9.2 Downstream user exposure scenarios

9.2.1 Exposure scenario 2: Use of Sn(II)MSA in formulation

9.2.1.1 Description of activities and processes covered in the exposure scenario

Tin MSA solutions are mixed with other liquids to form products for use in tin electroplating and other applications.

9.2.1.2 Operational conditions related to frequency, duration and amount of use

Table 16 outlines the frequency and duration of activities leading to potential exposure to Tin MSA during product formulation and the quantities of Tin MSA involved.

Table 16: Duration, frequency and amount

Information type	Data field	Explanation
Used amount of substance (as such or in preparation) per worker [workplace] per day	<0.1 kg – 50, 000 kg/d	Small quantities employed in laboratory analysis, substantial quantities involved in product mixing and blending
Duration of exposure per day at workplace [for one worker]	1h – 8h/shift	Lab analysis undertaken 1, monitoring other operations undertaken for full shift
Frequency of exposure at workplace [for one worker]	Daily	1 h / shift
Annual amount used per site	< 100000 tonnes/y	
Emission days per site	300 d/y	

9.2.1.3 Operational conditions and risk management measures related to product characteristics

Table 17 outlines the characteristics of Tin MSA that influence the potential for exposure to occur.

Table 14: Characteristics of Tin MSA used in product formulation

Information type	Data field	Explanation
Physical state	Supplied as 50% aqueous solution; non-volatile	
Concentration of substance in preparation	50%	
Concentration after dilution for use (if relevant)	20-50%	
Risk management measures related to the design of product	Supplied to end users in liquid form in sealed water tight packaging	

9.2.1.4 Operational conditions related to available dilution capacity and characteristics of exposed humans

Assumptions made in developing the exposure estimates are shown in Table 18.

Table 18: Operational conditions related to respiration and skin contact

Information type	Data field	Explanation
Respiration volume under conditions of use	10 m^3/d	ES does not involve significant manual work
Room size and ventilation rate	n/a	ES not site specific
Area of skin contact with the substance under conditions of use	1980 cm^2	Potential for dermal contact limited to the hands
Body weight	65 kg	Default for workers

9.2.1.5 Other operational conditions of use

The releases to air, water and waste before risk management are shown in Table 19.

Table 19: Technical fate of substance and losses from process/use to waste, waste water and air

Information type	Data field	Explanation
Fraction of applied amount lost from process/use to waste gas,	<0.000001 kg/kg	Tin MSA is non-volatile, handled in solution in enclosed processes, no losses to air
Fraction of applied amount lost from process/use to waste water	<0.000001 kg/kg	Process would not normally generate waste fluids containing tin MSA; waste fluids that may contain tin MSA or other tin compounds are treated on site to precipitate tin as tin oxide/hydroxide compounds that are removed by filtration and disposed of to a specialist contractor for tin reclamation or landfill at an appropriately licensed site
Fraction of applied amount lost from process/use to waste	<0.000001 kg/kg	No off-site disposal of wastes containing tin MSA
Fraction consumed in process/use	0.0001 kg/kg	Tin MSA repackaged in different formulations without conversion of Tin MSA to other substances
Fraction of applied amount leaving the site with products	>0.99 kg/kg	Process designed to ensure maximum efficiency of use of tin MSA brought on site

9.2.1.6 Risk management measures

The risk management measures in place to minimise workplace exposure and minimise releases to the wider environment are outlined in Table 20.

Table 20: Risk management measures for site where tin MSA used in formulation

Information type	Data field	Explanation
Containment and local exhaust ventilation		
Product supplied to site by road tanker and piped to sealed storage tanks	>99% reduction in exposure	No release of product during delivery and storage prior to use
Tin MSA is handled within a closed	99% reduction in exposure	No release of Tin MSA during normal

Information type	**Data field**	**Explanation**
system with limited occasional access for sampling		operation, minimal release during sampling
Local exhaust ventilation is in place when sampling is undertaken	90% reduction in exposure	Small volume of collected sample limits potential for exposure
Piped transfer of fluids containing tin MSA from storage tanks to mixing vessels	95% reduction in exposure	Small potential for exposure when switching between tanks
Tin MSA piped from mixing vessel to filling equipment, filling process automated and enclosed, dispatched from site in sealed containers	95% reduction in exposure	Infrequent low level of exposure if operator has to breach containment address a process problem
Product is handled in sealed container or fume cupboard during analysis	99% reduction in exposure	Minimal release of Tin MSA to room air during handling in fume cupboard
Personal protective equipment (PPE)		
Gloves, goggles, shield, apron, boots worn during sampling and during product transfer operations	>90% reduction in dermal exposure	
Other risk management measures related to workers		
Provision of appropriate training including training in safe working procedures with regard to human health and the environment		Efficiency of other RMMs dependent on proper use which requires training in the correct procedures and in the importance of following these procedures
Maintenance of good workplace hygiene, no eating, drinking or smoking where tin MSA handled		Eliminate inadvertent skin contact or ingestion
Risk management measures related to environmental emissions from industrial sites		
Onsite pre-treatment of waste water	<1% tin MSA remains in waste fluids after on-site treatment	Chemical precipitation
Resulting fraction of initially applied amount in waste water released from site to the external sewage system	<0.01 kg/kg	No offsite discharge of tin MSA in waste water
Air emission abatement - emitted fraction after on-site treatment compared to the fraction lost form the technical process	<0.001%	Process does not give rise to emissions of tin MSA in air; Scrubber used to treat process emissions to air (not specifically tin MSA)
Resulting fraction of applied amount in waste gas released to environment	<0.001 kg/kg	No discharge of tin MSA to air
Onsite waste treatment: fraction after on-site treatment compared to the fraction entered into waste treatment	<5%	Precipitated waste transferred to storage drums and deposited in an appropriately licensed controlled landfill or sent for tin recovery
Fraction of initially applied amount sent to external waste treatment. This is the sum of direct losses from processes to waste, and the residues from onsite waste water and waste gas treatment.	none	Waste water treated at onsite waste water treatment plant
Municipal or other type of external waste water treatment	No offsite waste water treatment	
Effluent (of the waste water treatment plant) discharge rate	m^3/d	*Default: 2.000* m^3/d
Recovery of sludge for agriculture or horticulture	No	

9.2.1.7 Waste related measures

Waste management measures and their effectiveness are described in Table 21.

Table 21: Fractions of substance in waste and waste management measures

Information type	Data field	Explanation
Amount of substances in waste resulting from identified uses covered in the exposure scenario	< 1 kg/y	Process waste containing tin MSA is treated on site; no offsite transfer of wastes containing tin MSA
Amount of substances in waste resulting from service life of articles	Not applicable	Tin MSA supplied to downstream users as a preparation; No tin MSA contained in articles created using tin MSA formulations by end users
Type of waste, suitable waste codes	06 03 15	Metallic oxides containing heavy metals – on-site treatment of wastes ensures that solid waste generated at formulators' sites does not contain tin MSA
Type of external treatment aiming at recycling or recovery of substances	No transfer of waste offsite	n.a. onsite wastewater treatment plant available
Fraction of the initially applied amount of substance recovered.	Not applicable	
Type of external treatment aiming at final disposal of the waste	Not applicable	Solid wastes generated by on-site treatment of wastes containing tin MSA are sent for tin recovery where appropriate facilities exist or disposed of to an appropriately licensed landfill; these wastes do not contain tin MSA
Fraction of substance released into the environment via air from waste handling	Not applicable	
Fraction of substance released into the environment via waste water from waste handling	<< 0.0001 kg/kg	
Fraction of substance disposed of as secondary waste	Not applicable	

9.2.2 Exposure estimation

9.2.2.1 Workers exposure

9.2.2.1.1 Acute/Short term exposure

Table 22 outlines derivation of the estimate of peak exposures associated with each subscenario identified for formulation.

Table 22: Acute exposure concentrations to workers

Routes of exposure	**Estimated Exposure Concentrations**		**Measured exposure concentrations**		**Explanation / source of measured data**
	value	**unit**	**Value**	**unit**	
Dermal exposure	20	mg	-		Fluid transfer operations and mixing operations - dermal exposure extremely intermittent and 75^{th} percentile of peak exposure estimated as if entire shift exposure occurred in single episode
	100	mg			Filling: dermal exposure likely to be intermittent throughout shift; 75^{th} percentile of peak exposure estimated as if entire shift exposure occurred in single episode
Inhalation exposure	0.153		-		PROC 5 Mixing or blending in batch processes: There are no measured inhalation exposure data. Inhalation exposures are anticipated to be small as tin MSA handled in solution, the mixing vessel is enclosed and LEV is in place. The 75^{th} percentile of peak exposure concentrations was estimated as 3x the predicted 75^{th} percentile exposure concentration for the activity, modelled using ART –0.051 mg/m3. The use of RPE (P3 filter) during addition of Tin MSA to the mixing vessel would reduce exposure by a factor >10.
	0.138	mg/ m3	-		PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no measured inhalation exposure data. Inhalation exposures are anticipated to be small as Tin MSA handled in solution and the transfer process is enclosed (piped). The 75^{th} percentile of peak exposure concentrations was estimated as 3x the predicted 75^{th} percentile exposure concentration for the activity, modelled using ART
	0.045	mg/ m3	-		PROC 9 Transfer of substance or preparation into small containers: there are no measured inhalation exposure data. Inhalation exposures are anticipated to be small as Tin MSA handled in solution, containers are filled using a pipe (ie process is semi-enclosed), the filling process is automated and LEV is in place. The 75^{th} percentile of peak exposure concentrations was estimated as 3x the predicted 75^{th} percentile exposure concentration for the activity, modelled using ART
	0.027	mg/ m3	-		PROC 15 Use as a laboratory agent: Inhalation exposure concentrations are anticipated to be small as Tin MSA kept within sealed containers and handled within a fume cupboard. The 75^{th} percentile of peak exposure concentrations was estimated as 3x the predicted 75^{th} percentile exposure concentration for the activity, as modelled using ART

The short-term exposure values are summarised in Table 23.

Table 23: Summary of acute exposure concentrations to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.05	Estimated 75th percentile of peak exposures for filling; assumes exposure confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	1.43	Estimated 75th percentile of exposures for operations other than cleaning and maintenance - assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No acute systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)	0.153	Estimated 75th percentile of peak exposure concentrations for routine operations associated with the highest predicted exposure levels (mixing or blending in batch processes).

