks

- Task 5: Bath make-up and addition, including decanting of substances and mixing them with water (PROC 5, PROC 8b)
- Task 6: Bath emptying and cleaning (PROC 28)
- Task 7: Waste management – Cleaning of empty chemical containers/bags (PROC 28)
- Task 8: Waste management – Handling of solid waste (PROC 8b)
- Task 9: Aliquot chemicals – Decanting of liquids (PROC 8b)
- Task 10: Aliquot chemicals – Measuring and weighing of solids (PROC 8b)

As tasks 5 to 10 are main tasks performed by the storage area workers, they are described in detail in the worker contributing scenario for storage area workers (see section 9.2.3.3).

Line operators might also be engaged in other activities not related to uses of Cr(VI) (e.g. loading/unloading of jigs or activities on non-Cr(VI) baths), and thus not be directly exposed. However, they may still experience indirect exposure when they perform tasks in the vicinity of running baths.

In the following sections, the conditions of use for each task with potential direct Cr(VI) exposure are specified and the individual activities are described in more detail.

**9.2.3.2.1 Conditions of use**

Table 9-18 summarises the conditions of use for the activities with direct Cr(VI) exposure related to passivation of stainless steel carried out by line operators.

**Table 9-18: Conditions of use – worker contributing scenario 1 – Line operators**

<b>Product (article) characteristics</b>
Product 1: Aqueous solution of CT or SD for Tasks 1 to 3 <ul style="list-style-type: none"> <li>▪ Concentration of substance in mixture for bath applications: up to 1.3% (w/w) Cr(VI) for CT bath or up to 2.2% (w/w) Cr(VI) for SD bath (based on ranges of CT (up to 2.5% (w/w)) or SD (up to 5.5% (w/w)) in the aqueous solution in the passivation bath)</li> <li>▪ Product type: Solids dissolved in a liquid or incorporated in a liquid matrix</li> <li>▪ Viscosity: Liquids with low viscosity (like water)</li> </ul>
Product 2: Solid SD (powder) for Task 4 (Preparation of touch-up solution) <ul style="list-style-type: none"> <li>▪ Substance product type: Powders, granules, or pelletised material</li> <li>▪ Dustiness: Powder</li> <li>▪ Moisture content: Dry product (&lt;5% moisture content)</li> <li>▪ Weight fraction: Pure material (100%)</li> <li>▪ Concentration in pure substance: 40% Cr(VI) for SD</li> </ul>

<p>Product 3: Aqueous solution of SD for Task 4 (Touch-up application with a brush or pad)</p> <ul style="list-style-type: none"> <li>▪ Concentration of substance in mixture for touch-up: up to 6% (w/w) Cr(VI) (based on SD concentration (15.2% SD (w/w)) in the aqueous solution used for touch-up applications)</li> <li>▪ Product type: Solids dissolved in a liquid or incorporated in a liquid matrix</li> <li>▪ Viscosity: Liquids with low viscosity (like water)</li> </ul>
<b>Amount used (or contained in articles), frequency and duration of use/exposure</b>
<p>Task 1: Surface treatment by dipping/immersion</p> <ul style="list-style-type: none"> <li>▪ Duration of activity 3-200 min/shift (time spent close to the bath)</li> <li>▪ Frequency of task: &lt;1-240 days/year (&lt;1-5 days/week, 48 weeks/year)</li> </ul>
<p>Task 2: Sampling of treatment baths</p> <ul style="list-style-type: none"> <li>▪ Amount: 50-300 mL sample</li> <li>▪ Duration of activity: 5-20 min/shift</li> <li>▪ Frequency of task: 12-240 days/year (&lt;1 day/week up to every day, 48 weeks/year)</li> </ul>
<p>Task 3: Cleaning of workplace, equipment, jigs</p> <ul style="list-style-type: none"> <li>▪ Duration of activity: 5-45 min/shift</li> <li>▪ Frequency of task: 24-240 days/year (1 day/2 weeks up to every day, 48 weeks/year)</li> </ul>
<p>Task 4: Touch-up – preparation of touch-up solution and application with a brush or pad</p> <ul style="list-style-type: none"> <li>▪ <u>Preparation of touch-up solution</u> <ul style="list-style-type: none"> <li>• Amount: 50-2000 mL</li> <li>• Duration of activity: up to 10 min/shift</li> <li>• Frequency of task: &lt;1-48 days/year (&lt;1 day/year up to once per week, 48 weeks/year)</li> </ul> </li> <li>▪ <u>Touch-up application with a brush or pad</u> <ul style="list-style-type: none"> <li>• Amount: 1-50 mL per application</li> <li>• Duration of activity: up to 60 min/shift</li> <li>• Frequency of task: &lt;1-48 days/year (&lt;1 day/year up to once per week, 48 weeks per year)</li> </ul> </li> </ul>
<b>Technical and organisational conditions and measures</b>
<p>Task 1: Surface treatment by dipping/immersion</p> <ul style="list-style-type: none"> <li>▪ LEV: yes</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<p>Task 2: Sampling of treatment baths</p> <ul style="list-style-type: none"> <li>▪ LEV: yes</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<p>Task 3: Cleaning of workplace, equipment, jigs</p> <ul style="list-style-type: none"> <li>▪ LEV: no</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>

Task 4: Touch-up – preparation of touch-up solution and application with a brush or pad

- LEV: yes, dedicated bench equipped with LEV
- Ventilation rate of general ventilation system: natural ventilation
- Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)

#### Conditions and measures related to personal protection, hygiene, and health evaluation

##### Gloves

Chemical resistant gloves are worn during all tasks (Task 1 to 4), except for Task 1 on an automatic or semi-automatic line.

All gloves used for the handling of chemicals are tested according to EN 374. A variety of materials are suited for protection against **CT** and **SD**.

The following materials have a breakthrough time  $\geq 8$ h for aqueous CT solutions (10% CT) and saturated aqueous SD solutions <sup>a</sup>:

- Natural rubber/Natural latex (0.5 mm)
- Polychloroprene (0.5 mm)
- Nitrile rubber/Nitrile latex (0.35 mm)
- Butyl rubber (0.5 mm)
- Fluorocarbon rubber (0.4 mm)
- Polyvinyl chloride (0.5 mm)

The following materials have a breakthrough time  $\geq 8$ h for aqueous CT solutions (50% CT) <sup>a</sup>:

- Fluorocarbon rubber (0.4 mm)

The following materials have a breakthrough time  $\geq 2$ h for aqueous CT solutions (50% CT) <sup>a</sup>:

- Polychloroprene (0.5 mm)
- Butyl rubber (0.5 mm)
- Polyvinyl chloride (0.5 mm)

The following material is assumed to have a breakthrough time  $\geq 4$ h for solid CT and SD:

- Butyl rubber (0.7 mm)

Type of gloves to be used for specific tasks is laid down in work instructions for the tasks.

##### Respiratory protection equipment

RPE is worn during all tasks not performed under an LEV for which industrial hygiene exposure assessment confirms RPE use is required.

The following types of RPE are used according to EN 529:2005 <sup>b</sup>:

- Half mask FFP3 (APF 10), half mask with P3 filter (APF 10), half mask with P3 combination filter (APF 10) or
- Full mask with P3 filter (APF 20), full mask with P3 combination filter (APF 20)

Type of RPE to be used for specific tasks is laid down in work instructions for the tasks.

##### Protective clothes

Chemical protective clothing must be worn during Tasks 1, 3 and 4. For all cleaning activities performed with a hose the workers wear an apron and waterproof boots.

Type of protective clothes to be used for specific tasks is laid down in work instructions for the tasks.

### Eye protection

Eye protection as per relevant risk assessment is worn during all tasks (Task 1 to 4).

Type of eye protection to be used for specific tasks is laid down in work instructions for the tasks.

### Other conditions affecting workers' exposure

Task 1: Surface treatment by dipping/immersion

- Place of use: indoors – any size workroom
- Temperature: up to 70 °C (range 20-70°C, typical ca. 55°C)
- Situation: Activities with open liquid surfaces or open reservoirs
- Open surface 0.1-3 m<sup>2</sup>
- Agitation: yes (not in every case)
- Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, <1 m)

Task 2: Sampling of treatment baths

- Place of use: indoors – any size workroom
- Temperature: up to 70 °C (range 20-70°C)
- Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, <1 m)
- Activity class: Activities with relatively undisturbed surfaces (no aerosol formation)
- Open surface 0.1-3 m<sup>2</sup>

Task 3: Cleaning of workplace, equipment, jigs

- Place of use: indoors – any size workroom
- Temperature: room temperature
- Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, <1 m)

Task 4: Touch-up – preparation of touch-up solution and application with a brush or pad

- Place of use: indoors – any size workroom
- Temperature: room temperature
- Preparation of touch-up solution
  - Activity class: Movement and agitation of powders, granules, or pelletised material
  - Situation: Transferring 0.1-1 kg/min
  - Containment of the process: Handling that reduces contact between product and adjacent air
- Touch-up application with a brush or pad
  - Situation: Spreading of liquid products
  - Spreading of liquids at surfaces or work pieces <0.1 m<sup>2</sup>/h

<ul style="list-style-type: none"> <li>▪ Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, &lt;1 m)</li> </ul>
<p><b>Additional good practice advice. Obligations according to Article 37(4) of REACH do not apply</b></p>
<ul style="list-style-type: none"> <li>▪ <i>None</i></li> </ul>

<sup>a</sup> <https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index.jsp>; accessed 8 December 2020.

<sup>b</sup> For selection of APF see Annex VI of this report.

### 9.2.3.2.2 Exposure and risks for workers

Between individual sites, the number of line operators working on passivation of stainless steel is variable, depending on the size of the site, the organisation of the treatment process (one individual bath vs. several baths organised in one or several lines, automatic vs. manual process) and the throughput and distribution of work. Also, the number of work shifts varies from site to site; one to three shifts per day are run at the sites. The shift duration is usually 8h but may also be up to 12h, depending on the organisation of the site and national law.

Usually, one to two line operators work per shift on lines where passivation of stainless steel is performed. It must be noted that passivation of stainless steel is commonly not a full-time activity of the line operators assigned to the line(s) where passivation of stainless steel takes place. At a maximum an operator working at this line spends 50% of his shift on passivation of stainless steel (and in most situations significantly less) and the other part of his shift on other Cr(VI) and Cr(VI)-free activities related to the line (e.g., conversion coating).

At some sites, also supervisors or process engineers who accompany the line operators may perform the tasks listed for line operators (spending a relevant part of their working time at the line). For those sites, the number of workers counted for line operators also includes these supervisors and process engineers.

We describe below in detail the relevant activities with direct Cr(VI) exposure for line operators and the working conditions.

#### Task 1: Surface treatment by dipping/immersion

The process of passivation of stainless steel is always carried out by immersion of stainless steel parts into a treatment bath. The parts are typically hung on or wired up to a grid, hook, or a jig (depending on the size and shape of the parts) and then immersed in the process bath. Often, when the parts are hung on a grid or wired up, the grid is also immersed in the bath.

Depending on the automation level of the process at the respective site, the line operator either

- manually transports the jig to the bath and hangs it in the bath, or
- moves it to the bath and immerses it by means of a crane, which he manoeuvres in short distance to the bath using a control device (semi-automated process), or,
- in the case of an automated process, he controls a pre-programmed, crane-controlled immersion process from a monitor located at some distance from the bath in a separate control area/room.

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The degree of automation for this process is highly dependent on the frequency of this application in the respective site (for high throughput applications processes are more likely to be automated), but the geometry and weight of the part also plays a decisive role in how far the process can be automated. All chemical treatment baths are equipped with LEV which is running while the bath is in use.

The immersion baths typically have a size of up to 3 m<sup>3</sup>. At some sites, only a small vessel with <10 L of volume is filled with the treatment solution and parts are dipped in, but the usual size of the treatment baths is between 0.02 and 3 m<sup>3</sup>. The Cr(VI) concentration in the bath ranges from 1.1 to 2.2% (w/w) and the process temperature is between 21 and 70 °C, but usually around 55°C. The immersion process is typically performed between <1 and 240 days per year, between <1 (at sites with frequencies of 1 time/year or less) and 50 times per week, which corresponds to <1 to 10 times per shift. The duration of the immersion process is between 3 and 60 min, but in case of an automated process, the line operator is not in the proximity of the bath during the treatment process. In case of a manual or semi-manual process, the line operator will only be close to the bath for up to 20 min (up to 10 min at the beginning and up to 10 min at the end) of the immersion process, in between he will leave the bath area. Based on this the duration, the time spent close to the bath ranges between 3 and 200 min per shift.

In rare cases, when stainless steel parts have been passivated, they may be subjected to a second passivation process to further increase the corrosion resistance of specific parts.

After the passivation bath, the parts are usually rinsed by immersion into one or two drag-out and/or rinsing tanks. In case of an automatic line, the parts may also be automatically rinsed with water steam while they are lifted by crane from the passivation bath, before they are immersed into a rinsing tank. The number of rinsing steps after the treatment process is variable from site to site and can depend on the Cr(VI) concentration in the treatment tank and on the wastewater treatment system of the site. The rinsed parts are then dried or cured (which may be at room temperature or with compressed air or in a heated oven) and do not undergo any further treatment involving Cr(VI).

When the passivation baths are not in use, they are usually cooled down to room temperature and usually covered with a lid to reduce the indirect Cr(VI) exposure for the workers in the vicinity.

Whenever the line operator is close to the treatment baths during the immersion process (including rinsing), he wears eye protection (as per relevant risk assessment), chemical resistant gloves, chemical protective clothing, as specified above in Table 9-18.

#### Task 2: Sampling of treatment baths

The treatment baths are sampled at regular intervals to determine the Cr(VI) concentration and potentially also other parameters of the treatment solution. Typically, the line operator takes a sample volume of 50-300 mL and performs sampling by one of the following techniques:

- Immersion of a sampling bottle or a vessel of typically 50-300 mL by hand into the treatment bath and filling it with up to 300 mL of bath solution. Then the vessel is rinsed several times in the rinsing bath(s) (located after the treatment bath) and closed for the transport to the laboratory. When using this technique, the line operator takes care that the glove itself does not encounter the bath solution.
- The sampling bottle is attached to a metal or plastic rod and is immersed
- A specific plastic sampling rod or a pipette is used with which a sample can be drawn up and transferred into a sample bottle (Figure 9-4 a-c).

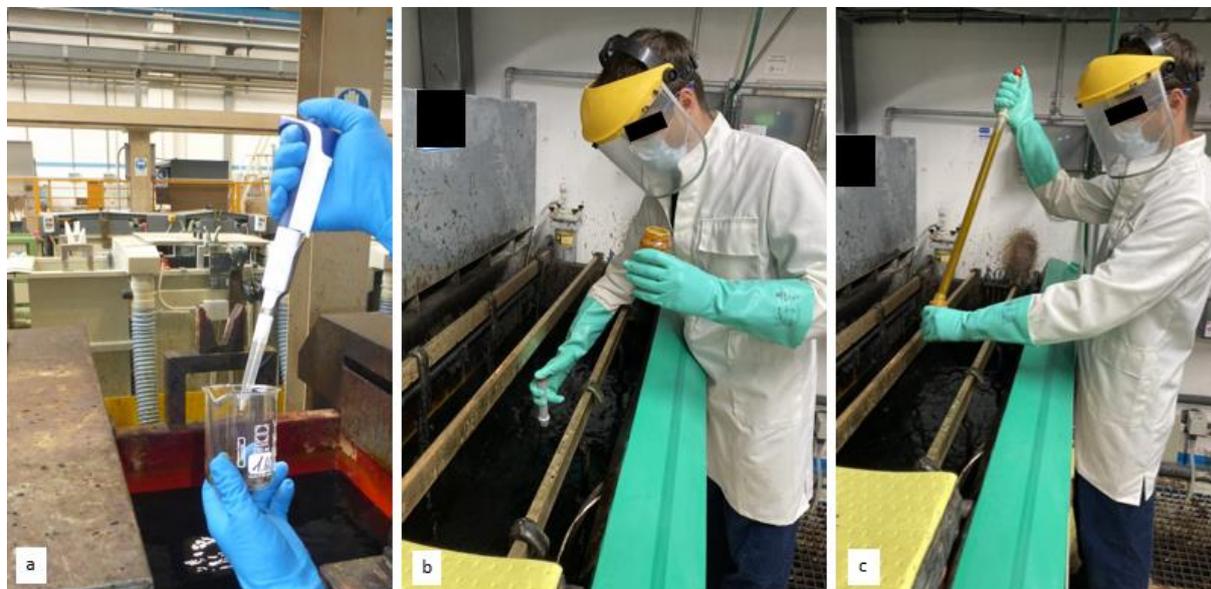
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The process of sampling and rinsing the sampling bottle/device takes up to 10 (typically 1-3) min. The concentration of the passivation bath is identical to that described for the immersion process (i.e., up to 2.2% Cr(VI)), the concentrations of the rinsing baths are much lower. The sampling can be carried out at temperatures between 20 and 70°C (typically around 55°C) and the LEV is running during this activity. The frequency of sampling is variable between different sites, depending on the frequency in which the immersion process is carried out and bath additions are necessary at the respective site, ranging between 10x/week (5 days/week, twice per day) and once per month.

During sampling, the line operator wears eye protection (as per relevant risk assessment) and chemical resistant gloves, and RPE (when sampling needs to be performed at a bath without a running LEV system and industrial hygiene exposure assessment confirms RPE use is required), as specified above in Table 9-18.

At some sites it may be the case that the sampling process as described above is not carried out by the line operator but by the storage area worker (see section 9.2.3.3) or the laboratory technician (see section 9.2.3.3).



**Figure 9-4: Sampling with a pipette for smaller (a) or larger (b + c) volumes**

### Task 3: Cleaning of workplace, equipment, jigs

General cleaning activities are regularly integrated in the daily routine and sporadic cleaning tasks are part of the responsibilities of line operators.

A typical regular cleaning activity performed at most sites is the cleaning of the floor around the bath at the end of a treatment sequence for the shift or working day. For this, the worker either rinses the floor around the baths with a hose, (the rinse water drains into the tank pits below the baths; see Figure 9-5), or he wipes the floor with a wiper mop (the cleaning water he disposes of in the on-site reduction plant).

Regular cleaning of external tank surfaces or of equipment such as jigs, hooks or containers used for bath additions/make-ups is typically performed by rinsing the equipment in the rinsing tanks or wiping the contaminated surfaces with paper towels or rags.

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Sporadic cleaning is, for instance, necessary when splashes occur from the immersion process, which the line operator rinses with water and/or wipes up with paper towels or rags, which are disposed of as hazardous solid waste. Another cleaning activity which occurs occasionally is when the baths are refilled with chemicals and some dust may deposit on the edges of the bath, which are then either removed, e.g., by wet cleaning with a rag, a hose, or vacuum cleaning (waste managed as solid hazardous waste).

For the present assessment, a regular general cleaning of the workplace, including equipment and jigs (if necessary), is considered as an integrated duty in the daily routine. Accordingly, line operators perform workplace cleaning between 6 times per day to at least once in two weeks, i.e., on up to 240 days per year, with a total duration of 5 to 45 min per shift where cleaning is performed. The cleaning is carried out at room temperature, and the line operators may come in contact with splashes of the treatment bath which contain a maximum of 2.2% Cr(VI) (the maximum concentration described for the immersion process above) or splashes of cleaning water from wiping solid dust (maximum Cr(VI) concentration in the cleaning water considered equal to that in the treatment baths). If cleaning is carried out with a hose the line operators may encounter aerosols formed from cleaning water and bath solution or cleaning water and solid chromate from bath solution dried on the floor or tanks. Cleaning with the hose results in rapid dilution of the bath solution of substance dried on the floor. Since any potential dust circulation is prevented by wet cleaning or vacuum cleaning negligible risk of dust exposure during cleaning activities exists. Technically it is impossible to have a suitable LEV installed wherever cleaning could occur and thus, cleaning is not performed under use of an LEV. For all these general cleaning activities the line operator wears eye protection (as per relevant risk assessment), chemical protective clothing (for all cleaning activities performed with a hose he also wears an apron and waterproof boots), chemical resistant gloves, and RPE (if not performed under an LEV and industrial hygiene exposure assessment confirms RPE use is required), as specified above in Table 9-18.



**Figure 9-5: Hose for cleaning the edges of the tanks and the walkways surrounding the baths**

**Task 4: Touch-up – preparation of touch-up solution and application with a brush or pad**

Passivation of stainless steel via a brush or pad is only performed at very few sites (<15% of all sites performing this use).

**Preparation of touch-up solution**

The line operator prepares a solution for touch-up applications by weighing the required amount of solid SD (40% Cr(VI)) in a fume hood and mixing it with water. He prepares at maximum 2 L of touch up solution (6% Cr(VI)) per event, but typically he prepares it afresh at smaller volumes several times per year (at maximum once per week, 48 times per year). For 2 L of touch-up solution the line operator weighs 0.122 kg Cr(VI) into a vessel and adds the appropriate amount of water. The weighing and mixing process is performed at room temperature and takes at maximum 10 min.

**Touch-up application with a brush or pad**

Touch-ups for passivation of stainless steel with a brush or pad are performed on small size components or small areas of parts. Typically, they are carried out on areas/parts that need to be reworked/corrected. Line operators perform the touch-up on dedicated work benches connected to an LEV. After the touch-up solution is applied, the treated parts are left to dry at room temperature.

The activity is typically performed up to 1x per week for up to 60 min (the duration depends on the geometry of the part(s)) by one line operator. Per event between 1 and 50 ml of touch-up solution are applied.

At sites where the preparation of touch-up solution and application with a brush or pad are performed, up to 11 line operators are qualified to do this task, but only one operator conducts the preparation and touch-up at a time (it may be a different line operator each time).

For the preparation of touch-up solution and application with a brush or pad the line operator wears eye protection (as per relevant risk assessment), chemical protective clothing and chemical resistant gloves, as specified above in Table 9-18.

**9.2.3.2.2.1 Inhalation exposure****Measured inhalation exposure concentration**

In total, 33 personal and 18 stationary measurements covering exposure from passivation of stainless steel are available for this SEG. Nine personal measurements were excluded from further analysis because they were below an unreasonably high LOQ (i.e., <2 and <10  $\mu\text{g}/\text{m}^3$ ). Also, seven stationary measurements were not considered in further analysis because they were below a high LOQ (i.e., <10  $\mu\text{g}/\text{m}^3$ ). Two additional stationary measurements (each 0.5  $\mu\text{g}/\text{m}^3$ ) were excluded because they were taken outside of the galvanic department and not close to a Cr(VI) source relevant for this SEG.

Of the remaining 24 personal monitoring data, 22 are long-term ( $\geq 2\text{h}$ )<sup>6</sup>, shift-representative and two are short-term (<2h) measurements. The remaining nine stationary measurements are eight long-term measurements and one short-term measurement.

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<sup>6</sup> All long-term measurements ( $\geq 2\text{h}$ ) are considered as shift-representative measurements and used as such as 8h TWA exposure values; no recalculation has been performed. Measurements <2h were not used to calculate 8h TWA exposure values.

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The personal monitoring data come from eight sites in four countries in the EEA (17 measurements) and from two sites in the UK (seven measurements). About 54% of the data (13 values, including one short-term measurement) are <LOQ and 46% (eleven values, including one short-term measurement) are >LOQ.

The nine stationary data come from five sites in two EEA countries. About 67% of the stationary measurements (six values, including one short-term measurement) are <LOQ and 33% (three values, all long-term measurements) are >LOQ.

A summary on the analytical methods for inhalation exposure monitoring and information on their LOQs is given in Annex IV of this report. The individual measurements can be provided upon request. An overview of the available data for line operators is given in Table 9-19.

**Table 9-19: Overview of available inhalation exposure measurements for WCS 1 – Line operators**

	n	>LOQ	<LOQ
<b>Personal</b>			
- Long-term (≥2h)	22	10	12
- Short-term (<2h)	2	1	1
<b>Stationary</b>			
- Long-term (≥2h)	8	3	5
- Short-term (<2h)	1	0	1

#### Personal measurements – long-term

Long-term personal measurements were taken at operators working at lines where passivation of stainless steel with CT or SD is performed. However, during many of the measurements, the line operators also had (potential) Cr(VI) exposure from other uses (e.g., pickling/etching, inorganic finish stripping, conversion coating, passivation of (non-Al) metallic coatings) with CT and/or other chromates). In addition, the workers may also have carried out Cr(VI) treatments for other industrial sectors (i.e., non-Aerospace and Defence sectors). During the personal measurements, the line operators were mainly engaged in performing and controlling the immersion process for passivation of stainless steel (Task 1) and other dipping processes with or without Cr(VI) (e.g., the uses described before). Also, during several measurements, the workers were hanging parts on racks, or unhooking them, cleaning the workplace or equipment (Task 3), performing touch-up activities (Task 4) and sometimes sampling of the treatment baths (Task 2).

