European Commission

Third study on collecting most recent information for a certain number of substances with the view to analyse the health, socio-economic and environmental impacts in connection with possible amendments of Directive 2004/37/EC

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Final Report for 4,4'-Methylene-bis(2-chloroaniline) (MOCA)

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Third study on collecting most recent information for a certain number of substances with the view to analyse the health, socio-economic and environmental impacts in connection with possible amendments of Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work

4,4'-Methylene-bis(2-chloroaniline) (MOCA)

8 February 2018

Final Report

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List of acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
ACSH	Advisory Committee on Safety and Health at Work
AfA	Application for authorisation
ACGIH	American Conference of Governmental Industrial Hygienists
B/C ratio	Benefit / cost ratio
BAR	Biologischer Arbeitsstoff-Toleranzwert; Biological Reference Value
BCF	Bioconcentration Factor
BDO	1,4-Butanediol
BGV	Benchmark Guidance Value
BLV	Biological Limit Value
BMGV	Biological Monitoring Guidance Value
BGV	Biological Guidance Value
BLV	Biological Limit Value
BR	Better regulation
BRMA	British Rubber Manufacturers Association
BRPPA	British Rubber and Polyurethane Products Association
CAPEX	Capital expenditure
CAS no	Chemical Abstract Service number
CBA	Cost-benefit assessment
CI	Confidence interval
C&L	Classification and Labelling
CLP	Classification, Labelling and Packaging [Regulation EC No 1272/2008]
CMD	The Carcinogens and Mutagens Directive
CSR	Chemical Safety Report
DALY	Disability adjusted life years
DECOS	Dutch Expert Committee on Occupational Safety
DMTDA	Dimethylthiotoluene diamine
DRR	Dose response relationship
ECHA	European Chemicals Agency
EEA	European Economic Area
ERR	Exposure-risk relationship
FFP2/FFP3	Types of filter masks
FIOH	Finnish Institute of Occupational Health
GC-FID	Gas Chromatography – Flame Ionization Detector
GM	Geometric mean
GSD	Geometric standard deviation
HDI	Hexamethylene diisocyanate
HEPA	High efficiency particulate air
HPLC	High-performance Liquid Chromatography
HSE	Health and Safety Executive
HQEE	Hydroquinone bis (2-hydroxyethyl) ether
IA	Impact Assessment
IARC	International Agency for Research on Cancer
IFA	Institut für Arbeitsschutz
ISO	The International Organization for Standardization
LEV	Local exhaust ventilation
LFMDI	low free methylene diphenyl diisocyanate
LFTDI	low free toluene diisocyanate
LOAEL	Lowest Observable Adverse Effect Level

LOD	Level of detection
LOQ	Limit of quantification
KOC	Organic carbon-water partition coefficient
MBOCA	4,4’-methylene-bis-ortho-chloroaniline = MOCA
M-CDEA	4,4-methylenebis-3-(chloro-2,6-diethyl)-aniline
MDA	2,2'-dichloro-4,4'-methylenedianiline
MDHS	Methods for the Determination of Hazardous Substances
MDI	Methylene diphenyl diisocyanate
MOCA	4,4’-methylene-bis-ortho-chloroaniline
MS	Member State(s)
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No Observed Adverse Effect Level
OEL	Occupational exposure limit
OELV	Occupational exposure limit value
OPEX	Operating Expenses
OSH	Occupational health and safety
OSHA	Occupational Safety and Health Administration
PBT	Persistent, Bioaccumulative and Toxic
PEL	The permissible exposure limit
PNEC	Predicted no-effect concentration
PPE	Personal protective equipment
PMA	Polyurethane Manufacturing Association [USA]
ppm	parts per million
PROC	REACH process categories
PU	Polyurethane
R&D	Research & Development
RAC	Committee for Risk Assessment
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals [Regulation]
RPE	Respiratory Protection Equipment
RMM	Risk management measure
SCOEL	Scientific Committee on Occupational Exposure Limits
SEAC	Committee for Socio-economic Analysis
SME	Small and medium-sized enterprise
SMR	Standardised mortality ratio
STEL	Short Term Exposure Limit
SU	Sector of Use
TDI	Toluene diisocyanate
T25	Dose of a carcinogen that will produce cancer in 25% of test animals that would not have developed cancer spontaneously
UV	Ultraviolet [radiation]
TWA	Time weighted average
WCS	Worker Contribution Scenario
WHO	World Health Organization
WTP	Willingness to pay

Executive summary

The Carcinogens and Mutagens Directive (Directive 2004/37/EC), hereinafter the CMD, protects workers from exposure to carcinogens or mutagens at work. The aim of this study is to support the European Commission's Impact Assessment of a potential Occupational Exposure Limit Value (OELV) and SKIN notation for 4,4'-Methylene-bis(2-chloroaniline) (MOCA).

MOCA is used as curing agent and chain extender by polyurethane moulders in the production of polyurethane elastomers. The substance is subject to authorisation. After the REACH Annex XIV sunset day of 22 November 2017, MOCA is used only by the downstream users in the supply chain of the only applicant for authorisation. The authorisation has still not been granted. Two scenarios have been considered:

- **Scenario 1:** Authorisation is not granted. The use of MOCA discontinues.
- **Scenario 2:** Authorisation is granted. The use of MOCA continues by the users of MOCA in the supply chain of the applicant under the conditions set for authorisation at least during the review period.

The study assesses the impacts of an OELV at three levels: 5, 10 and 20 µg/m^3. Furthermore, the impacts of introducing a skin notation has been assessed.

Users of MOCA - The moulders using MOCA are all micro, small or medium sized companies. The number of exposed workers is estimated to be approximately 350 at 89 sites across the EU. RAC has, in case authorisation is granted, suggested a number of additional RMMs, and it is estimated that the exposure levels with these additional measures with high certainty would be below the lowest of the assessed OELVs.

The costs and benefits (relative to the baseline) estimated in this report for the different reference OELVs are summarised below.

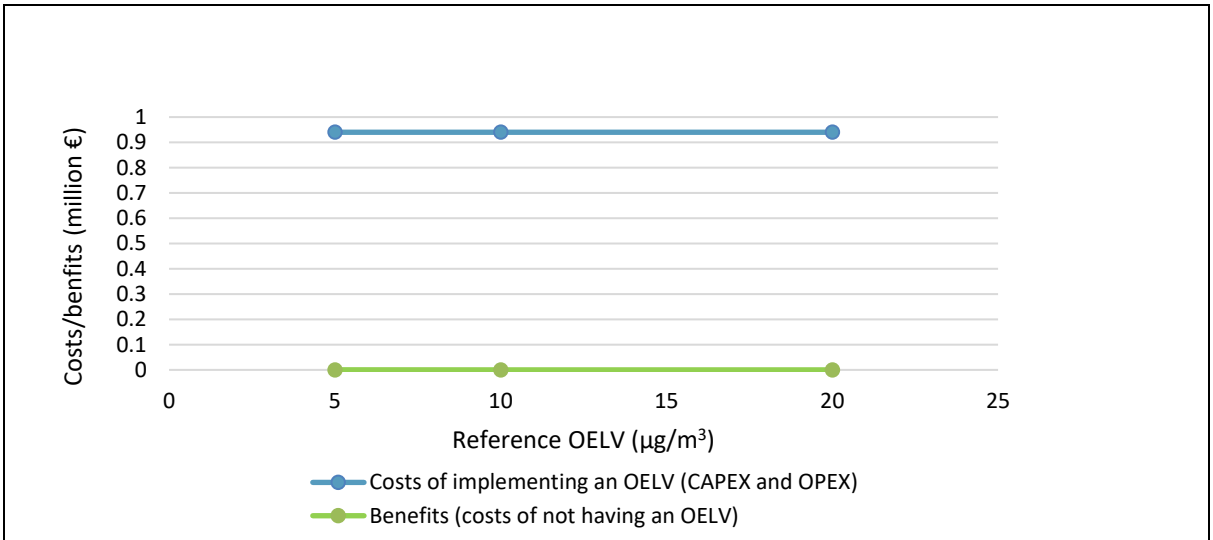


Figure 0-1: Costs/benefits of establishing an OELV for MOCA for all sectors in the EU. Estimated costs (CAPEX AND OPEX) for 60 year and benefits (costs of not having an OELV) for a static baseline with a declining discount rate (all relative to the baseline). Scenario 2.

The table below summarises both the monetised impacts as well as those that are assessed qualitatively.

Table 0-1: MOCA. Multi-criteria analysis, Scenario 2				
Impact	**Stakeholders affected**	**Reference OELV A 5 µg/m³**	**Reference OELV B 10 µg/m³**	**Reference OELV C 20 µg/m³**
Economic impacts				
Compliance costs	Companies exposing their workers	€0.7 million	€0.7 million	€0.7 million
Increased business	RMM suppliers	No impact	No impact	No impact
Enforcement costs	Public sector	€0.2 million	€0.2 million	€0.2 million
Benefits from reduced ill health	Employers	No impact	No impact	No impact
	Public sector	No impact	No impact	No impact
Single-market: competition		No impact	No impact	No impact
Single-market: consumers		No impact	No impact	No impact
Single-market: internal market	Companies. Positive impact of level playing field	Reduction of highest OEL/lowest OEL ratio from 44 to "no difference"	Reduction of highest OEL/lowest OEL ratio from 44 to 2	Reduction of highest OEL/lowest OEL ratio from 44 to 4
International competitiveness		No impact	No impact	No impact
SMEs	Companies	All impacted companies are micro-sized or SME – cost of monitoring could affect the smallest companies disproportionally, but monitoring costs are not significant		
Specific MS/regions	Public sector (MS with higher or without an OEL):	AT, BE, BU, CZ, CY, DK, EE, EL, ES, DE, FI, FR, HU, IT, LV, LT, LU, MT NL, PL, PT, RO, SK, SI	AT, BE, BU, CZ, CY, DK, EE, EL, ES, DE, FI, FR, HU, IT, LV, LT, LU, MT NL, PL, PT, RO, SK, SI	BE, BU, CZ, CY, DK, EE, EL, ES, DE, FI, FR, HU, IT, LV, LT, LU, MT NL, PT, RO
	Companies (in MS with higher or without an OEL)	BE, DK, FR, EL, NL, PT, ES, HU, IT	BE, DK, FR, EL, NL, PT, ES, HU, IT	BE, DK, FR, EL, NL, PT, ES, HU, IT
Social impacts				
Ill-health avoided, lung cancer	Workers & families	€143	Insignificant	Insignificant
Other health points, exposure pathways	Workers & families	Dermal exposure		
Employment	Workers	No impact	No impact	No impact
Environmental impacts				
Environmental releases		No impact	No impact	No impact
Recycling – loss of business*	Recycling companies	No impact	No impact	No impact
Recycling – durability of consumer goods*, etc.		No impact	No impact	No impact
+ small positive impact; - small negative impact;				

* MOCA is transformed by the use and not present at any significant concentration in recycled articles. For polyurethane elastomers, like other thermosets, energy recovery is currently the only recovery pathway.

Benefits - The conclusions are drawn on the basis that the current levels of exposure are typically below the lowest of the OELs assessed and consequently the estimates are not sensitive to the number of exposed workers, or to the relationship between exposure and effects and the costs of cancer cases. The uncertainty is consequently related to the estimated exposure levels.

As RAC suggests a number of best practice measures should be required in case an authorisation is granted, it is estimated to be very certain that the exposure levels would in the future be below 5 µg/m^3, which is the lowest of the assessed OELVs. The OELV of 5 µg/m^3 is today applied in the UK, Ireland and Croatia and well below the OELs applied in other EU MS.

Costs - The main costs elements are considered to be costs for the business of monitoring of MOCA in workplace air to demonstrate compliance and costs for public authorities of the transposition of the OELV. The estimate is sensitive to the assumption that monitoring of the workplace concentration will be required in all MS. In some MS the enforcement may be limited to requiring implementation of certain RMMs specified in the Commission Implementing Decision for granting the authorisation and biomonitoring. As the dermal route is the major exposure route it is likely that some MS would not require monitoring of workplace concentrations and the total costs could be significantly lower. The conditions suggested by RAC in case authorisation is granted focus on frequent biomonitoring as the method to demonstrate that workers are not exposed at an unacceptable level. However, in some MS, the authorities may require that the workplace air concentration is measured regularly and in this case the total costs over the next 60 years would be higher.

Conclusion of the cost/benefits assessment - Even the costs of establishing the OEL may be overestimated, it is considered to be very certain that the costs exceed the benefits.

Establishing an OELV will help to ensure that Member State Authorities have a clear regulatory backstop for enforcement purposes. With the current OEL levels in most MS, air monitoring would not ensure that the companies keep the workplace concentration at acceptable levels.

1 Introduction

1.1 Background

The Carcinogens and Mutagens Directive (Directive 2004/37/EC), hereinafter the CMD, aims to protect workers against health and safety risks from exposure to carcinogens or mutagens at work. To this end, it sets out the minimum requirements for protecting workers that are exposed to carcinogens and mutagens, including the so-called Binding Occupational Exposure Limit Values (OELVs)[1]. For each OELV, Member States (MS) are required to establish a corresponding national occupational exposure limit (OEL) value, from which they can only deviate to a lower but not to a higher value.

1.2 Objectives

This report is one of eight reports elaborated within the framework of a study undertaken for the European Commission by a consortium comprising RPA Risk & Policy Analysts (United Kingdom), FoBiG Forschungs- und Beratungsinstitut Gefahrstoffe (Germany), COWI (Denmark), and EPRD Office for Economic Policy and Regional Development (Poland).

The eight reports are:

- Methodological note
- OEL/STEL deriving systems
- Report for inorganic arsenic compounds
- Report for beryllium
- Report for cadmium and its inorganic compounds
- Report for formaldehyde
- Report for MOCA
- Report for chromium (VI) in fumes from welding, plasma cutting and similar processes

One of the key aims of the study is to provide the Commission with the most recent, updated and robust information on a number chemical agents with the a view to support the European Commission in the preparation of an Impact Assessment report to accompany a potential proposal to amend Directive 2004/37/EC.

The general objectives with regard to these chemical agents include a detailed assessment of the baseline scenario (past, current, and future), as well as the assessment of the impacts of introducing a new Occupational Exposure Limit Value (OELVs) and, where appropriate, a Short-Term Exposure Limits (STELs) and a skin notation.

The specific objective of this report is to assess the impacts of introducing an OELV, STEL and skin notation for 4,4'-Methylene-bis(2-chloroaniline) (MOCA).