9.2.2.1.2 Long-term exposure

Table 24 outlines derivation of the estimate of shift mean exposures associated with each subscenario identified for formulation.

Table 24: Long-term exposure concentrations to workers

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
Dermal exposure	20	mg/ day			PROC 5 Mixing or blending in batch processes: There are no dermal exposure data. Provided that appropriate protective clothing and gloves are used, the potential for dermal exposure is small as there should be no direct contact with Tin MSA or mixtures containing Tin MSA. The EASE model would predict exposures of 0.1-1 mg/cm2/day for incidental hand contact. If allowance is made for the use of suitable gloves, and that contact would be intermittent, dermal exposure is likely to be of the order of 20 mg/day.
	20	mg/ day			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no dermal exposure data. Provided that appropriate protective clothing and gloves are used, the potential for dermal exposure is small as the liquid is enclosed during the transfer operation. Tasks that might plausibly give rise to dermal exposure including the handling of pipe ends while switching between tanks would only be undertaken for a small proportion of the working shift. The EASE model would predict exposures of 0.1-1 mg/cm2/day for incidental hand contact. If allowance is made for the use of suitable gloves, and that contact would be intermittent, dermal exposure is likely to be of the order of 20 mg/day.
	100	mg/ day			PROC 9 Transfer of substance or preparation into small containers There are no dermal exposure data. Provided that appropriate protective clothing and gloves are used, the potential for dermal exposure is anticipated to be small as the liquid is enclosed during the filling operation, but greater than for charging and discharging larger vessels. The EASE model would predict exposures of 1-5 mg/cm2/day for intermittent hand contact. If allowance is made for the use of suitable gloves, and that contact would be intermittent, dermal exposure is likely to be of the order of 100 mg/day.
	0.1	mg/			PROC 15 Use as a laboratory agent: Dermal exposure is anticipated to be negligible as Tin MSA solution

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
		day			contained within appropriate containers. 75th percentile of shift mean exposure estimated as 0.1 mg/day.
Inhalation exposure	0.051	mg/ m3			PROC 5 Mixing or blending in batch processes: There are no measured inhalation exposure data. Inhalation exposures are anticipated to be small as Tin MSA handled in solution, the mixing vessel is enclosed and LEV is in place. The median exposure concentration predicted by ART (assuming a flow rate of 100-1000 L/minute) is 0.025 mg/m3, with an interquartile range of 0.012 mg/m3–0.051 mg/m3. The use of RPE (P3 filter) during addition of Tin MSA to the mixing vessel would reduce exposure by a factor >10.
	0.046	mg/ m3			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no measured inhalation exposure data. Inhalation exposures are anticipated to be small as Tin MSA handled in solution and the transfer process is enclosed (piped). The median peak exposure concentration predicted by ART (assuming a flow rate of 100-1000 L/minute) is 0.022 mg/m3, with an interquartile range of 0.011 mg/m3–0.046 mg/m3. The use of RPE (P3 filter) during liquid transfer operations would reduce exposure by a factor >10.
	0.015	mg/ m3			PROC 9 Transfer of substance or preparation into small containers: there are no measured inhalation exposure data. Inhalation exposures are anticipated to be small as Tin MSA handled in solution, containers are filled using a pipe (ie process is semi-enclosed), the filling process is automated and LEV is in place. The median exposure concentration predicted by ART (assuming a flow rate of 100-1000 L/minute) is 0.00074 mg/m3, with an interquartile range of 0.00036 mg/m3–0.015 mg/m3. The use of RPE (P3 filter) during liquid transfer operations would reduce exposure by a factor >10.
	0.045	mg/ m3			PROC 15 Use as a laboratory agent: Inhalation exposure negligible as Tin MSA in solution and handled within fume cupboards or contained in sealed vessels during transfer across open workspace. No exposure data are available and the median exposure concentration for the activity, modelled using ART is 0.0044 mg/m3 (for activity) with an interquartile range of 0.0022 mg/m3–0.0091 mg/m3 (no RPE). It is assumed that analysis of Tin MSA is undertaken for up to 4 hours and the 75th percentile shift mean exposures will be <50% of the modelled levels of that predicted by ART.

The long-term exposure values are summarised in Table 25.

Table 2515: Summary of long-term exposure concentration to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.05	Estimated 75th percentile of exposures for operations other than cleaning and maintenance; assumes exposure extremely intermittent, confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	1.43	Estimated 75th percentile of exposures for operations other than cleaning and maintenance - assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No adverse systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)/8h workday	0.051	Estimated 75th percentile of exposure concentrations for routine operations associated with the highest predicted exposure levels (mixing or blending in batch processes)

9.2.2.2 Indirect exposure of humans via the environment (oral)

There are no measurement data describing the indirect exposure of humans to tin MSA but emissions of tin MSA to the environment from the production process are negligible and any tin MSA released to the environment would have an extremely short lifetime. The indirect exposure of humans to tin MSA via the environment would be predicted to be nil.

9.2.2.3 Environmental exposure

9.2.2.3.1 Environmental releases

Releases of tin MSA to the environment as a result of the formulation of products containing tin MSA and the associated treatment of process wastes are exceedingly small and effectively nil (Table 26).

Table 26: Releases to the environment arising during use of tin MSA in formulation

Compartments	Predicted releases (kg/d)	Measured release (kg/d)	Explanation / source of measured data
Aquatic (without STP)	< 0.001 kg /day	No data	Process does not generate waste water. No process waste containing tin MSA is released to the aquatic environment. Tin MSA is unstable in water and would decompose to form other tin compounds
Aquatic (after STP)	< 0.001 kg /day	No data	Process waste is treated on site and no tin MSA is released to the aquatic environment. Tin MSA is unstable in water and would decompose to form other tin compounds prior to discharge of treated waste water from site.
Air (direct + STP)	< 0.001 kg /day	No data	Tin MSA is non-volatile, unstable in the solid form; any tin MSA that enters the waste gas stream is removed by scrubber (process emissions) or decomposes before emission (any other inadvertent releases)
Soil (direct only)	< 0.001 kg /day	No data	Waste from Tin MSA production is converted to insoluble tin salts before disposal to landfill or processesing for tin recovery

Table 27 the releases taken into account for the exposure estimation.

Table 27: Summary of the releases to the environment from the formulation of products containing Tin MSA

Compartments	Release from point source (kg/d) (local exposure estimation)	Total release for regional exposure estimation (kg/d)	Justification
Aquatic (without STP)	< 0.001 kg /day	none	Process waste is treated on site and no tin MSA is released to the aquatic environment. Tin MSA is unstable in water and would decompose to form other tin compounds prior to discharge of treated waste water from site.
Aquatic (after STP)	< 0.001 kg /day	none	Process waste is treated on site and no tin MSA is released to the aquatic environment. Tin MSA is unstable in water and would decompose to form other tin compounds prior to discharge of treated waste water from site.
Air (direct + STP)	< 0.001 kg /day	none	Tin MSA is non-volatile, unstable in the solid form and enter that enters the waste gas stream would decompose before emission
Soil (direct releases only)	< 0.001 kg /day	none	Waste from Tin MSA production is converted to insoluble tin salts before disposal to landfill

9.2.2.3.2 Exposure concentration in sewage treatment plants (STP)

The formulation of Tin MSA products does not lead to any emissions of Tin MSA to municipal sewage treatment plants. The concentrations of Tin MSA in sewage or sewage sludge arising from formulation of tin MSA products are << 1 ppb.

9.2.2.3.3 Exposure concentration in aquatic pelagic compartment

The formulation of Tin MSA products does not lead to any emissions of Tin MSA to the wider aqueous environment. The concentrations of Tin MSA in freshwater or marine waters from the formulation of tin MSA products are << 1 ppb.

9.2.2.3.4 Exposure concentration in sediments

The formulation of Tin MSA products does not lead to any emissions of Tin MSA to the wider aqueous environment. The concentrations of Tin MSA in sediments arising from the formulation of tin MSA products are << 1 ppb.

9.2.2.3.5 Exposure concentrations in soil and groundwater

There is no offsite transfer of solid waste containing Tin MSA from sites where it is used in product formulation. Exposure concentrations in soil and groundwater arising as a result of waste disposal from sites using tin MSA in product formulation are << 1 ppb.

9.2.2.3.6 Atmospheric compartment

No Tin MSA is emitted to air during product formulation. The concentrations of tin MSA arising in air as a result of the formulation of Tin MSA products would be << 0.0001 ng/m3.

9.2.2.3.7 Exposure concentration relevant for the food chain (Secondary poisoning)

No tin MSA enters the food chain as a result of the use of tin MSA in product formulation. Releases of tin MSA if any from manufacturing are vanishingly small and the lifetime of tin MSA in environmental media would be exceedingly short.

9.3 Exposure scenario 3: Use of Sn(II)MSA in automated electroplating

9.3.1.1 Description of activities and processes covered in the exposure scenario

The Tin(II)-methanesulfonate is supplied and used in aqueous solution. Articles are plated during immersion in a tank of Tin MSA: articles are loaded onto a jig, or conveyer, automatically immersed in the plating tank, removed from the tank, rinsed and allowed to dry prior to removal from the jig or conveyer. Dipping process is enclosed. No direct contact with Tin MSA occurs. Plating is undertaken at room temperature.

9.3.1.2 Operational conditions related to frequency, duration and amount of use

Tin plating is generally undertaken at dedicated facilities and workers are exposed on a daily basis (Table 28). The quantities of Tin MSA employed will depend partly on the size of the articles being coated and thickness of coating applied and partly on how many articles are coated during a typical shift. The tin MSA content of the plating bath is maintained by topping up. Plating baths are not routinely emptied prior to replenishment (<20 times/year). The concentration of tin MSA in spent fluids from plating baths is negligible and waste fluids are treated prior to disposal to remove any residual tin MSA that may be present. It is assumed that most automated plating shops will operate bigger baths and have higher throughputs than manual plating shops.