In addition, during three of the measurements, weighing/measuring of solids or liquids in combination with bath make-up/addition was performed (all secondary tasks of line operators).

The arithmetic mean (AM) over the total of long-term personal measurements is 0.313 µg/m<sup>3</sup> and the 90<sup>th</sup> percentile is 0.690 µg/m<sup>3</sup> (Table 9-20). All measurements were taken from operators working at manual or semi-manual lines. During nine of the long-term personal measurements (41%), the workers performed activities related to passivation of stainless steel (with SD), but not to any other Cr(VI) use (according to the information provided by the sites). The AM of these single-use measurements is 0.159 µg/m<sup>3</sup> (individual values: 1.0, 2x 0.5, and 6x 0.05 µg/m<sup>3</sup>), which is below the AM of the total

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personal long-term measurements. Six of these measurements (6x 0.05  $\mu\text{g}/\text{m}^3$ ) were taken while the operator performed touch-up activities by brushing. Touch-up was performed under an LEV and the workers wore RPE (half mask with ABEK1P3 filter). Exposure from touch-up activities (AM = 0.05  $\mu\text{g}/\text{m}^3$ ) is by factor 6 lower than the AM of all long-term personal measurements. The three single-use measurements not covering touch-up activities (1.0, 2x 0.5  $\mu\text{g}/\text{m}^3$ ) are slightly higher than the AM over the total of long-term personal measurements, but it is not possible to conclude whether exposure from passivation of stainless steel is lower than exposure from other Cr(VI) uses due to the low number of these single-use measurements and because it is not clear from the available information on the measured values whether workers spent as much or less time on Cr(VI) activities during these three measurements than during measurements that also covered other Cr(VI) uses.

No single-use measurements are available related to passivation of stainless steel where the workers exclusively handled CT.

Personal measurements – short term

The two short-term exposure values are 2.45 and 0.25  $\mu\text{g}/\text{m}^3$ . During the measurement with the exposure of 2.45  $\mu\text{g}/\text{m}^3$  the operator performed sampling of the treatment bath (Task 2) and analysed it in the laboratory. During these activities the worker wore RPE (half mask with ABEK1P3 filter). The second measurement (0.25  $\mu\text{g}/\text{m}^3$ ) was carried out while the worker operated the line and performed jiggling.

Stationary measurements

The AM of the eight long-term stationary measurements available for passivation of stainless steel is 0.266  $\mu\text{g}/\text{m}^3$ . Three of these measurements were taken adjacent to tanks for passivation of stainless steel containing CT or SD. One measurement cannot be clearly assigned to this use (as it is unclear from the data description adjacent to which Cr(VI) tank the device was positioned). Four measurements were taken in the area where touch-up by brushing was performed for passivation of stainless steel with SD. The AM of the eight measurements is comparable to the AM of the personal long-term measurements (0.256  $\mu\text{g}/\text{m}^3$ ).

The short-term measurement was taken for 60 minutes and has an exposure value of 2.6  $\mu\text{g}/\text{m}^3$ . It is described that line operators at this site wear RPE (half mask with FFABEK1P3 filter) when they perform immersion processes for passivation of stainless steel.

Table 9-20 shows the summary statistics of workplace measurements for line operators. For values <LOQ, half of the LOQ (LOQ/2) was considered for statistical evaluation. All measurements are from the period 2018-2021.

**Table 9-20: Summary statistics of inhalation exposure measurements for WCS 1 – Line operators**

Personal – long-term (measurement period 2018-2021)						
	N	% of total	AM [ $\mu\text{g}/\text{m}^3$ ]	SD [ $\mu\text{g}/\text{m}^3$ ]	Median [ $\mu\text{g}/\text{m}^3$ ]	90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]
Total	22	100	0.313	0.294	0.220	0.690

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- Only this use covered by the measurement, with one or more chromates	9	41	0.256	n.a.	n.a.	n.a. (MAX = 1.00)
- Only this use covered by the measurement, with only SD	9	41	0.256	n.a.	n.a.	n.a. (MAX = 1.00)
- Only this use covered by the measurement, with only SD, performing touch-up	6	27	0.0500	n.a.	n.a.	n.a. (MAX = 0.05)
<b>Personal – short-term (measurement period 2020-2021)</b>						
	<b>N</b>	<b>% of total</b>	<b>AM [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>SD [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>Median [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>90<sup>th</sup> Perc. [<math>\mu\text{g}/\text{m}^3</math>]</b>
Total	2	100	1.36 <sup>a</sup>	n.a.	n.a.	n.a. (MAX = 2.45)
<b>Stationary – long-term (Measurement period 2018 and 2021)</b>						
	<b>N</b>	<b>% of total</b>	<b>AM [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>SD [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>Median [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>90<sup>th</sup> Perc. [<math>\mu\text{g}/\text{m}^3</math>]</b>
Total	8	100	0.266	n.a.	n.a.	n.a. (MAX = 1.01)
- Touch-up only	4	50	0.05	n.a.	n.a.	n.a. (MAX = 0.05)
<b>Stationary – short-term (2021)</b>						
Total	1	100	n.a. <sup>b</sup>	n.a.	n.a.	n.a.

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

n.a. = not assessed; the statistical parameter was only determined if at least three (for AM) or ten (for SD, Median and 90<sup>th</sup> percentile) values were available.

<sup>a</sup> The individual values are 2.45 and 0.26  $\mu\text{g}/\text{m}^3$ .

<sup>b</sup> The individual value is 2.6  $\mu\text{g}/\text{m}^3$ .

Risk characterisation is based on the complete set of long-term personal measurements. Table 9-21 shows the resulting long-term inhalation exposure concentration for line operators used for risk assessment, based on the 90<sup>th</sup> percentile of personal sampling values.

As stated above, partial exposure from sources and processes not related to the use of passivation of stainless steel has possibly contributed to most of the exposure values assigned to this use. Based on the information that operators spend at maximum 50% of their shift on passivation of stainless steel and most of their working time on other Cr(VI) and Cr(VI)-free activities, we assign 50% of the shift average exposure value (90<sup>th</sup> percentile of all long-term measurements) to this use.

Typically, one to two operators work per shift and one to three shifts are operative per site, depending on their size and organisation. This leads to a theoretical range of one to six workers engaged per site

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per day. In the following we assume that as a conservative average, **four line operators** per day are engaged in this use per site. For sites where the work is distributed among a higher number of workers, a higher number of people would have to be considered, but their long-term average individual exposure concentration would be lower.

RPE is sometimes worn for specific, short-term activities only (e.g., during sampling, as described for the short-term measurements), but usually not for Task 1 (immersion) because LEV is in place. Therefore, no RPE is considered in the exposure assessment, which constitutes a further conservative element of the assessment.

**Table 9-21: Measured inhalation exposure concentration for WCS 1 – Line operators**

Type of measurement	Number of measurements	Exposure value (8h TWA) <sup>a</sup> [ $\mu\text{g}/\text{m}^3$ ]	Assigned protection factor (APF) for RPE <sup>b</sup>	Exposure value corrected for RPE [ $\mu\text{g}/\text{m}^3$ ]	Long-term exposure <sup>c</sup> [ $\mu\text{g}/\text{m}^3$ ]
Personal	22	0.690	1	0.690	0.345

All exposure values rounded to three significant figures for presentation, but unrounded values were used for calculation of exposure.

<sup>a</sup> Based on 90<sup>th</sup> percentile of measurements.

<sup>b</sup> No RPE is considered, see text above.

<sup>c</sup> A frequency/duration correction factor of 0.5 was applied (see text above).

#### 9.2.3.2.2.2 Dermal exposure

In Table 9-22 the dermal exposure concentrations for line operators are shown, based on modelling of the activities with Cr(VI) exposure. The parameters considered for dermal exposure modelling are described in detail in Annex V of this report. For a conservative assessment of dermal exposure, we consider for modelling that only one line operator performs all tasks listed above (main and secondary tasks, including tasks typically performed by another SEG, such as aliquoting chemicals), that exposure from each activity adds up and that all tasks are performed at the maximum frequency.

**Table 9-22: Dermal exposure modelling for WCS 1 – Line operators**

Task	PROC(s)	Cr(VI) concentration [%]	Annual average dermal exposure value [ $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$ ]
Task 1: Surface treatment by dipping/immersion	PROC 13	2.20	0.754
Task 2: Sampling of treatment baths	PROC 9	2.20	0.754
Task 3: Diverse cleaning activities – cleaning of workplace, equipment, jigs	PROC 28	0.220 *	1.31
Task 4: Touch-up – preparation of touch-up solution and application with a brush or pad	PROC 5, PROC 9, PROC 10	40.0	2.74

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Task 5: Bath make-up or addition	PROC 5, PROC 8b	40.0	2.74
Task 6: Bath emptying and cleaning	PROC 28	0.220 *	0.0109
Task 7: Waste management – Cleaning of empty chemical containers/bags	PROC 28	4.00 *	4.76
Task 8: Waste management – Handling of solid waste	PROC 8b	2.20	0.754
Task 9: Aliquot chemicals – Decanting of liquids	PROC 8b	30.0	4.11
Task 10: Aliquot chemicals – Measuring and weighing of solids	PROC 8b	40.0	2.74
<b>Combination of all tasks</b>			<b>20.7</b>

All values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* 10-fold dilution assumed due to cleaning activity; for details see Annex V.

Despite the very conservative approach as described above, the combined dermal exposure value from all tasks of 20.7 µg Cr(VI)/kg bw/d does not exceed the DNEL of 43 µg Cr(VI)/kg bw/d.

## 9.2.3.2.2.3 Risk characterisation

**Risk for carcinogenicity**

Table 9-23 shows the risk characterisation for carcinogenicity for line operators. The risk for carcinogenicity is based on measured Cr(VI) inhalation exposure data for line operators and the RAC dose-response relationship for the excess lifetime cancer risk for lung cancer (ECHA, 2013).

**Table 9-23: Risk characterisation for carcinogenicity for WCS 1 – Line operators**

Route of exposure and type of effects	Long-term exposure [µg/m <sup>3</sup> ]	Risk characterisation: Excess lifetime lung cancer risk * [1/µg/m <sup>3</sup> ]	Excess lifetime cancer risk (ELCR)
Inhalation: Systemic Long Term	0.345	4.00E-03	1.38E-03

All values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to 1 µg/m<sup>3</sup> Cr(VI) relates to an excess risk of 4x10<sup>-3</sup> for workers, based on 40 years of exposure; 8h/day; 5 days/week.

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**Risk for reproductive toxicity**

Table 9-24 shows the risk characterisation for reproductive toxicity for line operators. The risk characterisation for reproductive toxicity is based on measured Cr(VI) inhalation exposure data for line operators and modelled dermal Cr(VI) exposure values which are compared to the RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

**Table 9-24: Risk characterisation for reproductive toxicity for WCS 1 – Line operators**

Route of exposure and type of effects	Long-term exposure	Risk characterisation: RAC DNEL *	Risk characterisation ratio (RCR)
Inhalation: Systemic Long Term	0.345 µg/m <sup>3</sup>	43 µg Cr(VI)/m <sup>3</sup>	0.00802
Dermal: Systemic Long Term	20.7 µg/kg bw/d	43 µg Cr(VI)/kg bw/d	0.481
<b>Combined inhalation and dermal exposure</b>			<b>0.489</b>

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

Note that during handling of solid waste very infrequently (approx. 2x/year) also waste with higher Cr(VI) concentrations (e.g., empty chemical containers) of up to 40% is handled/discarded. Due to the low frequency of this activity this only increases the dermal exposure minimally to 20.8 µg/kg bw/d, leading to a dermal RCR of 0.484.

**Conclusion on risk characterisation:**Carcinogenicity:

The excess life-time cancer risk for line operators is 1.38E-03.

This risk estimate can be considered as conservative, because:

- it is based on a conservative exposure-risk relationship (ERR),
- it uses the 90th percentile of the reported long-term measurements,
- these measurements were not corrected for their duration but assumed to be shift representative values,
- and no correction for wearing RPE was applied although workers may wear RPE under certain conditions for some short-term activities (such as cleaning or sampling).

As described above, it is considered for the assessment that **four line operators** per day and site work on the line(s) where passivation of stainless steel is performed. The total workforce sharing this work may be higher at some sites.

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Reproductive toxicity:

The RCR for the endpoint reproductive toxicity based on a conservative assessment is well below 1 (0.489).

Based on the gathered information and considering the implemented RMMs we conclude that risk of exposure is minimised.

**Comparison of outcome with initial applications*****Inhalation exposure***

In the initial applications, long-term inhalation exposure was determined by personal monitoring of workers typically performing the following activities:

- Loading of jigs (PROC 4); no LEV
- Chemical pre-treatment (PROC 13); LEV was used
- Dipping/immersion (PROC 2, PROC 13); LEV was used
- Rinsing/drying (PROC 13); no LEV
- Chemical post-treatment (PROC 13); LEV was used
- Cleaning and unloading of jigs (PROC 4); no LEV
- Cleaning of equipment (PROC 8b); no LEV
- Maintenance of equipment (PROC 8a) (regular maintenance); no LEV

This task list is broadly comparable with the activities carried out by the SEG line operators in the present assessment. During measurements included in the present assessment, mostly immersion processes and some cleaning of workplace/equipment were performed.

Initial assessment				Present assessment	
Application ID	Chromate	Inhalation, long-term exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]	Inhalation, long-term exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]
0032-04	CT	1.25	5.00E-03	0.345	1.38E-03
0032-05	CT	1.25	5.00E-03		
0043-02	SD	1.26	5.04E-03		

As shown in the table above, the excess lifetime lung cancer risk for line operators in the present assessment is with **1.38E-03** slightly (approximately factor 3.5) lower than the risk calculated in the initial applications (up to 5.04E-03; for SD). The current assessment is based on a more recent database and supported by additional data (short-term and stationary measurements).

Sampling

In the initial applications, inhalation exposure from sampling was modelled with ART 1.5 as part of two sub-activities:

- Sub-activity 1: Drawing of sample and transfer to the laboratory (<30 min)
- Sub-activity 2: Laboratory analysis (<60 min)

Modelling assumed that sampling was performed under a capturing hood (90% efficiency), without RPE. The Cr(VI) concentrations were up to 50% for CT and up to 10% for SD.

For the present assessment, the laboratory analysis of samples is not considered as this activity is exempted from authorisation (see explanation in section 9.2.3.4). Sampling is covered by some shift average measurements and a few short-term measurements performed on line operators, the exposure during sampling is within the 90<sup>th</sup> percentile of shift average personal measurements.

As shown in the table below, the excess lifetime lung cancer risk based on modelled inhalation exposure was up to 2.76E-03  $\mu\text{g}/\text{m}^3$  in the initial applications. The excess lifetime lung cancer risk for shift average measurements (including sampling activities) in the present assessment is with **1.38E-03** slightly (factor 2) lower than the risk calculated in the initial applications, but since the measurements cover multiple Cr(VI) tasks it can be assumed that the exposure from only the sampling activity is much lower.

Initial assessment (covering sampling and lab. analysis)				Present assessment	
Application ID	Chromate	Inhalation exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]	Inhalation exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]
0032-04	CT	0.69	2.76E-03	included above (0.345)	included above (1.38E-03)
0032-05	CT	0.69	2.76E-03		
0043-02	SD	0.65	2.60E-03		

#### Touch-up with a brush or pad

The inhalation exposure from touch-up by rolling and brushing was modelled with ART 1.5 in the initial application for SD.

Modelling assumed that the touch-up was performed without LEV or RPE. The Cr(VI) concentration was up to 5% for rolling and brushing.

For the present assessment, six personal and four stationary worker monitoring data are available for the touch-up application. They all have exposure values of 0.05  $\mu\text{g}/\text{m}^3$  and are by approximately factor 7 lower than the 90<sup>th</sup> percentile of the exposure values from long-term personal measurements of line operators in the present assessment (0.345  $\mu\text{g}/\text{m}^3$ ). Accordingly, it can be assumed that the long-term shift-average measurements well cover exposure from touch-up with a brush or pad.

Initial assessment				Present assessment	
Application ID	Chromate	Inhalation exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]	Inhalation, long-term exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]
<b>WCS 16 – Rolling and brushing (PROC 10)</b> < 60 min, up to 5% Cr(VI), no LEV, no RPE				included above (0.345)	included above (1.38E-03)
0043-02	SD	0.23	9.20E-04		

As shown in the table above, the excess lifetime lung cancer risk based on modelled inhalation exposure was 9.20E-04  $\mu\text{g}/\text{m}^3$  for rolling/brushing in the initial applications. The excess lifetime lung cancer risk for line operators in the present assessment is with **1.38E-03** slightly (approximately

factor 1.5) higher than the risk calculated in the initial applications, but the exposure from only the touch-up activity is expected to be much lower. This is supported by the **measurements available for the present assessment covering exclusively the touch-up activity**, which show long-term exposure values of **0.05 µg/m<sup>3</sup>** and are by factor 4 lower than the modelled exposure values from the initial applications.

#### ***Dermal exposure***

No quantitative dermal exposure assessment has been performed in the initial applications.

### **9.2.3.3 Worker contributing scenario 2 – Storage area workers**

The SEG defined as “storage area workers” comprises workers who perform several relevant activities related to passivation of stainless steel with potential for Cr(VI)-exposure, but who may have different names at diverse sites (e.g., chemical lab department worker, chemical operator, ...). Storage area workers are involved in several activities related to passivation of stainless steel with potential for Cr(VI)-exposure, but these tasks account only for a small fraction of their working time and mostly they are occupied with activities not related to passivation of stainless steel and without Cr(VI) exposure.

The storage area workers are responsible for ordering, storing, transporting, delivering, and managing the chemicals used at a site. A considerable part of their working time they spend on transport and handling of chemicals in closed containers, where no opportunity for Cr(VI) exposure exists. Typical tasks with potential Cr(VI) exposure are:

#### Main tasks

- Task 1: Aliquot chemicals – Decanting of liquids (PROC 8b)
- Task 2: Aliquot chemicals – Measuring and weighing of solids (PROC 8b)
- Task 3: Waste management – Cleaning of empty chemical containers/bags (PROC 28)
- Task 4: Waste management – Handling of solid waste (PROC 8b)
- Task 5: Bath make-up or addition, including decanting of substances and mixing them with water (PROC 5, PROC 8b)
- Task 6: Bath emptying and cleaning (PROC 28)

#### Secondary task

- Task 7: Sampling of treatment baths (PROC 9)

As task 7 is a main task performed by line operators, it has already been described in detail in the worker contributing scenario for line operators (see section 9.2.3.2).

In addition to the tasks listed above, the storage area workers may also perform and control the wastewater and sludge treatment at sites where wastewater is treated on-site, but at some sites, this can also be the responsibility of the laboratory technicians. The treatment of wastewater and sludge typically includes refilling of reducing agents, sampling of reduced wastewater, analysis of the Cr(VI) content in the wastewater samples (e.g., by means of a photometric quick test; for verification that the Cr(VI) content in the wastewater is below a threshold value under which release to the external WWTP or STP is permitted), dewatering and removal of the sewage sludge (containing only Cr(III)) and cleaning of the sludge press. However, as the duration the worker spends close to non-reduced wastewater is negligible and the reduced wastewater typically only contains traces of Cr(VI) (<0.3

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mg/L), wastewater treatment is not considered a relevant task with Cr(VI) exposure in this CSR. Exposure from wastewater and sludge treatment is expected to be covered by the exposure assessment performed for the above listed tasks.

The activities related to the use with potential direct exposure to Cr(VI) and the working conditions are described below in detail and are supported by worker air monitoring data covering one or more of these tasks.

### 9.2.3.3.1 Conditions of use

Table 9-25 summarises the conditions of use for the activities with Cr(VI) exposure related to passivation of stainless steel carried out by storage area workers. In this table only the conditions of use for Tasks 1 to 6 are described, the use conditions for Task 7 are given in the worker contributing scenario for line operators, in Table 9-18.

**Table 9-25: Conditions of use – worker contributing scenario 2 – Storage area workers**

<b>Product (article) characteristics</b>
Product 1: Solid CT or SD (flakes or powder) for Task 2, Task 3, and Task 5 <ul style="list-style-type: none"> <li>▪ Substance product type: Powders, granules, or pelletised material</li> <li>▪ Dustiness: Flakes or powder</li> <li>▪ Moisture content: Dry product (&lt;5% moisture content)</li> <li>▪ Weight fraction: Pure material (100%)</li> <li>▪ Concentration in pure substance: 52% Cr(VI) for CT, 40% Cr(VI) for SD</li> </ul>
Product 2: Aqueous solution of SD for Task 1, Task 3, Task 4, and Task 5 <ul style="list-style-type: none"> <li>▪ Concentration of substance in mixture: max. 30% (w/w) Cr(VI) for SD solution (based on ranges of SD (50-75.5% (w/w)) in aqueous solution used for bath make-up or addition)</li> <li>▪ Product type: Solids dissolved in a liquid or incorporated in a liquid matrix</li> <li>▪ Viscosity: Liquids with low viscosity (like water)</li> </ul>
Product 3: Aqueous solution of CT or SD for Task 4 and Task 6 <ul style="list-style-type: none"> <li>▪ Concentration of substance in mixture for bath applications: up to 1.3% (w/w) Cr(VI) for CT bath or up to 2.2% (w/w) Cr(VI) for SD bath (based on ranges of CT (up to 2.5% (w/w)) or SD (up to 5.5% (w/w)) in the aqueous solution in the passivation bath)</li> <li>▪ Product type: Solids dissolved in a liquid or incorporated in a liquid matrix</li> <li>▪ Viscosity: Liquids with low viscosity (like water)</li> </ul>
<b>Amount used (or contained in articles), frequency and duration of use/exposure</b>
Task 1: Aliquot chemicals – Decanting of liquids <ul style="list-style-type: none"> <li>▪ Amount per aliquot: &lt;1 up to 31.7 kg Cr(VI); corresponding to up to 25 L product 2 (density 1.68 g/cm<sup>3</sup>; up to 75.5% SD)</li> <li>▪ Duration of activity: 5-15 min</li> <li>▪ Frequency of task: 2-96 days/year (2x/year for high amounts for bath make-up or 2x/week for small amounts for bath addition)</li> </ul>
Task 2: Aliquot chemicals – Measuring and weighing of solids <ul style="list-style-type: none"> <li>▪ Amount per aliquot: &lt;1 up to 48 kg Cr(VI), corresponding to up to 120 kg product 1</li> <li>▪ Duration of activity: 5-10 min</li> </ul>

<ul style="list-style-type: none"> <li>▪ Frequency of task: 1-48 days/year (1 day/week, 48 weeks/year)</li> </ul>
<p>Task 3: Waste management – Cleaning of empty chemical containers/bags</p> <ul style="list-style-type: none"> <li>▪ Duration of activity: &lt;1-10 min</li> <li>▪ Frequency of task: &lt;1-48 days/year (&lt;1 days/year up to 1 day/week, 48 weeks/year)</li> </ul>
<p>Task 4: Waste management – Handling of solid waste</p> <ul style="list-style-type: none"> <li>▪ Duration of activity: 2-10 min (exposure duration)</li> <li>▪ Frequency of task: 2-240 days/year (2 days/year up to 5 days/week, 48 weeks/year)</li> </ul>
<p>Task 5: Bath make-up or addition</p> <ul style="list-style-type: none"> <li>▪ Amount: &lt;1-48 kg Cr(VI) (bath make up); &lt;1 kg Cr(VI) (bath addition)</li> <li>▪ Duration of activity: 5-60 min</li> <li>▪ Frequency of task: &lt;1-2 days/year (bath make-up) or &lt;1-48 days/year (bath addition)</li> </ul>
<p>Task 6: Bath cleaning</p> <ul style="list-style-type: none"> <li>▪ Duration of activity: 30-45 min</li> <li>▪ Frequency of task: &lt;1-2 days/year</li> </ul>
<p><b>Technical and organisational conditions and measures</b></p>
<p>Task 1: Aliquot chemicals – Decanting of liquids</p> <ul style="list-style-type: none"> <li>▪ LEV: yes/no; depending on the site</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<p>Task 2: Aliquot chemicals – Measuring and weighing of solids</p> <ul style="list-style-type: none"> <li>▪ LEV: yes/no; depending on the site</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<p>Task 3: Waste management – Cleaning of empty chemical containers/bags</p> <ul style="list-style-type: none"> <li>▪ LEV: no</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<p>Task 4: Waste management – Handling of solid waste</p> <ul style="list-style-type: none"> <li>▪ LEV: no; use of LEV during handling of solid waste is technically impossible</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<p>Task 5: Bath make-up or addition</p> <ul style="list-style-type: none"> <li>▪ LEV: yes</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<p>Task 6: Bath cleaning</p> <ul style="list-style-type: none"> <li>▪ LEV: yes/no; depending on the site</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>

### Conditions and measures related to personal protection, hygiene, and health evaluation

#### Gloves

Chemical resistant gloves are worn during both tasks. All gloves used for the handling of chemicals are tested according to EN 374. A variety of materials are suited for protection against **CT**, **SD**.