[1] See http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:c11137

1.3 Structure of the report

The report is organised as follows:

- Section 2 sets out the background based on documents from the Scientific Committee on Occupational Exposure Limits (SCOEL), the Committee for Risk Assessment (RAC) and the Advisory Committee on Safety and Health at Work (ACSH) and the scope of the assessment for MOCA;
- Section 3 sets out the baseline;
- Section 4 sets out the benefits of the relevant measures;
- Section 5 sets out the costs of the relevant measures;
- Section 6 summarises the market effects;
- Section 7 describes the environmental impacts;
- Section 8 describes the distribution of any impacts;
- Section 9 provides the conclusions and the sensitivity analysis; and
- Section 10 provides the sensitivity analysis.

2 Background and scope of the assessment

This section comprises the following subsections:

- Section 2.1: Background
- Section 2.2: Study scope
- Section 2.3: Summary of epidemiological and experimental data
- Section 2.4: Deriving an Exposure-Risk-Relationship and a Dose-Response-Relationship
- Section 2.5: Reference OELVs
- Section 2.6: Scenarios for MOCA

2.1 Background

The SCOEL Recommendation (2013) concludes that MOCA is a genotoxic carcinogen. Based on the available data, MOCA is categorized into the SCOEL carcinogen group A as a genotoxic carcinogen to which a threshold cannot be assigned. The general population is not exposed to MOCA and MOCA in urinary samples of workers can be attributed to the occupational exposure as stated by SCOEL: "*Since the general population is not exposed to MOCA, MOCA is not detected in the urine of occupationally non-exposed people. This means that urinary levels of occupationally non-exposed stay below the detection limit of the method, which typically lay around 1–1.5 µg/l (3.7–5 nmol/l, ~ 0.37–0.5 µmol/mol creatinine) with commonly used analytical methods, some methods reported to reach the detection limit of 0.1 µg/l. Thus, the Biological Guidance Value (BGV) for MOCA corresponds to the detection limit of the biomonitoring method. In occupationally exposed populations, urinary MOCA levels (total MOCA in the urine) below 5 µmol/mol creatinine can be reached using good working practises at the workplace. According to the risk assessment presented above, this corresponds to a cancer risk of 3–4 × 10^{-6}. Urinary samples should be collected at the end of the work-shift.*" Furthermore, SCOEL notes that based on national industry exposure data, the U.K. Health and Safety Executive (HSE, 2009) has recommended that worker's exposure to MOCA should be as low as reasonably practicable, located below an airborne WEL (Working Exposure Limit) of 5 µg/m^3 MOCA and a BMGV (Biological Monitoring Guidance Value), based on the 90th percentile of data from workplaces with good control) of 15 µmol MOCA/mol (35 µg/g) creatinine. They also note that Cocker et al. (2009) have indicated that this value should be further reduced, as it would no longer act as an effective stimulus to reduce exposure.

The RAC (2017) opinion reaches similar conclusions and recommendations that in occupationally exposed populations, urinary MOCA levels (total MOCA in the urine) below 5 µmol/mol creatinine can be reached using good working practises at the workplace. Furthermore, "*RAC proposed a stringent set of conditions in case the authorisation would be granted. These conditions aim for a higher degree of automation and containment of the process, better extraction of process emissions, improved cleaning and maintenance procedures and improved overall occupational hygiene measures. Furthermore proper training and supervision of the workers needs to be ensured. In order to improve the exposure assessment and ensure the success of the previous conditions twice yearly biomonitoring programmes must be in place accompanied by testing for possible surface contamination.* "

A consolidated version of the RAC/SEAC[2] opinion was published November 2017 (RAC/SEAC, 2017). In this, "*RAC confirmed that there appear not to be any suitable alternatives that further reduce the risk".*

[2] Committee for Risk Assessment (RAC) and Committee for Socio-economic Analysis (SEAC).

Furthermore, *"RAC confirmed that the operational conditions and risk management measures described in the application do not limit the risk, however the suggested conditions and monitoring arrangements are expected to improve the situation."* In this consolidated opinion SEAC concludes *"Therefore, SEAC did not raise any reservations that would change the validity of the applicant's conclusion that overall benefits of the use outweigh the risk to human health, whilst taking account of any uncertainties in the assessment, provided that the suggested conditions and monitoring arrangements are adhered to."*

Classification

According to the CLP Regulation[3], MOCA (EC No 202-918-9) has a harmonised classification as Carc. 1B (H350: "May cause cancer").

MOCA, driver of carcinogenic potency or the mode of action

According to RAC (2017) the precise mechanism of action for carcinogenicity of MOCA is not fully understood; however, MOCA has the potential to form adducts with DNA (deoxyribonucleic acid) (see RAC (2017) for original references and more details.)

Unintentional formation

MOCA is intentionally used in production of polyurethane prepolymers/polymers. No data on unintentional formation of MOCA in other processes or presence of MOCA as impurity in other substances have been identified. Consequently, the study focuses on the intentional uses only.

Presence in articles

According to the REACH ANNEX XV draft background document (ECHA, 2012), unreacted MOCA may also be present in final articles (up to 4% reported by weight), which could lead to exposure. RAC (2017) notes that at industrial sites, usually technical means (e.g. stoichiometric relation between curing agent and monomers) are in place that ensure that content of unreacted MOCA is minimised (<< 0.1%). However, where such measures are not taken, the content of unreacted MOCA increases quickly and free MOCA might be present in final articles above amounts of 0.1% by weight (RAC, 2017). The presence of unreacted MOCA in final articles may lead to occupational exposure of workers in polyurethane production by the dermal route and thereby contribute to the total occupational body burden.

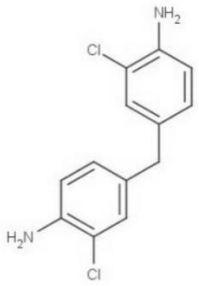
2.2 Study scope

This report assesses the impacts of establishing an OELV and/or a skin notation for MOCA.

[3] CLP Regulation: Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures

2.3 Summary of epidemiological and experimental data

2.3.1 Identity and classification

Table 2-1: Identity and classification of MOCA	
Chemical Substance	4,4'-methylenebis(2-chloroaniline) (MOCA, MBOCA)
CAS Number	101-14-4
EC Number	202-918-9
Sum Formula	$C_{13}H_{12}Cl_2N_2$
Synonyms	2,2'-dichloro-4,4'-methylenedianiline; Methylenebis(chloroaniline)
Chemical Structure	
Classification (ECHA C&L Inventory, 2017)	Acute Tox. 4 (H302); Carc. 1B (H350); STOT RE 1 (H372); Aquatic Acute 1 (H400); Aquatic Chronic 1 (H410) (harmonised)
Unit Transformation	1 ppm = 10.9 mg/m³; 1 mg/m³ = 0.09 ppm
Sources	Data taken from ECHA (2011b), ChemID (2017) and (SCOEL, 2013)

2.3.2 General toxicity profile, exposure, critical endpoints and mode of action

MOCA is well resorbed after inhalation, dermal contact or oral ingestion. Airborne concentrations of 0.2-0.5 µg/m³ have been reported at workplaces in Japan, with much higher levels around 9 µg/m³ at special conditions (IARC, 1993). In a study in Taiwan, the air concentration of MOCA varied greatly between workplaces, with concentrations ranging from less than 20 to as high as 410 µg/m³ (Chen et al., 2005).

However, occupational exposure also occurs by dermal contact leading to cutaneous absorption, as evidenced by urine analysis. Rapid skin permeation of MOCA has been confirmed experimentally *in vitro* with human skin, and it is generally considered that absorption through the skin is the major route of uptake of MOCA at the workplace (SCOEL, 2013). Urinary concentration of MOCA in urine of occupationally exposed workers were in the range of 1.7–50000 µg/L (mean 3.8-278 µg/L) or 0.16-15701 µg/mol creatinine) in MOCA production workers. In polyurethane production, the reported concentrations ranged from 0.5 to 1,600 µg/L, other studies reported concentrations based on creatinine excretion (2.4 to 1,400 µg/g creatinine) or expressed as molar concentrations (< 0.4 to 50 µmol/mol creatinine) (IARC, 2010).

The key effect relevant for the protection of workers is carcinogenicity (RAC, 2017; SCOEL, 2013):

- MOCA is a genotoxic carcinogen. Rats, dogs and humans metabolize MOCA to N-hydroxy-MOCA by hepatic cytochromes P450; DNA adducts are formed by reaction with N-hydroxy-MOCA, and MOCA is genotoxic in bacteria and mammalian cells. The same major MOCA-DNA

adduct formed in the target tissues for carcinogenicity in animals (rat liver and lung; dog urinary bladder) was also found in urothelial cells from a man with known occupational exposure to MOCA (IARC, 1993).

- According to RAC, as an aromatic amine with structural similarity to benzidine, the likely human target of carcinogenicity of MOCA is the urothelium, which is underlined by human case studies (RAC, 2017). The same conclusion has been presented by SCOEL (2013), also pointing to the structural similarity with other carcinogenic aromatic amines and the data in dogs and humans.

- The major exposure route for MOCA is the dermal route. Therefore, MOCA residues in urinary samples of workers are more appropriate than concentrations in air only, to indicate and assess exposure according to (RAC, 2017).

Skin absorption is emphasised by a "skin" notation in a number of OELs, and biological monitoring plays an important role in the surveillance of workplaces. Concentrations of MOCA in urine reflect recent exposure, since the biological half-life of this compound in humans is approximately 23 hours (IARC, 2010). There are no reliable measured data on correlations between urinary MOCA levels and MOCA concentrations in air, so it is not possible to directly calculate urinary levels which correspond to occupational exposure via air. However, biomonitoring should be complemented with air monitoring and, when appropriate, measurements of skin and surface contamination in order to identify exposure sources (2017).

2.3.3 Cancer endpoints – toxicological and epidemiological key studies

Human data

Few epidemiological data are available regarding the carcinogenicity of MOCA in humans.

Clinical and cytological examination of 31 workers with 6 months to 16 years of occupational exposure to MOCA (as confirmed by urine analysis) revealed no signs of cancer. There was also no evidence in a study of medical reports for 178 workers who had been exposed more than 10 years (Linch et al., 1971). A review reported that 13 new cases of bladder cancer had occurred in a cohort of MOCA production workers within a period of only 5 years; however, details of the study have not been published (Cartwright, 1983). In a cohort of 308 male workers, engaged in the manufacture of polyurethane elastomers using MOCA and with a minimum of 12 months employment, mortality from all cancers combined was below the expected value. There was one single death from bladder cancer (SMR 5.6, 95% CI 0.14-31.22). The incidence of all cancers combined was also below expectation, and there was a non-significant excess of bladder cancer based on two cases (SRR 3.28, 95% CI 0.40-11.84). The authors concluded that the findings for bladder cancer should be treated with caution as they related to a relatively early period of follow-up and are based on very small numbers (Dost et al., 2009).

Evidence for the carcinogenicity of MOCA in humans comes from a systematic examination of altogether 560 workers in a MOCA production plant. One man was diagnosed with bladder cancer 8 years after having worked for 1 year in the plant, a second case occurred in a man who had been employed for 9 months in the plant 11 years before diagnosis. A non-invasive papillary transitional cell tumour was diagnosed in the first worker, a papillary urothelial neoplasm in the second. Both workers had jobs in the plant with the greatest potential MOCA exposure, and both had no known exposure to potential bladder carcinogens besides MOCA. Later on, upon cytoscopic examination of 200 persons from the original cohort, a non-invasive papillary transitional cell carcinoma was detected in a third worker, an ex-smoker who had worked for 1.5 months in direct contact with MOCA followed by other jobs in the chemical industry (Ward et al., 1988; 1990).

Further cases of urothelial neoplasia were reported from Taiwanese workers exposed to MOCA (Chen et al., 2005; IARC, 2010; Liu et al., 2005). Compared to the group of 92 workers not involved in MOCA-processing, the group of 70 workers involved in MOCA-manufacturing processes had a borderline-significantly higher prevalence (p = 0.055) of positive occult blood in urine. Among these workers, there was one person with suspected malignant cells in urine cytology and two with atypical cytology. A further worker was not participating in the screening because of hospital admittance after a diagnosis of bladder cancer. This worker, a non-smoker without a history to other known bladder carcinogens, had worked in the area with highest MOCA concentrations in air and without personal protective equipment.

Animal data

Carcinogenicity studies have been conducted with oral exposure of rats, mice, and dogs (see Table 2-22), and with subcutaneous exposure of rats. In all species, exposure to MOCA led to the development of neoplasia. There are no known studies with inhalation or dermal (topical) exposure to MOCA.

As summarized by SCOEL (2013), oral exposure of MOCA increased the incidence of liver tumours in female mice. In a number of studies with rats, MOCA induced liver-cell tumours and malignant tumours in both sexes in one study, liver-cell tumours in males in another, lung and liver tumours in both sexes in a third and lung, mammary gland, zymbal gland and liver tumours in a fourth. MOCA also led to the development of malignant liver and lung tumours in rats after subcutaneous administration (Steinhoff und Grundmann, 1971).

No bladder tumours were observed in rodent studies, but such tumours occurred with 100% incidence in dogs after chronic oral administration of MOCA.

Latency: Brief exposure (months) to MOCA may be sufficient for carcinogenic outcome. The reported range for latency time is 8-26 years, for bladder cancer in general 15-50 years, repeatedly reported average is 11.5 years. The Hutchings & Rushton (2012) estimate (solid tumors peak latency: 36 years) appears to be at the upper end of this range. Animal data (dogs) do not contradict these figures, but are difficult for interpretation. Note that MOCA is classified Carc. Cat. 1B and other tumour sites but bladder cancer (with different associated latency time) may be critical.

A latency period of 20 years will be used for the calculations of costs.