Table 28: Duration, frequency and amount

Information type	Data field	Explanation
Used amount of substance (as such or in preparation) per worker [workplace] per day	<0.1-1000 kg/d	Small quantities employed in laboratory analysis, substantial quantities involved in plating process and even greater quantities handled during delivery and recharging of the tank
Duration of exposure per day at workplace [for one worker]	1-8h/day	Lab analysis undertaken for between 1 and 4 hours/shift, other operations undertaken for full shift
Frequency of exposure at workplace [for one worker]	Daily	
Annual amount used per site	1-10 tonnes/y	
Emission days per site	200 d/y	

9.3.1.3 Operational conditions and risk management measures related to product characteristics

Tin MSA is supplied in solution at a ready to use concentration and is added to other components of the plating fluids (Table 29).

Table 16: Characteristics of Tin MSA used in automated electroplating

Information type	Data field	Explanation
Physical state	Supplied in sealed containers as 30-50% aqueous solution	
Concentration of substance in preparation	30-50%	
Concentration after dilution for use (if relevant)	<10%	
Risk management measures related to	Supplied in liquid form	

Information type	Data field	Explanation
the design of product		

9.3.1.4 Operational conditions related to available dilution capacity and characteristics of exposed humans

Assumptions made in developing the exposure estimates are shown in Table 30.

Table 17: Operational conditions related to respiration and skin contact

Information type	Data field	Explanation
Respiration volume under conditions of use	10 m^3/d	ES does not involve significant manual work
Room size and ventilation rate	n/a	ES not site specific
Area of skin contact with the substance under conditions of use	1980 cm^2	Potential for dermal contact limited to the hands
Body weight	65 kg	Default for workers

9.3.1.5 Other operational conditions of use

The releases to air, water and waste before risk management are shown in Table 31. Any unused tin MSA would be returned to the supplier for recovery.

Table 31: Technical fate of substance and losses from automated electroplating operations to waste, waste water and air

Information type	Data field	Explanation
Fraction of applied amount lost from process/use to waste gas,	<0.00001 kg/kg	Non volatile substance, no losses to air
Fraction of applied amount lost from process/use to waste water	<0.00001 kg/kg	Tin MSA consumed in process, plating solution conserved, no discharge of plating fluids containing tin MSA during routine working
Fraction of applied amount lost from process/use to waste	<0.001 kg/kg	Tin MSA consumed in process, no transfer to the waste stream during normal operation
Fraction consumed in process/use	0.999 kg/kg	Tin MSA converted to tin during plating process; process managed to minimise wastage
Fraction of applied amount leaving the site with products	<0.00001 kg/kg	Tin MSA converted to Tin metal during plating process; all plated products thoroughly rinsed

9.3.1.6 Risk management measures

The risk management measures in place during automated electroplating employing tin MSA are outlined in Table 32 below.

Table 32: Risk management measures for automated electroplating operations

Information type	Data field	Explanation
Containment and local exhaust ventilation		
Product supplied in sealed plastic containers	>99% reduction in exposure	No release of product during delivery and storage prior to use
Product supplied in sealed plastic	>99% reduction in exposure	No release of product during delivery

Information type	**Data field**	**Explanation**
containers		and storage prior to use
The plating bath is enclosed and LEV is in place	90% reduction in exposure	Minimal release of Tin MSA to workplace air
Automation of the plating process	90% reduction in exposure	No requirement for workers to be in close proximity to plating tank
Piped transfer of fluids in and out of plating tank	95% reduction in exposure	Small potential for exposure when switching between tanks
LEV in place where fluid transfer operations undertaken	90% reduction in exposure	Potential for aerosolisation very small but LEV in place
Product is handled in sealed container or fume cupboard during analysis	99% reduction in exposure	Minimal release of Tin MSA to room air during handling in fume cupboard
Personal protective equipment (PPE)		
Use of gloves and protective clothing to minimise dermal contact	90%	Some penetration of protective clothing and gloves may occur
Mechanisation of plating process to avoid requirement for direct dermal contact with plating solution	90%	Process failures may lead to requirement for direct contact with articles being coated
Eye protection	99% reduction in exposure	Goggles expected to prevent exposure
Other risk management measures related to workers		
Provision of appropriate training including training in safe working procedures with regard to human health and the environment		Efficiency of other RMMs dependent on proper use which requires training in the correct procedures and in the importance of following these procedures
Maintenance of good workplace hygiene, no eating, drinking or smoking where tin MSA handled		Eliminate inadvertent skin contact or ingestion
Risk management measures related to environmental emissions from industrial sites		
Efficiency of removal of tin MSA by site pre-treatment of waste water (as fraction of product used)	<0.000001 kg/kg	Process waste not discharged as waste water; waste water generated by on-site treatment of process waste would not contain tin MSA
Resulting fraction of initially applied amount in waste water released from site to the external sewage system	<0.000001 kg/kg	Process waste not discharged as waste water
Air emission abatement	Not applicable	Non-volatile substance in solution, no emissions to air
Resulting fraction of applied amount in waste gas released to environment	Not applicable	Non-volatile substance in solution, no emissions to air
Onsite waste treatment	<0.1% of tin MSA remains in waste material following on-site treatment	Waste tin MSA/plating fluids are diluted by a factor of between 10 and 25, hydrogen peroxide (30% solution) is added at 10 ml/l - 25 ml/l for dilutions of between 25 and 10, allowed to react for 6 hours, pH is adjusted to 9.0 with lime milk and after 2-6 hours the mixture is passed through a filter press to removed the precipitated tin compounds. Alternatively waste solutions can be treated with a priority precipitant based on an organosulifide in order to convert tin MSA to insoluble tin compounds; conversion of tin MSA to other compounds highly efficient (>99.9%)
Fraction of initially applied amount sent	<0.000001 kg/kg	No requirement for routine disposal of

Information type	Data field	Explanation
to external waste treatment. This is the sum of direct losses from processes to waste, and the residues from onsite waste water and waste gas treatment.		tin MSA; any waste fluids containing tin MSA are pre-treated before leaving site to convert tin compounds to solid phase which is recovered by filtration
Municipal or other type of external waste water treatment	Not applicable	No tin MSA discharged in waste water
Effluent (of the waste water treatment plant) discharge rate	Not applicable	*Default: 2.000 m^3/d*
Recovery of sludge for agriculture or horticulture	No	

9.3.1.7 Waste related measures

Tin MSA is consumed during the plating process and would not normally be present in process waste. Plating fluid replenished by topping up rather than replacement during routine operation. Table 33 outlines the losses of Tin MSA to waste and during waste handling.

Table 18: Fractions of substance in waste and waste management measures

Information type	Data field	Explanation
Amount of substances in waste resulting from identified uses covered in the exposure scenario	< 0.1 kg/y	
Amount of substances in waste resulting from service life of articles	Not applicable	Tin plated articles do not contain tin MSA
Type of waste, suitable waste codes	11 02 07	Wastes from nonferrous hydrometallurgical processes, other wastes containing dangerous substances
Type of external treatment aiming at recycling or recovery of substances	Not applicable	Currently tin is not recovered from treated process residues
Fraction of the initially applied amount of substance recovered.	Not applicable	
Type of external treatment aiming at final disposal of the waste	Process wastes disposed of to appropriately licensed waste disposal site, most commonly landfill	Solid process wastes do not contain tin MSA or other leachable substances
Fraction of substance released into the environment via air from waste handling	<0.000001 kg/kg	
Fraction of substance released into the environment via waste water from waste handling	<0.000001 kg/kg	Solid process wastes do not contain tin MSA or other leachable substances
Fraction of substance disposed of as secondary waste	Not applicable	

9.3.2 Exposure estimation

9.3.2.1 Workers exposure

9.3.2.1.1 Acute/Short term exposure

Table 34 outlines derivation of the estimate of peak exposures associated with each subscenario identified for automated electroplating.

Table 19: Acute exposure concentrations to workers

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
Dermal exposure	20	mg			Fluid transfer operations and plating operations - dermal exposure extremely intermittent and 75th percentile of peak exposure estimated as if entire shift exposure occurred in single episode (ie assumed to be equivalent to the intake associated with the 75th percentile of full shift exposures). This may represent a significant over-estimate of peak exposures, if the full shift exposure typically results from 2 or more distinct episodes during the shift
	0.1	mg			Use as a laboratory agent: dermal exposure likely to be intermittent throughout shift; 75th percentile of peak exposure estimated as if entire shift exposure occurred in single episode
Inhalation exposure	0.69	mg/ m3			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day
	0.03	mg/ m3			PROC 13 Treatment of articles by dipping and pouring: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day.
	0.00135	mg/ m3			PROC 15 Use as a laboratory agent: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day.

The short-term exposure values are summarised in Table 35.

Table 20: Summary of acute exposure concentrations to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.01	Estimated 75th percentile of peak exposure for fluid transfer operations and plating based on estimated 75th percentile of full shift exposures for these operations; assumes exposure extremely intermittent such that it may occur over a single short period during the working shift, confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	0.023	Estimated 75th percentile of peak exposures for fluid transfer operations and plating based on estimated 75th percentile of full shift exposures for these operations, assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No adverse systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)	0.069	Estimated 75th percentile of peak concentrations for fluid transfer operations – the routine activity giving rise to the highest exposure. Peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day

9.3.2.1.2 Long-term exposure

Table 36 outlines derivation of the estimate of shift mean exposures associated with each subscenario identified for automated electroplating.