The following materials have a breakthrough time  $\geq 8$ h for aqueous CT solutions (10% CT) and saturated aqueous SD solutions <sup>a</sup>:

- Natural rubber/Natural latex (0.5 mm)
- Polychloroprene (0.5 mm)
- Nitrile rubber/Nitrile latex (0.35 mm)
- Butyl rubber (0.5 mm)
- Fluorocarbon rubber (0.4 mm)
- Polyvinyl chloride (0.5 mm)

The following materials have a breakthrough time  $\geq 8$ h for aqueous CT solutions (50% CT) <sup>a</sup>:

- Fluorocarbon rubber (0.4 mm)

The following materials have a breakthrough time  $\geq 2$ h for aqueous CT solutions (50% CT) <sup>a</sup>:

- Polychloroprene (0.5 mm)
- Butyl rubber (0.5 mm)
- Polyvinyl chloride (0.5 mm)

The following material has a breakthrough time  $\geq 4$ h for solid CT and SD:

- Butyl rubber (0.7 mm)

Type of gloves to be used for specific activities is laid down in work instructions for the activities.

#### Respiratory protection equipment

RPE is worn during Task 2 and 6. During Task 1, and Tasks 3 to 5 RPE is worn if not performed under an LEV and if industrial hygiene exposure assessment confirms that RPE use is required.

The following types of RPE are used according to EN 529:2005 <sup>b</sup>:

- Half mask FFP3 (APF 10), half mask with P3 filter (APF 10), half mask with P3 combination filter (APF 10) or
- Full mask with P3 filter (APF 20), full mask with P3 combination filter (APF 20)

Type of RPE to be used for specific tasks is laid down in work instructions for the tasks.

#### Protective clothes

Chemical protective clothing must be worn during all tasks. For all cleaning activities performed with a hose (may occur in tasks 3 and 6) the workers wear an apron and waterproof boots.

Type of protective clothes to be used for specific tasks is laid down in work instructions for the tasks.

#### Eye protection

Eye protection as per relevant risk assessment is worn during all tasks.

Type of eye protection to be used for specific tasks is laid down in work instructions for the tasks.

#### Other conditions affecting workers' exposure

##### Task 1: Aliquot chemicals – Decanting of liquids

- Place of use: indoors – any size workroom
- Temperature: room temperature
- Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, <1 m)
- Activity class: Falling liquids
- Situation: Transfer of liquid product with flow of 1–10 L/min
- Containment of the process: Handling that reduces contact between product and adjacent air

##### Task 2: Aliquot chemicals – Measuring and weighing of solids

- Place of use: indoors – any size workroom
- Temperature: room temperature
- Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, < 1 m)
- Activity class: Movement and agitation of powders, granules, or pelletised material
- Situation: Transferring 1-10 kg/min
- Containment of the process: Handling that reduces contact between product and adjacent air

##### Task 3: Waste management – Cleaning of empty chemical containers/bags

- Place of use: indoors – any size workroom
- Temperature: room temperature
- Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, <1 m)
- Activity class: Handling of contaminated solid objects or paste

##### Task 4: Waste management – Handling of solid waste

- Place of use: indoors – any size workroom
- Temperature: room temperature
- Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, <1 m)
- Activity class: Handling of contaminated solid objects or paste (worst case assumption, see section details in section 9.2.3.3.2.2)
- Handling type: Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.

##### Task 5: Bath make-up or addition

- Place of use: indoors – any size workroom
- Temperature: room temperature
- Situation: Activities with open liquid surfaces or open reservoirs
- Open surface 0.1-3 m<sup>2</sup>

<ul style="list-style-type: none"> <li>▪ Activity class: Movement and agitation of powders, granules or pelletised material or falling liquids</li> <li>▪ Situation: Transfer of 1-10 kg/min or transfer of liquid product with flow of 10-100 L/min</li> <li>▪ Containment of the process: Handling that reduces contact between product and adjacent air</li> <li>▪ Agitation: no (not in every case)</li> <li>▪ Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, &lt;1 m)</li> </ul>
<p>Task 6: Bath cleaning</p> <ul style="list-style-type: none"> <li>▪ Place of use: indoors – any size workroom</li> <li>▪ Temperature: room temperature or elevated temperature (up to 45°C)</li> <li>▪ Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, &lt;1 m)</li> </ul>
<p><b>Additional good practice advice. Obligations according to Article 37(4) of REACH do not apply</b></p>
<ul style="list-style-type: none"> <li>▪ <i>None</i></li> </ul>

<sup>a</sup> <https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index.jsp>; accessed 8 December 2020.

<sup>b</sup> For selection of APF see Annex VI of this report.

### 9.2.3.3.2 Exposure and risks for workers

The work system at a site can be divided in one to three shifts per day, with typically one or two workers per shift (up to seven workers per shift at some sites). The shift duration is usually 8h but may also be up to 12h, depending on the organisation of the site and national law.

We describe in detail below the relevant activities with direct Cr(VI) exposure for storage area workers and the working conditions.

#### Task 1 and Task 2: Aliquot chemicals – Decanting of liquids and decanting or weighing of solids

The aliquoting of chemicals needed for bath make-ups and additions is performed by the storage area workers either in the storage area (Figure 9-6 a), in the laboratory or close to the treatment bath. All measuring and weighing processes for solid chromates are carried out at a dedicated place. At sites where this is technically not possible, the storage area workers wear RPE during the measuring and weighing process if industrial hygiene exposure assessment confirms RPE use is required.

Task 1: To aliquot liquids, the storage area worker either carefully pours the required volume of the product into a graduated container or transfers it via a small hand pump (Figure 9-6 b). The measured volume per aliquot is at maximum 25 L chromate solution, depending on the required Cr(VI) concentration in the bath and the tank volume. Then the storage area worker closes the storage container or canister and the measurement vessel with lids. In case the chemical is measured in a measurement canister that cannot be closed, he transfers the measured liquid into a bottle which he then closes with a lid. The empty measurement vessel is rinsed with water and the rinsing water is collected

Task 2: For aliquoting solids, the worker opens the lid of a container with the solid substance (flakes or powder) and transfers the required quantity of the substance with a shovel into a measuring container or bag (Figure 9-6 c + d). The amount of substance to be aliquoted is at maximum 120 kg chromate per

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aliquot, depending on the required Cr(VI) concentration in the bath and the tank volume. Typically, during or after measuring, the storage area worker weighs the container or bag with the measured chemical on a scale to precisely adjust the required quantity (Figure 9-6 c + d). After this is achieved, the worker closes the container with the raw material and the container or bag with the aliquoted amount of substance. Whenever possible, entire containers or bags are used for bath make-ups and additives; aliquoting is then not required.



**Figure 9-6:** Storage room for chemicals (a), measuring of liquid chromate (b), measuring and weighing of solid chromate (c + d) in a dedicated area

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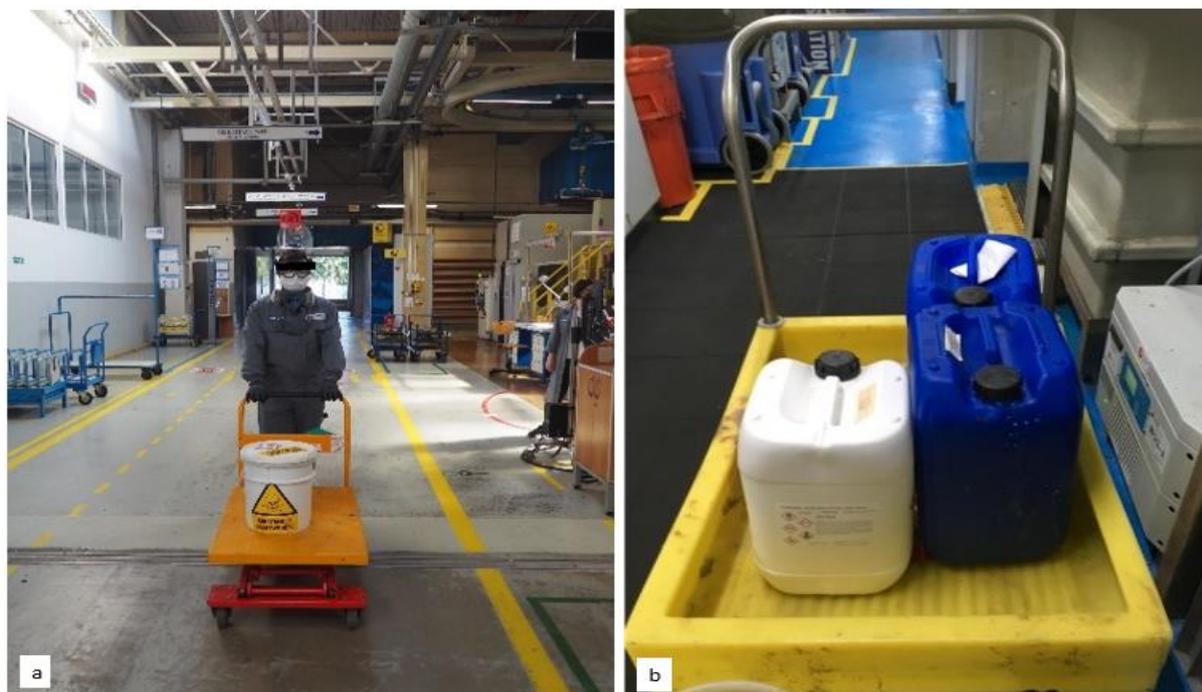
SD

**Task 1 + 2:** The closed containers, bags or bottles containing the aliquoted chemical are transported to the treatment bath where they are used for a bath make-up or addition (Figure 9-7). In cases where large quantities of chromates are required, the measuring of the solution or solid product is typically carried out at the bath.

The aliquoting procedure of either solids or liquids takes each approximately 5-10 min. Aliquoting of solids is performed typically up to 48 times per year and aliquoting of liquids typically up to 96 times per year, in each case as often as bath make-ups or additions are necessary. During aliquoting, the storage area worker wears eye protection (as per relevant risk assessment), chemical protective clothing, and chemical resistant gloves. At least at sites or in cases where it is technically impossible to aliquot within a fume hood or at a station equipped with an LEV, they also wear RPE (if industrial hygiene exposure assessment confirms RPE use is required), as described above. All relevant PPE is specified in Table 9-25.

At some sites, the storage area is equipped with an automatic filling station for solid substances. An automatic filling station is a closed system and requires no manual intervention by the workers. For plants equipped with such a system, the measured values recorded below represent a conservative exposure assessment.

The tasks of aliquoting chemicals as described above are at some sites not carried out by the storage area workers but by the line operators (secondary task of line operators; see section 9.2.3.2).



**Figure 9-7: Transport of solid (a) and liquid (b) chemicals to the treatment bath(s)**

**Task 3: Waste management – Cleaning of empty chemical containers/bags**

At sites where the containers in which the raw materials are delivered are rinsed and then disposed of as non-hazardous solid waste (see description below on Task 4), the cleaning of the containers is usually carried out by storage area worker. For this, he typically immerses the containers in the rinsing

bath and then carefully rinses them with a water hose above the rinsing bath until the wash water is clear. At some sites, he directly rinses the containers (without immersion prior to rinsing) above the drainage channel, so that the wastewater is drained to the on-site-wastewater treatment plant. When rinsing, the worker takes care not to splash the water out of the container.

Cleaning of chemical containers only occurs rarely, up to 48 times per year (at maximum as often as bath additions are necessary (see frequency described below), depending on the amount of chemical used per site for bath make up and the packaging size of the chromate used in the respective site). The storage area worker usually needs up to 10 min for one cleaning event of empty chemical containers/bags. As the rinsing baths are typically not equipped with LEV and it is practically impossible to rinse the empty chemical containers and bags at a place equipped with LEV, no LEV is used for this activity, but general ventilation is available at the workplace.

During cleaning of empty chemical containers/bags, the worker wears eye protection (as per relevant risk assessment), chemical protective clothing (for cleaning with a hose he also wears an apron and waterproof boots), chemical resistant gloves and RPE (if industrial hygiene exposure assessment confirms RPE use is required), as specified above in Table 9-25.

At some sites, the task of cleaning empty chemical containers is not carried out by the storage area workers but by the line operators (secondary task of line operators; see section 9.2.3.2).

#### Task 4: Waste management – Handling of solid waste

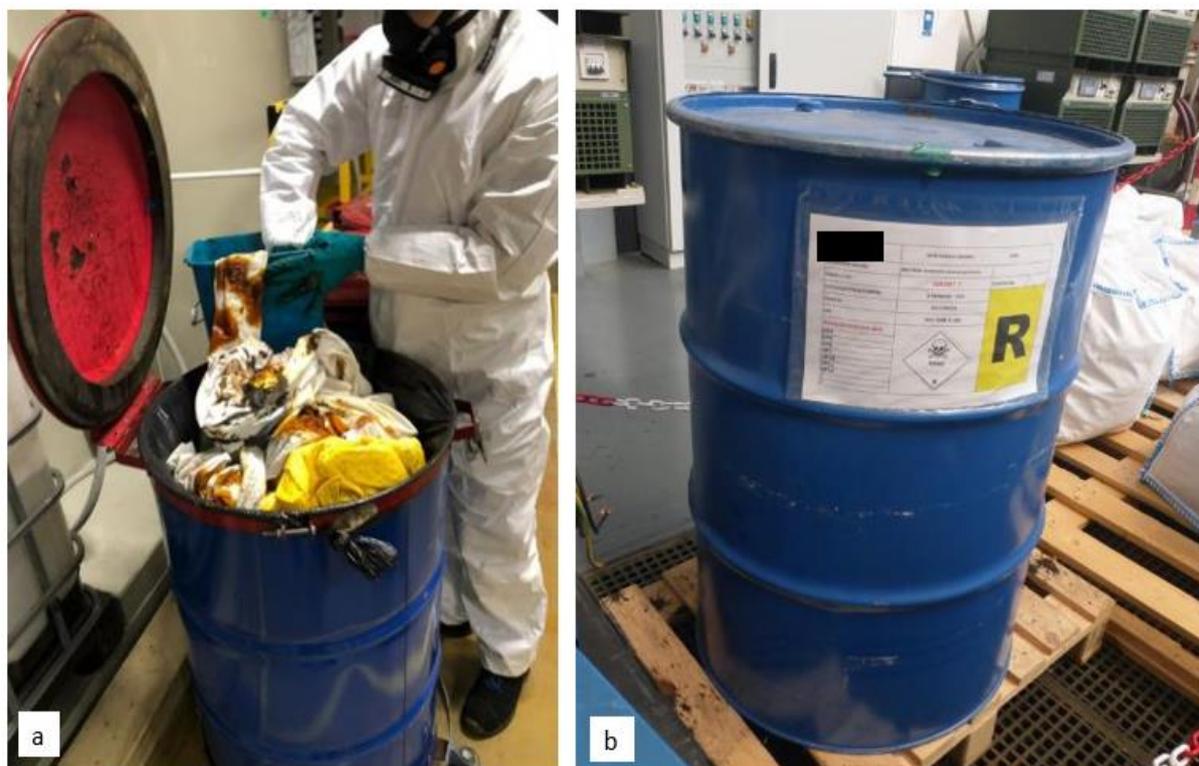
The hazardous solid waste generated from this use, especially from the passivation and cleaning activities (empty uncleaned bags and containers, contaminated wipes, brushes, or pads used for touch-ups, rags and PPE, sorbents, contaminated equipment, filter cartridges) is disposed of in a waste container, typically by the worker who generates the waste (Figure 9-8 a). In cases where there is a considerable amount of moisture in the waste, the worker may add a special sorbent to the waste to absorb the moisture. During the handling of empty bags, filters, and other process waste, the operator proceeds in accordance with appropriate standard operating procedures to reduce as low as possible the release of dust in the air during these operations.

At most sites, the waste container holds a waste bag in which the waste is collected. The waste container is placed e.g., near the passivation baths, in the storage area and/or in the laboratory, at a dedicated station and the container is closed when it is not in use (see Figure 9-8 b).

When the waste bag is full, the storage area worker will seal the waste bag and either remove it from the waste container and transport it to the storage area or leave the sealed waste bag in the storage container and transport both to the storage area. The waste remains in the storage area until it is sent to an external waste management company (licensed contractor) for disposal as hazardous waste. This activity is assumed to take place between two times per year and once per day at the end of a shift (the frequency may vary from site to site depending on the frequency at which the use is performed, and the amount of waste handled, as well as on the contribution of waste from other sources). The duration of the transport can be variable depending on the organization of the site, but the exposure duration (sealing of waste container/bag and transport to storage area/container) is maximum 10 min per day.

When handling solid waste, the worker wears eye protection (as per relevant risk assessment), chemical protective clothing, chemical resistant gloves and RPE (if industrial hygiene exposure assessment confirms RPE use is required), as specified above in Table 9-25.

At some sites, the handling of solid waste is not carried out by the storage area workers but by the line operators (secondary task of line operators; see section 9.2.3.2) or by the maintenance workers (secondary task of maintenance workers; see section 9.2.3.5).



**Figure 9-8: Operator discarding solid waste contaminated with Cr(VI) into a drum for hazardous waste (a); closed hazardous waste drum (b)**

#### Task 5: Bath make-up or addition

For bath make-up or addition, the storage area worker uses the appropriate amount of chemical (either pure solid substance or a solid or liquid mixture containing CT or SD) which he already aliquoted into a closed container, bottle, or bag (see description for Task 1 and 2 above; see Figure 9-9 a). Then he either mixes the aliquoted amount of chemical in a bucket with water and stirs it with a metal rod to prepare a homogenised pre-mixture (in case of solid chemical), or he fills it as it is (solid or liquid) in the treatment bath (Figure 9-9 b - c).

At some sites, bath make-up or addition is performed by first slightly moistening the solid to prevent dust formation, then transferring it to a fine-pored basket located on the bath. By adding water to the basket, a solution is then formed which runs directly into the bath.

For make-ups where high amounts of chromates are required, the storage area worker transfers the product directly from the original chemical container into the bath/basket, without it being aliquoted beforehand.

In case of bath make-up, the bath is either empty or filled by up to approximately 1/3 with water before the storage area worker slowly pours the chromate/mixture into the bath, taking care to pour at a minimum distance from the bottom of the bath or the water surface to avoid dust and/or splashing,

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and then tops it up with water. For bath addition the bath is already filled with treatment solution and the storage area worker only adds some chromate to adjust the Cr(VI) concentration in the bath (after the bath solution was sampled and the amount of chromate to be added to achieve the required chromate concentration was determined). Also here, the storage area worker slowly pours the chemical at a minimum distance from the surface of the bath solution to avoid dust and/or splashes.

Homogenous dilution of the chromate in the bath is often supported by permanent bath internal circulation or agitation. The LEV, with which all chemical treatment baths are equipped, is running during make-ups and additions.

During bath make-up and addition, the maximum Cr(VI) concentration is up to 52% when the raw material is handled, and the storage area workers use up to 48 kg Cr(VI) for bath make-up and up to 10 kg Cr(VI) for bath addition. Both tasks are carried out at room temperature. For bath make-up the whole process of mixing, transfer to the bath, pouring it in the bath and then filling the bath up with water takes up to several hours (at most sites 1-2 h). However, the operator may leave the bath in between (e.g., during filling of the bath), so that the exposure duration is at maximum 1 h per make-up. Typically, when a site performs very frequent bath additions (e.g., 1x/week), bath make-ups are rarely or never required.

For both, bath make-up and addition, the storage area worker wears eye protection (as per relevant risk assessment), chemical protective clothing, chemical resistant gloves and RPE (if industrial hygiene exposure assessment confirms RPE use is required), as specified above in Table 9-25.

At some sites it may be the case that bath make-up or addition is not carried out by the storage area workers but by the line operators (secondary task of line operators; see section 9.2.3.2).



**Figure 9-9:** Operator transfers a bucket with solid chromate to the tank (a); operator carefully pours the chromate into the bath for bath make-up or addition (b + c)

#### Task 6: Bath cleaning

The cleaning of the baths is carried out during a bath renewal. For this purpose, the storage area worker drains the old bath solution by gravity or by means of a pump and, depending on the site's

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wastewater management system and the concentration of the bath solution, either pumps it into an Intermediate Bulk Container (IBC) (see Figure 9-10 a), in which case it is later disposed of externally as a liquid hazardous waste<sup>7</sup>, or it is pumped to the on-site wastewater treatment plant, where it is reduced and neutralized (see a detailed description of the wastewater treatment process in section 9.2.2.3.2.2).

When the bath is drained, at some sites the storage area worker rinses it thoroughly with a hose and removes potential solid deposits in the bath with the water jet or wet and dry vacuum cleaner (Figure 9-10 b-d). The rinse water is pumped out and treated as wastewater. The water collected with the wet and dry vacuum cleaner is transferred to a special container and sent to an external company for treatment. When the bath is cleaned, it is ready for refilling (see description for bath make-up above). During the whole cleaning process the storage area worker usually spends up to 45 min at the bath, but during the draining process the worker may temporarily be away from the bath. Depending on the size of the plant and the number of passivation baths, bath cleaning is necessary up to two times per year. During the cleaning process, the treatment solutions and the rinsing water are in most events at room temperature, but sometimes they may be at elevated temperature (up to 45°C). At some sites, the LEV is running when the treatment bath is cleaned. For the bath cleaning the storage area worker wears eye protection (as per relevant risk assessment), chemical protective clothing (for cleaning with a hose he also wears an apron and waterproof boots; in case he enters the treatment bath he wears a chemical protective overall), chemical resistant gloves and RPE (at least at sites where the LEV is not running during bath cleaning and if industrial hygiene exposure assessment confirms RPE use is required), as specified above in Table 9-25.

At some sites it may be the case that bath cleaning is not carried out by the storage area workers but line operator but by the line operators (secondary task of line operators; see section 9.2.3.2) or by an external service provider.

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<sup>7</sup> At some sites, an external service provider pumps the contents of the IBC into a tank truck. Due to the low frequency of this activity (maximum 1x per month), the short duration in which the worker connects and disconnects the tank nozzle (approx. 5 min per event) and as the transfer is exclusively performed via closed lines this activity is not considered for a separate group of workers. It is expected that the exposure coming from this activity is covered by the number of workers, duration and frequency considered for the bath cleaning performed by the storage area workers.



**Figure 9-10: Bath emptying by transfer of old bath solution into an IBC (a) and bath cleaning with a hose and wet and dry vacuum cleaner (b, c, d)**

## 9.2.3.3.2.1 Inhalation exposure

**Measured inhalation exposure concentration**

Seven personal measurements covering exposure from passivation of stainless steel are available for storage area workers. One personal long-term measurement value was excluded from further analysis as it was below an unreasonably high LOQ (i.e.,  $<2 \mu\text{g}/\text{m}^3$ ). The remaining six values are four long-term ( $\geq 2\text{h}$ )<sup>8</sup>, shift-representative measurements, and two short-term ( $<2\text{h}$ ) measurement values. One stationary long-term measurement is available for storage area workers related to passivation of stainless steel.

It can be assumed that irrespective of the galvanic use, the exposure from the tasks listed above (e.g., weighing/measuring solids, bath make-ups/additions, bath cleaning) is comparable as they are performed in a similar manner. Also, measurements taken during the tasks assigned to storage area workers are typically related to numerous Cr(VI) uses, as it is either not possible to distinguish between exposure from different uses (e.g., when liquids or solids are aliquoted in batches (Tasks 1 and 2), when empty chemical containers are cleaned (Task 3), or when solid waste is handled (Task 4)) or the site providing the data did not further specify for which uses the tasks were performed during the measurement. Thus, all monitoring data for storage area workers available for diverse galvanic Cr(VI) uses (i.e., the galvanic Cr(VI) uses covered by ADCR) are pooled for the present exposure assessment of this SEG. Some of these measurements cover tasks not only related to galvanic but also to spraying uses (i.e., slurry coating and/or use of primer), e.g., when waste management was performed during these measurements. Since more than one chromate is used at many of the sites providing these measurements and the data are often not assignable to a single chromate, stratification according to substance is not reasonable.