Table 2-2: Carcinogenicity studies with oral exposure of animals to MOCA				
Species, strain, initial no. M+F per dose	**Exposure**	**Results***	**Remarks**	**Reference**
Mouse, HaM/ICR, 25 M, 25 F	1000, 2000 ppm	Haemangiomas + haemangiosarcomas M 3/13, 8/20; hepatomas F 9/21, 7/14	Controls: no such tumours observed. Authors state that incidence of vascular tumours at high dose was comparable to that in historic controls	Russfield et al., 1975
Rat, Wistar, 25 M, 25 F	1000 ppm in diet, 500 d	Hepatomas M 22/25, F 18/25; Lung tumours M 8/25; F 5/25	protein-deficient diet (not further specified), no hepatoma/lung tumours in controls	Grundmann and Steinhoff, 1970
Rat, CD-1, 25 M	500, 1000 ppm in diet, 18 months	Hepatomas: 1/11, 4/19	Control: no liver tumours	Russfield et al., 1975
Rat, CD, 50 M, 50 F	1000 ppm in diet, lifelong (78-89 weeks)	Lung adenocarcinomas M 21/44, F 27/44, squamous-cell carcinoma: 1/44 M, 1/44 F; lung adenomatosis M14/44, F 11/44, pleura mesothelioma M 4/44, F 2/44; hepatocellular adenomas M 3/44, F 2/44, carcinomas M 3/44, F 3/44	Control: no lung tumours; adenomatosis M + F each 1/44, no pleura tumours, no liver tumours	Stula et al., 1975
Rat, CD, 21 M, 21 F	1000 ppm, 16 months	Lung adenocarcinomas M 5/21, F 6/21; hepatocellular adenomas M 5/21, F 2/21, carcinomas M 11/21, F 1/21; mammary gland fibroadenoma F 17"1, adenocarcinomas F 6/21	Low protein diet; controls: no lung and liver tumours; fibroadenoma: 7/21, carcinomas 0/21	Stula et al., 1975
Rat, CD, M, 50-100	250, 500, 1000 ppm in diet, 18 months	% animals with tumours: all lung tumours (mostly adenocarcinomas) (M+F): 23, 37, 70; mammary adenocarcinomas 5, 11, 28; zymbal gland carcinomas 8, 7, 22; hepatocellular carcinomas 3, 4, 36	Sacrifice at 104 weeks (32-week post-exposure), % tumours in control: lung 1, mammary 1, liver 0. Tumours (with lower incidence) also in second study with rats on protein-deficient diet	Kommineni et al., 1979
Dog, Beagle, F, 6	100 mg/d, 3 d/ week (1st 6 weeks), then 5 d/ weeks, 9 a	transitional-cell carcinomas of the urinary bladder in 4/5, additionally one composite tumour (transitional-cell carcinoma/adenocarcinoma)	One dog died at about 2.4 a of treatment, no such tumours in 6 control dogs	Stula et al., 1978
*: No. of animals with tumour/no. examined, if not otherwise stated				

2.3.4 Non-cancer endpoints – toxicological and epidemiological key studies (existing assessments)

Very few data are available regarding non-carcinogenic toxic effects of MOCA. A worker accidentally sprayed with about 12 litres of molten MOCA complained of a mild burning sensation, but no symptoms were reported during the subsequent 14 d period. Tests for liver and kidney function yielded normal results, and there was no methaemoglobinaemia, proteinuria or haematuria. The detection of MOCA in urine (1,700 µg/L at 4 h after the accident) showed that systemic exposure had occurred, the excretion half-time was calculated to be 23 h (RAC, 2017).

In occupationally exposed humans, haematuria has been described with no further details, but otherwise, even after long-term occupational exposure, no non-neoplastic chronic effects were reported. In the carcinogenicity study with dogs (Stula et al., 1975), increased activities of transaminases in serum were noted during the first and last two years of treatment (RAC, 2017).

It is concluded that the database is insufficient for the assessment of non-carcinogenic effects of MOCA.

2.3.5 Biological monitoring – toxicological and epidemiological key studies (existing assessments)

The dose-dependence of haemoglobin adducts of MOCA has been studied experimentally in rats, but there is only limited data in humans (SCOEL, 2013).

Because of its low vapour pressure and its ability to pass the skin, dermal exposure to MOCA is often the most relevant route of exposure, and biological monitoring plays an important role in the assessment of MOCA exposure (SCOEL, 2013). For biological monitoring, the measurement of total (mostly conjugated) MOCA in post-shift urine appears a matter of choice (RAC, 2017).

In a study conducted in France (Robert et al., 1999a; b), urinary MOCA at the end of the work shift in 40 workers from four factories ranged between the limit of detection (1 µg/L) and 570 µg/L. Workers handling crystalized MOCA had the highest urinary excretion. Median values for various groups of workers (mixers, moulders, maintenance, others) reached 3.0 – 84.0 µg/L. In a recent study in the United Kingdom (Cocker et al., 2009), concentration of MOCA in urine from 78 workers in the manufacture polyurethane elastomers was below the detection limit in 49% of the samples. The 90th percentile reached 8.6 µmol/L (20.31 µg/g creatinine) (SCOEL, 2013). It was concluded that a guidance value based on the 90th percentile of data from workplaces with good control should be less than the 90% value of 8.6 µmol/mol creatinine found in the study of Cocker et al. (2009). It was also noted that the UK guidance value of 15 µmol/mol creatinine would be no longer a stimulus to further reduce exposure (Cocker et al., 2009; SCOEL, 2013).

In a follow-up, no MOCA could be detected in 170 of 446 post-shift urine samples from 90 workers. The median was 1.4 µmol/mol, the 90th percentile 10 µmol/mol creatinine. Improvements of work conditions led to a decrease, the 90th percentile falling to 3 µmol/mol creatinine (Keen et al., 2012; RAC, 2017; SCOEL, 2013).

2.4 Deriving an Exposure-Risk-Relationship (carcinogenic effects) and a Dose-Response-Relationship (non-carcinogenic effects)

2.4.1 Starting point

No health based OEL has been derived for MOCA by either SCOEL or RAC because the substance is regarded as a genotoxic carcinogen. However, RAC provided a unit risk for workers of 9.65 x 10^{-6} per µg/m³. This unit risk is adapted in this assessment and used for ERR.

Likewise, no health based BLV has been derived for MOCA by either SCOEL or RAC because the substance is regarded as a genotoxic carcinogen. However, RAC provided a linear risk relationship for workers, where 0.5 µmol/mol creatinine corresponds to a risk of 1.64 x 10^{-6} (level of detection) or 5 µmol/mol creatinine corresponds to a risk of 16.4 x 10^{-6}. This risk associated with biological monitoring is adapted in this assessment and used for ERR. MOCA received a "skin notation" by SCOEL. No Short Term Limit Value (STEL) is derived.

Discussion

As discussed below (see Sections 2.4.2, 2.4.5), because of the relevant percutaneous uptake the reported unit risk, which is derived from animal data, entails considerable uncertainties.

2.4.2 Carcinogenic effects

Approach

As reported above (starting point; Section 2.4.1), the unit risk (workers) was adapted unchanged for ERR:

Table 2-3: ERR for MOCA based on workplace exposure levels

Risk estimate	Remarks	Reference
9.65 x 10^{-6} per µg/m³	Calculated following most recent REACH guidance	(RAC, 2017)

A graphical presentation of this ERR is provided in Figure 2.1.

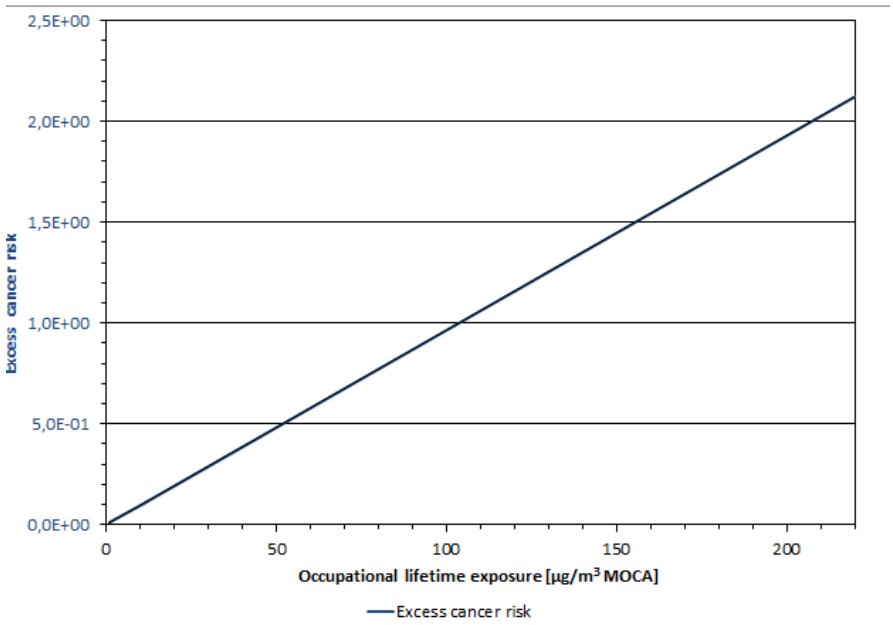


Figure 2.1: Exposure Risk Relationship (ERR) for lung cancer from occupational exposure by inhalation to MOCA

Discussion

Excess risk quantification for MOCA is from animal studies and entails the problems of interspecies extrapolation including the possibility that target organs may differ between animals and humans. In addition, there are no good correlations between air concentration and internal concentrations of MOCA, as measured by biological monitoring because skin penetration may lead to significant systemic uptake of the substance. Therefore, RAC also calculated a risk for workers by the dermal route of exposure of 3.38 x 10^{-5} per µg/(kg bw. x d) (RAC, 2017). Because of the relevant dermal exposure, biological monitoring (see Section 2.4.5) is suggested as a more qualified criterion to quantify systemically available MOCA and health risk from carcinogenic potential.

The assessment by IOM has not been adopted, as this was linked to human data. Based on the results of a study on workers (Dost et al., 2009), IOM used a risk estimate of 3.28 (95% CI 0.40-11.81) for the incidence of bladder cancer for "high" exposure to MOCA. The risk estimate for the "low" exposure was set to 1 (IOM, 2011). It must be noted that the observed SRR was not significantly increased and that there were no exposure data in the baseline study of Dost et al. (2009). Furthermore, setting the risk estimate to one for the "low" exposure is equivalent to assuming a threshold for the carcinogenic effect of MOCA, a genotoxic carcinogen.

2.4.3 Short Term Limit Value (STEL)

Only few European countries have derived a STEL (see Section 3.2). No STEL has been derived by SCOEL; therefore, no quantitative assessment of permissible peak exposure levels is performed in this assessment.

2.4.4 Non-carcinogenic effects

Approach

Because of limited data and no relevant assumed potency for non-carcinogenic effects, no dose response relationship (DRR) was derived for MOCA.

Discussion

No OEL based on non-carcinogenic effects were identified in the available literature.

In workers with occupational exposure to MOCA, haematuria has been occasionally described, but, even after long-term exposure, no non-neoplastic chronic effects (RAC, 2017). Furthermore, no NOAEL/LOAEL from animal studies has been identified for non-carcinogenic effects.

2.4.5 Biomonitoring values

Approach

As reported above (starting point; Section 2.4.1), the risk as linked to MOCA-elimination in urine (workers) was adapted unchanged for ERR:

Table 2-4: ERR for MOCA based on biomonitoring values

Risk estimate	Remarks	Reference
3.28 x 10^{-6} per µmol/mol creatinine	Based on inhalation risk estimate calculated following most recent REACH guidance	(RAC, 2017)

A graphical presentation of this ERR is provided in Figure 2.2 below.

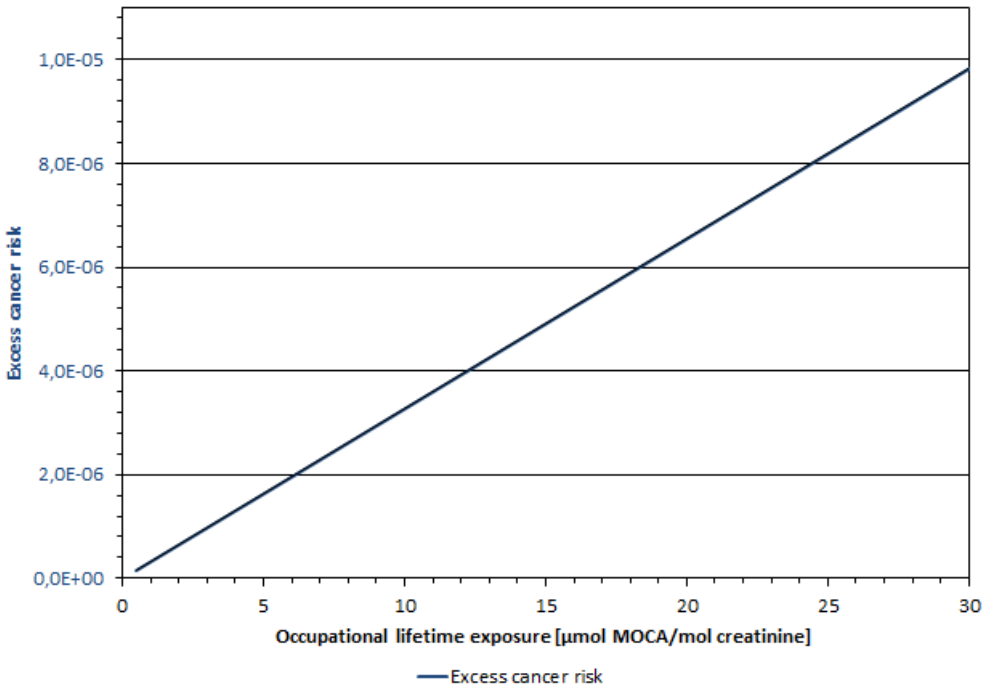


Figure 2.2: Exposure Risk Relationship (ERR) for cancer from occupational exposure to MOCA, based on biological monitoring

Discussion

RAC agreed that dermal exposure is a major route of exposure and therefore supports this skin notation (RAC, 2017). For biological monitoring, the measurement of total (mostly conjugated) MOCA in post-shift urine appears a matter of choice (RAC, 2017).

In a study in the United Kingdom (Cocker et al., 2009), the concentration of MOCA in urine from 78 workers in the manufacture polyurethane elastomers was below the detection limit in 49% of the samples. The 90th percentile reached 8.6 µmol/L (20.31 µg/g creatinine) (SCOEL, 2013). It was concluded that a guidance value based on the 90th percentile of data from workplaces with good control, should be less than the 90% value of 8.6 µmol/mol creatinine found in the study of Cocker et al. (Cocker et al., 2009). It was also noted that the UK guidance value of 15 µmol/mol creatinine would no longer be a stimulus to further reduce exposure (Cocker et al., 2009; SCOEL, 2013).

There are no reliable measured data on correlations between urinary MOCA excretion and MOCA concentrations in air. Therefore, it is not possible to directly calculate urinary levels which correspond to occupational exposure to a certain concentration in air (RAC, 2017).