Table 36: Long-term exposure concentrations to workers

	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
Routes of exposure	**value**	**unit**	**Value**	**unit**	
Dermal exposure	20	mg/ day			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no dermal exposure data. Provided that appropriate protective clothing and gloves are used, the potential for dermal exposure on is small as the task of topping up the plating tank is only be undertaken for a small proportion of the working shift, involves relatively small volumes of fluid and requires no direct dermal contact with fluids containing tin MSA. The EASE model would predict exposures of 0.1-1 mg/cm2/day for incidental hand contact. If allowance is made for the use of suitable gloves, dermal exposure is likely to be of the order of 20 mg/day. Levels of dermal exposure during emptying of the plating tank are likely to be lower than those associated with topping up as the tin MSA content of spent plating fluids is negligible, the fluid is enclosed in pipes and tasks that might lead to dermal contact such as securing pipe ends are only undertaken for a short period during the shift.
	0.1	mg/ day			PROC 13 Treatment of articles by dipping and pouring: Dermal exposures are anticipated to be small as automation would be anticipated to remove the necessity for routine immersion of hands in the plating solution or the handling of freshly plated pieces. There are no published dermal exposure data for tin plating and the published measurement data available for other metal plating processes are not specific to automated plating and are likely to include workers who did immerse their hands in the plating solution. Mainen and Linnainmaa (2004) reported that full body dermal exposure to the plating solution during chrome plating ranged from 0.17-28.1 mg/hour and hand exposure ranged from 0.04-6.37 mg/hour with significant individual variation. Measurements were made at for both automated and manual processes and it was found that automation did not necessarily reduce exposure as workers spent time sorting problems with the automated process. Only some workers wore impermeable gloves and in all the workplaces, workers took off their gloves in order to smoke. Roff et al (2004)[2] reported full body dermal metal exposures of metal plating workers to chrome as 0.037 mg/m2/hour (median of 26 oversuits; GSD 0.0035) and hand exposure (based on 25 pairs of sampling gloves worn inside sampling gloves) of 0.19 mg/m2/hour (GSD = 0.00275). Bavazzano et al (1994)[3] reported a median loading of Ni on workers' hands and faces of 0.009 mg/day (range 0.001-0.086 mg/day) in their study of Ni plating workers. The EURA (2008-9) for Ni metal[4] estimated that typical levels of dermal exposure to Ni during electroplating were 0.039 mg Ni/day of which 0.027mg Ni/day was as soluble species (assume median exposure) with the worst case exposure being 0.37 mgNi/day, all as soluble Ni (assume 90th percentile of exposures).

[2] Roff M, Bagon DA, Chambers H, Dilworth EM, Warren N. Dermal exposure to electroplating fluids and metalworking fluids in the UK. Ann Occup Hyg. 2004 Apr;48(3):209-17.

[3] Bavazzano P, Bolognesi R, Cassinelli C, Gori R, Li Donni V, Martellini F, Oliva G, Riccucci S. Skin contamination and low airborne nickel exposure of electroplaters. Sci Total Environ. 1994 Sep 30;155(1):83-6.

[4] EURA, 2008-2009. European Union Risk Assessment Report for Nickel Metal. Danish Environmental Protection Agency. Risk Assessment for Nickel Metal (CAS No. 7440-02-0)(EINECS No. 231-111-4) Prepared in Relation to Council Regulation (EEC) 793-93.. http://www.mst.dk/English/Chemicals/Substances_and_materials/Nickel/

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
					Assuming a log normal distribution of exposure, the estimated 75th percentile of exposure to Ni, all forms, would be 0.16 mg day. Given that no significant manual contact with Tin MSA would be expected to arise during the automated plating, exposures to Tin MSA would be anticipated to be significantly lower than published studies of plating workers. In the absence of relevant data, the 75th percentile dermal exposure to Tin MSA during automated electroplating is estimated as 0.1 mg/day.
	0.1	mg/ day			PROC 15 Use as a laboratory agent: Dermal exposure is anticipated to be negligible as Tin MSA solution contained within appropriate containers. 75th percentile of shift mean exposure estimated as 0.1 mg/day.
Inhalation exposure	0.023	mg/ m3			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no measured inhalation exposure data. Inhalation exposures are small as Tin MSA handled in solution, the transfer process is enclosed (piped) and process undertaken for only a small proportion of the working shift. The median exposure concentration for the activity predicted by ART (assuming a flow rate of 100-1000 L/minute) is 0.022 mg/m3, with an interquartile range of 0.011 mg/m3–0.046 mg/m3. Based on the assumption that the process of liquid transfer is unlikely to occupy the entire working shift, shift mean exposure concentrations likely to be <50% of predicted levels. The 75th percentile of shift mean exposure concentrations is anticipated to be ≤0.023 mg/m3
	0.01	mg/ m3			PROC 13 Treatment of articles by dipping and pouring: There are no measurement data for tin MSA and there are no readily available data for exposure to tin during tin plating. Inhalation exposure is anticipated to be very small as Tin MSA handled in solution and process mechanisation means that workers do not spend a substantial proportion of shift adjacent to plating bath. In the absence of detailed information about the workplace environment and the control measures in place, it is only possible to derive a broad indication of exposure levels using ART. The estimated median full shift exposure is 0.005 mg/m3 and the interquartile range is 0.0024 mg/m3 to 0.01 mg/m3. This estimate assumes LEV is in place where liquid transfer operations are undertaken and that plated objects are not handled until dry but no containment, general ventilation of the workplace or use of RPE. The use of RPE (P3 filter) would reduce exposure by a factor of 10. In most workplaces, the use of additional control measures would lead to lower exposure concentrations. There are some reported exposure data for other metals used in electroplating that may be helpful to interpreting possible levels of exposure to tin (all soluble compounds rather than specifically Tin MSA) during the use of Tin MSA in electroplating. Lui et al (1998)[5] reported geometric mean concentrations of chromium in chrome plating workers of 0.0032

[5] Liu CS, Kuo HW, Lai JS, Lin TI. Urinary N-acetyl-beta-glucosaminidase as an indicator of renal dysfunction in electroplating workers. Int Arch Occup Environ Health. 1998 Jul;71(5):348-52.

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
					mg/m3 for hard-chrome plating and 0.00058 mg/m3 for Ni-chrome electroplating. Blade et al (2007)[6] reported personal exposure concentrations of 0.003-0.016 mg Cr(VI)/m3 associated with electroplating using chromate where there were engineering controls on the plating tanks. Mainen and Linnainmaa (2004)[7] reported that personal exposure concentrations of chromium during electroplating ranged from <0.01-0.04 mg/m3 with an arithmetic mean and median of 0.01 mg/m3 (standard deviation 0.01 mg/m3), based on 29 measurements. Bright et al (1997)[8] reported personal exposure concentrations for 60 workers exposed to chromate at 6 plating shops. Bath operators (decorative plating, 34 measurements) had mean exposures to Cr(VI) of 0.00964 ug/m3 (range 0.0005-0.039 mg/m3) and to Ni of 0.0265 mg/m3 (0.005-0.093 mg/m3). Jiggers (22 measurements) had mean exposures to Cr (VI) of 0.0149 (0.0005-0.05) mg/m3 and to Ni of 0.0212 (0.0005-0.083) mg/m3. Managers (4 measurements, hard plating) had mean exposures to Cr (VI) of 0.0115 (0-.004-0.019) mg/m3 and to Ni of 0.0026 (0.0005-0.006) mg/m3. Bavazzano et al (1994) reported personal exposure concentrations for airborne Ni of 0.0001-0.042 mg/m3 for 41 workers working in 21 small factories. The EURA (2008-9) report for Ni provides an estimate of exposure concentrations for total Ni exposure for Ni plating (soluble and insoluble) of 0.025 Ni/m3. The reasonable worst case exposure was estimated as 0.4 mg Ni/m3 as soluble Ni. Assuming a log normal distribution of exposure, the estimated 75th percentile of exposure to Ni would be 0.14 mg Ni/m3. These information sources provide variable information about RMMs including the degree of mechanisation and enclosure. It is assumed that the degree of mechanisation and enclosure is likely to have increased during recent years. This implies that exposure concentrations of tin are likely to be low end of the reported range of other substances used in plating. The concentrations of Tin MSA would be lower than the total concentration of airborne tin. In the absence of substantive data, the 75th percentile of shift mean exposure concentrations anticipated to be ≤0.01 mg/m3 without taking account of the use of RPE.
	0.00045				PROC 15 Use as a laboratory agent: Inhalation exposure anticipated to be negligible as Tin MSA in solution and handled within fume cupboards or contained in sealed vessels during transfer across open workspace. No exposure data are available. The median exposure concentration for the activity, modelled using ART is 0.0044 mg/m3 (for activity) with an interquartile range of 0.0022 mg/m3–0.0091 mg/m3 (without consideration of RPE). It is assumed that analysis of Tin MSA is undertaken for up to 4 hours and shift mean exposures will be <50% of the modelled levels.

[6] Blade LM, Yencken MS, Wallace ME, Catalano JD, Khan A, Topmiller JL, Shulman SA, Martinez A, Crouch KG, Bennett JS. Hexavalent chromium exposures and exposure-control technologies in American enterprise: results of a NIOSH field research study. J Occup Environ Hyg. 2007 Aug;4(8):596-618.

[7] Mäkinen M, Linnainmaa M. Dermal exposure to chromium in electroplating. Ann Occup Hyg. 2004 Apr;48(3):277-83.

[8] Bright P, Burge PS, O'Hickey SP, Gannon PF, Robertson AS, Boran A. Occupational asthma due to chrome and nickel electroplating. Thorax. 1997 Jan;52(1):28-32.

The long-term exposure values for automated electroplating are summarised in Table 357.

Table 3821: Summary of long-term exposure concentration to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.01	Estimated 75th percentile of exposures for operations other than cleaning and maintenance; assumes exposure extremely intermittent, confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	0.023	Estimated 75th percentile of exposures for operations other than cleaning and maintenance - assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No adverse systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)/8h workday	0.023	Estimated 75th percentile of exposure concentrations for routine operations associated with the highest predicted exposure levels (fluid transfer operations)

9.3.2.2 Indirect exposure of humans via the environment (oral)

There are no measurement data describing the indirect exposure of humans to tin MSA but environmental concentrations of tin MSA as a result of emissions from its use in automated plating operations are negligible. Any tin MSA released to the environment would have an extremely short lifetime. The indirect exposure of humans to tin MSA via the environment would be predicted to be nil.

9.3.2.2.1 Exposure concentration in sewage treatment plants (STP)

The use of Tin MSA in automated tin plating does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in sewage or sewage sludge arising from tin MSA production are << 1 ppb. If tin MSA passed into a waste water stream that entered a STP, the tin MSA would react to form insoluble tin salts within sewage sludge.

9.3.2.2.2 Exposure concentration in aquatic pelagic compartment

The use of Tin MSA in automated tin plating does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in freshwater or marine waters arising from tin MSA production are << 1 ppb.

9.3.2.2.3 Exposure concentration in sediments

The use of Tin MSA in automated tin plating does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in sediments arising from the use of tin MSA in automated plating are << 1 ppb. The release of tin MSA to the aqueous environment could contribute to the inorganic tin content of sediments.

9.3.2.2.4 Exposure concentrations in soil and groundwater

The landfilling of any solid waste material generated by automated tin plating based on Tin MSA does not lead to any emissions of Tin MSA to landfill leachate. The landfilled waste contains less than 1 mg/kg tin MSA and any tin MSA present would decompose on contact with water.