In total, 139 personal measurements are available for storage area workers but three values are excluded from further analysis: the one value described above plus one long-term measurement value ( $13 \mu\text{g}/\text{m}^3$ ) which is considered as an outlier as it was performed in 2018 at one site and the same site reported three additional measurements for the years 2018 and 2019, during which the same activities were performed (weighing/measuring of solids, bath make-ups/additions, cleaning of empty chemical containers; even the same amount of chromate was used for bath make-ups during these measurements) at the same line, while the exposure values for these measurements were all between 0.3 and  $0.9 \mu\text{g}/\text{m}^3$ . In addition, one short-term measurement was excluded, taken in 2018 at the same site and bath where the long-term measurement from 2018 described above was taken. This short-term measurement of 15 min only covers the bath make-up and the exposure value of  $170 \mu\text{g}/\text{m}^3$  is orders of magnitude higher than other short-term measurements taken exclusively for bath make-ups (three measurements,  $0.05\text{-}0.55 \mu\text{g}/\text{m}^3$ , durations of 7-44 min). We assume that a problem occurred during this short-term measurement, as another short-term measurement of this site covering bath make-up from 2021 showed much lower exposure ( $0.55 \mu\text{g}/\text{m}^3$ , 7 min).

Of the remaining 136 personal monitoring data, 44 are long-term, shift-representative and 92 are short-term measurements. The personal monitoring data come from 27 sites in nine countries in the EEA (121 measurements) and from six sites in the UK (15 measurements). About 47% of the data (64

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<sup>8</sup> All long-term measurements ( $\geq 2\text{h}$ ) are considered as shift-representative measurements and used as such as 8h TWA exposure values; no recalculation has been performed. Measurements  $<2\text{h}$  were not used to calculate 8h TWA exposure values.

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values, including 45 short-term measurements) are <LOQ and 53% (72 values, including 47 short-term measurements) are >LOQ.

A total of twelve stationary measurements related to diverse Cr(VI) uses is available. Thereof, ten values are from long-term and two from short-term measurements. The twelve stationary measurements come from seven sites in the EEA. No stationary measurements for storage area workers are available from the UK. About 42% (five values, including one short-term measurement) are <LOQ and 58% (seven values, including one short-term measurement) are >LOQ.

A summary on the analytical methods for inhalation exposure monitoring and information on their LOQs is given in Annex IV of this report. The individual measurements can be provided upon request. An overview of the available data for storage area workers is given in Table 9-26.

**Table 9-26: Overview of available inhalation exposure measurements for WCS 2 – Storage area workers**

	n	>LOQ	<LOQ
<b>Personal – related to passivation of stainless steel</b>			
- Long-term (≥2h)	4	1	3
- Short-term (<2h)	2	2	0
<b>Personal – related to any Cr(VI) use</b>			
- Long-term (≥2h)	44	25	19
- Short-term (<2h)	92	47	45
<b>Stationary – related to passivation of stainless steel</b>			
- Long-term (≥2h)	1	0	1
<b>Stationary – related to any Cr(VI) use</b>			
- Long-term (≥2h)	10	6	4
- Short-term (<2h)	2	1	1

Personal measurements – related to passivation of stainless steel (long-term and short-term measurements)

The four long-term personal measurements were taken at storage area workers performing tasks related to passivation of stainless steel with CT and/or SD. During all measurements the storage area workers also had potential Cr(VI) exposure from other uses (e.g., pickling/etching, inorganic finish stripping, anodising, conversion coating, anodise sealing, chromate rinsing after phosphating, primer applications) with CT and/or other chromates, as storage area workers are typically responsible for providing chemicals for all baths and the spraying areas operating at a site. During these personal measurements, the workers mainly performed logistic activities related to chemical storage (transport, ordering), measuring of liquids (Task 1), weighing/measuring of solids (Task 2), bath make-ups or additions (Task 5) and sampling of treatments baths (secondary task of storage area workers). The arithmetic mean (AM) of the long-term personal measurements is 0.463 µg/m<sup>3</sup>. For none of these values it is reported that the workers wore RPE during the measurement.

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Of the two short-term measurements, one was taken for 5 min and has an exposure value of 1.21  $\mu\text{g}/\text{m}^3$ . It covers the weighing of 55 g SD (Task 2) in a fume cupboard with recirculation for either passivation of stainless steel, conversion coating or anodise sealing (not further specified in the data description). The other measurement was taken for 6 min and has an exposure value of 78.9  $\mu\text{g}/\text{m}^3$ . This measurement covers weighing of solid CT (Task 2) and bath addition (Task 5). No use of LEV is reported by the site. During both short-term measurements the workers wore RPE.

As described above, the measurements covering tasks assigned to storage area workers are typically related to numerous Cr(VI) uses and/or a distinction between the different uses is not possible. Therefore, the pooled monitoring data from all Cr(VI) uses are considered and discussed for the exposure assessment.

Personal measurements – related to any Cr(VI) use (long-term measurements)

The AM of the total long-term measurements is 0.374  $\mu\text{g}/\text{m}^3$  and the 90<sup>th</sup> percentile is 0.870  $\mu\text{g}/\text{m}^3$  for the pooled personal monitoring data. The exposure values cover decanting of liquids (Task 1), measuring/weighing of solids (Task 2), cleaning of empty chemical containers (Task 3), Handling of solid waste (Task 4), bath make-up or addition (Task 5), bath emptying and cleaning (Task 6), sampling of treatment baths (secondary task of storage area workers), logistic activities related to chemical storage (transport, ordering), and wastewater treatment. The pooled long-term measurements cover all the tasks described for the storage area workers, so there is an overlap with the data related to passivation of stainless steel. However, due to the limited number of values, the latter only include part of the tasks of storage area workers and therefore we consider it reasonable to pool the data from all galvanic Cr(VI) uses to cover all relevant tasks during the measurements. The AM of the pooled personal monitoring data is comparable to the AM of the monitoring data related to passivation of stainless steel (0.463  $\mu\text{g}/\text{m}^3$ ), supporting the assumption that exposure from tasks assigned to storage area workers is comparable between different galvanic uses, as they are performed in a similar manner.

Use of RPE (e.g., 3M protective half mask with filters 5935 P3 + absorber 6057ABE1 or RPE full face 3M model 7500, filter 6057 ABE1) was documented for approximately half of the long-term measurements (20 values).

Nine of the long-term measurements cover activities related to wastewater/sludge treatment (e.g., neutralization of Cr(VI) in sewage, packing of dried sludge) as the only potential Cr(VI) exposure source. The values of these measurements are within a range of 0.01-0.9  $\mu\text{g}/\text{m}^3$ .

Personal measurements – related to any Cr(VI) use (short-term measurements)

The 92 short-term measurements cover all relevant tasks performed by storage area workers:

- Task 1: Decanting of liquids (four values, 0.052-13.9  $\mu\text{g}/\text{m}^3$ , 9-101 min; all values also cover bath make-up/addition, and one value also includes bath cleaning)
- Task 2: Measuring and weighing of solids (37 values; 0.04-172  $\mu\text{g}/\text{m}^3$ , 3-115 min; 19 values also cover bath make-up/addition, and one value also includes bath cleaning)
- Task 3: Cleaning of empty chemical containers/bags (one value, 28  $\mu\text{g}/\text{m}^3$ , 15 min)
- Task 4: Handling of solid waste/waste management (nine values, 0.0425-0.54  $\mu\text{g}/\text{m}^3$ , 15-118 min, two values also include diverse cleaning activities)
- Task 5: Bath make-up or addition, including decanting of substances and mixing them with water (55 values, 0.018-105  $\mu\text{g}/\text{m}^3$ , 2-115 min; 24 values also cover measuring/weighing of solids or liquids, and one value also includes bath cleaning)

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- Task 6: Bath emptying and cleaning (four values, 0.018-11  $\mu\text{g}/\text{m}^3$ , 44-67 min; all values also cover bath make-up/addition, and two values also include weighing/measuring of solids or liquids)
- Wastewater treatment (six values, 0.09-6  $\mu\text{g}/\text{m}^3$ , 10-75 min; one value also covers bath cleaning)

Note that some of the measurements cover more than one task and are thus be listed above more than once.

Although some measurements result in high exposure values due to the short measurement duration (e.g., the highest short-term exposure value is 172  $\mu\text{g}/\text{m}^3$  with a measurement duration of 7 min during measuring/weighing of solids, RPE with a high APF (Breathing apparatus - Constant flow airline) was used) the long-term measurements covering such tasks show that these activities only contribute to a low extent to the shift-average exposure of storage area workers.

In addition, workers wear respiratory protection for such short-term activities for which industrial hygiene exposure assessment confirms RPE use is required. Use of RPE is documented for many of the short-term measurements listed above, i.e., all measurements with exposure values  $>1 \mu\text{g}/\text{m}^3$  and most of measurements covering measuring/weighing of solids and bath make-up/additions.

#### Stationary measurements – related to passivation of stainless steel (long-term measurement)

The long-term stationary measurements available for passivation of stainless steel were taken in the area in front of open containers for collection of process wastewater, in which the workers are only present irregularly and for short periods of time. The tank collects wastewater related to the Cr(VI) uses passivation of stainless steel, conversion coating and anodise sealing. The exposure values are 1.21 and 78.9  $\mu\text{g}/\text{m}^3$ .

#### Stationary measurement – related to any Cr(VI) use (long-term and short-term measurements)

The AM of the ten pooled long-term stationary measurements for all galvanic Cr(VI) uses is 0.108  $\mu\text{g}/\text{m}^3$  and the 90<sup>th</sup> percentile is 0.245  $\mu\text{g}/\text{m}^3$ . During two of these measurements, decanting of liquids (0.05  $\mu\text{g}/\text{m}^3$ ) and measuring/ weighing of solids (0.0565  $\mu\text{g}/\text{m}^3$ ) was performed. Three measurements were taken in the area where wastewater is collected and/or treated (including the one mentioned above; 0.004-0.376  $\mu\text{g}/\text{m}^3$ ) and five values are from stationary sampling in the storage area (0.036-0.23  $\mu\text{g}/\text{m}^3$ ), e.g., in front of a chemical cabinet, in which Cr(VI) containing products are stored. By the AM and 90<sup>th</sup> percentile of stationary exposure values being lower than the AM (0.374  $\mu\text{g}/\text{m}^3$ ) and 90<sup>th</sup> percentile (0.870  $\mu\text{g}/\text{m}^3$ ) of the shift-average exposure concentration for this SEG it is indicated that the background exposure concentration for storage area workers is lower than when they perform specific Cr(VI)-related tasks.

Of the two static short-term measurements, one was taken next to a collection tank and diverse activities of waste management and cleaning were performed during the measurement (0.14  $\mu\text{g}/\text{m}^3$ , 30 min), the other the stationary sampling device was positioned in the wastewater treatment area (0.06  $\mu\text{g}/\text{m}^3$ , 111 min).

Table 9-27 shows the summary statistics of workplace measurements for storage area workers. For values  $<\text{LOQ}$ , half of the LOQ (LOQ/2) was considered for statistical evaluation. All measurements are from the period 2016-2021.

**Table 9-27: Summary statistics of inhalation exposure measurements for WCS 2 – Storage area workers**

<b>Personal – related to any Cr(VI) use (measurement period 2016-2021)</b>						
	<b>N</b>	<b>% of total</b>	<b>AM [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>SD [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>Median [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>90<sup>th</sup> Perc. [<math>\mu\text{g}/\text{m}^3</math>]</b>
Long-term	44	100	0.373	0.512	0.195	0.870
Short-term	92	100	9.76	26.4	0.978	23.2
<b>Personal – related to passivation of stainless steel (measurement period 2018-2021)</b>						
	<b>N</b>	<b>% of total</b>	<b>AM [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>SD [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>Median [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>90<sup>th</sup> Perc. [<math>\mu\text{g}/\text{m}^3</math>]</b>
Long-term	4	9	0.463	n.a.	n.a.	n.a. (MAX = 1.00 $\mu\text{g}/\text{m}^3$ )
Short-term	2	2.2	n.a. <sup>a</sup>	n.a.	n.a.	n.a.
<b>Stationary – related to any Cr(VI) use (measurement period 2020-2021)</b>						
	<b>N</b>	<b>% of total</b>	<b>AM [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>SD [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>Median [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>90<sup>th</sup> Perc. [<math>\mu\text{g}/\text{m}^3</math>]</b>
Long-term	10	100	0.108	0.119	0.0593	0.245
Short-term	2	100	0.100 <sup>b</sup>	n.a.	n.a.	n.a. (MAX = 0.140)
<b>Stationary – related to passivation of stainless steel (measurement from 2021)</b>						
Long-term	1	10	n.a. <sup>c</sup>	n.a.	n.a.	n.a.

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

n.a. = not assessed; the statistical parameter was only determined if at least three (for AM) or ten (for SD, Median and 90<sup>th</sup> percentile) values were available.

<sup>a</sup> The individual values are 1.21 and 78.9  $\mu\text{g}/\text{m}^3$ .

<sup>b</sup> The individual values are 0.06 and 0.14  $\mu\text{g}/\text{m}^3$ .

<sup>c</sup> The value is 0.004  $\mu\text{g}/\text{m}^3$ .

All pooled personal long-term measurements of storage area workers are included in the assessment of inhalation exposure. Table 9-28 shows the resulting long-term inhalation exposure concentration for storage area workers used for risk assessment, based on the 90<sup>th</sup> percentile of personal sampling values.

As stated above, exposure from sources and processes not related to the use of passivation of stainless steel contributed to most of the exposure values. Considering that storage area workers typically spend only a minor part of their working time on activities related to passivation of stainless steel

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(rounded up to 2%<sup>9</sup>), we assign 2% of the shift average exposure value (90<sup>th</sup> percentile of all long-term measurements) to this use.

Typically, one or two workers per shift are engaged, with one to three shifts per site. On average, we assume that **four storage area workers per day** are engaged per site and that **each worker spends a maximum of 2% of his working time on activities related to passivation of stainless steel**. Consequently, the long-term exposure concentration is corrected by a factor of 0.02. For sites where the work is distributed among a higher number of workers, a higher number of people would have to be considered, but their long-term average individual exposure concentration would be lower.

RPE is worn during short-term activities for which industrial hygiene exposure assessment requires it. As these activities usually only account for shorter periods of the shift average measurements, no RPE is considered in the exposure assessment, which constitutes a further conservative element of the assessment.

**Table 9-28: Measured inhalation exposure concentration for WCS 2 – Storage area workers**

Type of measurement	Number of measurements	Exposure value (8h TWA) <sup>a</sup> [ $\mu\text{g}/\text{m}^3$ ]	Assigned protection factor (APF) for RPE <sup>b</sup>	Exposure value corrected for RPE [ $\mu\text{g}/\text{m}^3$ ]	Long-term exposure <sup>c</sup> [ $\mu\text{g}/\text{m}^3$ ]
Personal	44	0.870	1.00	0.870	0.0174

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

<sup>a</sup> Based on 90<sup>th</sup> percentile of measurements.

<sup>b</sup> No RPE is considered, see text above.

<sup>c</sup> The frequency/duration correction factor of 0.02 was applied for storage area workers: each of the four storage area workers spend up to 2% of his shift on activities related to passivation of stainless steel with Cr(VI).

#### 9.2.3.3.2.2 Dermal exposure

In Table 9-29 the dermal exposure concentrations for storage area workers are shown, based on modelling of the activities with Cr(VI) exposure. The parameters considered for dermal exposure modelling are described in detail in Annex V of this report. For a conservative assessment of dermal exposure, we consider for modelling that only one storage area worker performs all tasks described above (also the tasks typically performed by a different SEG, such as sampling of treatment bath), that exposure from each activity adds up and that all tasks are performed at the maximum frequency.

<sup>9</sup> Considering the maximum durations (exposure time) and frequencies of all main tasks performed by storage area workers as described in section 9.2.3.3.2 and considering 1920h working time per year for one worker (8h per day, 240 days per year), the exposure time related to passivation of stainless steel accounts for 6.7% of his shift (15 min 96x/year (Task 1) + 10 min 48x/year (Task 2) + 10 min 48x/year (Task 3) + 10 min 240x/year (Task 4) + 60 min 48x/year (Task 5) + 45 min 2x/year (Task 6) = 7770 min = 129.5h; 129.5h/1920h = 6.7%), assuming that one worker performs all activities; if the activities are divided between four workers the percentage is 1.69% per worker, conservatively rounded up to 2%.

**Table 9-29: Dermal exposure modelling for WCS 2 – Storage area workers**

Task	PROC(s)	Cr(VI) concentration [%]	Annual average dermal exposure value [ $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$ ] <sup>b</sup>
Task 1: Aliquot chemicals – Decanting of liquids	PROC 8b	30.0	4.11
Task 2: Aliquot chemicals – Measuring and weighing of solids	PROC 8b	40.0	2.74
Task 3: Waste management – Cleaning of empty chemical containers/bags	PROC 28	4.00 *	4.76
Task 4: Waste management – Handling of solid waste	PROC 8b	2.20	0.754
Task 5: Bath make-up or addition	PROC 5 PROC 8b	40.0	2.74
Task 6: Bath emptying and cleaning	PROC 28	0.220	0.0109
Task 7: Sampling of treatment baths	PROC 9	2.20	0.754
<b>Combination of all tasks</b>			<b>15.9</b>

All values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* 10-fold dilution assumed due to cleaning activity; for details see Annex V.

Despite the very conservative approach as described above, the combined dermal exposure value from all tasks of 15.9  $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$  does not exceed the DNEL of 43  $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$ .

#### 9.2.3.3.2.3 Risk characterisation

##### Risk for carcinogenicity

Table 9-30 shows the risk characterisation for carcinogenicity for storage area workers. The risk for carcinogenicity is based on measured Cr(VI) inhalation exposure data for storage area workers and the RAC dose-response relationship for the excess lifetime cancer risk for lung cancer (ECHA, 2013).

**Table 9-30: Risk characterisation for carcinogenicity for WCS 2 – Storage area workers**

Route of exposure and type of effects	Long-term exposure [ $\mu\text{g}/\text{m}^3$ ]	Risk characterisation: Excess lifetime lung cancer risk * [ $1/\mu\text{g}/\text{m}^3$ ]	Excess lifetime cancer risk (ELCR)
Inhalation: Systemic Long Term	0.0174 $\mu\text{g}/\text{m}^3$	4.00E-03	6.96E-05

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All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to 1 µg/m<sup>3</sup> Cr(VI) relates to an excess risk of 4x10<sup>-3</sup> for workers, based on 40 years of exposure; 8h/day; 5 days/week.

**Risk for reproductive toxicity**

Table 9-31 shows the risk characterisation for reproductive toxicity for storage area workers. The risk characterisation for reproductive toxicity is based on measured Cr(VI) inhalation exposure data for storage area workers and modelled dermal Cr(VI) exposure values which are compared to the RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

**Table 9-31: Risk characterisation for reproductive toxicity for WCS 2 – Storage area workers**

Route of exposure and type of effects	Long-term exposure	Risk characterisation: RAC DNEL *	Risk characterisation ratio (RCR)
Inhalation: Systemic Long Term	0.0174 µg/m <sup>3</sup>	43 µg Cr(VI)/m <sup>3</sup>	0.000405
Dermal: Systemic Long Term	15.9 µg/kg bw/d	43 µg Cr(VI)/kg bw/d	0.369
<b>Combination of inhalation and dermal exposure</b>			<b>0.370</b>

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

Note that during handling of solid waste very infrequently (approx. 2x/year) also waste with higher Cr(VI) concentrations (e.g., empty chemical containers) of up to 40% is handled/discarded. Due to the low frequency of this activity this only increases the dermal exposure minimally to 16.0 µg/kg bw/d, leading to a dermal RCR of 0.372.

**Conclusion on risk characterisation:**Carcinogenicity:

The Excess life-time cancer risk for storage area workers is 6.96E-05.

This risk estimate can be considered as conservative, because:

- it is based on a conservative ERR,
- it uses the 90<sup>th</sup> percentile of the reported long-term measurements,
- these measurements were not corrected for their duration but assumed to be shift representative values,
- and no correction for wearing RPE was applied although workers typically wear RPE for exposure-relevant tasks (as shown by the short-term measurements, such as weighing/measuring of solids and bath make-ups/additions).

As described above, it is considered for the assessment that **four storage area workers** per day and site perform all tasks assigned to this SEG related to passivation of stainless steel.

Reproductive toxicity

The RCR for the endpoint reproductive toxicity based on a conservative assessment is well below 1 (0.370).

Based on the gathered information and considering the implemented RMMs we conclude that risk of exposure is minimised.

**Comparison of outcome with initial application*****Inhalation exposure***

The tasks considered in the present assessment typically performed by the storage area workers were described in the initial applications as separate tasks that were not assigned to a specific SEG and were not aggregated in their exposure. These separate tasks were modelled with ART 1.5 in the initial applications and no typical frequencies were specified. Consequently, we only can compare the modelling results for individual tasks with the shift-average inhalation exposure values measured for the storage area workers in the current assessment.

As shown in the table below, the excess lifetime lung cancer risks based on inhalation exposure modelling in the initial applications were between 1.00E-04 and 6.00E-03 for the individual activities performed by the storage area workers. RPE with an assigned protection factor (APF) of 30 was considered for all activities where solid chromates are handled.

In the present assessment, the excess lifetime lung cancer risk is **6.96E-05**, covering all individual tasks and considering durations and frequencies in which these tasks are performed in relation to passivation of stainless steel. In contrast to the modelling approach in the initial applications, **use of RPE is not considered in the present assessment** based on shift-average values, although it is used during exposure-relevant tasks. This constitutes a very conservative approach.

Initial assessment				Present assessment	
Application ID	Chromate	Inhalation exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]	Inhalation, long-term exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]
<b>Decanting of liquids (PROC 8b)</b> CT: <60 min, up to 50% Cr(VI), containment (99%), no RPE SD: <60 min, up to 20% Cr(VI), containment (99%), no RPE				0.0174	6.96E-05
0032-04	CT	0.69	2.76E-03		
0032-05	CT	0.69	2.76E-03		
0043-02	SD	0.42	1.68E-03		
<b>Decanting and weighing of solids (PROC 8b)</b> CT: <60 min, up to 50% Cr(VI), no containment/LEV, RPE (APF 30) SD: <15 min, up to 40% Cr(VI), no containment/LEV, RPE (APF 30)					
0032-04	CT	1.5	6.00E-03		
0032-05	CT	1.5	6.00E-03		
0043-02	SD	0.5	2.00E-03		
<b>Mixing of liquids (PROC 5)</b> CT: <60 min, up to 50% Cr(VI), containment (90%), no RPE SD: <15 min, up to 20% Cr(VI), containment (90%), no RPE					

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0032-04	CT	0.69	2.76E-03		
0032-05	CT	0.69	2.76E-03		
0043-02	SD	0.11	4.40E-04		
<b>Mixing of solids (PROC 5)</b>					
CT: <60 min, up to 50% Cr(VI), containment (90%), RPE (APF 30)					
SD: <15 min, up to 40% Cr(VI), containment (90%), RPE (APF 30)					
0032-04	CT	0.5	2.00E-03		
0032-05	CT	0.5	2.00E-03		
0043-02	SD	0.17	6.80E-04		
<b>Re-filling of baths – liquids (PROC 8b)</b>					
CT: <60 min, up to 50% Cr(VI), fixed capturing hood (90%)					
SD: <10 min, up to 20% Cr(VI), fixed capturing hood (90%)					
0032-04	CT	1.1	4.40E-03		
0032-05	CT	1.1	4.40E-03		
0043-02	SD	0.76	3.04E-03		
<b>Re-filling of baths – solids (PROC 8b)</b>					
CT: <10 min, up to 50% Cr(VI), fixed capturing hood (90%), RPE (APF 30)					
SD: <10 min, up to 40% Cr(VI), fixed capturing hood (90%), RPE (APF 30)					
0032-04	CT	0.025	1.00E-04		
0032-05	CT	0.025	1.00E-04		
0043-02	SD	0.066	2.64E-04		
<b>Waste management (PROC 8b)</b>					
CT: 30 min, up to 50% Cr(VI), containment (90%), RPE (APF 30)					
SD: <30 min, up to 40% Cr(VI), containment (90%), RPE (APF 30)					
0032-04	CT	0.22	8.80E-04		
0032-05	CT	0.22	8.80E-04		
0043-02	SD	0.22	8.80E-04		
<b>Dermal exposure</b>					
No quantitative dermal exposure assessment has been performed in the initial applications.					

**9.2.3.4 Worker contributing scenario 3 – Laboratory technicians**

Usually, there is a group of 1 to 4 laboratory technicians per site (depending e.g. on the size of the site). Laboratory technicians may be involved in activities related to passivation of stainless steel with potential for Cr(VI)-exposure, but these tasks only account for a small fraction of their time and most of their work is not related to passivation of stainless steel.