As the major exposure route for MOCA is the dermal route, MOCA residues in urinary samples of workers are more appropriate than concentrations in air only, to indicate and assess exposure. However, biomonitoring should be complemented with air monitoring and, when appropriate, measurements of skin and surface contamination in order to identify exposure sources (RAC, 2017).

2.5 Reference OELVs

SCOEL - The Scientific Committee on Occupational Exposure Limits (SCOEL 2010) has recommended the following reference values:

- *"8-hour TWA[4] : not feasible to derive a health-based limit (see Recommendation)*
- *STEL (15 min) : not feasible to derive a health-based limit (see Recommendation)*
- *Additional classification : "Skin" notation*
- *SCOEL carcinogen group : A (non-threshold genotoxic carcinogen)*
- *Biological monitoring : See Recommendation "*

According to SCOEL, based on the available data, MOCA is categorized into the SCOEL carcinogen group A as a genotoxic carcinogen to which a threshold cannot be assigned. Hence, a health-based OEL cannot be assigned to MOCA.

It is further noted that MOCA is easily absorbed via the skin. Therefore a "skin" notation is warranted. This underlines the relevance of biological monitoring. For biological monitoring, the measurement of total (mostly conjugated) MOCA in post-shift urine appears as a means of choice.

Regarding the Biological Guidance Value (BGV), SCOEL sets it at "Detection limit of the method".

ACSH - The Advisory Committee on Safety and Health at Work concludes in its opinion (ACSH, 2017):

- "*The major exposure route of MOCA is the dermal route. Therefore there should be a skin notation in Annex III. The three interests groups agreed that biomonitoring is currently the best method to assess the total exposure to MOCA in occupational settings. However biomonitoring can be complemented with air monitoring. The three interests groups agreed an EU occupational airborne limit value for MOCA set at 10 µg/m^3 (8hrs TWA). Biomonitoring can be used to show compliance with this limit value.*
- *The ACSH strongly recommends the Commission to adopt a skin notation preferably with a footnote and recital advising on the importance of biomonitoring under Directive 2004/37/EC.*
- *The ACSH recognizes the challenge of establishing in the existing legal framework the most appropriate approach to effective risk management practice for MOCA, where biomonitoring is the best method for exposure assessment.*
- *The BGV of 5 µmol/mol creatinine stated in the previous opinion remains appropriate*. "

OELVs assessed - The study assessed the impacts of an OELV for a number of levels, summarised in the table below:

[4] TWA: Time weighted average

Table 2-5: OELVs acting as reference points for this study	
Option	**Reference OEL (µg/m3)**
Lowest current national OEL in EU Member States	5 µg/m^3
Median and mode of national OELs in EU Member States	20 µg/m^3
ACHS opinion (ACSH, 2017)	10 µg/m^3

2.6 Scenarios for MOCA

Two scenarios for the future use of MOCA have been considered:

- Scenario 1: Authorisation under REACH is not granted. Downstream use is prohibited. No identified intermediate use.

- Scenario 2: Authorisation is granted. Downstream use continues at least for the review period. The use may likely not continue for the next 60 years, as MOCA has already been replaced by alternatives for many applications. Some downstream users may phase out MOCA already during the first review period.

3 The baseline scenario

3.1 Introduction

This section comprises the following subsections:

- Section 3.2: Existing national limits
- Section 3.3: Relevant sectors, uses, and operations
- Section 3.4: Exposed workforce
- Section 3.5: Exposure concentrations
- Section 3.6: Current Risk Management Measures (RMMs)
- Section 3.7: Voluntary industry initiatives
- Section 3.8: Best practice
- Section 3.9: Standard monitoring methods/tools
- Section 3.10: Exposures not covered by REACH
- Section 3.11: Market analysis
- Section 3.12: Alternatives
- Section 3.13: Future burden of disease

3.2 Existing national limits

3.2.1 OELs

National OELs, STELs and skin notations in EU Member States and selected non-EU countries are summarised in Table 3.2. OELs span from 5 – 220 µg/m³. Notably, the UK, Ireland and Croatia with an OEL of 5 µg/m³ has a limit value well below any other MS. A number of Member States have an OEL at 20 µg/m³ (Poland, Portugal, Slovakia, Austria and others). The highest OELs are established in France, Greece and Romania with an OEL of 220 µg/m³. Fifty percent of the Member States have not established an OEL for MOCA. The background of most of the OELs is not published. However, many OELs are quantitatively identical to the ACGIH TVL from 1992 of 110 µg/m³. ACGIH only provides a qualitative justification for this OEL: "*An 8-hour TLV-TWA …with skin notation, should protect workers against the significant risks of cyanosis, methaemoglobinemia, kidney irritation, and bladder cancer*". This justification has only been changed minimally in 2002, referring to the identical TLV: *"… should minimize the significant risks of cyanosis, methemoglobinemia, adverse effects on the kidney, and bladder or other forms of cancer*" (ACGIH, 2001, with a history of earlier TLVs on MOCA). Before 1992, the TLV was 220 µg/m³ in 1972 (no background document). It is suggested that this early TLV by ACGIH is the background to the OELs in Romania, Greece or France.

National procedures were identical with respect to a "SKIN" notation, which was assigned unanimously, where an OEL has been derived.

The Dutch Expert Committee on Occupational Safety (DECOS) calculated risks from four of the carcinogenicity studies described in section 2.3 (Grundmann and Steinhoff, 1970; Kommineni et al., 1979; Russfield et al., 1975; Stula et al., 1978; Stula et al., 1975) (see Table 2-2), which met the criteria for risk estimation. The highest cancer incidence in the above studies, calculated from the study of Grundmann and Steinhoff (1970) and Steinhoff and Grundmann (1971), was used as starting point for quantitative risk estimation in occupationally exposed humans. DECOS estimated that the additional

lifetime cancer risk for MOCA for 40 years of occupational exposure amounts to 4 x 10^{-5} at 20 µg/m^3 and 4 x 10^{-3} at 2,000 µg/m^3 (HCN, 2000).

SCOEL (2013) did not calculate an exposure risk relationship for the carcinogenic potency of MOCA in its evaluation. In the Annex to the SCOEL Recommendation for MOCA, SCOEL refers to the unit cancer risk estimate derived by DECOS and further describes a risk estimation performed by FIOH (Finnish Institute of Occupational Health) for the excretion of MOCA in urine of occupationally exposed workers (see below in section 2.3.3).

The REACH registrant derived a DMEL of 0.776 µg/m³ for MOCA inhalation exposure and of 0.00445 mg/(kg bw. x d) for dermal exposure (reported by DECOS, 2012 and RAC, 2017).

A recent quantitative risk assessment in accordance with present REACH guidance was performed by RAC (2017). The most complete dose-response study, although with high mortality, is that of Kommineni et al. (1979) in which rats with an adequate protein diet (a further treated group had inadequate protein) were treated orally with MOCA (see Table 2-2). The use of T25[5] in the cancer risk estimates using the lower dose tumour incidences counters this higher mortality in the study (RAC, 2017). The calculation used the total number of all lung tumours:

T25 derivation (RAC, 2017):

- lowest dose with a significantly increased frequency (C) of 9.4 mg/kg bw/day
- Incidence at C, 0.23
- control incidence, 0.01.

T25 is derived using the following calculation:

C x (Reference incidence 0.25)/(incidence at C – control incidence) x (1-control incidence)/1

$T25_{(oral, rat)}$ = 9.4 x 0.25/0.23-0.01 x 1-0.01/1 = 10.6 mg/kg bw/day.

Workers inhalation risk estimate

The $T25_{(oral, rat)}$ was corrected for inhalation exposure assuming 100% absorption and correcting for:

- rat oral intake (mg/kg bw/day) to rat inhalation (0.8 l/min/8 h);0.384 m^3/kg bw/8 h
- oral absorption rat/inhalation humans (50/100)
- activity driven difference for workers (standard respiratory volume for humans, 6.7/respiratory volume in light work for workers,10 m^3)

$T25_{(inhalation, human)}$ = 10.6 x 1/0.384 x 6.7/10 x 50/100 = 9.25 mg/m^3

Correcting for worker exposure:

- workers exposure is 5 day/week, 48 weeks/year, 40 years in an average lifespan of 75 years
- correction factor for workers' exposure of 7/5 x 52/48 x 75/40 = 2.8

$T25_{(inhalation, workers)}$ = 9.25. mg/m^3 x 2.8 correction factor = 25.9 mg/m^3

Assuming linearity of response the cancer risk for lifetime exposure to each unit amount of MOCA will increase in proportion, leading to a risk for workers by inhalation of 9.65 x 10^{-3} µg/m³ (RAC, 2017).

The following table summarises the risk estimates for occupational exposure which were derived by DECOS (HCN, 2000) and RAC (RAC, 2017).

[5] T25: Dose of a carcinogen that will produce cancer in 25% of test animals that would not have developed cancer spontaneously

Table 3-1: Risk estimates for MOCA		
Risk estimate	**Remarks**	**Reference**
2 x 10^{-6} per µg/m³	Also referred to in SCOEL (2013)	(HCN, 2000)
9.65 x 10^{-6} per µg/m³	Calculated following most recent REACH guidance	(RAC, 2017)

Table 3-2: OELs and STELs for MOCA in EU Member States and selected non-EU countries						
Country	**Value [mg/m³ (ppm)]§**	**Specification of value (year)**	**OEL definition**	**Study details**	**STEL [mg/m³(ppm)]§**	**Specification of STEL**
Austria[1]	0.02 (0.002)	-SKIN	SE/T	Not known or not reported	0.08 (0.007)	-15 min, SKIN
Belgium[1]	0.11 (0.01)	-SKIN	SE/T		-	n.a.
Bulgaria	-		n.a.		-	n.a.
Croatia**	0.005 (0.0005)	-SKIN	SE/T		-	n.a.
Cyprus	-		n.a.		-	n.a.
Czech Republic	-		n.a.		-	n.a.
Denmark[1]	0.11 (0.01)	-SKIN	SE/T		- [+]	n.a.
Estonia	-		n.a.		- [+]	n.a.
Finland[1,9] **	0.11 (0.01)	-SKIN	SE/T		-	n.a.
France[1, 6, §§]	0.22 (0.2)	-SKIN (2013)	SE/T		-	n.a.
Germany	-		n.a.		-	n.a.
Greece	0.22 (0.2)	-SKIN	SE/T		-	n.a.
Hungary	-		n.a.		-	n.a.
Ireland[1]	0.005 (0.0005)	-SKIN	HB		-	n.a.
Italy	-		n.a.		-	n.a.
Latvia[4]	-		n.a.		-	n.a.
Lithuania	-		n.a.		-	n.a.
Luxembourg	-		n.a.		-	n.a.
Malta	-		n.a.		-	n.a.

Table 3-2: OELs and STELs for MOCA in EU Member States and selected non-EU countries						
Country	**Value [mg/m³ (ppm)]§**	**Specification of value (year)**	**OEL definition**	**Study details**	**STEL [mg/m³(ppm)]§**	**Specification of STEL**
Netherlands	0.02 (0.002)[1]	-SKIN	SE/T	Grundmann and Steinhoff, 1970; Kommineni et al., 1979; Russfield et al., 1975; Stula et al., 1978; Stula et al., 1975 Species: animal studies, carcinogenicity	-	n.a.
Poland[11,12]	0.02 (0.002)	-SKIN	HB	Not known or not reported	-	n.a.
Portugal[10] **	0.11 (0.01)	-SKIN	HB		-	n.a.
Romania	0.22 (0.2)	-SKIN	Not known		-	n.a.
Slovakia	0.02 (0.002)	-SKIN	SE/T			n.a.
Slovenia[10]	0.02 (0.002)	-SKIN	SE/T		0.08 (0.007)	-SKIN
Spain[1]	0.1 (0.01)	-SKIN	SE/T		-	n.a.
Sweden[1, 10]	###		n.a.		-	n.a.
United Kingdom[1, 8]	0.005 (0.0005)	-SKIN	SE/T		-	n.a.
SCOEL **	-[2,3]	-SKIN	n.a.		-	n.a.
RAC[2]	-[2]		HB	Grundmann and Steinhoff, 1970; Kommineni et al., 1979; Russfield et al., 1975; Stula et al., 1978; Stula et al., 1975 Species: animal studies, carcinogenicity	-[2]	n.a.
Non-EU countries						
Australia[1]	0.22 (0.02)	-SKIN	Not known	Not known or not reported	-	n.a.
Brazil	-	-SKIN	Not known		-	n.a.
Canada, Ontario[1]	0.005 (0.0005)	-SKIN	Not known		-	n.a.
Canada, Québec[1]	0.22 (0.02)		Not known		-	n.a.

Table 3-2: OELs and STELs for MOCA in EU Member States and selected non-EU countries						
Country	Value [mg/m³ (ppm)]§	Specification of value (year)	OEL definition	Study details	STEL [mg/m³(ppm)]§	Specification of STEL
China	-		n.a.		-	n.a.
India	-		n.a.		-	n.a.
Japan, JSOH[1,**]	0.005 (0.0005)	-SKIN	HB		-	n.a.
South Korea[1]	0.11 (0.01)	-SKIN	SE/T		-	n.a.
USA; ACGIH[4] **	0.11 (0.01)	-SKIN	HB	(ACGIH, 2001)	-	n.a.
USA, OSHA[7]	-		n.a.	Not known or not reported	-	n.a.
USA, NIOSH[1,7,13,$] **	0.003 (0.0003)	-SKIN	SE/T		-	n.a.

+ contradictory data from questionnaire responses or GESTIS.
- not established/assigned
§ Unit transformation according to specific country rounding or according to 1 ppm = 10.9 mg/m³; 1 mg/m³ = 0.09 ppm.
SKIN: Skin notation assigned.
n.a. = not applicable
n.r. = not reported
SE/T = influenced by socio-economic and/or technical considerations; HB = health or risk-based
**Limit values are indicative.*

§§ Limit values are recognised values – not according to decree modified on 30 June 2004 – thus not legally binding.
Handling of this substance requires authorisation from the Swedish Work Environment Authority.
$ "For NIOSH recommended exposure limits (RELs), "TWA" indicates a time-weighted average concentration for up to a 10-hour workday during a 40-hour workweek."; Online: https://www.cdc.gov/niosh/npg/pgintrod.html#exposure, assessed December 2017

References:

Questionnaire information (this project) or GESTIS (IFA, 2017), or country specific lists of OEL from web-search, if not stated otherwise (references 2-13, below).