9.3.2.2.5 Atmospheric compartment

Tin MSA is handled entirely in liquid form and no Tin MSA is emitted to air as a result of automated tin plating processes. The concentrations of tin MSA arising in air as a result of Tin MSA manufacture would be << 0.0001 ng/m3.

9.3.2.2.6 Exposure concentration relevant for the food chain (Secondary poisoning)

No tin MSA enters the food chain as a result of tin MSA manufacture. Tin MSA should not be released to the environment as a result of automated plating operations and the lifetime of tin MSA in environmental media would be exceedingly short.

9.3.3 Exposure scenario 4: Use of Sn(II)MSA in manual electroplating

9.3.3.1 Description of activities and processes covered in the exposure scenario

The Tin(II)-methanesulfonate is supplied and used in aqueous solution. Articles are plated during immersion in a tank of Tin MSA: articles are loaded onto a jig, immersed in the plating tank, removed from the tank, rinsed and allowed to dry prior to removal from the jig. Plated articles are handled with tongs and no direct contact with Tin MSA occurs. Plating is undertaken at room temperature.

9.3.3.2 Operational conditions related to frequency, duration and amount of use

Tin plating is generally undertaken at dedicated facilities and workers would be expected to be exposed on a daily basis (Table 39). The quantities of Tin MSA employed will depend partly on the size of the articles being coated and the thickness of applied coating and partly on the size of the operation, how many articles are coated during a typical shift. It is assumed that manual plating shops will generally operate bigger smaller baths and have a lower throughput than automated plating shops. The tin MSA content of the plating bath is maintained by topping up. Plating baths are not routinely emptied prior to replenishment (<20 times/year). The concentration of tin MSA in spent fluids from plating baths is negligible and waste fluids are treated prior to disposal to remove any residual tin MSA that may be present.

Table 39: Duration, frequency and amount

Information type	Data field	Explanation
Used amount of substance (as such or in preparation) per worker [workplace] per day	1-10 kg/d	Estimated daily usage for manual coating; Much smaller quantities employed in laboratory analysis; Larger quantities handled during delivery, but entirely contained in water tight containers
Duration of exposure per day at workplace [for one worker]	1-8h/day	Lab analysis undertaken for between 1 and 4 hours/shift, other operations undertaken for full shift
Frequency of exposure at workplace [for one worker]	Daily	
Annual amount used per site	<1000 kg/y	
Emission days per site	200 d/y	

9.3.3.3 Operational conditions and risk management measures related to product characteristics

Tin MSA is supplied in solution at a ready to use concentration (Table 40).

Table 40: Characteristics of Tin MSA used in manual electroplating

Information type	Data field	Explanation
Physical state	Supplied as 30-50% aqueous solution; non-volatitle	
Concentration of substance in preparation	30-50%	
Concentration after dilution for use (if relevant)	<10%	Mixed with other substances/preparations to form coating solution
Risk management measures related to the design of product	Supplied in liquid form in sealed containers	

9.3.3.4 Operational conditions related to available dilution capacity and characteristics of exposed humans

Assumptions made in developing the exposure estimates are shown in Table 41.

Table 41: Operational conditions related to respiration and skin contact

Information type	Data field	Explanation
Respiration volume under conditions of use	10 m^3/d	ES does not involve significant manual work
Room size and ventilation rate	n/a	ES not site specific
Area of skin contact with the substance under conditions of use	1980 cm^2	Potential for dermal contact limited to the hands
Body weight	65 kg	Default for workers

9.3.3.5 Other operational conditions of use

The releases to air, water and waste before risk management are shown in Table 42. Any unused tin MSA would be returned to the supplier for recovery.

Table 42: Technical fate of substance and losses from manual electroplating operations to waste, waste water and air

Information type	Data field	Explanation
Fraction of applied amount lost from process/use to waste gas,	<0.00001 kg/kg	Non volatile substance, no losses to air
Fraction of applied amount lost from process/use to waste water	<0.00001 kg/kg	Tin MSA consumed in process, plating solution conserved, no discharge of plating fluids containing tin MSA during routine working
Fraction of applied amount lost from process/use to waste	<0.001 kg/kg	Tin MSA consumed in process, no transfer to the waste stream during normal operation
Fraction consumed in process/use	0.999 kg/kg	Tin MSA converted to tin during plating process
Fraction of applied amount leaving the site with products	<0.00001 kg/kg	Tin MSA converted to Tin metal during plating process; all plated products thoroughly rinsed

9.3.3.6 Risk management measures

The risk management measures in place are outlined in Table 43 below.

Table 43: Risk management measures for manual electroplating operations

Information type	Data field	Explanation
Containment and local exhaust ventilation		
Product supplied in sealed plastic containers	>99% reduction in exposure	No release of product during delivery and storage prior to use
LEV is in place	90% reduction in exposure	Reduced release of Tin MSA to workplace air
Partial cover of plating fluids	50% reduction in exposure	Reduced formation of mists
Piped transfer of fluids in and out of plating tank	95% reduction in exposure	Small potential for exposure when switching between tanks
LEV in place where fluid transfer operations undertaken	90% reduction in exposure	Potential for aerosolisation very small but LEV in place to lower concentrations of any aerosol formed
Product is handled in sealed container or fume cupboard during analysis	99% reduction in exposure	Minimal release of Tin MSA to room air during handling in fume cupboard
Personal protective equipment (PPE)		
Use of gloves and protective clothing to minimise dermal contact	90%	Some penetration of protective clothing and gloves may occur
Process designed to avoid requirement for direct dermal contact with plating solution	90%	Process failures may lead to requirement for direct contact with articles being coated
Eye protection	99% reduction in exposure	Goggles expected to prevent exposure
Other risk management measures related to workers		
Provision of appropriate training including training in safe working procedures with regard to human health and the environment		Efficiency of other RMMs dependent on proper use which requires training in the correct procedures and in the importance of following these procedures
Maintenance of good workplace hygiene, no eating, drinking or smoking where tin MSA handled		Eliminate inadvertent skin contact or ingestion
Risk management measures related to environmental emissions from industrial sites		
Onsite pre-treatment of waste water	<0.000001 kg/kg	Process waste not discharged as waste water; waste water generated by on-site treatment of process waste would not contain tin MSA
Resulting fraction of initially applied amount in waste water released from site to the external sewage system	<0.000001 kg/kg	Process waste not discharged as waste water
Air emission abatement	Not applicable	Non-volatile substance in solution, no emissions to air
Resulting fraction of applied amount in waste gas released to environment	Not applicable	Non-volatile substance in solution, no emissions to air
Onsite waste treatment	<0.1% of tin MSA remains in waste material following on-site treatment	Waste tin MSA/plating fluids are diluted by a factor of between 10 and 25, hydrogen peroxide (30% solution) is added at 10 ml/l - 25 ml/l for dilutions of between 25 and 10, allowed to react for 6 hours, pH is adjusted to 9.0 with lime milk and after 2-6 hours the mixture is passed through a filter press to removed the

Information type	Data field	Explanation
		precipitated tin compounds. Alternatively waste solutions can be treated with a priority precipitant based on an organosulifide in order to convert tin MSA to insoluble tin compounds; conversion of tin MSA to other compounds highly efficient (>99.9%)
Fraction of initially applied amount sent to external waste treatment. This is the sum of direct losses from processes to waste, and the residues from onsite waste water and waste gas treatment.	<0.000001 kg/kg	No requirement for routine disposal of tin MSA; any waste fluids containing tin MSA are pre-treated before leaving site to convert tin compounds to solid phase which is recovered by filtration
Municipal or other type of external waste water treatment	Not applicable	No tin MSA discharged as process waste water or discharged in waste water generated from on site waste treatment
Effluent (of the waste water treatment plant) discharge rate	Not applicable	*Default: 2.000 m^3/d*
Recovery of sludge for agriculture or horticulture	No	

9.3.3.7 Waste related measures

Tin MSA is largely conserved during the plating process. Table 44 outlines the losses of Tin MSA to waste and during waste handling arising from manual electroplating operations.

Table 44: Fractions of substance in waste and waste management measures

Information type	Data field	Explanation
Amount of substances in waste resulting from identified uses covered in the exposure scenario	< 0.1 kg/y	
Amount of substances in waste resulting from service life of articles	Not applicable	Tin plated articles do not contain tin MSA
Type of waste, suitable waste codes	11 02 07	Wastes from nonferrous hydrometallurgical processes, other wastes containing dangerous substances
Type of external treatment aiming at recycling or recovery of substances	Not applicable	Currently tin is not recovered from treated process residues
Fraction of the initially applied amount of substance recovered.	Not applicable	
Type of external treatment aiming at final disposal of the waste	Process wastes disposed of to appropriately licensed waste disposal site, most commonly landfill	Solid process wastes do not contain tin MSA or other leachable substances
Fraction of substance released into the environment via air from waste handling	<0.000001 kg/kg	
Fraction of substance released into the environment via waste water from waste handling	<0.000001 kg/kg	Solid process wastes do not contain tin MSA or other leachable substances
Fraction of substance disposed of as secondary waste	Not applicable	

9.3.4 Exposure estimation

9.3.4.1 Workers exposure

9.3.4.1.1 Acute/Short term exposure

Table 45 outlines derivation of the estimate of peak exposures associated with each subscenario identified for manual electroplating.

Table 45: Acute exposure concentrations to workers

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
Dermal exposure	20	mg			Fluid transfer operations and plating operations - dermal exposure extremely intermittent and 75th percentile of peak exposure estimated as if entire shift exposure occurred in single episode (ie assumed to be equivalent to the intake associated with the 75th percentile of full shift exposures). This may represent a significant over-estimate of peak exposures, if the full shift exposure typically results from 2 or more distinct episodes during the shift
	0.1	mg			Use as a laboratory agent: dermal exposure likely to be intermittent throughout shift; 75th percentile of peak exposure estimated as if entire shift exposure occurred in single episode
Inhalation exposure	0.06	mg/ m3			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day
	0.15	mg/ m3			PROC 13 Treatment of articles by dipping and pouring: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day.
	0.00135	mg/ m3			PROC 15 Use as a laboratory agent: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day.

Short-term exposure values are summarised in Table 46.