Typical activities with possible Cr(VI) exposure performed by laboratory technicians are:

Main task

- Task 1: Laboratory analysis of treatment bath sample (PROC 15)

Secondary task

- Task 2: Sampling of treatment baths (PROC 9)

Moreover, at some sites, the laboratory technicians are also responsible for the sampling and analysis of wastewater after the reduction process at the reduction facility, while at other sites this task is performed by the storage area workers. In the wastewater samples, the Cr(VI) content is determined by means of a photometric rapid test, to verify that the Cr(VI) content in the wastewater is below a regulatory limit concentration under which release to the external WWTP or STP is permitted. As the reduced wastewater usually contains only traces of Cr(VI) (<0.3 mg/L), the sampling and analysis of wastewater is not considered a relevant activity with Cr(VI) exposure in this CSR.

As the handling of substances in laboratories for quality control purposes under controlled conditions and in amounts below 1 t/year falls under the exemption for authorisation for the use of substances in scientific research and development<sup>10</sup> according to REACH Art. 56(3), no exposure assessment is performed for the laboratory analysis of treatment bath samples.

The activity of sampling the treatment bath typically consumes a small fraction of the lab technician's time. This task is described in detail in the worker contributing scenario for line operators (main task for line operators, see section 9.2.3.2).

#### 9.2.3.5 Worker contributing scenario 4 – Maintenance and/or cleaning workers

Maintenance and/or cleaning workers may be involved in activities related to passivation of stainless steel with potential for Cr(VI)-exposure, but these tasks constitute only a small fraction of their time and most of their work is not related to passivation of stainless steel.

The activities with potential Cr(VI) exposure performed by maintenance and/or cleaning workers are summarized for the present assessment as the following tasks:

##### Main task

- Task 1: Maintenance and cleaning of equipment (PROC 28)

##### Secondary task

- Task 2: Waste management – Handling of solid waste (PROC 8b)

Typical activities during maintenance and cleaning of equipment related to the use with potential direct exposure to Cr(VI) as well as the working conditions are described below in detail and are supported by worker air monitoring data covering maintenance activities.

Since task 2 is a typical main task performed by storage area workers, it is described in detail in the worker contributing scenario for storage area workers (see section 9.2.3.3).

##### 9.2.3.5.1 Conditions of use

Table 9-32 summarises the conditions of use for maintenance and cleaning activities with Cr(VI) exposure related to passivation of stainless steel carried out by maintenance workers.

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<sup>10</sup> Q&A Reference number: ID 0585; <https://echa.europa.eu/de/support/qas-support/browse/-/qa/70Qx/view/ids/585-1442-1443-1498-1565>; assessed in March 2021

**Table 9-32: Conditions of use – worker contributing scenario 4 – Maintenance and/or cleaning workers**

<b>Product (article) characteristics</b>
<p>Product: Aqueous solution of CT or SD</p> <ul style="list-style-type: none"> <li>▪ Concentration of substance in mixture for bath applications: up to 1.3% (w/w) Cr(VI) for CT bath or up to 2.2% (w/w) Cr(VI) for SD bath (based on ranges of CT (up to 2.5% (w/w)) or SD (up to 5.5% (w/w)) in the aqueous solution in the passivation bath)</li> <li>▪ Product type: Solids dissolved in a liquid or incorporated in a liquid matrix</li> <li>▪ Viscosity: Liquids with low viscosity (like water)</li> </ul>
<b>Amount used (or contained in articles), frequency and duration of use/exposure</b>
<p>Task 1: Maintenance and cleaning of equipment</p> <ul style="list-style-type: none"> <li>▪ Duration of activity: up to 240 min (at some sites, specific maintenance activities are performed for 480 min once per year)</li> <li>▪ Frequency of task: 48 days/year (once per week, 48 weeks per year)</li> </ul>
<b>Technical and organisational conditions and measures</b>
<p>Task 1: Maintenance and cleaning of equipment</p> <ul style="list-style-type: none"> <li>▪ LEV: yes/no (depends on the place maintenance takes place)</li> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<b>Conditions and measures related to personal protection, hygiene, and health evaluation</b>
<p><b>Gloves</b></p> <p>Chemical resistant gloves are worn during all activities with possible exposure to Cr(VI). All gloves used for the handling of chemicals are tested according to EN 374. A variety of materials are suited for protection against CT and SD.</p> <p>The following materials have a breakthrough time <math>\geq 8</math>h for aqueous CT solutions (10% CT) and saturated aqueous SD solutions <sup>a</sup>:</p> <ul style="list-style-type: none"> <li>○ Natural rubber/Natural latex (0.5 mm)</li> <li>○ Polychloroprene (0.5 mm)</li> <li>○ Nitrile rubber/Nitrile latex (0.35 mm)</li> <li>○ Butyl rubber (0.5 mm)</li> <li>○ Fluorocarbon rubber (0.4 mm)</li> <li>○ Polyvinyl chloride (0.5 mm)</li> </ul> <p>The following materials have a breakthrough time <math>\geq 8</math>h for aqueous CT solutions (50% CT) <sup>a</sup>:</p> <ul style="list-style-type: none"> <li>○ Fluorocarbon rubber (0.4 mm)</li> </ul> <p>The following materials have a breakthrough time <math>\geq 2</math>h for aqueous CT solutions (50% CT) <sup>a</sup>:</p> <ul style="list-style-type: none"> <li>○ Polychloroprene (0.5 mm)</li> <li>○ Butyl rubber (0.5 mm)</li> <li>○ Polyvinyl chloride (0.5 mm)</li> </ul>

Type of gloves to be used for specific activities is laid down in work instructions for the activities.
<p><b>Respiratory protection equipment</b></p> <p>RPE is worn during all tasks not performed under an LEV for which industrial hygiene exposure assessment confirms RPE use is required.</p> <p>The following types of RPE are used for activities with CMR substances according to EN 529:2005<sup>b</sup>:</p> <ul style="list-style-type: none"> <li>▪ Half mask FFP3 (APF 10), half mask with P3 filter (APF 10), half mask with P3 combination filter (APF 10) or</li> <li>▪ Full mask with P3 filter (APF 20), full mask with P3 combination filter (APF 20)</li> </ul> <p>Type of RPE to be used for specific tasks is laid down in work instructions for the tasks.</p>
<p><b>Protective clothes</b></p> <p>Chemical protective clothing must be worn during activities with possible Cr(VI) exposure.</p> <p>Type of protective clothes to be used for specific activities is laid down in work instructions for the activities.</p>
<p><b>Eye protection</b></p> <p>Eye protection as per relevant risk assessment is worn during Task 1.</p> <p>Type of eye protection to be used for specific activities is laid down in work instructions for the activities.</p>
<b>Other conditions affecting workers' exposure</b>
<p>Task 1: Maintenance and cleaning of equipment</p> <ul style="list-style-type: none"> <li>▪ Place of use: indoors – any size workroom</li> <li>▪ Temperature: typically, at room temperature</li> <li>▪ Primary emission source proximity: The primary emission source is in the breathing zone of the worker (near field, &lt;1 m)</li> <li>▪ Activity class and subclass: Handling of contaminated objects</li> </ul>
<b>Additional good practice advice. Obligations according to Article 37(4) of REACH do not apply</b>
<ul style="list-style-type: none"> <li>▪ <i>None</i></li> </ul>

<sup>a</sup> <https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index.jsp>; accessed 8 December 2020.

<sup>b</sup> For selection of APF see Annex VI of this report.

### 9.2.3.5.2 Exposure and risks for workers

At each site, a group of maintenance and/or cleaning workers is engaged the size of which can vary largely (depending, e.g., on the size of the site). At some sites, the maintenance workers are subcontracted service providers. The work system at a site is divided in one to three shifts per day, with one to seven workers per shift. However, these workers are only infrequently engaged in activities related to Cr(VI) exposure and it can be assumed that only one worker per shift is dealing with Cr(VI)-related activities (see below). The shift duration is usually 8h but may also be up to 12h, depending on the organisation of the site and national law.

We describe below in detail relevant activities of maintenance and cleaning with direct Cr(VI) exposure for maintenance and/or cleaning workers and the working conditions.

### Task 1: Maintenance and cleaning of equipment

Typical maintenance tasks comprise for example the repair or replacement of electrical installations such as heating and mixing equipment installed in the treatment baths, pumps and valves, filters, joints of baths and hydraulic installations and LEV systems (exemplarily, the replacement of a filter is shown in Figure 9-11). Some of these activities can be performed in situ but in cases where this is not possible, the part needs to be dismantled for repair either in the workshop or externally by a specialized company. Prior to maintenance cases, either the line operators or the maintenance workers clean the part to be maintained/repared. During maintenance/repair, additional cleaning by the maintenance worker in situ and/or in the workshop may be necessary.

The repair of heaters in the passivation bath is described in the following as a typical maintenance case and is considered a representative worst case for other maintenance activities related to the use.

When a heater in a treatment bath must be replaced, the treatment bath is cooled down to room temperature, emptied and the heater and bath are cleaned by the storage area worker (see description for bath cleaning in section 9.2.3.3) in preparation for the maintenance work. Then the maintenance worker enters the empty bath and either repairs the heater in situ, if this is possible, or he removes the heater and transports it to the workshop for repair (exemplarily, cleaning and repair of equipment in a cleaned treatment bath is shown in Figure 9-12 a + b). In the workshop, when the heater is being repaired, additional cleaning may be necessary, either by wiping the heater with e. g. a cloth or by rinsing it with water over a collection vessel (the liquid waste is fed to the on-site reduction unit). After repair, the maintenance worker brings the heater back to the treatment bath and reinstalls it. In total, including dismantling, repair, and re-installation, such a maintenance case takes about 240 min.

The duration and frequency of maintenance activities can be highly variable between different sites, with frequencies between 1 and 48 times per year and durations typically between 10 and 240 min per maintenance case. At some sites, specific maintenance activities are performed for 480 min once per year. For the present exposure assessment, we consider a frequency of 48 times per year and a duration of 240 min per maintenance/cleaning event as a worst-case estimate.

Maintenance activities are typically performed at room temperature. The maximum Cr(VI) concentration in the treatment bath at which maintenance may be necessary is 2.2% Cr(VI). During maintenance in and at the treatment bath, the LEV of the bath is running and when contaminated parts are handled in the workshop a mobile LEV is used wherever this is technically and practically possible. For maintenance activities performed in the workshop the maintenance worker wears eye protection (as per relevant risk assessment), and chemical resistant gloves; for activities with potential Cr(VI) exposure (e.g., during cleaning and when entering the treatment bath) he additionally wears chemical protective clothing and RPE (if industrial hygiene exposure assessment confirms RPE use is required) , as specified above in Table 9-32.



**Figure 9-11: Maintenance of equipment - Filter change**



**Figure 9-12: Cleaning of equipment (a + b)**

#### 9.2.3.5.2.1 Inhalation exposure

##### **Measured inhalation exposure concentration**

For maintenance and/or cleaning workers, five personal measurements covering exposure from passivation of stainless steel are available. One personal long-term measurement value was excluded from further analysis as it was below an unreasonably high LOQ (i.e.,  $<2 \mu\text{g}/\text{m}^3$ ). The remaining four values are long-term ( $\geq 2\text{h}$ )<sup>11</sup> measurements. No stationary measurements are available for maintenance and/or cleaning workers.

It is stated by the sites providing monitoring data that maintenance tasks are hard to schedule for days on which monitoring is performed (as monitoring campaigns usually need to be planned months in advance and as, per definition, repair activities are difficult to predict). Due to this, monitoring data on maintenance tasks were rather difficult to collect, which is reflected in the comparably low number of measurements. Furthermore, the maintenance activities performed during the measurements usually cannot be assigned to a single use but relate to all uses performed at one site, which makes it difficult to discern between exposures from different galvanic Cr(VI) uses. Considering these restrictions all measurement data for maintenance and/or cleaning workers available for diverse Cr(VI) uses performed in galvanic areas (i.e., the galvanic Cr(VI) uses covered by ADCR) are pooled for the exposure

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<sup>11</sup> All long-term measurements ( $\geq 2\text{h}$ ) are considered as shift-representative measurements and used as such as 8h TWA exposure values; no recalculation has been performed. Measurements  $<2\text{h}$  were not used to calculate 8h TWA exposure values.

assessment of maintenance and/or cleaning workers. Since the same types of tasks are carried out under comparable conditions of intervention, we consider it reasonable to not distinguish between exposure from maintenance activities related to different uses. Some of these measurements cover maintenance activities not only related to galvanic but also to spraying uses (i.e., slurry coating and/or use of primer), as multiple tasks including maintenance on galvanic- and spraying-related equipment were performed during these measurements. More than one chromate is used at many of the sites providing these measurements and measurements are often not assignable to a single chromate. Therefore, stratification according to substance is not reasonable.

In total, 34 personal monitoring values are available, but two values were excluded from the analysis: the one value described above plus one long-term measurement from a worker who experienced high exposure due to inappropriate individual behaviour, resulting in an increased exposure value (6.94  $\mu\text{g}/\text{m}^3$ ). Of the remaining 32 personal measurements, 17 long-term, shift-representative and 15 short-term personal measurements are available.

The pooled personal monitoring data come from 13 sites in four countries in the EEA (27 measurements) and from three sites in the UK (five measurements). About 44% of the data (14 values, including seven short-term measurements) are <LOQ and 56% (18 values, including eight short-term measurements) are >LOQ. A summary on the analytical methods for inhalation exposure monitoring and information on their LOQs is given in Annex IV of this report. The individual measurements can be provided upon request. An overview of the available data for maintenance and/or cleaning workers is given in Table 9-33.

**Table 9-33: Overview of available inhalation exposure measurements for WCS 4 – Maintenance and/or cleaning workers**

	n	>LOQ	<LOQ
<b>Personal – related to passivation of stainless steel</b>			
- Long-term ( $\geq 2\text{h}$ )	4	3	1
<b>Personal – related to any Cr(VI) use</b>			
- Long-term ( $\geq 2\text{h}$ )	17	10	7
- Short-term (<2h)	15	8	7

Personal measurements – related to passivation of stainless steel (long-term measurements)

The four long-term personal measurements were taken at workers performing maintenance activities related to passivation of stainless steel. The arithmetic mean (AM) for these measurements is 0.570  $\mu\text{g}/\text{m}^3$ . None of these measurements is exclusively related to this use, all values cover activities related to multiple Cr(VI) uses (e.g., deoxidising, pickling/etching, inorganic finish stripping, passivation of stainless steel, anodising, passivation of (non-Al) metallic coatings, conversion coating, anodise sealing, chromate rinsing after phosphating, primer application). Activities performed during the measurements include general maintenance and cleaning throughout the site and specific tasks such as replacement of heaters, repair of pipes and vacuum, and refilling of chemicals for the wastewater treatment plant. For none of these measurement use of RPE was reported.

As described above, the long-term measurements usually cover activities from multiple uses as the maintenance activities performed during the measurements cannot be assigned to a single use but

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usually relate to all uses performed at one site. Therefore, the pooled monitoring data from all Cr(VI) uses are considered and discussed for the exposure assessment.

Personal measurements – related to any Cr(VI) use (long-term measurements)

The AM of the total long-term measurements is 0.721  $\mu\text{g}/\text{m}^3$  and the 90<sup>th</sup> percentile is 1.92  $\mu\text{g}/\text{m}^3$  for the pooled personal monitoring data. The exposure values cover general inspections, maintenance and cleaning throughout the site and specific activities such as replacement of heaters, repair of pipes, pumps, or dampers in the baths, cleaning, and replacement of demisters of the air purification systems, cleaning and repair of wet scrubbers, removal of anodes from treatment baths or refilling of chemicals for the wastewater treatment plant. The activities reported for the pooled long-term measurements show an overlap with the activities reported for the monitoring data covering maintenance activities related to passivation of stainless steel, which further supports the total long-term measurements to be considered for the assessment.

The AM of the pooled personal monitoring data is comparable to the AM of the monitoring data related to passivation of stainless steel (0.570  $\mu\text{g}/\text{m}^3$ ) while the 90<sup>th</sup> percentile is by approximately factor 2 higher than the maximum value of the data related to passivation of stainless steel (1.0  $\mu\text{g}/\text{m}^3$ ), suggesting that it may be a conservative approach to consider the 90<sup>th</sup> percentile of the pooled monitoring data for the exposure assessment of maintenance and/or cleaning workers for passivation of stainless steel.

For four of the pooled long-term measurements use of RPE was reported (e.g., reusable half mask – particle filter or 3M Jupiter Air Powered Respirator with filter A2P3 and S 333G head cover). During one measurement, infrequent maintenance activities were performed, and “removal of anodes” was reported for another case. No details are available for the other two measurements.

Personal measurements – related to any Cr(VI) use (short-term measurements)

For the total of 15 short-term measurements the AM is 0.325  $\mu\text{g}/\text{m}^3$  and the 90<sup>th</sup> percentile is 0.870  $\mu\text{g}/\text{m}^3$ . During these measurements the workers performed regular maintenance of the baths and related equipment such as LEV, rectifier, pumps, panels and sensors, inspection and cleaning of wet scrubbers, or aspiration of extraction filters above treatment baths with a vacuum cleaner.

For all short-term measurements it is documented that RPE (e.g., reusable half mask – particle filter, or half mask, or full face mask in case of splashes) is used, e.g., during line breakdowns or during maintenance of equipment.

Table 9-34 shows the summary statistics of workplace measurements for maintenance and/or cleaning workers. For values <LOQ, half of the LOQ (LOQ/2) was considered for statistical evaluation. All measurements are from the period 2018-2021.

**Table 9-34: Summary statistics of inhalation exposure measurements for WCS 4 – Maintenance and/or cleaning workers**

Personal – related to any Cr(VI) use (measurement period 2018-2021)						
	N	% of total	AM [ $\mu\text{g}/\text{m}^3$ ]	SD [ $\mu\text{g}/\text{m}^3$ ]	Median [ $\mu\text{g}/\text{m}^3$ ]	90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]
Long-term	17	100	0.721	1.28	0.240	1.92

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Short-term	15	100	0.325	0.399	0.170	0.870
<b>Personal – related to passivation of stainless steel (measurement period 2018-2021)</b>						
	<b>N</b>	<b>% of total</b>	<b>AM [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>SD [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>Median [<math>\mu\text{g}/\text{m}^3</math>]</b>	<b>90<sup>th</sup> Perc. [<math>\mu\text{g}/\text{m}^3</math>]</b>
Long-term	4	24	0.570	n.a.	n.a.	n.a. (MAX = 1.00)

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

n.a. = not assessed; the statistical parameter was only determined if at least three (for AM) or ten (for SD, Median and 90<sup>th</sup> percentile) values were available.

All personal long-term measurements of maintenance and/or cleaning workers performing tasks related to any galvanic Cr(VI) use are included in the assessment of inhalation exposure. Table 9-35 shows the resulting long-term inhalation exposure concentration for maintenance workers used for risk assessment, based on the 90<sup>th</sup> percentile of personal sampling values.

As stated above, exposure from sources and processes not related to the use of passivation of stainless steel contributed to most of the exposure values. Considering that maintenance workers typically spend only a minor part of their working time on activities related to passivation of stainless steel (at maximum 5%<sup>12</sup>), we assign 5% of the shift average exposure value (90<sup>th</sup> percentile of all long-term measurements) to this use. We further assume that one worker per shift (**three maintenance and/or cleaning workers per day**) is engaged with activities potentially leading to Cr(VI) exposure (**each worker spending a maximum of 5% of his working time on activities related to passivation of stainless steel**). Consequently, the long-term exposure concentration is corrected by a factor of 0.05. For sites where the work is distributed among a higher number of workers, a higher number of people would have to be considered, but their long-term average individual exposure concentration would be lower.

RPE may be worn during specific maintenance and/or cleaning activities as its use was documented for all short-term measurements. However, it is assumed that RPE was worn during certain short periods of the shift average measurements. Therefore, no RPE is considered in the exposure assessment, which constitutes a further conservative element of the assessment.

**Table 9-35: Measured inhalation exposure concentration for WCS 4 – Maintenance and/or cleaning workers**

Type of measurement	Number of measurements	Exposure value (8h TWA) <sup>a</sup> [ $\mu\text{g}/\text{m}^3$ ]	Assigned protection factor (APF) for RPE <sup>b</sup>	Exposure value corrected for RPE [ $\mu\text{g}/\text{m}^3$ ]	Long-term exposure <sup>c</sup> [ $\mu\text{g}/\text{m}^3$ ]
Personal	17	1.92	1	1.92	0.0960

<sup>12</sup> Considering the durations of all main tasks performed by maintenance and/or cleaning workers as described in section 9.2.3.5.2 and assuming conservatively 48 maintenance activities per year, with a duration of 4h each, the exposure time related to passivation of stainless steel accounts for (48 x 4h = 192h; 192h/(1920h working time per year) = 10%. If tasks are divided between three workers, this would consume 3.3% of their working time, which is conservatively rounded to 5%).

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All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

<sup>a</sup> Based on 90<sup>th</sup> percentile of measurements.

<sup>b</sup> No RPE is considered, see text above.

<sup>c</sup> The frequency/duration correction factor of 0.05 was applied for maintenance and/or cleaning activities related to passivation of stainless steel: each of the three maintenance workers spends up to 5% of his shift on activities related to passivation of stainless steel with Cr(VI).

## 9.2.3.5.2.2 Dermal exposure

In Table 9-36 the dermal exposure concentrations for maintenance and/or cleaning workers are shown, based on modelling of the activities with Cr(VI) exposure. The parameters considered for dermal exposure modelling are described in detail in Annex V of this report. For a conservative assessment of dermal exposure, we consider for modelling that only one maintenance and/or cleaning worker performs all tasks potentially carried out by maintenance and/or cleaning workers (also the tasks typically performed by a different SEG such as waste management – handling of solid waste), that exposure from each activity adds up and that all tasks are performed at the maximum frequency.

**Table 9-36: Dermal exposure modelling for WCS 4 – Maintenance and/or cleaning workers**

Task	PROC(s)	Cr(VI) concentration [%]	Annual average dermal exposure value [ $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$ ]
Task 1: Maintenance and cleaning of equipment	PROC 28	2.20	0.151
Task 2: Waste management – Handling of solid waste	PROC 8b	2.20	0.754
<b>Combination of all tasks</b>			<b>0.905</b>

All values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

Despite the very conservative approach as described above, the combined dermal exposure value from all tasks of 0.905  $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$  does not exceed the DNEL of 43  $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$ .

## 9.2.3.5.2.3 Risk characterisation

**Risk for carcinogenicity**

Table 9-37 shows the risk characterisation for carcinogenicity for maintenance and/or cleaning workers. The risk for carcinogenicity is based on measured Cr(VI) inhalation exposure data for maintenance and/or cleaning workers and the RAC dose-response relationship for the excess lifetime cancer risk for lung cancer (ECHA, 2013).

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**Table 9-37: Risk characterisation for carcinogenicity for WCS 4 – Maintenance and/or cleaning workers**

Route of exposure and type of effects	Long-term exposure [ $\mu\text{g}/\text{m}^3$ ]	Risk characterisation: Excess lifetime lung cancer risk * [ $1/\mu\text{g}/\text{m}^3$ ]	Excess lifetime cancer risk (ELCR)
Inhalation: Systemic Long Term	0.0960	4.00E-03	3.84E-04

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to  $1 \mu\text{g}/\text{m}^3$  Cr(VI) relates to an excess risk of  $4 \times 10^{-3}$  for workers, based on 40 years of exposure; 8h/day; 5 days/week.

### Risk for reproductive toxicity

Table 9-38 shows the risk characterisation for reproductive toxicity for maintenance and/or cleaning workers. The risk characterisation for reproductive toxicity is based on measured Cr(VI) inhalation exposure data for maintenance and/or cleaning workers and modelled dermal Cr(VI) exposure values which are compared to the RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

**Table 9-38: Risk characterisation for reproductive toxicity for WCS 4 – Maintenance and/or cleaning workers**

Route of exposure and type of effects	Long-term exposure	Risk characterisation: RAC DNEL *	Risk characterisation ratio (RCR)
Inhalation: Systemic Long Term	0.0960 $\mu\text{g}/\text{m}^3$	43 $\mu\text{g Cr(VI)}/\text{m}^3$	0.00223
Dermal: Systemic Long Term	0.905 $\mu\text{g}/\text{kg bw}/\text{d}$	43 $\mu\text{g Cr(VI)}/\text{kg bw}/\text{d}$	0.0210
<b>Combination of inhalation and dermal exposure</b>			<b>0.0233</b>

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

Note that during handling of solid waste very infrequently (approx. 2x/year) also waste with higher Cr(VI) concentrations (e.g., empty chemical containers) of up to 40% is handled/discarded. Due to the low frequency of this activity this only increases the dermal exposure minimally to  $1.02 \mu\text{g}/\text{kg bw}/\text{d}$ , leading to a dermal RCR of 0.0237.