1: IFA (2017) Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung. GESTIS – Internationale Grenzwerte für chemische Substanzen.
2: RAC Opinion on 4,4'-methylene-bis-[2-chloroaniline] (MOCA) (2017)
3: SCOEL (SUM 174, 2013) Recommendation from the Scientific Committee on Occupational Exposure Limits for 4,4'-Methylene-bis-(2-chloroaniline) [MOCA]
4: ACGIH (2001) 4,4'-Methylene bis(2-chloroaniline). In: Documentation of the Threshold Limit Values and Biological Exposure Indices. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio. The background of this TLV is from 1992
5: DECOS (2000, 2012) 4,4'-Methylene bis (2-chloroaniline). Health based calculated occupational cancer risk values. No. 2000/09OSH, The Hague, 6 September 2000
6: INRS (2013) 4,4'-méthylènebis(2-chloroaniline). Fiche toxicologique n°292. Online: http://www.inrs.fr/dms/ficheTox/FicheFicheTox/FICHETOX_292-3/FicheTox_292.pdf
7: NIOSH (last update 2011): 1988 OSHA PEL Project Documentation. Online: https://www.cdc.gov/niosh/pel88/101-14.html sowie NIOSH (last update 2015): 4,4'-METHYLENE BIS(2-CHLOROANILINE). Online: https://www.cdc.gov/niosh/ipcsneng/neng0508.html
8: HSE (2011) EH40/2005 Workplace exposure limits (Second edition, published 2011). Online: http://www.hse.gov.uk/pUbns/priced/eh40.pdf
9: Social- och Hälsovårdsministeriet (2016). Online: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79110/STM_9_2016_HTP-varden_2016_Ruotsi_22122016_NETTI.pdf
10: EU-OSHA (2009). Exploratory Survey of Occupational Exposure Limits for Carcinogens, Mutagens and Reprotoxic substances at EU Member States Level. Online: https://osha.europa.eu/en/tools-and-publications/publications/reports/548OELs
11: Skowroń (2015) Rules and recent trends for setting health-based occupational exposure limits for chemicals. Online:

Table 3-2: OELs and STELs for MOCA in EU Member States and selected non-EU countries						
Country	Value [mg/m³ (ppm)]§	Specification of value (year)	OEL definition	Study details	STEL [mg/m³(ppm)]§	Specification of STEL
http://ijomeh.eu/pdf-1960-2056?filename=Rules%20and%20recent%20trends.pdf 12: Skowroń (2013) Zasady ustalania dopuszczalnych poziomów narażenia dla czynników rakotwórczych w środowisku pracy w Polsce i w krajach Unii Europejskiej. Online: http://medpr.imp.lodz.pl/pdf-491-545?filename=Zasady%20ustalania.pdf 13: National Center for Biotechnology Information. PubChem Compound Database; CID=7543. Online: https://pubchem.ncbi.nlm.nih.gov/compound/7543 (accessed Dec 14, 2017).						

3.2.2 STELs

A STEL of 80 µg/m³ is reported for Austria and Slovenia. The background of this STEL is not provided. No STELs are established in other national or international assessments.

3.2.3 Biological Monitoring

In Germany, a BAR (Biologischer Arbeitsstoff-Toleranzwert; Biological Reference Value) of < 1 µg MOCA (after hydrolysis)/L urine has been established. No health-based exposure limit or biological limit value (BLV) for MOCA has been derived because the database was regarded as insufficient (DFG, 2013).

SCOEL (2013) used the risk estimate of 3.7 x 10^{-2} per mg/(kg bw. x d) derived by DECOS (HCN, 2000) to calculate a BGV. SCOEL points to a "biological action limit" value for MOCA of 5 µmol/mol creatinine for total MOCA, which was proposed by FIOH in 2008. FIOH, using the risk estimate of DECOS (HCN, 2000), calculated that 5 µmol MOCA/mol creatinine in a Friday afternoon sample corresponds to a cumulative life-time cancer risk of 3 x 10^{-6}. Based on these data, SCOEL calculated cancer risks for different concentrations of MOCA in urine of occupationally exposed workers (SCOEL, 2013). SCOEL concluded that there is no exposure of the general population to MOCA, and, thus, MOCA is not detected in the urine of occupationally non-exposed people. The urinary level of occupationally non-exposed persons therefore is below the limit of detection, which typically amounts to 1-1.5 µg/L (3.7-5 nmol/L or ~ 0.37-0.5 µmol/mol creatinine) and, with some methods reported to reach 0.1 µg/L. Thus, the current Biological Guidance Value (BGV) by SCOEL for MOCA corresponds to the detection limit of the biomonitoring method (SCOEL, 2013).

The worker's exposure risk by inhalation derived by RAC (2017) of 9.65 x 10^{-6} per µg/m³ (see above) was used by RAC to also calculate the risk level for different urinary MOCA levels, following a similar approach by SCOEL. An open one-compartment model to calculate the daily dose corresponding to urinary MOCA level of 5 µmol/mol creatinine in the Friday afternoon (end of shift) sample was described by (SCOEL, 2013):

For a substance following first order elimination kinetics, the decrease in urinary level follows the formula $Ct = Cp \times e^{-t \times k_{elim}}$, with Ct = concentration at time point t after the peak concentration, Cp = peak concentration, and k_{elim} = elimination rate constant (= $\ln 2/T_{1/2}$).

Assuming that the half-time of MOCA is 23 hours (see section 2.3.2) and the steady state is reached after one-week exposure, an average urinary concentration of MOCA at steady state is 2.6 µmol/mol creatinine when the concentration in the Friday afternoon sample is 5 µmol/mol creatinine. Urinary excretion of 5 µmol/mol creatinine in the Friday afternoon can then be calculated as $D = C_{ss} \times Cr_{24h} \times M/BW \times f_{ue}$, with D = daily dose, C_{ss} = average concentration in urine, Cr_{24h} = average daily excretion of creatinine for a 50-year old man with 70 kg bode weight (12 mmol), M = mol. mass of MOCA (267.16

g/mol), and f_{ue} = proportion of dose excreted in urine (for MOCA: 50% = 0.5). This leads to a dose of 2.6 x 0.012 x 267.17 : 0.5 = 17 µg/day.

The risk estimates derived by RAC (see section 2.4.2) can then be used to calculate the risk level for different urinary MOCA levels. Since 1 µg/m³ exposure (which corresponds to a daily dose of 10 µg in occupational exposure) represents a cancer risk of 9.65 x 10^{-6}, 5 µmol/mol creatinine in a Friday afternoon sample (corresponding to a daily dose of 17 µg) corresponds to a risk of 16.4 x 10^{-6}, and 0.5 µmol/mol creatinine (detection limit of current analytical techniques) corresponds to cancer risk of 1.64 x 10^{-6} (RAC, 2017).

3.3 Relevant sectors, uses, and operations

3.3.1 Overview

The relevant sectors and uses where occupational exposure is expected to take place are summarised below.

Table 3-3: Relevant sectors and uses – MOCA

Sector	Group	Use/activity	Number of companies
Plastics industry, chemicals sector	Suppliers of the polyurethane sector	Providing MOCA and MOCA containing polyurethane systems	5
Plastics industry	Polyurethane (PU) moulders	Catalyst and chain extender by manufacture of polyurethane	89 (best estimate but it is noted that the maximum is less than 120)
Laboratories	Research and commercial laboratories	Analysis of MOCA in biological samples and workplace air	Not investigated

Source: based on REACHLaw (2016a)

3.3.2 The most relevant sectors/uses

According to the application for authorisation, the supply chain for MOCA is as illustrated below:

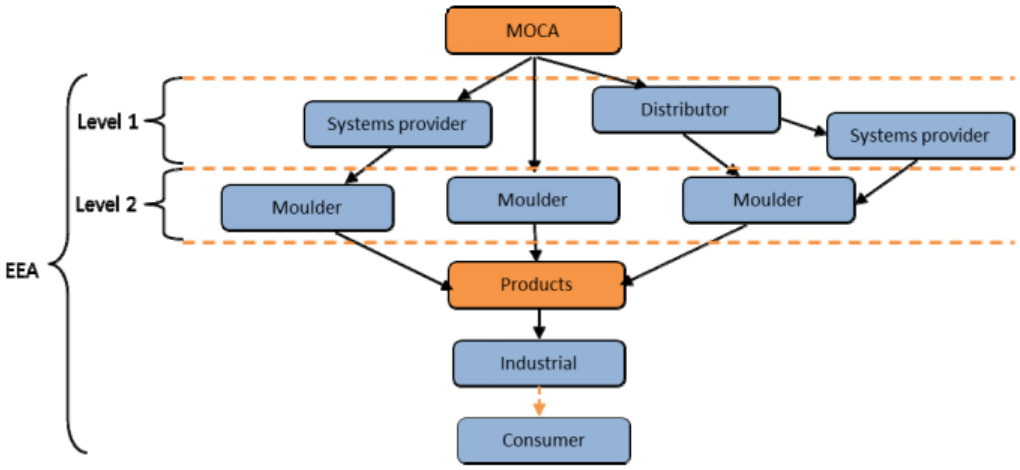


Figure 3.1: Supply chain for MOCA (reproduced from REACHLaw, 2016b; courtesy of REACHLaw)

The scope of possible occupational exposure is limited to the importers of MOCA into the EEA (distributors and system providers) and their direct customers designated Level 1 (system providers) and Level 2 (moulders) in the figure. The following is extracted from the documents for the application for authorisation (REACHLaw, 2016b).

Level 1: System providers sell cast polyurethane systems (e.g. prepolymers, curatives, additives, and also machinery) to moulders. There are 5 companies on this level of the supply chain and these are spread across Europe. The companies generally supply both machines and reagents to their customers and the systems they have available to moulders cover a wide spectrum of castable polyurethane formulations combining most diisocyanates and polyols available.

Level 2: Moulders produce polyurethane articles. The application for authorisation contains information on moulders based on questionnaire responses representing about 66% of the EU tonnage within this supply chain. The document distinguishes between three categories of moulders and their relative percentage in the supply chain is given below:

- Generalised moulders (60%) who produce make-to-order products, low quantity per products, serving a large number of industries. MOCA range from a few percent to 100% of production. Typically quantities: 0.1-12 t/year.

- Specialised moulders (15%) who produce a large quantity of specific products, serving specific industries. MOCA used in 80-100% of production. Typical quantities: 7-80 t/year.

- Mixed moulders (25%) who have mixed characteristics. MOCA used in 30-95% of production. Typical quantities: 6-40 t/year.

It is in the application estimated that about 89 companies operate at this level across the entire EU. The information on the amount of moulders in the supply chain comes directly from the system providers that supply MOCA to them and it is concluded in the application that there is a defined number of moulding companies that does not exceed 120 businesses. The average consumption of MOCA in the companies can be estimated at approximately 5.6 t/year if the number of 89 is used.

All moulders are in the application for authorisation surveyed as micro- (< 10 employee; 20%), small- (10-50 employee; 65%) or medium- (50-250 employee; 15%) sized enterprises as defined by the European Commission.

As part of the preparation of the application, a questionnaire was undertaken by the applicant in order to gather information about use conditions, company size and exposure. The application estimates in the socioeconomic analysis (of the application) that moulders have a median number of 23 employees with 1 employee as minimum; the mean number is not provided. The companies answering the questionnaire survey in total had 892 employees and represented 65% of the total volume of MOCA. If this number is extrapolated on a number of employees per tonne basis, the total number of workers would be 1,526, which is considered the best estimate.

Chemtura, which until recently has been supplier of MOCA for the EU market, performed another market survey in 2015. They identified a total of around 50 MOCA users who collectively used some 350 tonnes of MOCA per year (Corden and Tyrer, 2017) i.e. on average the consumption of MOCA in these companies was 7 t/year. The same data showed that the maximum MOCA usage in one company within these 50 companies was around 50 tonnes per year and the smallest amount used was 1 tonne. This survey indicated that the largest producers employ some 60 employees; the smallest around 5 and the average company employed 12 people (Corden and Tyrer, 2017). Even the average is somewhat lower in this survey as compared to the number indicated in the application for authorisation, the data are quite well in accordance with those provided in the application and support that the majority of the users are micro and small- sized companies.

According to the Annex XV report (ECHA, 2011a), based on the information from the industry, the supply chain around year 2010 consisted of importers, distributors and industrial users with a total of more than 200 use sites within the EU. MOCA was supplied as substance of its own or in mixtures containing the substance. A decrease from 200 sites to less than 100 in 2017 is well in accordance with general information from the sector indicating a decline in the use of MOCA.

According to Cocker et al. (2009), in late 2005/2006 around 25 companies in the UK were using MOCA in the manufacture of polyurethane elastomers. Twenty of the 25 companies visited in a survey ranged from micro companies (<10 workers) to small–medium enterprises (10–250 workers). The average number of workers per site is not reported but it is indicated that ~300 workers are directly exposed to MOCA during polyurethane elastomer production and ~1000 workers are indirectly exposed i.e. around 12 employees per company are directly exposed and 40 indirectly exposed. This could indicate that the average size of UK companies using MOCA at that time were somewhat larger than the average within the supply chain of the applicant. This will be discussed further in the use of the data from the UK surveys to extrapolate to the EU level.

3.3.3 Manual vs. automatic processing

As indicated in the application for authorisation, the users of MOCA "*either perform their tasks in manual processes or using machines. The exposure potential of the hot casting processes can, consequently, be divided into automated and manual processes. In the automated process the substance handling, melting and mixing are performed inside an enclosed machine, whereas in manual process these steps are performed manually. The highest potential for exposure during the casting processes is the manual handling, mixing steps and maintenance tasks.*"

According to the survey undertaken by the applicant most of the moulding shops use automated moulding machines, but some still use manual moulding e.g. when producing smaller articles. As discussed later, the application provides risk estimates for the manual and automatic processes separately.

As the data from the UK surveys of worker exposure will be extensively used on the description of exposure levels, it is relevant to discuss to what extent the UK survey results also represent manual processes. According to Cocker et al. (2009), manual methods were used in 15 of the 20 visited sites. It is reported that the handling of MOCA during polyurethane elastomer production was essentially the same in all firms using the manual method. "*MOCA pellets or granules were scooped from a keg and placed in a container (pan or beaker). Then, under an LEV system, the container was heated on a hot plate to 98–110 ˚C and stored until mixed with a liquid pre-polymer resin, at 60–80 ˚C, containing TDI or HDI. Colourants may be added at this stage and then mixed. The ratio of MbOCA to resin is generally 1:10 but may be up to 3:10*" (Cocker et al., 2009). Five companies used automated methods to process MOCA but according to the authors there was still potential for spillage and exposure during the filling, dispensing, and mixing stages. "*The mixed polyurethane was de-gassed and poured into moulds preheated to 90–95 ˚C. Following casting, the moulds were cured in ovens at 100–120 ˚C for 4–24 h. After curing, the products were released from the moulds and excess ash and spurs were removed by trimming with a knife or scissors*."