Table 22: Summary of acute exposure concentrations to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.01	Estimated 75th percentile of peak exposure for fluid transfer operations and plating based on estimated 75th percentile of full shift exposures for these operations; assumes exposure extremely intermittent such that it may occur over a single short period during the working shift, confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	0.06	Estimated 75th percentile of peak exposures for treatment of articles by dipping and pouring (plating) based on estimated 75th percentile of full shift exposures for these operations, assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No adverse systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)	0.15	Estimated 75th percentile of peak concentrations for routine plating operations. Peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day

9.3.4.1.2 Long-term exposure

Table 47 outlines derivation of the estimate of shift mean exposures associated with each subscenario identified for manual electroplating.

Table 47: Long-term exposure concentrations to workers

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
Dermal exposure	20	mg/ day			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no dermal exposure data. Provided that appropriate protective clothing and gloves are used, the potential for dermal exposure is anticipated to be small as the liquid is enclosed during the transfer operation and tasks that might plausibly give rise to dermal exposure such as the handling of pipe ends while switching between tanks would only be undertaken for a small proportion of the working shift. Provided that appropriate protective clothing and gloves are used, the potential for dermal exposure is anticipated to be small as the liquid is enclosed during the transfer operation. Tasks that might plausibly give rise to dermal exposure including the handling of pipe ends while switching between tanks would only be undertaken for a small proportion of the working shift. The EASE model would predict exposures of 0.1-1 mg/cm2/day for incidental hand contact. If allowance is made for the use of suitable gloves, and that contact would be extremely intermittent, dermal exposure is likely to be of the order of 20 mg/day.
	20	mg/ day			PROC 13 Treatment of articles by dipping and pouring: Published dermal exposure data for other metal plating processes indicate very variable exposure levels (see exposure scenario 3). Given that no significant direct dermal contact with Tin MSA would be expected to arise during routine plating operations, exposures to Tin MSA during manual plating would be anticipated to be small but potentially greater than for automated processes (exposure scenario 3) and closer to the upper rather than lower end of the wide range of published dermal exposures associated with plating (see exposure

Routes of exposure	Estimated Exposure Concentrations value	unit	Measured exposure concentrations Value	unit	Explanation / source of measured data
					scenario 3). The EASE model would predict exposures of 0.1-1 mg/cm2/day for incidental hand contact. If allowance is made for the use of suitable gloves, and that contact would be largely limited to fingers, and articles being dipped are handled with tongs, dermal exposure is likely to be of the order of 0.01 mg/cm2/day (=20 mg/day).
	0.1	mg/ day			PROC 15 Use as a laboratory agent: Dermal exposure is anticipated to be negligible as Tin MSA solution contained within appropriate containers. 75th percentile of shift mean exposure estimated as 0.1 mg/day.
Inhalation exposure	0.01	mg/ m3			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no measured inhalation exposure data and the large scale transfer of fluids containing tin MSA would only be rarely undertaken eg on complete renewal of the plating fluids in the bath. The tin MSA content of waste fluids removed from the plating bath would be very small. Small scale fluid handling operations, specifically the topping up of the plating tank are likely to be undertaken at least once per shift but involve much smaller volumes of fluid. Inhalation exposures during fluid transfer operations are anticipated to be small as Tin MSA handled in solution. The median exposure concentration for topping up the plating tank with tin MSA predicted by ART (assuming a flow rate of <10 L/minute and falling liquid) is 0.039 mg/m3, with an interquartile range of 0.019 mg/m3–0.079 mg/m3. Based on the assumption that the process of topping up the tank is unlikely to occupy more than an hour during entire working shift, shift mean exposure concentrations likely to be <12% of predicted levels. The 75th percentile of shift mean exposure concentrations is anticipated to be 0.01 mg/m3 (or less). The use of RPE (P3 filter) during liquid transfer operations would reduce exposure by a factor >10. Inhalation exposures associated with discharging spent fluid from plating tanks would be infrequent and negligible given that the tin MSA content of spent fluids would be negligible and the fluids are contained within pipes.
	0.05	mg/ m3			PROC 13 Treatment of articles by dipping and pouring: The estimated median full shift exposure was 0.024 mg/m3 and the interquartile range is 0.0012 mg/m3 to 0.049 mg/m3. This estimate assumes a manual process, that plated objects are handled (with tongs) while still wet, the process is not contained, there is no general ventilation of the workplace and no RPE is used. The estimate includes time spent topping up the tank. It is likely that in most workplaces, the use of additional control measures would lead to lower exposure estimates. The use of RPE (P3 filter) or effective LEV during the topping up of the plating tank and while handling wet plated articles would reduce exposure by a factor >10. Reported exposure data for other metals used in electroplating that may be helpful to interpreting possible levels of exposure to tin (all soluble compounds) during the use of Tin MSA in electroplating is described above for Exposure Scenario 3. These various published information sources provide variable information about RMMs including the degree of mechanisation and enclosure and the relationship between the reported variability of exposure concentrations and the RMMs is unclear. Exposure levels are likely to reduce with increased automation and mechanisation and workers are also likely to spend more time in the

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
					immediate vicinity of the plating bath than for automated operations. Exposures would be expected to be greater than for automated processes of the same size, but this may be partly offset by the smaller scale of operations. Overall, exposure concentrations of tin for manual plating are likely to be towards the upper end of the reported range of other substances used in plating. The concentrations of Tin MSA would be anticipated to be lower than the total concentration of soluble Tin species. In the absence of substantive data, the 75th percentile of shift mean exposure concentrations anticipated to be 0.05 mgm^{-3} (as predicted by ART), assuming no use of RPE or LEV.
	0.00045				PROC 15 Use as a laboratory agent: Inhalation exposure anticipated to be negligible as Tin MSA in solution and handled within fume cupboards or contained in sealed vessels during transfer across open workspace. No exposure data are available and the median exposure concentration for the activity, modelled using ART is 0.0044 mg/m3 (for activity) with an interquartile range of 0.0022 mg/m3–0.0091 mg/m3 (without consideration of RPE). It is assumed that analysis of Tin MSA is undertaken for up to 4 hours and shift mean exposures will be <50% of the modelled levels.

The long-term exposure values for manual electroplating are summarised in Table 48.

Table 48: Summary of long-term exposure concentration to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.01	Estimated 75th percentile of exposures for operations other than cleaning and maintenance; assumes exposure extremely intermittent, confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	0.023	Estimated 75th percentile of exposures for operations other than cleaning and maintenance - assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No adverse systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)/8h workday	0.05	Estimated 75th percentile of exposure concentrations for routine operations associated with the highest predicted exposure levels (treatment of articles by dipping or pouring)

9.3.4.2 Indirect exposure of humans via the environment (oral)

There are no measurement data describing the indirect exposure of humans to tin MSA but environmental concentrations of tin MSA as a result of emissions from its use in manual plating operations are negligible. Any tin MSA released to the environment would have an extremely short lifetime. The indirect exposure of humans to tin MSA via the environment would be predicted to be nil.

9.3.4.2.1 Exposure concentration in sewage treatment plants (STP)

The use of Tin MSA in manual tin plating operations does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in sewage or sewage sludge arising from the use of tin MSA in manual plating operations are << 1 ppb. If tin MSA passed into a waste water stream that entered a STP, the tin MSA would react to form insoluble tin salts within sewage sludge.

9.3.4.2.2 Exposure concentration in aquatic pelagic compartment

The use of Tin MSA in manual tin plating operations does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in freshwater or marine waters arising from tin MSA production are << 1 ppb.

9.3.4.2.3 Exposure concentration in sediments

The use of Tin MSA in manual tin plating operations does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in sediments arising from the use of tin MSA in manual electroplating are << 1 ppb. The release of tin MSA to the aqueous environment could contribute to the inorganic tin content of sediments.

9.3.4.2.4 Exposure concentrations in soil and groundwater

The landfilling of waste material from manual electroplating based on Tin MSA does not lead to any emissions of Tin MSA to landfill leachate. The landfilled waste contains less than 1 mg/kg tin MSA that would decompose on contact with water.

9.3.4.2.5 Atmospheric compartment

Tin MSA is handled entirely in liquid form and no Tin MSA is emitted to air as a result of automated tin plating processes. The concentrations of tin MSA arising in air as a result of Tin MSA manufacture would be << 0.0001 ng/m3.

9.3.4.2.6 Exposure concentration relevant for the food chain (Secondary poisoning)

No tin MSA enters the food chain as a result of the use of tin MSA manual electroplating. Tin MSA should not be released to the environment as a result of manual electroplating operations and the lifetime of tin MSA in environmental media would be exceedingly short.

9.3.5 Exposure scenario 5: Use of Sn(II)MSA in immersion plating

9.3.5.1 Description of activities and processes covered in the exposure scenario

The Tin(II)-methanesulfonate is supplied in solution; articles are plated during immersion in a tank of Tin MSA; articles to be coated are loaded onto enclosed conveyor and passed through flood chamber or dipped into a plating tank. The Tin(II)-methanesulfonate is supplied and used in aqueous solution. Articles are plated during immersion in a tank of Tin MSA: articles are loaded onto a jig, immersed in the plating tank, removed from the tank and allowed to dry prior to removal from the jig. No direct contact with Tin MSA occurs. The temperature of the plating bath is between 20 and 80 ^{o}C.

9.3.5.2 Operational conditions related to frequency, duration and amount of use

Tin plating is generally undertaken at dedicated facilities and workers would be expected to be exposed on a daily basis (Table 49). The quantities of Tin MSA employed will depend partly on the size of the articles being coated and partly on the size of the operation – how many articles are coated during a typical shift. The tin MSA content of the plating bath is maintained by topping up. Plating baths are not routinely emptied prior to replenishment (<20 times/year). The concentration of tin MSA in spent fluids from plating baths is negligible and waste fluids are treated prior to disposal to remove any residual tin MSA that may be present. It is assumed that immersion plating is generally used in small to medium sized plating operations and is predominantly used in manual processes, although larger immersion plating shops are likely to employ automated processes.