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**Conclusion on risk characterisation:**Carcinogenicity

The Excess life-time cancer risk for maintenance and/or cleaning workers is  $3.84E-04$ .

This risk estimate can be considered as conservative, because:

- it is based on a conservative ERR,
- it uses the 90th percentile of the reported long-term measurements,
- these measurements were not corrected for their duration but assumed to be shift representative values, and
- no correction for wearing RPE was applied although workers may wear RPE under certain conditions for some activities (such as removal of anodes from treatment baths).

As described above, it is considered for the assessment that **three maintenance and/or cleaning workers** per day and site perform all maintenance and/ or cleaning activities related to passivation of stainless steel.

Reproductive toxicity

The RCR for the endpoint reproductive toxicity based on a conservative assessment is well below 1 (0.0233).

Based on the gathered information and considering the implemented RMMs we conclude that risk of exposure is minimised.

**Comparison of outcome with initial applications*****Inhalation exposure***

In the initial applications, regular maintenance of equipment at the baths (e.g., change of LEV or pump) is covered by personal monitoring of workers who also perform the surface treatment by dipping/immersion. As these measured values also cover such treatment activities and other tasks that are usually carried out by line operators (see the comparison with initial applications in section 9.2.3.2.2.3), this value is not suitable for a direct comparison.

Infrequent maintenance activities (PROC 8a)

In addition to such regular maintenance and cleaning activities, infrequent maintenance activities are considered as a separate task in the applications 0032-04 and 0032-05 but not in 0043-02. For such infrequent maintenance activities inhalation exposure was estimated by modelling with ART 1.5. It was assumed for modelling that infrequent maintenance was performed for filter change 1x per month for 240 min. For this activity handling of solids/ powders with a Cr(VI) weight fraction of up to 10% was considered, without use of LEV but with RPE (APF 30). As shown in the table below, the excess lifetime lung cancer risk based on inhalation exposure modelling was  $1.00E-03$  in the initial applications. In the present assessment, inhalation exposure from maintenance and cleaning of equipment is evaluated by personal monitoring of maintenance and/or cleaning workers performing typical maintenance tasks.

The excess lifetime lung cancer risk for the present assessment is with  **$3.84E-04$**  slightly lower than the risk calculated in the initial applications. However, measured exposures in the breathing zone of

workers are much lower than those modelled. As we did not consider RPE in our risk calculations although it may be used for specific maintenance tasks, this is a conservative risk estimate.

Initial assessment				Present assessment	
Application ID	Chromate	Inhalation, long-term exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]	Inhalation, long-term exposure, 90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]	Excess lifetime lung cancer risk [ $1/\mu\text{g}/\text{m}^3$ ]
0032-04	CT	0.25	1.00E-03	0.0960	3.84E-04
0032-05	CT	0.25	1.00E-03		
0043-02	SD	not assessed as separate task	n.a.		
0063-02	SD	not assessed as separate task	n.a.		

#### ***Dermal exposure***

No quantitative dermal exposure assessment has been performed in the initial applications.

### **9.2.3.6 Worker contributing scenario 5 – Incidentally exposed workers**

Incidentally exposed workers are defined as workers who spend a relevant part (10% or more) of their working time in the work area where the treatment baths for passivation of stainless steel are located, but do not carry out tasks with direct Cr(VI) exposure potential themselves. These workers may incidentally be exposed from such activities due to inhalation background exposure in the work area. Their tasks are required to be performed in this work area, as they are essential activities related to either the passivation process or to other processes necessary to be carried out in the same workplace. The activities performed by incidentally exposed workers are summarized for the present assessment as the following task:

- Task 1: Activities with indirect Cr(VI) exposure (PROC 0)

In the following sections, we specify the conditions of use under which indirect exposure these workers can occur, and we describe typical activities they perform while indirectly exposed.

#### **9.2.3.6.1 Conditions of use**

Table 9-39 summarises the conditions of use for various tasks performed by incidentally exposed workers working in the hall and in the vicinity of the bath(s) where passivation of stainless steel is carried out, from which the workers are incidentally exposed.

**Table 9-39: Conditions of use – worker contributing scenario 5 – Incidentally exposed workers**

<b>Product (article) characteristics</b>
Product 1: Aqueous solution of CT or SD

<ul style="list-style-type: none"> <li>▪ Concentration of substance in mixture for bath applications: up to 1.3% (w/w) Cr(VI) for CT bath or up to 2.2% (w/w) Cr(VI) for SD bath (based on ranges of CT (up to 2.5% (w/w)) or SD (up to 5.5% (w/w)) in the aqueous solution in the passivation bath)</li> <li>▪ Product type: Solids dissolved in a liquid or incorporated in a liquid matrix</li> <li>▪ Viscosity: Liquids with low viscosity (like water)</li> </ul>
<b>Amount used (or contained in articles), frequency and duration of use/exposure</b>
Task 1: Activities with indirect Cr(VI) exposure <ul style="list-style-type: none"> <li>▪ Duration of activity: up to 480 min</li> <li>▪ Frequency of task: 240 days/year</li> </ul>
<b>Technical and organisational conditions and measures</b>
Task 1: Activities with indirect Cr(VI) exposure <ul style="list-style-type: none"> <li>▪ Ventilation rate of general ventilation system: natural ventilation</li> <li>▪ Process temperature: room temperature</li> <li>▪ Occupational health and safety management system: advanced (see section 9.2.2.3.1.2)</li> </ul>
<b>Conditions and measures related to personal protection, hygiene, and health evaluation</b>
Task 1: Activities with indirect Cr(VI) exposure <ul style="list-style-type: none"> <li>▪ Standard PPE (not intended for protection against chromates) as described in work instructions for the tasks</li> </ul>
<b>Other conditions affecting workers exposure</b>
Task 1: Activities with indirect Cr(VI) exposure <ul style="list-style-type: none"> <li>▪ Place of use: indoors – any size workroom</li> <li>▪ Primary emission source proximity: The primary emission source is usually in the far field (&gt;1 m)</li> </ul>
<b>Additional good practice advice. Obligations according to Article 37(4) of REACH do not apply</b>
<ul style="list-style-type: none"> <li>▪ <i>None</i></li> </ul>

### 9.2.3.6.2 Exposure and risks for workers

The number of incidentally exposed workers for the passivation process can be highly variable, depending on the size of the site, the organisation of process lines (e.g., numerous lines in one hall vs. one line per hall) and the organisation of work. Typically, there are between zero to 15 incidentally exposed workers per site (zero to five per shift). It has to be noted that in compliance with Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (EU, 2013), wherever a carcinogen or mutagen is used, the sites keep the number of workers exposed or potentially to be exposed as low as possible and only essential activities are carried out in the vicinity of the treatment bath(s). During activities performed by operators involving solid CT/SD (e.g., bath addition, see WCS1) these workers (i.e., incidentally exposed workers) keep large distances from these activities.

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The work system at a site can be divided in one to three shifts per day. The shift duration is usually 8h but may also be up to 12h, depending on the organisation of the site and national law.

Usually, at least three different uses with Cr(VI) are carried out in one work area, such that only one third of the worker exposure for incidentally exposed workers arises from passivation of stainless steel. Considering

- the typical number of incidentally exposed workers per site (zero to 15) and
- that only 1/3 of the exposure during this time comes from the use under consideration,

it is estimated that between zero and five incidentally exposed workers are to be considered per site for the use passivation of stainless steel. For risk characterisation, an average of six workers (working part of their shift in the hall where passivation of (non-Al) metallic coatings is performed, 240 days per year, being indirectly exposed to Cr(VI) during 50% of their working time) per site is assumed.

We describe below the potential activities that can be performed by incidentally exposed workers and the working conditions under which indirect Cr(VI) exposure from passivation of stainless steel may occur. Workers may also be incidentally exposed from additional Cr(VI) uses performed in the same hall as passivation of stainless steel (e.g., conversion coating).

#### Task 1: Activities without direct Cr(VI) exposure

The tasks of incidentally exposed workers of passivation of stainless steel can be very diverse, but at many sites, workers who are not working directly with Cr(VI) sources may regularly carry out activities near the treatment bath(s), including, but not limited to the following:

- line operations at other process baths (not using Cr(VI))
- supervision of processes
- quality assessment of parts
- un-/jigging of parts and cleaning of jigs (Figure 9-13)
- un-/masking of parts
- transportation of closed chemical containers
- machining activities (on parts, where no Cr(VI) exposure is possible)



**Figure 9-13: Workers responsible for un-/jigging**

During all tasks performed by incidentally exposed workers at the same location as the treatment bath(s) for passivation of stainless steel, the workers wear standard PPE, as specified above in Table 9-39.

Depending on the organisation of the site, some of the above-mentioned activities may also be performed by line operators.

#### 9.2.3.6.2.1 Inhalation exposure

##### **Measured inhalation exposure concentration**

In total, 18 personal and eight stationary measurements are available for incidentally exposed workers in galvanic departments. Two personal long-term measurements were excluded from further analysis due to unreasonably high LOQs (i.e., above  $1 \mu\text{g}/\text{m}^3$ ).

Of the remaining 16 personal monitoring data, 15 are long-term ( $\geq 2\text{h}$ )<sup>13</sup>, shift-representative and one is a short-term ( $< 2\text{h}$ ) measurement.

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<sup>13</sup> All long-term measurements ( $\geq 2\text{h}$ ) are considered as shift-representative measurements and used as such as 8h TWA exposure values; no recalculation has been performed. Measurements  $< 2\text{h}$  were not used to calculate 8h TWA exposure values.

The personal monitoring data come from five sites in five countries in the EEA (eight measurements) and from two sites in the UK (eight measurements). Approximately 63% of the data (ten values, including the one short-term measurement) are <LOQ and 37% (six values) are >LOQ. A summary on the analytical methods for inhalation exposure monitoring and information on their LOQs is given in Annex IV of this report. The individual measurements can be provided upon request. An overview of the available data for incidentally exposed workers is given in Table 9-40.

**Table 9-40: Overview of available inhalation exposure measurements for WCS 6 – Incidentally exposed workers**

	n	>LOQ	<LOQ
<b>Personal</b>			
- Long-term (≥2h)	15	6	9
- Short-term (<2h)	1	0	1
<b>Stationary</b>			
- Long-term (≥2h)	8	0	8

#### Personal measurements – long-term

Long-term personal measurements were taken in the hall where immersion processes in baths containing Cr(VI) were performed, e.g., in the area where un-/jigging or masking are carried out or in the control area. Six of these measurements cover exposure from passivation of stainless steel in combination with exposure from other Cr(VI) uses, but none of them relates exclusively to exposure from passivation of stainless steel. As we expect incidental exposure to be comparable between diverse Cr(VI) uses, the monitoring data for all Cr(VI) immersion uses were pooled regardless of whether they also cover incidental exposure from passivation of stainless steel or only from other Cr(VI) uses. The arithmetic mean (AM) over the total of long-term personal measurements is 0.316 µg/m<sup>3</sup>, the median is 0.290 µg/m<sup>3</sup> and the 90<sup>th</sup> percentile is 0.500 µg/m<sup>3</sup>.

#### Personal measurements – short term

The short-term measurement has an exposure value of 1.0 µg/m<sup>3</sup> and was taken in a hall where passivation of stainless steel and electroplating (both with Cr(VI)) were performed.

#### Stationary measurements

The eight stationary monitoring data are long-term measurements. The arithmetic mean (AM) over of these measurements is 0.0564 µg/m<sup>3</sup>. The measurements were taken in halls where in most cases multiple immersion uses were performed, (e.g., anodising, conversion coating and passivation of (non-Al) metallic coatings), positioned e.g. in the un-/jigging area, in the area where finished parts are stored or in the broader vicinity of treatment baths with or without Cr(VI). During two measurements also machining activities and touch-ups with brush or pen stick were carried out in approximately 2 m distance to where the static sampling device was positioned. None of the static measurements covers incidental exposure from passivation of stainless steel.

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Table 9-41 shows the summary statistics of workplace measurements for incidentally exposed workers. For values <LOQ, half of the LOQ (LOQ/2) was considered for statistical evaluation. All measurements are from 2018-2021.

**Table 9-41: Summary statistics of inhalation exposure measurements for WCS 6 – Incidentally exposed workers**

Personal (measurement period 2018-2021)						
	N	% of total	AM [ $\mu\text{g}/\text{m}^3$ ]	SD [ $\mu\text{g}/\text{m}^3$ ]	Median [ $\mu\text{g}/\text{m}^3$ ]	90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]
Long-term	15	94	0.316	0.254	0.290	0.500
Short-term	1	6	n.a. <sup>a</sup>			
Stationary – (measurement period 2018-2021)						
	N	% of total	AM [ $\mu\text{g}/\text{m}^3$ ]	SD [ $\mu\text{g}/\text{m}^3$ ]	Median [ $\mu\text{g}/\text{m}^3$ ]	90 <sup>th</sup> Perc. [ $\mu\text{g}/\text{m}^3$ ]
Long-term	8	100	0.0564	n.a.	n.a.	n.a.

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

n.a. = not assessed; the statistical parameter was only determined if at least three (for AM) or ten (for SD, Median and 90<sup>th</sup> percentile) values were available.

<sup>a</sup> The value is 1.0  $\mu\text{g}/\text{m}^3$

All personal long-term measurements of incidentally exposed workers operating in halls where Cr(VI) uses were performed are included in the assessment of inhalation exposure. Table 9-42 shows the resulting long-term inhalation exposure concentration for incidentally exposed workers used for risk assessment, based on the 90<sup>th</sup> percentile of personal sampling values.

As stated above, partial exposure from sources and processes not related to the use of passivation of stainless steel may have contributed to all exposure values assigned to this use. It was estimated above that for risk characterisation, an average of **six workers** (exposed for 50% of their shifts) needs to be considered per site.

**Table 9-42: Measured inhalation exposure concentration for WCS 6 – Incidentally exposed workers**

Type of measurement	Number of measurements	Exposure value (8h TWA) <sup>a</sup> [ $\mu\text{g}/\text{m}^3$ ]	Assigned protection factor (APF) for RPE <sup>b</sup>	Exposure value corrected for RPE [ $\mu\text{g}/\text{m}^3$ ]	Long-term exposure <sup>c</sup> [ $\mu\text{g}/\text{m}^3$ ]
Personal	15	0.500	1	0.500	0.250

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

<sup>a</sup> Based on 90<sup>th</sup> percentile of measurements.

<sup>b</sup> No RPE is considered.

<sup>c</sup> Workers are assumed to be exposed during 50% of their shift and thus a reduction factor of 2 was applied.

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## 9.2.3.6.2.2 Dermal exposure

No dermal exposure is considered for incidentally exposed workers, as they are not in direct contact with Cr(VI).

## 9.2.3.6.2.3 Risk characterisation

**Risk for carcinogenicity**

Table 9-43 shows the risk characterisation for carcinogenicity for incidentally exposed workers. The risk for carcinogenicity is based on measured Cr(VI) inhalation exposure data for incidentally exposed workers and the RAC dose-response relationship for the excess lifetime cancer risk for lung cancer (ECHA, 2013).

**Table 9-43: Risk characterisation for carcinogenicity for WCS 5 – Incidentally exposed workers**

Route of exposure and type of effects	Long-term exposure [ $\mu\text{g}/\text{m}^3$ ]	Risk characterisation: Excess lifetime lung cancer risk * [ $1/\mu\text{g}/\text{m}^3$ ]	Excess lifetime cancer risk (ELCR)
Inhalation: Systemic Long Term	0.250	4.00E-03	1.00E-03

All values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to  $1 \mu\text{g}/\text{m}^3$  Cr(VI) relates to an excess risk of  $4 \times 10^{-3}$  for workers, based on 40 years of exposure; 8h/day; 5 days/week.

**Risk for reproductive toxicity**

Table 9-44 shows the risk characterisation for reproductive toxicity for incidentally exposed workers. The risk characterisation for reproductive toxicity is based on measured Cr(VI) inhalation exposure data, as no dermal exposure is considered for these workers. The exposure values are compared to the RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

**Table 9-44: Risk characterisation for reproductive toxicity for WCS 5 – Incidentally exposed workers**

Route of exposure and type of effects	Long-term exposure	Risk characterisation: RAC DNEL *	Risk characterisation ratio (RCR)
Inhalation: Systemic Long Term	0.250 $\mu\text{g}/\text{m}^3$	43 $\mu\text{g}/\text{m}^3$	0.00581

All exposure values rounded to three significant figures for presentation, but unrounded values used for calculation of exposure.

\* RAC DNEL for workers, derived for effects on fertility (ECHA, 2015).

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**Conclusion on risk characterisation:**Carcinogenicity

The Excess life-time cancer risk for incidentally exposed workers is 1.00E-03.

This risk estimate can be considered as conservative, because:

- it is based on a conservative ERR,
- it uses the 90th percentile of the reported long-term measurements,
- these measurements were not corrected for their duration but assumed to be shift representative values.

As described above, on average **six workers** (exposed for 50% of their shift) might be incidentally exposed at a site where this use is performed.

Reproductive toxicity

The RCR for the endpoint reproductive toxicity based on the assessment of inhalation exposure is well below 1 (0.00581).

Based on the gathered information and considering the implemented RMMs we conclude that risk of exposure is minimised.

**Comparison of outcome with initial application**

Exposure of incidentally exposed workers was not considered in previous applications.

## **10 RISK CHARACTERISATION RELATED TO COMBINED EXPOSURE**

### **10.1 Human health (related to combined, shift-long exposure)**

#### **10.1.1 Workers**

Efforts were undertaken to clearly identify and describe groups of workers exposed to chromates. These SEGs (similar exposure groups) typically perform more than one task. Exposure data provided cover the various activities performed during the work routine of these workers and are used to describe long-term exposure. Therefore, the combined exposure from performing several tasks is already covered in the exposure assessment.

The situation where workers are exposed due to activities related to other uses with Cr(VI) are discussed in the respective worker contributing scenarios.

#### **10.1.2 Consumers**

No consumer uses are addressed in this CSR.

### **10.2 Environment (combined for all emission sources)**

#### **10.2.1 All uses (regional scale) – regional assessment**

In accordance with RAC's conclusions (see e.g., the RAC/SEAC "Opinion on an Application for Authorisation for Use of Sodium dichromate for surface treatment of metals such as aluminium, steel, zinc, magnesium, titanium, alloys, composites and sealings of anodic films"<sup>14</sup>), no regional assessment has been carried out as it can be assumed that Cr(VI) from any source will be reduced to Cr(III) in most environmental situations and therefore the effects of Cr(VI) as such are likely to be limited to the area around the source, as described in the EU Risk Assessment Report for chromates (ECB, 2005). Therefore, combined exposures from various sources on the regional scale do not need to be considered.

On the local scale all relevant exposures from the emission source to air and wastewater are assessed (see section 9.2.3.1).

#### **10.2.2 Local exposure due to all wide dispersive uses**

There are no wide dispersive uses covered in this CSR.

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<sup>14</sup> RAC/SEAC, consolidated version, 2016; <https://echa.europa.eu/documents/10162/658d42f4-93ac-b472-c721-ad5f0c22823c>

### **10.2.3 Local exposure due to combined uses at a site**

The assessment of exposure of humans via the environment was performed using site-specific emission data for all substances used for this use, taking into account the relative amounts consumed for this use. Therefore, the total releases at a specific site from all uses performed at the site are higher in cases, where several uses are performed in parallel. The total releases per site are between 0.0205 and 6.57 kg/year to air (compared to 0.000157-0.084 kg/year for passivation of stainless steel only) and between 0 and 1.42 kg/year to water (compared to 0-0.0114 kg/year for passivation of stainless steel only), as summarised in Table 9-15 and as shown in detail in Annex III (Table Annex III-1) of this CSR.

## 11 Annexes

### 11.1 Annex I – Comparative assessment of physico-chemical input parameters for EUSES modelling

In the following tables the physico-chemical properties of the four chromates covered by the ADCR consortium other than chromium trioxide (CT) are shown. The physico-chemical properties of CT are given in section 9.1.2.4.

With these physico-chemical properties as input parameters we carried out a comparative EUSES assessment with an example scenario in which only the substance-specific physico-chemical properties of the five chromates covered by the ADCR consortium were exchanged.

#### Physico-chemical properties of the other chromates covered by the ADCR consortium

##### Physico-chemical properties of sodium dichromate (SD), required for EUSES modelling

Property	Description of key information	Value selected for EUSES modelling	Comment
CAS	10588-01-9		
Molecular weight	262 g/mol	262 g/mol	Refers to SD; value used in ECB (2005)
Melting/freezing point	Becomes anhydrous at 100 °C (ECB, 2005), salt melts at ca. 357 °C	357 °C at 101.3 kPa	Refers to SD; value used in ECB (2005)
Boiling point	decomposes above 400 °C (ECB, 2005)	400 °C	Refers to SD; value used in ECB (2005)
Vapour pressure	n/a: inorganic ionic compound	0.00001 Pa	n/a; dummy value entered
Log Kow	n/a: inorganic ionic compound	0	n/a; dummy value entered
Water solubility	2355 g/L at 20°C; (a 1% solution has a pH ~4)	2355 g/L at 20°C	Refers to SD; value used in ECB (2005)

##### Physico-chemical properties of sodium chromate (SC), required for EUSES modelling

Property	Description of key information	Value selected for EUSES modelling	Comment
CAS	7775-11-3		

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Property	Description of key information	Value selected for EUSES modelling	Comment
Molecular weight	161.99 g/mol	161.99 g/mol	Refers to SC, value used in ECB (2005); Registration dossier
Melting/freezing point	decahydrate loses H <sub>2</sub> O and melts at ~20°C; anhydrous salt melts at ~762°C (acc. to ECB, 2005); 792°C (acc. to registration dossier)	500°C (highest value possible for EUSES)	Refers to SC, value used in ECB (2005); Registration dossier
Boiling point	n/a; inorganic compound	500°C (highest value possible for EUSES)	
Vapour pressure	n/a: inorganic ionic compound	0.00001 Pa	n/a; dummy value entered
Log Kow	n/a: inorganic ionic compound	0	n/a; dummy value entered
Water solubility	~530 g/l at 20°C (the aqueous solution is alkaline (pH 9))	530 g/L at 20°C	Refers to SC, value used in ECB (2005)

**Physico-chemical properties of potassium dichromate (PD) required for EUSES modelling**

Property	Description of key information	Value selected for EUSES modelling	Comment
CAS	7778-50-9		
Molecular weight	294.22 g/mol	294.22 g/mol	Refers to PD, value used in ECB (2005)
Melting/freezing point	~398°C	398	Refers to PD, value used in ECB (2005)
Boiling point	n/a decomposes above 500°C	500	Refers to PD, value used in ECB (2005)
Vapour pressure	n/a: inorganic ionic compound	0.00001 Pa	n/a; dummy value entered
Log Kow	n/a: inorganic ionic compound	0	n/a; dummy value entered

Property	Description of key information	Value selected for EUSES modelling	Comment
Water solubility	~115 g/L at 20°C (a 10% solution has a pH ~3.5)	115 g/L at 20°C	Refers to PD, value used in ECB (2005)

#### Physico-chemical properties of dichromium trischromate (DtC) required for EUSES modelling

Property	Description of key information	Value selected for EUSES modelling	Comment
CAS	24613-89-6		
Molecular weight	451.97 g/mol	451.97 g/mol	Refers to DtC, value used in SVHC support document (ECHA, 2011)
Melting/freezing point	The substance melts above 300°C	300	Refers to DtC, value used in SVHC support document (ECHA, 2011)
Boiling point	n/a	300	Refers to DtC, value used in SVHC support document (ECHA, 2011)
Vapour pressure	n/a: inorganic ionic compound	0.00001 Pa	n/a; dummy value entered
Log Kow	n/a: inorganic ionic compound	0	n/a; dummy value entered
Water solubility	96.6 g/L at 20°C	96.6 g/L	Refers to DtC, value used in SVHC support document (ECHA, 2011)

#### Comparative EUSES assessment with an example scenario

The outcome of the comparative EUSES assessment is shown in the Table below. The test was carried out using the partition coefficients determined under alkaline conditions and no use of a biological STP was assumed. As can be seen from the table, the modelling results are largely identical, except for the daily dose through intake of drinking water, which is slightly higher based on CT data. Although the difference is very small, we used CT data for EUSES modelling of Cr(VI) exposure for all sites for reasons of conservatism.