The processes applied will be further described in the section on exposure levels.

3.3.4 Downstream uses

The polyurethane parts are used by a wide array of industries for many different applications. Occupational exposure to MOCA in the workplace air, by downstream users of the cured polyurethane parts, is considered low or insignificant and not further assessed.

3.3.5 Laboratories

Small amounts of analytical standards for MOCA are used in laboratories for analysis of MOCA in biological samples and in workplace air. The occupational exposure by the analysis is considered insignificant. MOCA is not used as analytical reagent for any known laboratory analysis.

3.3.6 Applications

MOCA is used as a curing agent/chain extender in cast polyurethane elastomer production. Castable polyurethanes form a part of the overall polyurethane industry. They are prepared by mixing 3 main constituents: the polyol, the diisocyanate (which together form the prepolymer) and a curing agent/chain extender such as MOCA. Before mixing with the prepolymer, MOCA is first melted at ca. 120 °C. The resulting molten polyurethane is then moved to a moulding area and poured into the moulds. The moulding process can be performed either manually or in an automated system. Finally, when the moulds are cast they are cured at 70-80 °C.

MOCA is used in the production of polyurethane elastomers to give specific properties (such as heat, fuel, and solvent resistance, high abrasion properties, and high load-bearing and favourable mechanical and dynamic properties) to the polyurethane products.

According to Corden and Tyrer (2017) in a report prepared for Chemtura (a previous provider of MOCA and now provider of alternatives), typical products in which MOCA-based cast polyurethanes are used are*:*

- Rolls;
- Wheels;
- Hydrocyclones;
- Dynamic bend stiffeners;

- Power transmission belts;
- Vibratory bowls for metal finishing;
- Gaskets;
- Pump impellers;
- Pipeline pigs;
- Belt scrapers;
- Snow plough blades;
- Internal pipe liners;
- Die pads;
- Railway components; and
- Bushings.

According to the application for authorisation "*Products made with a MOCA cured system include wheels and rollers covered by polyurethane; technical machine parts; timing and other types of belts used in many applications e.g. printers, money sorting machines security cameras, sprinkler systems etc.; textile and paper manufacturing; and general machinery uses. MOCA cured systems are used for roller coating for any industrial sector, cone separators for paper industry, roller covers for steel industry, street furniture, sheets and scrapers. Polyurethane covered rollers are used especially in the steel, aluminium, paper, carton, wood and textile industry.*"

3.4 Exposed workforce

The application for authorisation estimates the total number of exposed workers by the moulders at 89 sites across the EU is 213. This figure was derived from the number of potentially exposed workers reported in survey responses, giving a potential exposure worker per tonne ratio of 0.41. The total was then calculated by extrapolating to the total MOCA use of 516 t/year.

This figure would correspond to less than 3 workers per site. As indicated in the previous section the total number of workers by the users of MOCA in the supply chain of the applicant can be estimated at 1,526. Consequently, the percentage of the total workforce in the companies which is exposed to MOCA would be 14%. This seems to be relatively low as compared with information from a UK survey.

The Health and Safety Executive (HSE) in the UK estimated that in the years 2005/2006, 300 workers in the UK were directly exposed to MOCA during polyurethane-elastomer production, and more than 1,000 workers, such as office staff, were indirectly exposed (Cocker et al., 2007). The directly exposed workers represent 23% of all exposed workers, which is assumed to be identical to the total number of workers of the companies. Indirect exposure would be by the dermal route by touching surfaces with MOCA contaminated by workers directly exposed by production work processes. The total use of MOCA in the UK is reported at >200 tonnes in 2006 which is an increase from a level of 90-120 tonnes in 1995. The consumption of MOCA per employee was significantly lower in the UK in 2005/2006 as compared to the data from the supply chain of the application which presumably reflects an increase in the efficiency in the companies with larger production output per worker due to increased automation.

As the data from the UK is based on a systematic survey of 20 out of 25 companies in the industry with extensive measurements of workplace exposure concentration and urinary MOCA concentration, the results are considered to better reflect the actual exposure situation in the industry than the results of the survey of the applicant. Consequently, it is assumed that 23% of the total number of 1,526 employees, corresponding to 350 workers would be the exposed. The remaining approximately 1,200 workers may potentially be indirectly exposed. The estimated 350 workers is only slightly higher than the 300 workers in the UK alone in 2005/2006, where the total consumption was reported at >200

t/year. This indicates that the number of workers per tonne used was higher in the UK in 2005/2006 than in the supply chain of the applicant today, but this is considered to be in accordance with the higher share of automatic processes in the supply chain of the applicant.

Regional distribution. According to the survey undertaken for the application for authorisation, moulders within the supply chain of the applicant are located in Belgium, Denmark, France, Italy, Ireland, Greece, Hungary, Portugal, Spain, the Netherlands, and the United Kingdom. In addition, some moulders not responding to the survey may be located in other MS. The distribution of the consumption by MS is not provided.

Suppliers. Suppliers do not handle MOCA directly but supply filled drums as delivered by the manufacturer. Cooker et al. (2009) took samples from two UK importers/suppliers of MOCA in 2005/2006. At the two suppliers, samples (n =28) were collected from the outside surfaces of recently imported kegs, pallets, and the floor around kegs. Six samples had detectable levels and four of these were from the floor and pallets in both suppliers. Samples were also taken of staff of suppliers but the results are not reported separately. The application for authorisation does not address exposure by the suppliers. According to information obtained from REACHLaw (2017) for this study, the MOCA is packed in drums in China. The MOCA drums are inspected with Swype tests in the factory in China before shipping to ensure that there is no contamination on the surface of the drums. Any exposure by the suppliers would be by the dermal route to contaminants on the surface of the packaging and not further assessed.

Historical exposure

Carex (1999) estimated the numbers of workers potentially occupationally exposed to MOCA in the EU at 3,300 distributed within the following sectors:

- Manufacture of plastic products not elsewhere classified: 1,390
- Manufacture of rubber products: 1,360
- Manufacture of industrial chemicals: 100
- Manufacture of miscellaneous products from petroleum and coal: 10
- Research and scientific institutes: 430

Polyurethane elastomers are considered by some to be "rubber" whereas by others "plastic", and the figures for manufacture of the two materials probably both represent the manufacture of polyurethane elastomers, so the total for this sector is 2,750 exposed workers. MOCA was at that time manufactured within the EU, but has for more than 10 years only been imported.

The Carex data was used by IOM (2011) in a previous study where it was estimated that 2,500 workers were exposed to MOCA in the EU, of which about 1,400 were estimated to potentially be exposed in high-exposure industries (manufacture of rubber and plastics products).

Trend in number of exposed workers

No data exist on the trend in number of exposed workers. An indication of the trend in number of exposed workforce could be derived from the trend in the consumption of MOCA in the EU, but detailed data on this trend is not available. Furthermore, it could be expected that more workers were exposed in the past because manual processes were more widespread. The Annex XV report for MOCA

indicates that the total used volume in 2010 is confidential (data may be available from a confidential annex to that report).

In the UK, the import of MOCA increased from 90 - 120 tonnes in 1995 to ~200 tonnes in 2006.

Chemtura estimates that, LFTDI & TDI systems with MOCA today account for 17% of the total polyurethane elastomer market in the EU while LFTDI & TDI systems without MOCA account for a similar market share (Cordon and Tyrer, 2017) (further discussed later). According the company, MOCA remains the most important curing agent for cast polyurethane outside Europe and it accounts for around 70% of the sales in North America and Australia, and around 85% in Asia. According to Chemtura, the European cast polyurethane industry had similarly high penetration of MOCA several decades ago, illustrating the ongoing move away from the use of MOCA to alternatives (Cordon and Tyrer, 2017). This would indicate that the consumption of MOCA in the 1990's would have been at a level significantly higher than in the EU today. This is not supported by the data from the UK but could be true for the EU market in general.

Summary

The available data on number of exposed worker is summarised in the table below. A distribution by MS is not available.

Table 3-4: Number of workers exposed to MOCA

Sector	Country/Region	Number of sites	No. of exposed workers
Plastics sector Moulding of polyurethane elastomer parts	EU 28	89 (best estimate)	350 directly exposed Indirectly exposed workers by the dermal route ~ 1200
Source: RPA/COWI			

3.5 Exposure concentrations

As mentioned by RAC (2017) and indicated above, the major occupational exposure route for MOCA is the dermal route. "*Therefore, MOCA residues in urinary samples of workers are more appropriate than concentrations in air only, to indicate and assess exposure. However, biomonitoring should be complemented with air monitoring and, when appropriate, measurements of skin and surface contamination in order to identify exposure sources*" (RAC, 2017).

Due to the fact that exposure to MOCA in workplace air is not the main exposure route, relatively little data on exposure levels in workplace air are available, whereas much data is available on urinary MOCA concentrations. As discussed below, the most comprehensive dataset with data on personal samples of air exposure and urinary MOCA levels did not show any correlation between MOCA in urine and in workplace samples (n=75) (HSL, 2007).

3.5.1 Workplace air

Literature data

UK

The most comprehensive data from the literature is from the UK where the Health and Safety Executive (HSE) has studied exposure to MOCA for more than three decades.

Cocker et al. (2009) published results from an occupational survey of the Health and Safety Executive of 2 suppliers of MOCA and 20 out of the 25 workplaces known to be using MOCA in the UK during 2005 and 2006. They collected air samples, surface wipes, gloves, and urine samples and made observations to assess exposure and the adequacy of controls.

Air concentration was measured by personal and static samplers. Personal air samples were collected in the breathing zone of workers. Typically 200 L of air were drawn at 2 L/min through an acid-coated filter in a seven-hole inhalable sampler head. The sampling time was ~100 min and was typical of exposures during the whole shift: all the results were reported as 8-h TWAs. Samples were collected from workers directly exposed to MOCA, such as during scooping, weighing, melting, mixing, etc., and also from workers in the vicinity not directly exposed. Static background samples were placed either to collect an average background measurement or close to processes that could release MOCA vapour (such as melting) to check the effectiveness of ventilation. Because of the low volatility of MOCA, the static samplers were placed around melting, mixing, and casting where concentrations were thought to be higher.

Of 80 personal assessed exposures to MOCA by inhalation, only 16% were above the limit of detection (LOD was 1 µg/m^3 for 220-l sample; LOQ not reported) for MOCA and only two (2.5%) exceeded the UK workplace exposure limit of 5 µg/m^3. The two highest values at 11 µg/m^3 came from workers in different companies who were pouring mixed liquid polyurethane into moulds without any extraction. The mean value of those samples above the detection limit was 2.4 µg/m^3 for the personal samples and 3.7 µg/m^3 for the static samples. Statistical tests suggested no differences between the static and personal samples (mentioned in HSL, 2007 on the same dataset). Differences between automatic and manual processes are not reported.

Table 3-5: MOCA in air, 8-h TWA, µg/m^3

Samples	<LOD[a]	>LOD	90th percentile	Max	Median[b]	Mean[b]	SD[b]	GM[b]	GSD[b]
Personal	67 (84%)	13 (16%)	<1	11	1	2.4	3.1	1.3	2.9
Static	116 (91%)	12 (9%)	<1	11	3.2	3.7	3.1	2.3	3.3
Total	183	25	<1	11	1.5	3	3.1	1.7	3.1

GM: geometric mean; GSD: geometric standard deviation.
[a]LOD (1 µg m^{-3} for a 200-l sample).
[b]Of those values >LOD.
Source: Cocker et al., 2009.

Of the 20 studied companies, manual methods were used in 15 companies. The handling of MOCA during polyurethane elastomer production was essentially the same in all companies using the manual method (see section 3.3 on processing of MOCA).

Surface samples (n=334) were collected from MOCA users and suppliers and 60% had detectable levels of MOCA ranging from 0.019 to 400 µg/cm^3. The highest levels were around a hopper, ovens, and the weighing and pouring areas demonstrating the dispersion via the workplace air from these processes. But MOCA was also detected in 8 of the 75 samples collected from areas not likely to be in contact with MOCA.

Urine samples (n=79) were collected and 49% were below the LOD for MOCA (LOD was 10 nmol/L corresponding to three times background levels) and only three samples had levels of MOCA that exceeded the biological monitoring guidance value (BMGV) of 15 mmol/mol creatinine. The highest

urinary MOCA concentrations were in samples from workers casting and moulding. The data from the study is compared with historical data later in this section.

The authors suggest on the basis of the survey improving housekeeping to reduce surface contamination, wearing appropriate PPE such as gloves during all MOCA handling stages, changing gloves frequently to prevent a build-up of contamination, ensuring that all LEV systems are well maintained and regularly checked, and providing appropriate health surveillance.

USA. Fairfax and Porter (2006) reported in an evaluation of worker exposure to TDI, MOCA, and methylene chloride, that MOCA exposure levels in the workplace air were undetectable (LOQ not reported). The study provides examples of wipes samples collected from different locations in the manufacturing areas which clearly demonstrated that the MOCA is spread in the air and contaminates all surfaces in the factory. For example, high levels were found on top of transformer adjacent to electric oven, on top of metal scale table and on a chair seat next to the transformer.

Australia. Skanker et al. (2017) studied MOCA exposure levels in New South Wales, Australia. Most of the seven polyurethane manufacturing workplaces included in the study were small to medium sized enterprises. The MOCA workers wore P2 disposable masks during the whole procedure and typically used cotton gloves inside long rubber gloves during the MOCA handling tasks. The process described involved mechanically dispensing the pelletized, flaked solid MOCA from a hopper located within a LEV system into a melting pot placed underneath. At some sites, the use of a hand scoop was employed to take 7-10 scoops of MOCA pellets and transfer them into a melting pot located within the exhaust ventilation system. Inhalation exposure was assessed by performing personal and static air monitoring and potential skin exposure was assessed by detecting surface contamination. Biological monitoring was used to assess all routes of exposure.

Personal and static air monitoring was carried out in accordance with US Occupational Safety & Health Administration (OSHA) Method 71 which involved collection of air samples on glass fibre filters that had been pre-treated with sulphuric acid.