Table 49: Duration, frequency and amount

Information type	Data field	Explanation
Used amount of substance (as such or in preparation) per worker [workplace] per day	<4 kg/d	Product supplied in quantities of 30, 250 or 1000 kg in solution. Small quantities employed in laboratory analysis, substantial quantities involved in plating process and even greater quantities handled during delivery and recharging of the tank
Duration of exposure per day at workplace [for one worker]	1-8h/day	Lab analysis undertaken for between 1 and 4 hours/shift, other operations undertaken for full shift
Frequency of exposure at workplace [for one worker]	Daily	
Annual amount used per site	<1000 kg/y	
Emission days per site	200 d/y	

9.3.5.3 Operational conditions and risk management measures related to product characteristics

Tin MSA is supplied in solution at a ready to use concentration (Table 50) and is mixed with other preparations to form the plating solution.

Table 230: Characteristics of Tin MSA used in immersion plating

Information type	Data field	Explanation
Physical state	Supplied as 26% aqueous solution	
Concentration of substance in preparation	26%	
Concentration after dilution for use (if relevant)	4.16%	
Risk management measures related to the design of product	Supplied in liquid form	

9.3.5.4 Operational conditions related to available dilution capacity and characteristics of exposed humans

Assumptions made in developing the exposure estimates are shown in Table 51.

Table 51: Operational conditions related to respiration and skin contact

Information type	Data field	Explanation
Respiration volume under conditions of use	10 m^3/d	ES does not involve significant manual work
Room size and ventilation rate	n/a	ES not site specific
Area of skin contact with the substance under conditions of use	1980 cm^2	Potential for dermal contact limited to the hands
Body weight	65 kg	Default for workers

9.3.5.5 Other operational conditions of use

The releases to air, water and waste before risk management are shown in Table 52. Any unused tin MSA would be returned to the supplier for recovery.

Table 52: Technical fate of substance and losses from process/use to waste, waste water and air

Information type	Data field	Explanation
Fraction of applied amount lost from process/use to waste gas,	<0.00001 kg/kg	Non volatile substance, no losses to air
Fraction of applied amount lost from process/use to waste water	<0.00001 kg/kg	Tin MSA consumed in process, plating solution conserved, no discharge of plating fluids containing tin MSA during routine working
Fraction of applied amount lost from process/use to waste	<0.001 kg/kg	Tin MSA consumed in process, no transfer to the waste stream during normal operation
Fraction consumed in process/use	0.999 kg/kg	Tin MSA converted to tin during plating process
Fraction of applied amount leaving the site with products	<0.00001 kg/kg	Tin MSA converted to Tin metal during plating process; all plated products thoroughly rinsed

9.3.5.6 Risk management measures

The risk management measures in place are outlined in Table 53 below.

Table 53: Risk management measures for the use of tin MSA in manual plating

Information type	Data field	Explanation
Containment and local exhaust ventilation		
Product supplied in sealed plastic containers	>99% reduction in exposure	No release of product during delivery and storage prior to use
LEV if in place	90% reduction in exposure	Reduced release of Tin MSA to workplace air
Partial cover of plating fluids	50% reduction in exposure	Reduced formation of mists
Piped transfer of fluids in and out of plating tank	95% reduction in exposure	Small potential for exposure when switching between tanks
LEV in place where fluid transfer operations undertaken	90% reduction in exposure	Potential for aerosolisation very small but LEV in place to lower concentrations of any aerosol formed
Product is handled in sealed container or fume cupboard during analysis	99% reduction in exposure	Minimal release of Tin MSA to room air during handling in fume cupboard
Personal protective equipment (PPE)		
Use of gloves and protective clothing to minimise dermal contact	90%	Some penetration of protective clothing and gloves may occur
Process designed to avoid requirement for direct dermal contact with plating solution	90%	Process failures may lead to requirement for direct contact with articles being coated
Eye protection	99% reduction in exposure	Goggles expected to prevent exposure
Other risk management measures related to workers		
Provision of appropriate training including training in safe working procedures with regard to human health and the environment		Efficiency of other RMMs dependent on proper use which requires training in the correct procedures and in the importance of following these procedures
Maintenance of good workplace hygiene, no eating, drinking or smoking where tin MSA handled		Eliminate inadvertent skin contact or ingestion
Risk management measures related to environmental emissions from industrial sites		
Onsite pre-treatment of waste water	<0.000001 kg/kg	Process waste not discharged as waste water; waste water generated by on-site treatment of process waste would not contain tin MSA
Resulting fraction of initially applied amount in waste water released from site to the external sewage system	<0.000001 kg/kg	Process waste not discharged as waste water
Air emission abatement	Not applicable	Involatile substance in solution, no emissions to air
Resulting fraction of applied amount in waste gas released to environment	Not applicable	Involatile substance in solution, no emissions to air
Onsite waste treatment	<0.1% of tin MSA remains in waste material following on-site treatment	Waste tin MSA/plating fluids are diluted by a factor of between 10 and 25, hydrogen peroxide (30% solution) is added at 10 ml/l - 25 ml/l for dilutions of between 25 and 10, allowed to react for 6 hours, pH is adjusted to 9.0 with lime milk and after 2-6 hours the mixture is passed through a filter press to removed the

Information type	Data field	Explanation
		precipitated tin compounds. Alternatively waste solutions can be treated with a priority precipitant based on an organosulifide in order to convert tin MSA to insoluble tin compounds; conversion of tin MSA to other compounds highly efficient (>99.9%)
Fraction of initially applied amount sent to external waste treatment. This is the sum of direct losses from processes to waste, and the residues from onsite waste water and waste gas treatment.	<0.000001 kg/kg	No requirement for routine disposal of tin MSA; any waste fluids containing tin MSA are pre-treated before leaving site to convert tin compounds to solid phase which is recovered by filtration
Municipal or other type of external waste water treatment	Not applicable	No tin MSA discharged as process waste water or discharged in waste water generated from on site waste treatment
Effluent (of the waste water treatment plant) discharge rate	Not applicable	*Default: 2.000 m^3/d*
Recovery of sludge for agriculture or horticulture	No	

9.3.5.7 Waste related measures

Tin MSA is largely conserved during the plating process. Table 54 outlines the losses of Tin MSA to waste and during waste handling.

Table 54: Fractions of substance in waste and waste management measures

Information type	Data field	Explanation
Amount of substances in waste resulting from identified uses covered in the exposure scenario	< 0.1 kg/y	
Amount of substances in waste resulting from service life of articles	Not applicable	Tin plated articles do not contain tin MSA
Type of waste, suitable waste codes	11 02 07	Wastes from nonferrous hydrometallurgical processes, other wastes containing dangerous substances
Type of external treatment aiming at recycling or recovery of substances	Not applicable	Currently tin is not recovered from treated process residues
Fraction of the initially applied amount of substance recovered.	Not applicable	
Type of external treatment aiming at final disposal of the waste	Process wastes disposed of to appropriately licensed waste disposal site, most commonly landfill	Solid process wastes do not contain tin MSA or other leachable substances
Fraction of substance released into the environment via air from waste handling	<0.000001 kg/kg	
Fraction of substance released into the environment via waste water from waste handling	<0.000001 kg/kg	Solid process wastes do not contain tin MSA or other leachable substances
Fraction of substance disposed of as secondary waste	Not applicable	

9.3.6 Exposure estimation

9.3.6.1 Workers exposure

9.3.6.1.1 Acute/Short term exposure

Table 55 outlines derivation of the estimate of peak exposures associated with each subscenario identified for immersion plating.

Table 55: Acute exposure concentrations to workers

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
Dermal exposure	5	mg			Fluid transfer operations and plating operations - dermal exposure extremely intermittent and 75th percentile of peak exposure estimated as if entire shift exposure occurred in single episode (ie assumed to be equivalent to the intake associated with the 75th percentile of full shift exposures). This may represent a significant over-estimate of peak exposures, if the full shift exposure typically results from 2 or more distinct episodes during the shift
	0.1	mg			Use as a laboratory agent: dermal exposure likely to be intermittent throughout shift; 75th percentile of peak exposure estimated as if entire shift exposure occurred in single episode
Inhalation exposure	0.03	mg/ m3			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day
	0.15	mg/ m3			PROC 13 Treatment of articles by dipping and pouring: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day; assumes manual plating operation in which articles are handled while still wet and no process enclosure, LEV or use of RPE.
	0.00135	mg/ m3			PROC 15 Use as a laboratory agent: 75th percentile of peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day.

Short-term exposure values are summarised in Table 56.

Table 56: Summary of acute exposure concentrations to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.0025	Estimated 75th percentile of peak exposure for fluid transfer operations and plating based on estimated 75th percentile of full shift exposures for these operations; assumes exposure extremely intermittent such that it may occur over a single short period during the working shift, confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	0.007	Estimated 75th percentile of peak exposures for treatment of articles by dipping and pouring (plating) based on estimated 75th percentile of full shift exposures for these operations, assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No adverse systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)	0.15	Estimated 75th percentile of peak concentrations for plating operations – the routine activity giving rise to the highest exposure. Peak concentrations estimated as 3x the 75th percentile of shift mean exposure concentrations in order to allow for the probable variability of exposure during the working day; assumes manual plating operation in which articles are handled while still wet and no process enclosure, LEV or use of RPE.

9.3.6.1.2 Long-term exposure

Table 57 outlines derivation of the estimate of shift mean exposures associated with each subscenario identified for immersion plating.