**Outcome of the comparative EUSES assessment of the impact of the physico-chemical properties of the five different chromates on the concentrations in the considered Cr(VI) uptake media drinking water, fish, and air**

Chromate	Daily dose through intake of drinking water [mg/kg/day]	Daily dose through intake of fish [mg/kg/day]	Daily dose through intake of air [mg/kg/day]	Sum of daily dose through intake of drinking water, fish, and air [mg/kg/day]
SD	1.77E-07	1.02E-08	1.74E-07	3.61E-07
CT	<b>3.41E-07</b>	1.02E-08	1.74E-07	<b>5.25E-07</b>
SC	1.77E-07	1.02E-08	1.74E-07	3.61E-07
PD	1.77E-07	1.02E-08	1.74E-07	3.61E-07
DtC	1.77E-07	1.02E-08	1.74E-07	3.61E-07

## 11.2 Annex II – EUSES sensitivity analysis of impact of partition coefficients

We assessed the impact of the selected partition coefficients (under acidic or alkaline conditions) in a sensitivity analysis with EUSES. We carried out an exemplary exposure scenario (with no biological STP) using (a) the coefficients for acidic conditions, (b) the coefficients for alkaline conditions or (c) the calculated mean values. The outcome of the assessment is shown in the table below. From the table it becomes obvious that the variation of Cr(VI) exposure of HvE via the combined exposure routes air, drinking water and fish was lower than 2%. Accordingly, it can be concluded that the selected set of partition coefficients had close to no impact on the modelling result.

**Outcome of the comparative EUSES assessment of the impact of the partition coefficients on the concentrations in the considered Cr(VI) uptake media drinking water, fish, and air**

Set of partition coefficients used	Daily dose through intake of drinking water [mg/kg/day]	Daily dose through intake of fish [mg/kg/day]	Daily dose through intake of air [mg/kg/day]	Sum of daily dose through intake of drinking water, fish, and air [mg/kg/day]	Variation of sum of daily dose through intake of drinking water, fish, and air from calculation with mean partition coefficients [%]
Mean values	1.74E-07	1.00E-08	1.74E-07	3.58E-07	0%
Acid	1.72E-07	9.89E-09	1.74E-07	3.56E-07	0.59%
Alkaline	1.77E-07	1.02E-08	1.74E-07	3.61E-07	- 0.89%

### **11.3 Annex III – EUSES input data and release fractions derived from environmental monitoring data of representative sites**

The table below shows site-specific information on releases, on wastewater (biological treatment, dilution in the treatment plant and in the receiving water) and on the share of passivation of stainless steel of the overall emission.

The Cr(VI) amounts used by the sites shown in Annex III-1 for passivation of stainless steel range from <1 to 22 kg/year.

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**Table Annex III-1 – EUSES input data and release fractions derived from environmental monitoring data of representative sites**

Site	Fraction of tonnage released to air	Release to air [kg/year]	Fraction of tonnage released to water	Release to water [kg/year]	Share of air emission relevant for this use	Share of water emission relevant for this use	STP discharge rate [m <sup>3</sup> /day]	Application of sewage sludge to agricultural soil/grassland	Dilution factor receiving water
Site 1	2.04E-04	0.547	5.31E-04	1.42	0.00801	0.00801	2000 <sup>a</sup>	assume yes <sup>d</sup>	1000 <sup>b</sup>
Site 2	1.76E-04	0.374	8.89E-05	0.188	0.00260	0.00260	275 000	no	2.7 <sup>e</sup>
Site 3	1.80E-02	0.475	2.56E-06	0.0000675	0.0455	0.0455	2000 <sup>a</sup>	assume yes <sup>d</sup>	10 <sup>c</sup>
Site 4	7.47E-03	0.934	0, no water emission	0	0.00320	0.00320	-	-	-
Site 5	3.92E-05	0.0205	2.14E-03	1.12	0.00763	0.00763	2000 <sup>a</sup>	assume yes <sup>d</sup>	1000 <sup>f</sup>
Site 6	2.00E-03	4.48	1.79E-08	0.0000400	0.00625	0.00625	2000 <sup>a</sup>	assume yes <sup>d</sup>	10 <sup>c</sup>
Site 7	5.54E-03	6.57	6.32E-05	0.0750	0.0128	0.0128	2000 <sup>a</sup>	assume yes <sup>d</sup>	10 <sup>c</sup>
MIN	3.92E-05	0.0205	0	0	0.00260	0.00260			
<b>MAX</b>	<b>1.80E-02</b>	<b>6.57</b>	<b>2.14E-03</b>	<b>1.42</b>	<b>0.0455</b>	<b>0.0455</b>			
Median	2.00E-03	0.547	6.32E-05	0.0750	0.00763	0.00763			
90th percentile	1.17E-02	5.32	1.18E-03	1.24	0.0259	0.0259			

<sup>a</sup> No site-specific information is available for the STP discharge rate and thus the EUSES default of 2000 m<sup>3</sup>/day was used.

<sup>b</sup> According to site-specific data, the receiving water has a minimum flow rate of 500 000 – 5 000 000 m<sup>3</sup>/day; a maximum dilution factor of 1000 is used for EUSES calculation.

<sup>c</sup> No site-specific information is available for the flow rate of the receiving water and thus the EUSES default of 18 000 m<sup>3</sup>/day was used.

<sup>d</sup> Application of STP sludge to agricultural soil/grassland is considered since no information to the contrary is available.

<sup>e</sup> According to site-specific data, a minimum flow rate of the receiving water of 100 000 – 1 000 000 m<sup>3</sup>/day and a treatment plant discharge of 100 000 – 1 000 000 m<sup>3</sup>/day results in a dilution factor of 2.7.

<sup>f</sup> According to site-specific data, the receiving water has a minimum flow rate of 10 000 000 – 100 000 000 m<sup>3</sup>/day; a maximum dilution factor of 1000 is used for EUSES calculation.

In the following table the exposure concentrations for humans via the environment (on a local scale) are shown. Note that the exposure concentrations are based on the **overall releases of the sites, of which only a certain share is generated by passivation of stainless steel.**

**Table Annex III-2: Exposure concentrations for humans via the environment – on local scale (based on total emissions from site)**

Site	Inhalation	Oral (drinking water and fish)		
	Local Cr(VI) PEC in air [ $\mu\text{g}/\text{m}^3$ ]	Drinking water * [ $\mu\text{g Cr(VI)}/\text{kg x d}$ ]	Fish * [ $\mu\text{g Cr(VI)}/\text{kg x d}$ ]	Oral exposure (water and fish) [ $\mu\text{g Cr(VI)}/\text{kg x d}$ ]
Site 1	4.16E-04	8.10E-03	3.24E-07	8.10E-03
Site 2	2.84E-04	7.02E-06	1.20E-07	7.14E-06
Site 3	3.62E-04	9.34E-06	1.11E-08	9.35E-06
Site 4	7.11E-04	1.76E-05	1.20E-08	1.76E-05
Site 5	1.56E-05	8.92E-07	9.26E-09	9.01E-07
Site 6	3.41E-03	8.46E-05	3.10E-08	8.46E-05
Site 7	5.00E-03	5.50E-04	1.70E-06	5.52E-04
MIN	1.56E-05	8.92E-07	9.26E-09	9.01E-07
<b>MAX</b>	<b>5.00E-03</b>	<b>8.10E-03</b>	<b>1.70E-06</b>	<b>8.10E-03</b>
Median	4.16E-04	1.76E-05	3.10E-08	1.76E-05
90 <sup>th</sup> percentile	4.05E-03	3.57E-03	8.74E-07	3.57E-03

\* See explanations on oral uptake via drinking water and fish in CSR section 9.1.2.4.2.

#### Remarks on measured exposure:

The maximum local exposure concentrations based on the **overall releases of the sites** are 5.00E-03  $\mu\text{g}/\text{m}^3$  for the PEC in air and 8.10E-03  $\mu\text{g Cr(VI)}/\text{kg}$  per day for oral exposure via drinking water and fish. Note that for the exposure via drinking water and fish a reduction factor of 5 was applied, as described in section 9.1.2.4.2 of the CSR.

## **11.4 Annex IV – Inhalation exposure measurements for workers**

For inhalation exposure measurements, diverse analytical methods were used. Frequently reported analytical methods are NIOSH 7600 (VIS), NIOSH 7605 2003, ion chromatography, OSHA 215, UV/VIS spectrometry, IFA 6665: 2014-10 with ion chromatography or UV/VIS Spectroscopy, ISO 16740 PN-87/Z-04126/03.

According to the diversity of analytical methods used, the reported LOQs are heterogeneous, ranging from 0.01  $\mu\text{g}/\text{m}^3$  to 10  $\mu\text{g}/\text{m}^3$ .

Available Information on methods and LOQs for individual measurements are documented in a separate excel file.

## 11.5 Annex V – Dermal exposure modelling

### 11.5.1 EXCEL-based exposure assessment

Table Annex V-1 shows a generic, Excel-based exposure assessment developed for the purpose of this review report. It is based on the upper end of the range for the dermal load (0.1 mg/cm<sup>2</sup>/d) as provided in the EU RAR (ECB, 2005), which was based on EASE for non-dispersive use with direct handling with incidental contact, which is similar to the situation relevant here. The rationale for the selection of the parameters used is provided in the table below.

As a conservative assumption exposure of one side of both hands is assumed for most activities except cleaning related activities. For those activities with possible exposure to splash water exposure of larger parts of the body is assumed. The consumer module of ECETOC TRA (ECETOC, 2009; 2012) assumes exposure of half of the surface of the body (corresponding to 8750 cm<sup>2</sup>). However, this approach seems overly conservative taking into consideration that mostly impermeable personal protection equipment including boots, apron, gloves, and face shield are worn during the cleaning activities. Further, in case of bath cleaning the workers stand outside next to the approximately waist-high bath, which covers the lower half of the body. Therefore, for cleaning activities a skin contact area of 2083 cm<sup>2</sup> has been assumed, which corresponds to the surface of both hands and forearms, i.e. ca. ¼ of the front of the body. As described in section 9.2.3.2.2 cleaning of the workplace is usually performed with wiper mops or rags. Incidental hand exposure can reasonably be assumed for this scenario. However, at some sites the workplace is also cleaned with a water hose. In a conservative manner Cr(VI) exposure to hands and forearms of the body is used for the aggregated assessment of the WCS.

The actual dermal exposure to the product is calculated under consideration of body weight (ECHA, 2012) and PPE efficiency (EC, 2010). For the calculation of the dermal exposure to Cr(VI) the concentration of Cr(VI) in the solid or liquid product or bath solution is considered. In general, in case more than one substance is used only the molecular weight fraction of Cr(VI) for the substance with the highest molecular weight fraction is considered to calculate the Cr(VI) exposure concentration in a conservative manner (molecular weight fraction of Cr(VI) for SD, PD and SC: 0.40, 0.35, and 0.32, respectively). When cleaning with a hose is performed a rapid dilution (at least 10-fold) of the Cr(VI) containing product or bath solution is assumed. This assumption seems to be justified taking into consideration the large water volumes used for cleaning, that only small splashes are usually on the floor surrounding the bathes, that chemical containers are partially cleaned by immersion in the rinsing tanks, and that the chemical containers are thoroughly rinsed with enough water so that the containers could be discharged with normal waste.

It should be noted that SD is classified for skin corrosion. Consequently, dermal exposure to any neat substance must be prevented. The assumption of permeation of gloves by 5 % of the potential dermal dose is a purely hypothetical assumption since dermal exposure must be prevented due to local effects alone. The same is essentially true for other tasks, since SD concentrations ≥0.1 % require labelling as Skin Sens. 1 (H317) according to the CLP Regulation, implying that such low concentrations may be sensitising to the skin.

For the sake of comparison the results of the Riskofderm model are also included in Table Annex V-1 below. Annual average exposure estimates with the Riskofderm model resulted in estimates in the same order of magnitude or lower than the estimates with the generic model. Therefore, the results

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of the generic model are used for the calculation of the aggregated exposure and risk assessment of the different worker contributing scenarios. In a conservative manner all tasks possibly performed by one SEG are considered in the aggregated dermal exposure assessment. There are slight organisational differences between the sites, for example at one site line operators and at another site storage area workers perform sampling of treatment baths. To cover the situation of all sites, dermal exposure from any activity possibly related to a certain SEG is considered for all SEGs that could perform this activity. Modelling with Riskofderm is explained in section 11.5.2.

**Table Annex V-1: Modelled Exposure for Workers for all tasks (main tasks and secondary tasks; Excel-based approach)**

Parameter	Unit	Surface treatment by dipping/immersion	Sampling of treatment baths	Bath make-up and addition	Bath emptying and cleaning	Diverse cleaning activities - Cleaning of workplace, equipment, jigs	Touch-up – preparation of touch-up solution and application with a brush or pad	Waste management – Cleaning of empty chemical containers / bags	Waste management – Handling of solid waste	Maintenance and cleaning of equipment	Aliquot chemicals – Decanting of liquids	Aliquot chemicals – Measuring and weighing of solids	Rationale (Reference)
Exposed part of the body		(hand)	(hand)	(hand)	(hands and forearms)	(hands and forearms)	(hand)	(hands and forearms)	(hand)	(hand)	(hand)	(hand)	
PROCs		PROC 13	PROC 9	PROC 5, PROC 8b	PROC 28	PROC 28	PROC 5, PROC 9, PROC 10	PROC 28	PROC 8b	PROC 28	PROC 8b	PROC 8b	
EU RAR modelling assumption (0-0.1 mg/cm <sup>2</sup> )	mg/cm <sup>2</sup>	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	Upper end of range (EU RAR (ECB, 2005) from EASE for non-dispersive use with direct handling with incidental contact which is similar to the scenarios relevant here

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Parameter	Unit	Surface treatment by dipping/immersion	Sampling of treatment baths	Bath make-up and addition	Bath emptying and cleaning	Diverse cleaning activities - Cleaning of workplace, equipment, jigs	Touch-up – preparation of touch-up solution and application with a brush or pad	Waste management – Cleaning of empty chemical containers / bags	Waste management – Handling of solid waste	Maintenance and cleaning of equipment	Aliquot chemicals – Decanting of liquids	Aliquot chemicals – Measuring and weighing of solids	Rationale (Reference)
Exposed part of the body		(hand)	(hand)	(hand)	(hands and forearms)	(hands and forearms)	(hand)	(hands and forearms)	(hand)	(hand)	(hand)	(hand)	
Skin contact area	cm <sup>2</sup>	480	480	480	2083	2083	480	2083	480	480	480	480	One side of both hands used as a conservative assumption; for cleaning activities hands and forearms assumed as a worst case, contact area from ECETOC TRA consumer module (ECETOC, 2009; 2012)
Dermal load	mg	48	48	48	208	208	48	208	48	48	48	48	Calculated

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Parameter	Unit	Surface treatment by dipping/immersion	Sampling of treatment baths	Bath make-up and addition	Bath emptying and cleaning	Diverse cleaning activities - Cleaning of workplace, equipment, jigs	Touch-up – preparation of touch-up solution and application with a brush or pad	Waste management – Cleaning of empty chemical containers / bags	Waste management – Handling of solid waste	Maintenance and cleaning of equipment	Aliquot chemicals – Decanting of liquids	Aliquot chemicals – Measuring and weighing of solids	Rationale (Reference)
Exposed part of the body		(hand)	(hand)	(hand)	(hands and forearms)	(hands and forearms)	(hand)	(hands and forearms)	(hand)	(hand)	(hand)	(hand)	
Body weight	kg	70	70	70	70	70	70	70	70	70	70	70	Body weight for workers (Guidance IR & CSA, R.8 (ECHA, 2012))
Potential dermal exposure to product	mg/kg bw	0.686	0.686	0.686	2.98	2.98	0.686	2.98	0.686	0.686	0.686	0.686	Calculated
PPE efficiency (gloves, protective clothing, or apron)	%	95	95	95	80	80	95	80	95	95	95	95	For efficiency of gloves and protective clothing 95% and 80%, respectively, are assumed; see (EC, 2010)

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Parameter	Unit	Surface treatment by dipping/immersion	Sampling of treatment baths	Bath make-up and addition	Bath emptying and cleaning	Diverse cleaning activities - Cleaning of workplace, equipment, jigs	Touch-up – preparation of touch-up solution and application with a brush or pad	Waste management – Cleaning of empty chemical containers / bags	Waste management – Handling of solid waste	Maintenance and cleaning of equipment	Aliquot chemicals – Decanting of liquids	Aliquot chemicals – Measuring and weighing of solids	Rationale (Reference)
Exposed part of the body		(hand)	(hand)	(hand)	(hands and forearms)	(hands and forearms)	(hand)	(hands and forearms)	(hand)	(hand)	(hand)	(hand)	
Actual dermal exposure to product	mg/kg bw	0.0343	0.0343	0.0343	0.595	0.595	0.0343	0.595	0.0343	0.0343	0.0343	0.0343	Calculated
Cr(VI) concentration in product	%	2.20	2.20	40.0	0.220	0.220	40.0	4.00	2.20	2.20	30.0*	40.0*	See WCS specific conditions of use as described in sections 9.2.3.2 to 9.2.3.3; for cleaning with a water hose a 10-fold dilution is assumed
Task specific dermal exposure to Cr(VI)	µg/kg bw	<b>0.754</b>	<b>0.754</b>	<b>13.7</b>	<b>1.31</b>	<b>1.31</b>	<b>13.7</b>	<b>23.81</b>	<b>0.754</b>	<b>0.151</b>	<b>10.3</b>	<b>13.7</b>	Calculated

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Parameter	Unit	Surface treatment by dipping/immersion	Sampling of treatment baths	Bath make-up and addition	Bath emptying and cleaning	Diverse cleaning activities - Cleaning of workplace, equipment, jigs	Touch-up – preparation of touch-up solution and application with a brush or pad	Waste management – Cleaning of empty chemical containers / bags	Waste management – Handling of solid waste	Maintenance and cleaning of equipment	Aliquot chemicals – Decanting of liquids	Aliquot chemicals – Measuring and weighing of solids	Rationale (Reference)
Exposed part of the body		(hand)	(hand)	(hand)	(hands and forearms)	(hands and forearms)	(hand)	(hands and forearms)	(hand)	(hand)	(hand)	(hand)	
Frequency	d/year	240	240	48	2	240	48	48	240	48	96	48	See WCS specific conditions of use as described in sections 9.2.3.2 to 9.2.3.3
Annual average dermal exposure to Cr(VI)	µg/kg bw/d	0.754	0.754	2.74	0.0109	1.31	2.74	4.76	0.754	0.151	4.11	2.74	Calculated
Annual average dermal exposure to Cr(VI)			0.033	0.027-0.558							0.498-1.403	0.027	Results of Riskofderm model, see Table Annex V-2
Tasks to be considered		X	X	X	X	X	X	X	X	-	X	X	Resulting aggregated

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Parameter	Unit	Surface treatment by dipping/immersion	Sampling of treatment baths	Bath make-up and addition	Bath emptying and cleaning	Diverse cleaning activities - Cleaning of workplace, equipment, jigs	Touch-up – preparation of touch-up solution and application with a brush or pad	Waste management – Cleaning of empty chemical containers / bags	Waste management – Handling of solid waste	Maintenance and cleaning of equipment	Aliquot chemicals – Decanting of liquids	Aliquot chemicals – Measuring and weighing of solids	Rationale (Reference)
Exposed part of the body		(hand)	(hand)	(hand)	(hands and forearms)	(hands and forearms)	(hand)	(hands and forearms)	(hand)	(hand)	(hand)	(hand)	
for WCS 1 – Line operators													dermal exposure per WCS: <b>20.7 µg/kg bw/d</b>
Tasks to be considered for WCS 2 – Storage area workers		-	X	X	X	-		X	X	-	X	X	Resulting aggregated dermal exposure per WCS: <b>15.9 µg/kg bw/d</b>
Tasks to be considered for WCS 4 – Maintenance and/or cleaning workers		-	-	-	-	-		-	X	X	-	-	Resulting aggregated dermal exposure per WCS: <b>0.905 µg/kg bw/d</b>

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Parameter	Unit	Surface treatment by dipping/immersion	Sampling of treatment baths	Bath make-up and addition	Bath emptying and cleaning	Diverse cleaning activities - Cleaning of workplace, equipment, jigs	Touch-up – preparation of touch-up solution and application with a brush or pad	Waste management – Cleaning of empty chemical containers / bags	Waste management – Handling of solid waste	Maintenance and cleaning of equipment	Aliquot chemicals – Decanting of liquids	Aliquot chemicals – Measuring and weighing of solids	Rationale (Reference)
Exposed part of the body		(hand)	(hand)	(hand)	(hands and forearms)	(hands and forearms)	(hand)	(hands and forearms)	(hand)	(hand)	(hand)	(hand)	
<b>Tasks to be considered for WCS 5 – Incidentally exposed workers</b>		-	-	-	-	-		-	-	-	-	-	No dermal exposure

All values rounded to three significant figures, but unrounded values used in calculation.

\* In case both substances, sodium and potassium dichromate, are used in parallel only the conversion factor for sodium dichromate is considered in a conservative manner (conversion factor for Cr(VI) fraction of SD and PD: 0.40 and 0.35, respectively)

## Discussion and conclusions

In summary, modelled long-term dermal exposure to Cr(VI) as calculated with Riskofderm is in the same order of magnitude or about 10-fold lower than the Cr(VI) exposure calculated with the Excel based model, which shows that the Excel based model is a rather conservative approach. As discussed above, dermal exposure to neat SD (and even to solutions containing SD at relatively low concentrations) will need to be prevented due to the corrosive nature of the substance. Therefore, the dermal exposure estimates should be considered theoretical rather than reflecting true exposure levels.

### 11.5.2 Riskofderm modelling

The Riskofderm model (v.2.1) only contains a limited number of modules (DEO units), which are applicable to the worker activities described in sections 9.2.3.2 to 9.2.3.3. Exposure can only reasonably be estimated for activities relating to DEO 1 (filling, mixing, loading; only hand, not body exposure covered by the model), like aliquot chemicals, bath addition/make-up and sampling. We have refrained from modelling of surface treatment by dipping/immersion (DEO 5: immersion) as the data underlying the model for this DEO largely relate to *“mechanical immersing of objects into baths”*, which describes activities where hands are immersed or are in contact with contaminated surfaces and does not cover automated or semi-automated (by means of a manual controlled crane) immersion processes which are typical for this use. Further, the developer of the Riskofderm model stated that *“the immersion model is the least satisfactory of the developed models ... having large residual errors for both the hand and the body...and includes just 13 measurements ... all relating to degreasing of machine parts”* (Warren et al., 2006).

The conditions of use applied for the Riskofderm model are described in the following table (for details see in sections 9.2.3.2 to 9.2.3.3).

**Table Annex V-2: Conditions of use (Riskofderm modelling, DEO 1, realistic input parameters)**

	Method
<b>Product (article) characteristics</b>	
<ul style="list-style-type: none"> <li>• Physical form of the used product:               <ul style="list-style-type: none"> <li>• Aliquot chemical, bath addition/make-up: liquid</li> <li>• Aliquot chemical, bath addition/make-up: solid</li> <li>• Sampling: liquid</li> </ul> </li> </ul>	Riskofderm 2.1
<b>Amount used (or contained in articles), frequency and duration of use/exposure</b>	
<ul style="list-style-type: none"> <li>• Duration of dermal exposure:               <ul style="list-style-type: none"> <li>• Liquid: Aliquot chemical (5-10 min), bath addition/make-up (5-60 min)</li> <li>• Solid: Aliquot chemical (5 min), bath addition/make-up (5-60 min)</li> <li>• Sampling (10 min)</li> </ul> </li> </ul>	Riskofderm 2.1
<ul style="list-style-type: none"> <li>• Frequency of skin contact: Rare contact</li> </ul>	Riskofderm 2.1

	Method
<ul style="list-style-type: none"> <li>Use rate of the product: <ul style="list-style-type: none"> <li>Liquid: Aliquot chemical (0.2-2.0 L/min), bath addition/make-up (0.2-0.33 L/min)</li> <li>Solid: Aliquot chemical (0.04*-9.0 kg/min), bath addition/make-up (0.04*-0.75 kg/min)</li> <li>Sampling (0.02 L/min)</li> </ul> </li> </ul> <p>* not covered by the measurement data used for the model; results not further processed</p>	Riskofderm 2.1
<b>Technical and organisational conditions and measures</b>	
<ul style="list-style-type: none"> <li>Level of automation of the task: Manual task</li> </ul>	Riskofderm 2.1
<b>Conditions and measures related to personal protection, hygiene, and health evaluation</b>	
<ul style="list-style-type: none"> <li>Dermal protection: Yes (Chemically resistant gloves conforming to EN374 with specific activity training) and (other) appropriate dermal protection [Effectiveness Dermal: 95%]</li> </ul>	Riskofderm 2.1
<b>Other conditions affecting workers exposure</b>	
<ul style="list-style-type: none"> <li>Generation of aerosols or splashes during task: No</li> </ul>	Riskofderm 2.1
<ul style="list-style-type: none"> <li>Type of skin contact: Light skin contact</li> </ul>	Riskofderm 2.1

The 90<sup>th</sup> percentile exposure estimate from Riskofderm modelling was used for an estimate of potential dermal exposure. The results of the Riskofderm model are documented in section 11.5.2.1 of this Annex.