The results of personal and static samples are shown collectively in the figure below (data for the two types of samples are not reported separately). Of the 24 air samples taken, 8 (30%) gave levels below the Limit of Quantitation (LOQ) of 0.01 µg/filter sample equivalent to 0.03-0.05 µg/m^3, depending on the air volume. The values, that were less than the LOQ, were included in the statistical analysis as a value half the LOQ. Across all sites, the data gave a geometric mean (GM) of 0.08 µg/m^3 and a geometric standard deviation (GSD) of 2.70 and a 95% percentile of the lognormal distribution of 0.29 µg/m^3. The maximum level measured was 0.30 µg/m^3. This new data from Australia demonstrates about 10 times lower concentration than the UK studies from 2005/2006.

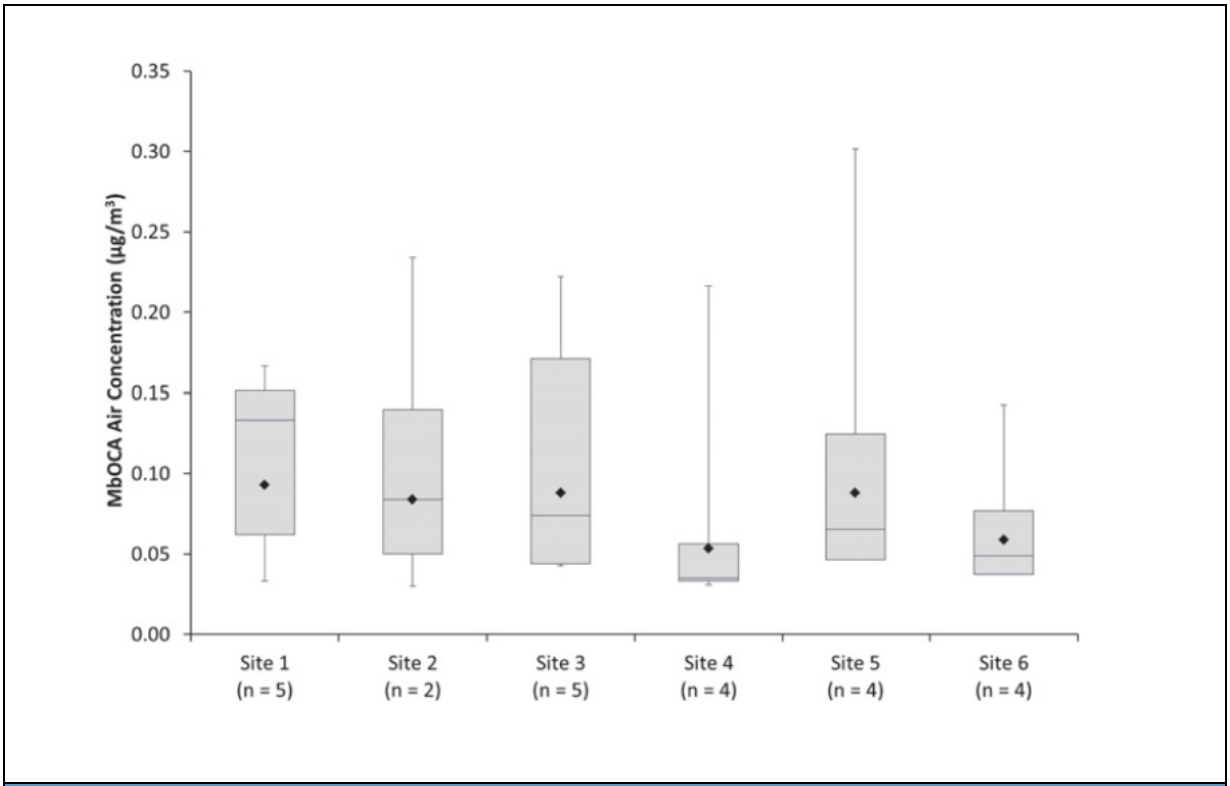


Figure 3.2: Personal and static air monitoring of MOCA from six polyurethane manufacturing work sites in NSW, Australia. Box represents 25-75% confidence interval; horizontal line in the box is the median; black diamond is the arithmetic mean and vertical lines are the ranges of the data.

Source: Shankar et al., 2017 reproduced with courtesy of Journal of Occupational Health.

China. MOCA is not produced in the EU but imported from China. Liu et al. (2005) reported on a case of bladder cancer in a worker exposed to MOCA in the production of MOCA. Concentrations in the workplace air in the purification process area are reported to be 230-410 µg/m^3. The worker did not wear any personal protection equipment during work.

Data from stakeholder consultation

Questionnaires for stakeholder consultation were distributed through the supply chain by ReachLaw, the applicant for authorisation. No answers were obtained. According to REACHLaw (2017), the users would not have any difficulties in complying with an exposure level of 5 µg/m^3.

The British Rubber and Polyurethane Products Association Ltd. (BRPPA) has, for the stakeholder consultation, answered that UK companies have no difficulties in being in compliance with the OEL of 5 µg/m^3 in the UK (BRPPA, 2017).

Data from application for authorisation

The application for authorisation distinguishes between two exposure scenarios: Manual moulding process (Exposure Scenario, ES1) and automated moulding process (Exposure Scenario, ES2). According to the survey undertaken for the application, most of the moulding shops today use automated moulding machines, but some still use manual moulding e.g. when producing smaller articles.

Workplace air levels in moulding shops are shown below as reported in the application for authorisation. Of the estimated 89 sites in the EU, six companies responded to a survey with measured workplace concentrations. The geographical location of the companies is not indicated.

The highest quantified concentrations, 0.22 and 1.32 µg/m^3, were measured in a moulding shop using manual moulding, but the limit of quantification (LOQ) was in most of the measurements at a relatively high level so it is not possible to estimate whether the concentration using manual moulding was different from machine moulding. None of the measurements exceeded the level of 5 µg/m^3 applied in Ireland and the UK, but some of the measurements had a LOQ above this level. The data are not in contradiction with the more detailed datasets presented from UK above.

Table 3-6: MOCA exposure levels

Company	Company using auto or machine moulding	Year	Sampling type	Concentration/Comments
Q	Machine	2009	Static	Not detected (OSHA 71)
E	Machine	2015	Static	<32 µg/m³ (moulding)
			Personal	<32 µg/m³ (moulding)
E	Machine	2011	Static	<20 µg/m³ (moulding)
			Personal	<20 µg/m³ (moulding)
B	Machine	2012	Static	0.05 µg/cm^2 (workbench in the mixing area)
K	Machine	2014	Personal	C_{max} < 0.6 µg/m³
I	Manual	-	Personal	0.22 to 1.32 µg/m³ (HSE method MDHS 75)
J	Machine	2015	Personal	<1.6 µg/m³
			Static	Static by dispenser < 1.7 µg/m³
		2014	Personal	<1.9 µg/m³
			Static	<1.2 & < 2.2 µg/m³
		2012	Personal	<2.3 µg/m³
			Static	<0.2 µg/m³ & 1.9 µg/m³

Source: REACHLaw, 2016b

Modelled data - Besides presenting measured data from downstream users, the CSR developed for the application includes a modelling of workplace concentrations for two exposure scenarios:

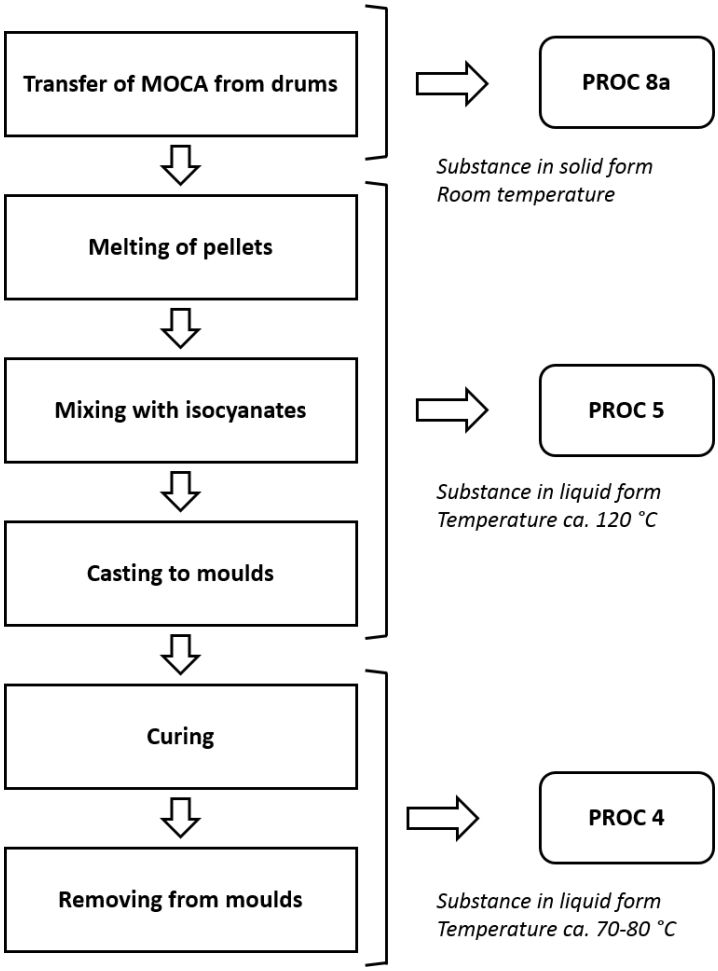
- Exposure scenario 1: Use at industrial site - Use as curing agent/chain extender in manual polyurethane moulding process
- Exposure scenario 2: Use at industrial site - Use as curing agent/chain extender in automatic polyurethane moulding process

Exposure scenario 1 calculate exposure concentration for five Worker Contribution Scenarios

- WCS 1 Transfer of MOCA pellets from the drums to smaller containers
- WCS 2 Melting and mixing of MOCA in polyurethane casting process
- WCS 3 Moulding and curing of PU mixture containing MOCA
- WCS 4 Maintenance and cleaning activities
- WCS5 Sampling

Scenario 2 exclude "Transfer of MOCA pellets from the drums to smaller containers" and consists of the four other scenarios as described later in this section.

The flowchart for the manual process as presented in the application for authorisation is shown below.



As described by the applicant "*MOCA is first brought to dedicated storage area in drums or kegs..... MOCA drums are opened and pellets are transferred to smaller containers by scooping or by moving the pellets to a hopper. The pellets are melted at ca. 120 °C. Weighing of MOCA can be done after melting or before melting. Molten MOCA is mixed with the prepolymer to form the PU mixture. Mixing is performed mechanically with mixer under an extraction system. At some sites polyurethane is de-gassed after mixing. The polyurethane is then moved to moulding/moulding area and casted to moulds and moved to curing ovens. After curing the articles are finished, e.g. articles are trimmed to remove extensive material. Curing time depends on the size of the article and composition of PU mix, with some big articles taking more than 12 hours. Temperature during the curing is usually 70-80 °C.*"

It should be noted that this description of manual processes is well in accordance with the manual processes for which exposure concentrations were measured in the UK and Australia as presented above.

Information from the RMM (Risk Management Measures) overview and the CSR (Chemical Safety Report) of MOCA for "Exposure scenario 1: Use at industrial site - Use as curing agent/chain extender in manual polyurethane moulding process" is shown in Table 3-7. The data are shown as they are provided in the dossier and clearly some interpretation is necessary for the proper use of the data in this

context. For two of the processes the estimated levels exceed the OEL for MOCA in the UK, Ireland and Croatia of 5 µg/m^3 and discussed further below the tables.

Table 3-7: RMM overview and the CSR of MOCA for an authorisation dossier ("Exposure scenario 1: Use at industrial site - Use as curing agent/chain extender in manual polyurethane moulding process")					
WCS	**WCS 1**	**WCS 2**	**WCS 3**	**WCS 4**	**WCS5**
Task	**Transfer of MOCA pellets from the drums to smaller containers**	**Melting and mixing of MOCA in polyurethane casting process**	**Moulding and curing of PU mixture containing MOCA**	**Maintenance and cleaning activities**	**Sampling**
Technical RMMs	Level of containment of workers: low. Manual handling of MOCA pellets. LEV depending on the site	Level of containment of workers: low. Manual mixing of melted MOCA with diisocyanates (MOCA reacts quickly during mixing). LEV depending on site	Level of containment of workers: low Ready polyurethane mix contains very small concentrations of free MOCA. LEV depending on site	Level of containment of workers: low. Ready polyurethane mix contains very small concentrations of free MOCA	Sampling for quality analysis
General comment on LEV	"*All manual moulders in the survey claimed to use LEV during the process, but there is no specific information on the efficiencies*" (estimation model assumes "only good general ventilation")				
Organisational RMMs	Duration: ca. 5-20 minutes. Biological monitoring, personal or static sampling and surface swype tests are conducted depending from the site	Duration: ca. 5-10 minutes	Duration: ca. 1-20 minutes	Duration: 1-60 minutes. All PPEs accordingly based on task/exposure potential	Duration: ca. 5 minutes
PPE (characteristics)	Chemical goggles or face shield, chemically resistant gloves (EN 374), RPE typically filtering dust masks (FFP2,FFP3) or half face masks (P3 or P2 filters) *(efficiency of 95% used in estimation model)*		-	All PPEs accordingly based on task/exposure potential	As in WCS1+2
Assessment method	Modelling (modelling is done without LEV to cover worst case scenario)	Modelling (modelling is done without LEV to cover worst case scenario)	Modelling (modelling is done without LEV and RPE to cover worst case scenario)	Modelling (modelling is done without LEV to cover worst case scenario)	Modelling [no information on LEV]

Table 3-7: RMM overview and the CSR of MOCA for an authorisation dossier ("Exposure scenario 1: Use at industrial site - Use as curing agent/chain extender in manual polyurethane moulding process")					
WCS	**WCS 1**	**WCS 2**	**WCS 3**	**WCS 4**	**WCS5**
Task	**Transfer of MOCA pellets from the drums to smaller containers**	**Melting and mixing of MOCA in polyurethane casting process**	**Moulding and curing of PU mixture containing MOCA**	**Maintenance and cleaning activities**	**Sampling**
Number of exposed workers					
Exposure duration	20 minutes	15 minutes	60 minutes	20 minutes	5 minutes
Estimated inhalation exposure level, systemic, long-term	8 µg/m³ (ART 1.5)	0.85 µg/m³ (ART 1.5)	0.012 µg/m³ (ART 1.5)	7.5 µg/m³ (ART 1.5)	0.0185 µg/m³ (ART 1.5)
Dermal, systemic, long-term	13.07 µg/kg bw/day (RISKOFDERM 2.2.1)	14.5 µg/kg bw/day (RISKOFDERM 2.2.1)	0.0598 µg/kg bw/day (RISKOFDERM 2.2.1)	1.53 µg/kg bw/day (RISKOFDERM 2.2.1)	0.045 µg/kg bw/day (Riskofderm)
Combined routes, systemic, long- term : 29.3 µg (Measured HH (calculated daily dose) (Highest 90th percentile biological measurement value for manual moulder 2014)) *Source: REACHLaw, 2016b*					

According to the application, "*the automated hot moulding process is similar at all of the polyurethane moulding shops. In machine moulding, the loading of MOCA is done inside a glove box and the weighting and mixing steps are done inside a reactor and therefore the exposure to worker is minimal. The ready polyurethane mix is then dispensed to smaller beakers and taken to moulding similarly to the manual moulding process. With bigger sized products, polyurethane mix is poured directly to moulds with hose".*

A picture of glove box and automated moulding machine used in polyurethane moulding is shown below (from ReachLaw, 2016a).