Table 57: Long-term exposure concentrations to workers

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
Dermal exposure	5	mg/ day			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no dermal exposure data. Provided that appropriate protective clothing and gloves are used, the potential for dermal exposure is small as the tasks of topping up the plating tank or transferring tin MSA from drums to smaller containers are undertaken for a small proportion of the working shift, involve relatively small volumes of fluid and require no direct dermal contact with fluids containing tin MSA. The EASE model would predict exposures of 0.1-1 mg/cm2/day for incidental hand contact. If allowance is made for the use of suitable gloves, the concentration of tin MSA in plating fluids (26%) and that contact would be intermittent, dermal exposure is likely to be of the order of 5 mg/day. Exposures associated with emptying the plating tank would be infrequent (<20 times/year) and the tin MSA content of the waste fluid would be negligible. There would be no requirement for direct dermal contact with fluids and levels of dermal exposure to tin MSA should be no greater than on other shifts.
	5	mg/ day			PROC 13 Treatment of articles by dipping and pouring: Published dermal exposure data for other metal plating processes indicate very variable exposure levels (see Exposure Scenario 3). Given that no significant direct dermal contact with Tin MSA would be expected to arise during routine plating operations, exposures to Tin MSA would be anticipated to be small. Exposures associated with manual operations are likely to be potentially greater

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	**unit**	**Value**	**unit**	
					than for automated processes and closer to the upper rather than lower end of the wide range of published dermal exposures associated with plating. Based on the estimate developed for manual electroplating (Exposure Scenario 4), and taking account of the use of suitable gloves, the concentration of tin MSA in plating fluids (26%) and the intermittent contact with fluids, dermal exposure is likely to be of the order of 5 mg/day. In the absence of relevant data, the 75th percentile dermal exposure to Tin MSA during immersion plating is estimated as 5 mg/day for manual processes. If the immersion plating process is automated, less dermal contact with plating fluids would be anticipated and dermal exposures would be << 5 mg/day.
	0.1	mg/ day			PROC 15 Use as a laboratory agent: Dermal exposure is anticipated to be negligible as Tin MSA solution contained within appropriate containers. No exposure data are available but it is anticipated that exposure levels would be below the limit of analytical detection, ie <0.1 mg/day.
Inhalation exposure	0.01	mg/ m3			PROC 8B Transfer of substance (charging/discharging) from/to vessels/large containers: There are no measured inhalation exposure data and the large scale transfer of fluids containing tin MSA would only be rarely undertaken eg on complete renewal of the plating fluids in the bath. Small scale operations involving the topping up of the plating tank are likely at least once per shift but involve much smaller volumes of fluid. Inhalation exposures during fluid transfer operations are small as Tin MSA handled in solution. The median exposure concentration for topping up the plating tank with tin MSA predicted by ART (assuming a flow rate of <10 L/minute and falling liquid) is 0.039 mg/m3, with an interquartile range of 0.019 mg/m3–0.079 mg/m3. Based on the assumption that the process of topping up the tank is unlikely to occupy more than an hour during entire working shift, shift mean exposure concentrations likely to be <12% of predicted levels. The 75th percentile of shift mean exposure concentrations is anticipated to be 0.01 mg/m3 (or less). Other fluid transfer operations may include piping tin MSA from drums to smaller containers. The quantities of tin MSA involved would be small, and the tin MSA would be contained during the fluid transfer process. Exposure concentrations are likely to be lower than associated with topping up the tank. Inhalation exposures associated with discharging spent fluid from plating tanks be infrequent and negligible given that the tin MSA content of spent fluids would be negligible and the fluids are contained within pipes. The use of RPE (P3 filter) during liquid transfer operations would reduce exposure by a factor >10
	0.05	mg/ m3			PROC 13 Treatment of articles by dipping and pouring: there are no measurement data for tin MSA and there are no readily available data for exposure to tin during tin plating. Inhalation exposure is anticipated to be relatively small as Tin MSA handled in solution. In the absence of detailed information about the workplace environment and the control measures in place during immersion tin plating, it is only possible to derive a broad indication of exposure levels using ART. The estimated median full shift exposure was 0.024 mg/m3 and the interquartile range is 0.0012 mg/m3 to 0.049 mg/m3. This estimate assumes a manual process, that plated objects are handled (with tongs) while still wet, the process is not

Routes of exposure	Estimated Exposure Concentrations		Measured exposure concentrations		Explanation / source of measured data
	value	unit	Value	unit	
					contained, there is no general ventilation of the workplace and no RPE is used. The estimate includes time spent topping up the tank. It is likely that in most workplaces, the use of additional control measures would lead to lower exposure estimates. For manual processes, the use of RPE (P3 filter) or effective LEV during the topping up of the plating tank and while handling wet plated articles would reduce exposure by a factor >10. Where processes are automated and enclosed, the median full shift exposure concentration predicted by ART is 0.016 mg/m3 and the interquartile range is 0.0081 – 0.034 mg/m3, assuming articles are not handled until nearly dry, but no LEV in place or use of RPE. The reported exposure data for other metals used in electroplating reviewed in Exposure Scenario 3 (above) may be helpful to interpreting possible levels of exposure to tin (all soluble compounds) during the use of Tin MSA in immersion plating. The concentrations of Tin MSA would be anticipated to be substantially lower than the total concentration of soluble Tin species or total tin concentrations. These published information sources provide variable information about RMMs including the degree of mechanisation and enclosure and the relationship between the reported variability of exposure concentrations and the RMMs is unclear. Exposure levels are likely to reduce with increased automation and mechanisation as workers are likely to spend less time in the immediate vicinity of the plating bath and have less need to handle objects coated in plating solution. Automation is likely to be coupled with process enclosure which will substantially reduce worker exposure, particularly if coupled with exhaust ventilation. In the absence of directly relevant measurement data, but taking account of relevant published data for other comparable processes, the 75th percentile of shift mean exposure concentrations is predicted to be 0.05 mg/m3 (as predicted by ART), assuming no automation, process enclosure or use of RPE. Automation and process enclosure would be expected to substantially reduce exposure.
	0.00045				PROC 15 Use as a laboratory agent: Inhalation exposure anticipated to be negligible as Tin MSA in solution and handled within fume cupboards or contained in sealed vessels during transfer across open workspace. No exposure data are available and the median exposure concentration for the activity, modelled using ART is 0.0044 mg/m3 (for activity) with an interquartile range of 0.0022 mg/m3–0.0091 mg/m3 (without consideration of RPE). It is assumed that analysis of Tin MSA is undertaken for up to 4 hours and shift mean exposures will be <50% of the modelled levels.

The long-term exposure values are summarised in Table 58.

Table 58: Summary of long-term exposure concentration to workers

Routes of exposure	Concentrations	Justification
Dermal local exposure (in mg/cm2)	0.0025	Estimated 75^{th} percentile of exposures for operations other than cleaning and maintenance; assumes exposure extremely intermittent, confined to the hands and limited by process design and use of appropriate gloves
Dermal systemic exposure (in mg/kg bw/d)	0.007	Estimated 75^{th} percentile of exposures for operations other than cleaning and maintenance - assumes an absorption efficiency of 10% which may be a substantial over-estimate. Efficiency of absorption of Tin MSA through the skin is unknown, but is known to be less than 100%. No adverse systemic effects have been observed following dermal application.
Inhalation exposure (in mg/m3)/8h workday	0.05	Estimated 75^{th} percentile of exposure concentrations for routine operations associated with the highest predicted exposure levels (treatment of articles by dipping or pouring); assumes manual process in which plated articles are handled while still wet, does not assume LEV, RPE or process containment

9.3.6.2 Indirect exposure of humans via the environment (oral)

There are no measurement data describing the indirect exposure of humans to tin MSA but environmental concentrations of tin MSA as a result of emissions from its use in immersion plating operations are negligible. Any tin MSA released to the environment would have an extremely short lifetime. The indirect exposure of humans to tin MSA via the environment would be predicted to be nil.

9.3.6.2.1 Exposure concentration in sewage treatment plants (STP)

The use of Tin MSA in immersion tin plating operations does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in sewage or sewage sludge arising from the use of tin MSA in immersion plating operations are << 1 ppb. If tin MSA passed into a waste water stream that entered a STP, the tin MSA would react to form insoluble tin salts within sewage sludge.

9.3.6.2.2 Exposure concentration in aquatic pelagic compartment

The use of Tin MSA in immersion tin plating does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in freshwater or marine waters arising from tin MSA production are << 1 ppb.

9.3.6.2.3 Exposure concentration in sediments

The use of Tin MSA in immersion tin plating does not lead to any emissions of Tin MSA to the wider aqueous environment. Tin MSA is unstable in water in the absence of MSA and the dilution of any tin MSA that was accidentally released to the aqueous environment would result in the formation of insoluble tin salts. The concentrations of Tin MSA in sediments arising from the use of tin MSA in immersion plating are << 1 ppb. The release of tin MSA to the aqueous environment could contribute to the inorganic tin content of sediments.

9.3.6.2.4 Exposure concentrations in soil and groundwater

The landfilling of waste material from immersion tin plating based on Tin MSA does not lead to any emissions of Tin MSA to landfill leachate. The landfilled waste contains less than 1 mg/kg tin MSA that would decompose on contact with water.

9.3.6.2.5 Atmospheric compartment

Tin MSA is handled entirely in liquid form and no Tin MSA is emitted to air as a result of immersion tin plating processes. The concentrations of tin MSA arising in air as a result of Tin MSA manufacture would be << 0.0001 ng/m3.

9.3.6.2.6 Exposure concentration relevant for the food chain (Secondary poisoning)

No tin MSA enters the food chain as a result of the use of tin MSA in immersion plating. Tin MSA should not be released to the environment as a result of its use in immersion plating operations and the lifetime of tin MSA in environmental media would be exceedingly short.

9.4 Overall exposure (combined for all relevant emission/release sources)

9.4.1 Human health (combined for all exposure routes)

Human exposure to tin MSA is confined to the workplace and there no indirect exposure via the environment or exposure to tin MSA in consumer goods. Estimated levels of workplace exposure to Tin MSA are summarised in Table 59 below. It is assumed that the typical worker inhales 10 m3/air over an 8 hour working shift and that 10% of the tin MSA deposited on skin is absorbed

Table 59: Summary of estimated human exposure to tin MSA

Exposure scenarios	Workplace exposure: dermal mg/day	Workplace exposure: inhalation (peak) mg/m3	Workplace exposure: inhalation (long term) mg/m3	Workplace exposure: absorbed dose, all routes mg/day
ES 1: Production of tin MSA	2	0.0091 (sampling and analysis)	0.0053	0.253
ES 2: Use in product formulation	100	0.153 (mixing and blending)	0.051	10.5
ES 3: Use in automated electroplating	20	0.069 (fluid transfer)	0.023	2.23
ES 4: Use in manual electroplating	20	0.15 (dipping of articles)	0.05	2.5
ES 5: Use in immersion plating	5	0.15 (dipping of articles)	0.05	1.0

Table 24: Risk characterisation for combined relevant emission

Relevant combination of exposure scenario	Risk characterisation ratio
Combination 1	
Combination 2	

9.4.2 Environment (combined for all emission sources)

Environmental concentrations of tin MSA arising from releases during production or use are vanishingly small (<<1 ppb in water or soil; <0.0001 ng/m3 in air). It is conceivable that the release of tin MSA from user sites, particularly smaller operations, could lead to marginally increased concentrations of dissolved tin in affected water bodies or marginally increased concentrations of inorganic tin in affected sediments or soil.