### Modelling results

The exposure estimates modelled with Riskofderm are shown in the following table.

**Table Annex V-3: Modelled Exposure for workers based on Riskofderm results**

Parameter	Unit	Aliquot liquid chemical		Aliquot solid chemical	Bath addition – liquid*	Bath make-up liquid*	Sampling	Rationale (Reference)
		Small amount	Large amount	Large amount*				
		(hands)	(hands)	(hands)	(hands)	(hands)	(hands)	
Potential dermal exposure to product per event	µl	9.74	166.0		9.74	186.0	2.29	Riskofderm result, 90 <sup>th</sup> percentile
Density	g/cm <sup>3</sup>	1.68	1.68		1.68	1.68	1	Information from SDS
Potential dermal exposure to product per event	mg	16.4	279	11.50	16.4	312.48	1.68	Riskofderm result for solid; calculated under consideration of Riskofderm result and density
Body weight	kg	70	70	70	70	70	70	Body weight for workers (Guidance IR & CSA, R.8 (ECHA, 2012))
Potential dermal exposure to product	mg/kg bw	0.234	3.98	0.164	0.234	4.46	0.033	Calculated
PPE efficiency (gloves, protective clothing, or apron)	%	95	95	95	95	95	95	see (EC, 2010)
Actual dermal exposure to product	mg/kg bw	0.012	0.199	0.008	0.012	0.223	0.002	Calculated
Cr(VI) concentration in product	%	30	30	40	30	30	2	See WCS specific conditions of use as described in sections 9.2.3.2 to 9.2.3.3

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<b>Actual dermal exposure to Cr(VI)</b>	<b>µg/kg bw</b>	<b>3.506</b>	<b>59.76</b>	<b>3.29</b>	<b>3.506</b>	<b>66.96</b>	<b>0.033</b>	<b>Calculated</b>
Frequency	d/year	96	2	2	48	2	240	
<b>Annual average dermal exposure to Cr(VI)</b>	<b>µg/kg bw/d</b>	<b>1.403</b>	<b>0.498</b>	<b>0.027</b>	<b>0.701</b>	<b>0.558</b>	<b>0.033</b>	<b>Calculated</b>

All values rounded to three significant figures, but unrounded values used in calculation

\* Use rate for aliquot solid small amounts and bath addition as well as use duration for bath make-up not covered by data base for model (lower than the lowest value used for the model or higher than highest duration used for the model, see section 11.5.2.1)

With realistic input parameters task-related dermal exposure estimates ranged from 0.03 to 66.9  $\mu\text{g}/\text{kg}$  bw/d, with all estimates being  $\leq 3.5 \mu\text{g}/\text{kg}$  bw/d except those for aliquoting large amounts of solids or liquids to be performed for bath make-up on rare occasions. However, taking into consideration the low frequency of this activity an annual average dermal exposure to Cr(VI) of  $<1.5 \mu\text{g}/\text{kg}$  bw/d results for all tasks.

### 11.5.2.1 Riskofderm modelling results

#### Aliquot liquid – small amount

Filling, mixing or loading (DEO unit 1)			
You can move the input messages with the input fields by dragging and dropping			
Question	Answer	Additional explanation	Measured range as basis for model
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	0,56-225 $\mu\text{g}/\text{min}$ for powders; 0,008-257 $\mu\text{g}/\text{min}$ for liquids  Scroll up or down The sheet "Fillmixload_results" provides an overview of the results of this assessment
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Liquid	The product handled is a liquid	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	0,2 L/min		
Percentile for the exposure rate distribution to be assessed	90 percentile		
Resulting exposure rate hands		median	percentile distribution
Resulting exposure rate body		,224	1,95
		only hand exposure is estimated with this model	
What is the cumulative duration of the scenario during a shift?	5 minutes		1-20 min for powders; 0,33-125 for liquids
Exposure loading per shift hands		median	percentile distribution
Exposure loading per shift body		1,120	9,740
		only hand exposure is estimated with this model	
See the guidance for some remarks on different criteria for the performance of the model.			
No model for potential body exposure is available for this scenario due to lack of data			Scroll up or down

## Aliquot liquid – large amount

Filling, mixing or loading (DEO unit 1)			
<i>You can move the input messages with the input fields by dragging and dropping</i>			<i>Scroll down to see the remainder!</i>
Question	Answer	Additional explanation	Measured range as basis for model
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Liquid	The product handled is a liquid	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	2	L/min	
Percentile for the exposure rate distribution to be assessed	90	percentile	<p>Overview results</p> <p>Back</p> <p>0,56-225 kg/min for powders; 0,008-257 L/min for liquids</p> <p><i>Scroll up or down</i> The sheet "Fillmixload_results" provides an overview of the results of this assessment</p>
		median	percentile distribution
Resulting exposure rate hands	1,91	16,6	µL/min or mg/min
Resulting exposure rate body	only hand exposure is estimated with this model		µL/min or mg/min
What is the cumulative duration of the scenario during a shift?	10	minutes	1-20 min for powders; 0,33-125 for liquids
		median	percentile distribution
Exposure loading per shift hands	19,100	166,000	µL or mg
Exposure loading per shift body	only hand exposure is estimated with this model		µL or mg
See the guidance for some remarks on different criteria for the performance of the model.			
No model for potential body exposure is available for this scenario due to lack of data			<i>Scroll up or down</i>

**Aliquot solid – small amount**

<b>Filling, mixing or loading (DEO unit 1)</b>			
<i>You can move the input messages with the input fields by dragging and dropping</i>			<i>Scroll down to see the remainder!</i>
Question	Answer	Additional explanation	Measured range as basis for model
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	for powders: always Manual task 0,56-225 kg/min for powders; 0,008-257 L/min for liquids <i>Scroll up or down The sheet "Fillmixload_results" provides an overview of the results of this assessment</i>
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Low or moderately dusty solid	A low or moderately dusty solid either does not	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	0,04 kg/min	<input type="button" value="Overview results"/> <input type="button" value="Back"/>	
Percentile for the exposure rate distribution to be assessed	90 percentile		
<b>Resulting exposure rate hands</b>		median ,001726	percentile distribution ,01499
<b>Resulting exposure rate body</b>		only hand exposure is estimated with this model	
			µL/min or mg/min µL/min or mg/min
What is the cumulative duration of the scenario during a shift?	5 minutes		1-20 min for powders; 0,33-125 for liquids
<b>Exposure loading per shift hands</b>		median 0,009	percentile distribution 0,075
<b>Exposure loading per shift body</b>		only hand exposure is estimated with this model	
			µL or mg µL or mg
<i>See the guidance for some remarks on different criteria for the performance of the model.</i>			
<b>No model for potential body exposure is available for this scenario due to lack of data</b>			<i>Scroll up or down</i>

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## Aliquot solid – large amount

Filling, mixing or loading (DEO unit 1)			
<i>You can move the input messages with the input fields by dragging and dropping</i>			
Question	Answer	Additional explanation	Measured range as basis for model
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	Scroll down to see the remainder!  for powders: always Manual task  0,58-225 kg/min for powders; 0,008-257 L/min for liquids  Scroll up or down The sheet "Fillmixload_results" provides an overview of the results of this assessment
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Low or moderately dusty solid	A low or moderately dusty solid either does not	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	9	kg/min	
Percentile for the exposure rate distribution to be assessed	90	percentile	
		<div style="text-align: center;"> <span>Overview results</span>  <span>Back</span> </div>	
		<div style="text-align: center;"> <b>median</b>                      <b>percentile distribution</b> </div>	
Resulting exposure rate hands	,266	2,31	µL/min or mg/min
Resulting exposure rate body	only hand exposure is estimated with this model		µL/min or mg/min
What is the cumulative duration of the scenario during a shift?	5	minutes	1-20 min for powders; 0,33-125 for liquids
		<div style="text-align: center;"> <b>median</b>                      <b>percentile distribution</b> </div>	
Exposure loading per shift hands	1,330	11,500	µL or mg
Exposure loading per shift body	only hand exposure is estimated with this model		µL or mg
See the guidance for some remarks on different criteria for the performance of the model.			
No model for potential body exposure is available for this scenario due to lack of data			Scroll up or down

**Bath addition – liquid**

<b>Filling, mixing or loading (DEO unit 1)</b>			
<i>You can move the input messages with the input fields by dragging and dropping</i>			<i>Scroll down to see the remainder!</i>
Question	Answer	Additional explanation	Measured range as basis for model
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	0,56-225 kg/min for powders; 0,008-257 L/min for liquids
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Liquid	The product handled is a liquid	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	0,2	L/min	
Percentile for the exposure rate distribution to be assessed	90	percentile	<i>Scroll up or down</i> <i>The sheet "Fillmixload_results" provides an overview of the results of this assessment</i>
		median	percentile distribution
Resulting exposure rate hands	,224		1,95
Resulting exposure rate body	only hand exposure is estimated with this model		
What is the cumulative duration of the scenario during a shift?	5	minutes	1-20 min for powders; 0,33-125 for liquids
		median	percentile distribution
Exposure loading per shift hands	1,120		9,740
Exposure loading per shift body	only hand exposure is estimated with this model		
<i>See the guidance for some remarks on different criteria for the performance of the model.</i>			
No model for potential body exposure is available for this scenario due to lack of data			<i>Scroll up or down</i>

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## Bath make-up – liquid

Filling, mixing or loading (DEO unit 1)			
<i>You can move the input messages with the input fields by dragging and dropping</i>			
Question	Answer	Additional explanation	Measured range as basis for model
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	0,56-225 kg/min for powders; 0,008-257 L/min for liquids
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Liquid	The product handled is a liquid	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	0,33	L/min	
Percentile for the exposure rate distribution to be assessed	90	percentile	0,56-225 kg/min for powders; 0,008-257 L/min for liquids
		<b>median</b>	<b>percentile distribution</b>
Resulting exposure rate hands	,358		3,1
Resulting exposure rate body	only hand exposure is estimated with this model		
What is the cumulative duration of the scenario during a shift?	60	minutes	1-20 min for powders; 0,33-125 for liquids
		<b>median</b>	<b>percentile distribution</b>
Exposure loading per shift hands	21,500		186,000
Exposure loading per shift body	only hand exposure is estimated with this model		
See the guidance for some remarks on different criteria for the performance of the model.			
No model for potential body exposure is available for this scenario due to lack of data			Scroll up or down

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## Bath addition – solid

Filling, mixing or loading (DEO unit 1)			Measured range as basis for model
<i>You can move the input messages with the input fields by dragging and dropping</i>			<i>Scroll down to see the remainder!</i>
Question	Answer	Additional explanation	
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	for powders: always Manual task
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Low or moderately dusty solid	A low or moderately dusty solid either does not	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	0,54	kg/min	
Percentile for the exposure rate distribution to be assessed	90	percentile	0,56-225 kg/min for powders; 0,008-257 L/min for liquids
		<b>Overview results</b>	<i>Scroll up or down</i>
		<b>Back</b>	<i>The sheet "Fillmixload_results" provides an overview of the results of this assessment</i>
		<b>median</b>	<b>percentile distribution</b>
Resulting exposure rate hands	,01942	,169	µL/min or mg/min
Resulting exposure rate body	only hand exposure is estimated with this model		µL/min or mg/min
What is the cumulative duration of the scenario during a shift?	5	minutes	1-20 min for powders; 0,33-125 for liquids
		<b>median</b>	<b>percentile distribution</b>
Exposure loading per shift hands	0,097	0,843	µL or mg
Exposure loading per shift body	only hand exposure is estimated with this model		µL or mg
<i>See the guidance for some remarks on different criteria for the performance of the model.</i>			
No model for potential body exposure is available for this scenario due to lack of data			<i>Scroll up or down</i>

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## Bath make-up solid

Filling, mixing or loading (DEO unit 1)			
<i>You can move the input messages with the input fields by dragging and dropping</i>			
Question	Answer	Additional explanation	Measured range as basis for model
What is the quality of the ventilation related to the task done?	Normal or good ventilation	Good (mechanical) ventilation and/or proper local exhaust ventilation	Scroll down to see the remainder!  for powders: always Manual task  0,56-225 kg/min for powders; 0,008-257 L/min for liquids  Scroll up or down The sheet "Fillmixload_results" provides an overview of the results of this assessment
What is the frequency of (skin) contact with the contaminant?	Rare contact	It happens sometimes, but on average less than once per scenario	
What kind of (skin) contact with the contaminant occurs?	Light contact	Touching of contaminated surfaces and/or limited deposition of dust or aerosols	
What type of product is handled?	Low or moderately dusty solid	A low or moderately dusty solid either does not	
Are significant amounts of aerosols or splashes generated in the task?	No	Task does not lead to substantial interaction between product and air, nor to dropping of product on a hard surface	
What is the level of automation of the task done by the worker?	Manual task	The task is largely done manually with substantial interaction between worker and package, contaminated installation or product	
What is the use rate of the product?	0,75 kg/min	<input type="button" value="Overview results"/> <input type="button" value="Back"/>	
Percentile for the exposure rate distribution to be assessed	90 percentile		
<b>Resulting exposure rate hands</b> <b>Resulting exposure rate body</b>		median: ,02636 percentile distribution: ,229 only hand exposure is estimated with this model	µL/min or mg/min µL/min or mg/min
What is the cumulative duration of the scenario during a shift?	60 minutes	Model was based on values up to 20 minutes for powders!	1-20 min for powders; 0,33-125 for liquids
<b>Exposure loading per shift hands</b> <b>Exposure loading per shift body</b>		median: 1,580 percentile distribution: 13,700 only hand exposure is estimated with this model	µL or mg µL or mg
See the guidance for some remarks on different criteria for the performance of the model.			
No model for potential body exposure is available for this scenario due to lack of data			Scroll up or down



## 11.6 Annex VI – Respiratory protection – Assigned protection factors (APF)

The European Standard EN 529 – “Respiratory protective devices. Recommendations for selection, use, care and maintenance” provides guidance on the selection and use of RPE. It also lists “Assigned protection factors” as recommended in various European countries. As can be seen in the Table below, APFs vary numerically between countries and no generally accepted factors exist. In a conservative approach in this review report we use the lowest value per device over all countries listed in the Table. As it is not always possible to differentiate between companies using combined gas-particle or pure particle filters P3, the same APF (20) is used for full masks with combined gas particle filter Gas X P3 and with particle filter P3.

### Assigned protection factors according to EN 529 and APFs used for assessment.

Type	Specific EU norm	Example	APFs as used in some countries according to EN 529						APF used in this report
			Fin	D	I	S	UK	FR <sup>1</sup>	
Filtering half mask FFP3 (non-reusable)	EN 149		20	30	30	20	20	10	<b>10</b>
Half mask with particle filter P3	EN 140 (mask) EN 143 (filter)		-	30	30	-	20	10	<b>10</b>
Half mask with combined gas-particle filter Gas X P3	EN 405		-	30	-	-	10	-	<b>10</b>
Full mask (all types) with particle filter P3	EN 136 (mask) EN 143 (filter)		500	400	400	500	40	30	<b>20</b>

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Full mask (all types) with combined gas-particle filter Gas X P3	EN 136 (mask) EN 143 (filter)		-	400	-	-	20	-	<b>20</b>
Powered filtering device incorporating a hood or a helmet (PAPR, powered & supplied air respiratory protection) TH3	EN 12941		200	100	200	200	40	40	<b>40</b>
Powered filtering device incorporating a full mask TM3	EN 12942		100 0	500	400	100 0	40	60 (120 l/min) 100 (160 l/min)	<b>40</b>
fresh air hose breathing apparatus - full mask or hood or helmet	EN 138		500	100 0	400	500	40	-	<b>40</b>
Supplied-air respirator (SAR) Continuous flow compressed airline breathing apparatus 4A/4B	EN 14594		-	-	-	-	-	250	<b>40</b>

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Compressed air line breathing apparatus with demand valve - Apparatus with a full face mask	EN 14593-1		100 0	100 0	400	100 0	40	-	<b>40</b>
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<sup>1</sup> Source: INRS guidance ED6106

## 12 REFERENCES

ANSES, Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (2017)

Valeurs limites d'exposition en milieu professionnel. Evaluation des indicateurs biologiques d'exposition et recommandation de valeurs biologiques pour le Chrome VI et ses composés, Rapport d'expertise collective, 26/07/2017

<https://www.anses.fr/fr/content/l%E2%80%99anses-publie-de-nouvelles-recommandations-de-valeurs-limites-d%E2%80%99exposition-en-milieu>

de Bruin, Y.B.; de Knecht, J.; Hollander, A.; Bakker, J.; van Jaarsveld, H.; Hogendoorn, E. (2010)

Risk assessment using EUSES; Refinement options to estimate atmospheric transportation by its Operational Priority Substances Model (OPS)

*Human and Ecological Risk Assessment: An International Journal*, 16, 945-961

Drexler, H.; Hartwig, A. (2009)

Biologische Arbeitsstoff-Toleranz-Werte (BAT-Werte), Expositionsäquivalente für krebserzeugende Arbeitsstoffe (EKA), Biologische Leitwerte (BLW) und Biologische Arbeitsstoff-Referenzwerte (BAR). Arbeitsmedizinisch-toxikologische Begründungen

16. Lfg., DFG Deutsche Forschungsgemeinschaft, WILEY-VCH Weinheim

EC, European Commission (2010)

Default protection factors for protective clothing and gloves. HEEG opinion 9

Joint Research Centre. Institute for Health and Consumer Protection. Chemical Assessment and Testing. [https://echa.europa.eu/documents/10162/19680902/heeg\\_opinion\\_9\\_default\\_protection\\_factors\\_for\\_clothing\\_and\\_gloves\\_en.pdf](https://echa.europa.eu/documents/10162/19680902/heeg_opinion_9_default_protection_factors_for_clothing_and_gloves_en.pdf)

ECB, European Chemicals Bureau (2005)

European Union Risk Assessment Report: Chromium Trioxide, Sodium Chromate, Sodium Dichromate, Ammonium Dichromate, Potassium Dichromate. 3rd Priority List, Vol. 53.

EUR 21508 EN. European Commission. Joint Research Centre

ECETOC, European Centre for Ecotoxicology and Toxicology of Chemicals (2009)

Technical Report No. 107. Addendum to ECETOC Targeted Risk Assessment Report No. 93

Brussels, Belgium

ECETOC, European Centre for Ecotoxicology and Toxicology of Chemicals (2012)

Technical Report No. 114. ECETOC TRA version 3: Background and Rationale for the Improvements

Brussels, Belgium. <http://www.ecetoc.org/wp-content/uploads/2014/08/ECETOC-TR-114-ECETOC-TRA-v3-Background-rationale-for-the-improvements.pdf>

Passivation of stainless steel

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ECHA, European Chemicals Agency (2011)

Member State Committee Support Document for Identification of Dichromium tris(chromate) as a Substance of Very High Concern because of its CMR Properties. SVHC Support Document. Adopted on 24 November 2011

[https://echa.europa.eu/documents/10162/13638/suppdoc\\_dichromium+tris\\_20111129\\_en.pdf](https://echa.europa.eu/documents/10162/13638/suppdoc_dichromium+tris_20111129_en.pdf)

ECHA, European Chemicals Agency (2012)

Guidance on Information Requirements and Chemical Safety Assessment. Chapter R.8: Characterisation of dose [concentration]-response for human health. Version 2.1, November 2012

Helsinki, Finland. <https://echa.europa.eu/guidance-documents/guidance-on-information-requirements-and-chemical-safety-assessment>

ECHA, European Chemicals Agency (2013)

Application for Authorisation: Establishing a Reference Dose Response Relationship for Carcinogenicity of Hexavalent Chromium

Helsinki, 04 December 2013. RAC/27/2013/06 Rev.1. (Agreed at RAC-27).

[http://echa.europa.eu/documents/10162/13579/rac\\_carcinogenicity\\_dose\\_response\\_crvi\\_en.pdf](http://echa.europa.eu/documents/10162/13579/rac_carcinogenicity_dose_response_crvi_en.pdf)

ECHA, European Chemicals Agency (2015)

Amendment of the RAC note "Application for Authorisation: Establishing a reference dose-response relationship for carcinogenicity of hexavalent chromium" to include the intrinsic property "Toxic to reproduction" of the Cr(VI) compounds (RAC/27/2013/06 Rev.1 agreed on 4 December 2013 at RAC-27)

35th Meeting of the Committee for Risk Assessment 24-27 November \_ 1-4 December 2015, Helsinki, Finland.

[https://echa.europa.eu/documents/10162/21961120/rac\\_35\\_09\\_1\\_c\\_dnel\\_cr-vi\\_en.pdf/8964d39c-d94e-4abc-8c8e-4e2866041fc6](https://echa.europa.eu/documents/10162/21961120/rac_35_09_1_c_dnel_cr-vi_en.pdf/8964d39c-d94e-4abc-8c8e-4e2866041fc6)

ECHA, European Chemicals Agency (2016a)

Guidance on Information Requirements and Chemical Safety Assessment. Chapter R.16: Environmental exposure assessment. Version 3.0, February 2016

Helsinki, Finland. <https://echa.europa.eu/guidance-documents/guidance-on-information-requirements-and-chemical-safety-assessment>

ECHA, European Chemicals Agency (2016b)

Guidance on Information Requirements and Chemical Safety Assessment. Chapter R.14: Occupational exposure assessment. Version 3.0, August 2016

Helsinki, Finland. <https://echa.europa.eu/guidance-documents/guidance-on-information-requirements-and-chemical-safety-assessment>

ECHA, European Chemicals Agency (2021)

Passivation of stainless steel

SD

How to apply for authorisation. Version 1.2, February 2021. ECHA-21-G-01-EN

<http://echa.europa.eu/>

EFSA, European Food Safety Authority (2014)

Scientific Opinion on the risks to public health related to the presence of chromium in food and drinking water. EFSA Panel on Contaminants in the Food Chain (CONTAM)

*The EFSA Journal*, 12(3):3595, <http://www.efsa.europa.eu/de/efsajournal/doc/3595.pdf>

EU, European Union (2013)

Directive 2004/37/EC of the European Parliament and of the Council of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at

work (Sixth individual Directive within the meaning of Article 16(1) of Council Directive 89/391/EEC) (codified version)

*Official Journal of the European Union*, L 226/1,

Greim, H. (2000)

Analytische Methoden zur Prüfung gesundheitsschädlicher Arbeitsstoffe. Band 2: Analysen in biologischem Material

Deutsche Forschungsgemeinschaft, Arbeitsgruppe "Analytische Chemie" der Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe

14. Lfg., Wiley-VCH, Weinheim

Morton, M.; Lion, K. (2016)

Estimation with Values Below the Limit of Quantitation

Presented at CORESTA Congress - Berlin, Germany - 9-13 October 2016

RIVM, National Institute of Public Health and the Environment (2004)

European Union System for the Evaluation of Substances 2.0 (EUSES 2.0). Background report. RIVM Report no. 601900005/2004

RIVM, Bilthoven, The Netherlands Prepared for the European Chemicals Bureau

Succop, P.A.; Clark, S.; Chen, M.; Galke, W. (2004)

Imputation of data values that are less than a detection limit

*Journal of Occupational and Environmental Hygiene*, 1, 436-441

Toet, C.; de Leeuw, F.A.A.M. (1992)

Passivation of stainless steel

SD

Risk Assessment System for New Chemical Substances: Implementation of atmospheric transport of organic compounds. RIVM Rapport 679102008

RIVM, National Institute for Public Health and the Environment, Bilthoven, The Netherlands

U.S. EPA, Environmental Protection Agency (2019)

Guidelines for Human Exposure Assessment. EPA/100/B-19/001

Washington, D.C.: Risk Assessment Forum, U.S. EPA. [https://www.epa.gov/sites/production/files/2020-01/documents/guidelines\\_for\\_human\\_exposure\\_assessment\\_final2019.pdf](https://www.epa.gov/sites/production/files/2020-01/documents/guidelines_for_human_exposure_assessment_final2019.pdf)

Warren, N.D.; Marquart, H.; Christopher, Y.; Laitinen, J.; van Hemmen, J.J. (2006)

Task-based dermal exposure models for regulatory risk assessment

*Annals of Occupational Hygiene*, 50, 491-503