Figure 3.3: Glove box and automated moulding machine used in polyurethane moulding
Reproduced with courtesy of REACHLaw

Because the loading of MOCA happens inside the glove box with only minimal exposure and the weighing and all steps before dispensing ready polyurethane mixture to smaller containers is done inside a closed system, PROC 2 was chosen by the applicant to present exposure during these processes.

Table 3-8: RMM overview and the CSR of MOCA for an authorisation dossier ("Exposure scenario 2: Use at industrial site - Use as curing agent/chain extender in automatic polyurethane moulding process")

WCS (Worker Contributing Scenario)	WCS 1	WCS 2	WCS 3	WCS 4
Task	**Melting and mixing of MOCA in polyurethane casting process**	**Moulding and curing of PU mixture containing MOCA**	**Maintenance and cleaning activities**	**Sampling**
Technical RMMs	Level of containment of workers: high. Loading of the substance is done inside glovebox. Melting and mixing are done inside enclosed system	Level of containment of workers: low. Ready polyurethane mix contains very small concentrations of free MOCA. LEV depending on site	Variable tasks and exposure potentials	Sampling for quality analysis
General comment on LEV	"*All manual moulders in the survey claimed to use LEV during the process, but there is no specific information on the efficiencies*" (estimation model assumes "only good general ventilation")			

Table 3-8: RMM overview and the CSR of MOCA for an authorisation dossier ("Exposure scenario 2: Use at industrial site - Use as curing agent/chain extender in automatic polyurethane moulding process")				
WCS (Worker Contributing Scenario)	**WCS 1**	**WCS 2**	**WCS 3**	**WCS 4**
Task	**Melting and mixing of MOCA in polyurethane casting process**	**Moulding and curing of PU mixture containing MOCA**	**Maintenance and cleaning activities**	**Sampling**
Organisational RMMs	Duration ca. 5-60 minutes. Biological monitoring, personal or static sampling and surface swype tests are conducted depending from the site	Duration ca. 1-60 minutes	Type of task, duration and frequencies varies	Duration ca. 5 minutes
PPE (characteristics)	Chemical goggles, chemically resistant gloves (EN 374), RPE typically filtering dust masks (FFP2, FFP3) or half face masks (P3 or P2 filters)		All PPEs accordingly based on task/exposure potential	As in WCS1+2
Assessment method	Modelling (modelling is done without LEV to cover worst case scenario)	Modelling (modelling is done without LEV to cover worst case scenario)	Modelling (modelling is done without LEV to cover worst case scenario)	Modelling
Number of exposed workers				
Exposure duration	20 minutes	60 minutes	20 minutes	2 minutes
Estimated inhalation exposure level, systemic, long-term	0.005 µg/m³ (ART 1.5)	0.012 µg/m³ (ART 1.5)	7.5 µg/m³ (ART 1.5)	0.0185 µg/m³ (ART 1.5)
Dermal, systemic, long-term	0.1307 µg/kg bw day (RISKOFDERM 2.2.1)	0.0598 µg/kg bw (RISKOFDERM 2.2.1)	1.53 µg/kg bw (RISKOFDERM 2.2.1)	0.045 µg/kg bw (RISKOFDERM 2.2.1)
Combined routes, systemic, long- term : 34.3 µg (Measured HH (calculated daily dose) (Highest 90th percentile biological measurement value for manual moulder 2014)) *Source: ReachLaw, 2016b*				

The major difference between the manual and automatic scenario is the exposure by WCS 1: "Transfer of MOCA pellets from the drums to smaller containers" for which the manual scenario estimates a level of 8 µg/m³, whereas this is not included in the automatic where no exposure takes place by the automatic feeding of the process.

For both scenarios a level of 7.5 µg/m³ is estimated for "Maintenance and cleaning activities". The modelling describes activity with high exposure potential, e.g. when raw MOCA is handled during

cleaning of a spill or when changing a very contaminated filter. Typical duration of this activity is estimated as very short (ca. 20 min). The modelling was done without LEV to cover the worst case scenario. As the exposure duration is assumed to be 20 minutes, the resulting 8-h TWA will be well below the 5 µg/m^3 level.

3.5.2 Biological monitoring

Data from the UK

As for the exposure concentrations described above the most comprehensive data on urinary MOCA levels have been obtained in the UK. Urinary MOCA concentrations from surveys in the UK are summarised in Table 3-9. After the 2008 survey, detailed advice and guidance was given to each workplace at the end of the survey and as a result the 90% value was reduced from 10 to 3 µmol MOCA/mol creatinine in samples collected since (Keen et al., 2012).

Table 3-9: Urinary MOCA concentrations in the UK, µmol/mol creatinine

Group	Year	No of measurements		Exposure level		
		<LOD	>LOD	Median	Mean	90th percentile
All exposed	2005/6	38	40	3.2	3.2 *	8.6
- Indirectly exposed (subgroup of above)	*2005/6*	*15*	*4*	*2.5*	*3.4**	*2.9*
Directly exposed	2008	142	264	1.6	n.d.	11.1
Indirectly exposed	2008	25	10	<LOD	n.d.	2.1

LOD: 5 nmol/L (~0.4 µmol/mol)
* of those above the LOD
Sources: 2005/6: Cocker et al. (2009); 2008: Keen et al., 2010).

HSL (2007), describing the same dataset, clearly demonstrates the differences in urinary MOCA concentrations between the worker groups. Highest concentrations were found in workers involved in casting (pouring into moulds only) and moulding (includes removal and trimming of product from moulds), whereas the level in maintenance and weighing workers were at about half of the concentration in workers involved in moulding and workers involved in all parts were in between. The data indicates that the majority of workers involved in the production are exposed to a certain level, even they are not directly handling the MOCA.

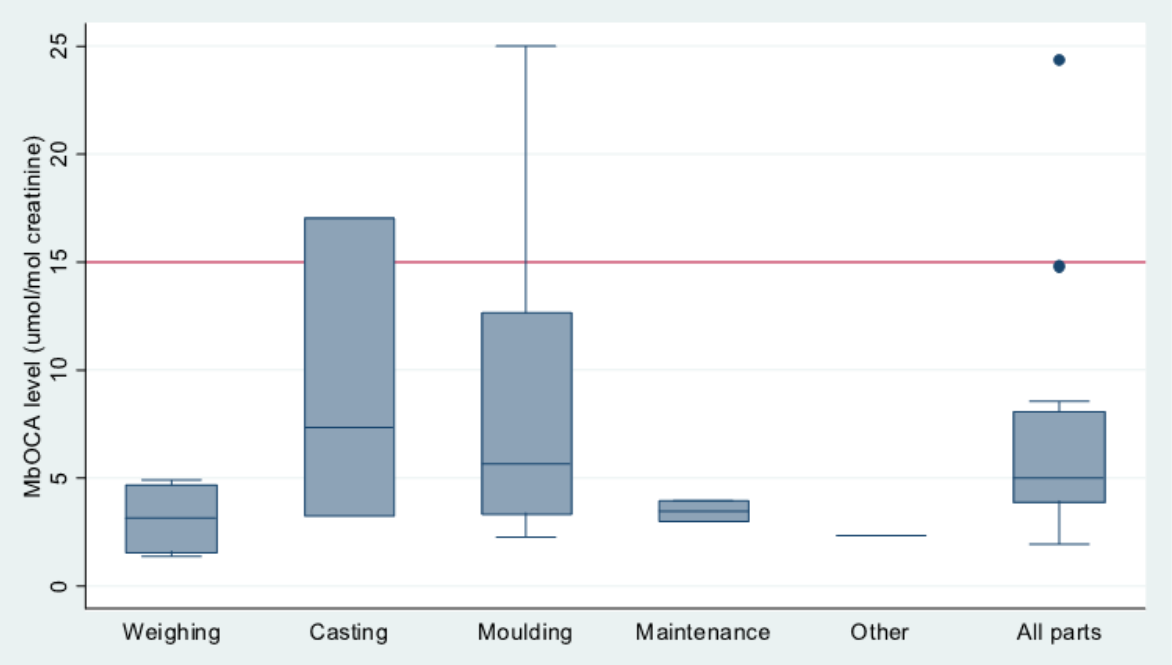


Figure 3.4: Urinary MOCA concentrations by job classification in the UK. Data above the detection level (38 of 78 samples). The figure indicates the ranges and median value, and boxes representing the range of the arithmetic mean ± standard deviation. The red line shows the UK Biological Monitoring Guidance Value of 15 µmol/mol creatinine.

Source: HSL, 2007, reproduced with courtesy of Health and Safety Executive, UK[6]

Correlation between MOCA in urine and personal air samples - A formal statistical analysis of correlation between MOCA in urine and in workplace samples (n=75) showed there was no evidence to suggest an association between MOCA concentrations in urine and personal air samples (p= 0.54) (HSL, 2007). This indicates that the direct exposure via air would, even by the highest exposure concentrations, only contribute with a minor part to the total exposure.

Correlation between MOCA in urine and gloves - Keen et al. (2012) measured in a follow-up study urine samples (n = 446) collected from 90 different workers. The authors conclude that the exposure route for MOCA is clearly dermal and there was a positive correlation between MOCA on gloves and urine. A wide range of glove regimes was used at the sites visited. Much of the production process involves the handling of hot items, and gloves must provide both thermal and chemical protection. Typically thermal protection was provided by the use of a heavy fabric or leather glove or gauntlet. Most frequently they were used in conjunction with a second inner glove of either a lighter fabric or disposable PVC or nitrile glove. Due to the wide range of glove regimes used across the sites visited, and sometimes within a single site, it was not possible to investigate the correlation between glove type and urinary MOCA. However, low urinary MOCA results were observed where fabric-only gloves were used and when adequate training was given on the correct use of gloves.

[6] Contains public sector information licensed under the Open Government Licence v3.0. at http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

Correlation between urinary MOCA levels and weekday - Keen et al. (2012) did not find any correlation between urinary MOCA levels and the weekday.

Correlation between urinary MOCA levels and closed systems - Five of the sites studied by Keen et al. (2012) had enclosed systems for weighing and melting of MOCA. However, statistical analysis indicated no correlation between the use of enclosed handling systems and urinary MOCA levels. At sites where MOCA was weighed and melted on open benches, this was carried out within the influence of LEV. However, casting was performed on open benches, outside the influence of LEV at 8 sites. The type of LEV, and its efficacy, varied greatly from site to site and significant faults were noted at some sites. No correlation between the LEV and urinary MOCA levels was demonstrated.

Data from application for authorisation

According the application for authorisation, overall 17 sites reported to conduct biological monitoring by urine sampling, and from these 12 companies (9 machine moulders and 3 manual moulders) reported measurements values in the survey, but only 4 reported 90th percentile values of the measurements. Six of the companies reported that they do not conduct biological monitoring. None of the companies provided the raw data sets of the measurements. The data is shown in the table below. The dataset is too small to estimate any difference between automatic and manual moulding, but apparently the variation within each of the two groups is quite large. The median values varies around values quite similar to those reported in UK surveys while the reported 90th percentiles are lower, however, the 90th percentile is not reported from the company with the highest median value.

Table 3-10: Biological measurements from 2014

Company	Company using auto or machine moulding	No of measurements/ employees tested	Max observed (µmol/mol creatinine)	Median level value (µmol/mol creatinine)	90th percentile value (µmol/mol creatinine)
A	Machine	13	23	<4	-
B	Machine	10 *	3.8	0.95 *	3.02
C	Machine	13	2.1	0.3	1.2
D	Machine	10	19.6	10.3 ***	-
F	Machine	7	0	0	0
G	Machine	12	-	-	-
J	Machine	20	6	1.78	3.6
K	Machine	15	10.4	4.4	7.1 **
H	Manual	2	-	1.2	-
I	Manual	4	13.3	6	8.8
L	Manual	16x2	3.8	n.d.	-

Source: REACHLaw, 2016b; original notes below, i.e. risk calculation of the application mentioned
*No measurement data available from 2014, therefore the latest values from 2013 are reported in this table.
** Highest 90th percentile values for machine and manual moulders, manual moulder value used for risk calculation.
*** Highest median value with no reported 90th percentile value, used for risk calculation.

Finnish data - According to RAC (2017), "*the Finnish Institute of Occupational Health (FIOH) publishes yearly results from monitorings of the Finnish industry. The total number of MOCA measurements during the years 2000–2008 was 49 (FIOH 2000-2008). Most of the samples were derived from workers involved in the manufacturing of polyurethane coatings. MOCA was measured as total MOCA using alkaline hydrolysis. Most of the values were < 5 µmol/mol creatinine, the range being between below the LOD (1 µmol/mol creatinine) and 10 µmol/mol creatinine (FIOH 2000-2008). The 95th percentile of*

these measurements (n = 49) was 3.4 µmol/mol creatinine (FIOH, unpublished data). Based on these data, FIOH proposed in 2008 a "biological action limit" value of 5 µmol/mol creatinine for total MOCA (FIOH 2008)".

3.5.3 Trends in exposure

No data is available to demonstrate the trend in exposure concentration from actual measurements in the workplace air, but the trend in urinary MOCA concentration of exposed workers can be used as an indication of the level of MOCA in the working environment even the major exposure route is dermal uptake.

From 1986 to 1999 in the UK, the 90th percentile values for urinary MOCA in monitored workers decreased from ~30 µmol/mol to ~7 µmol/mol in 1999 and stabilised at a level of 5-8 µmol/mol during 1999 to 2007. Before 1986 the exposure was even higher and as shown in HSL (2007) the 90th percentile value in 1975 was as high as 180 µmol/mol.

Data for the last ten years has not been published.

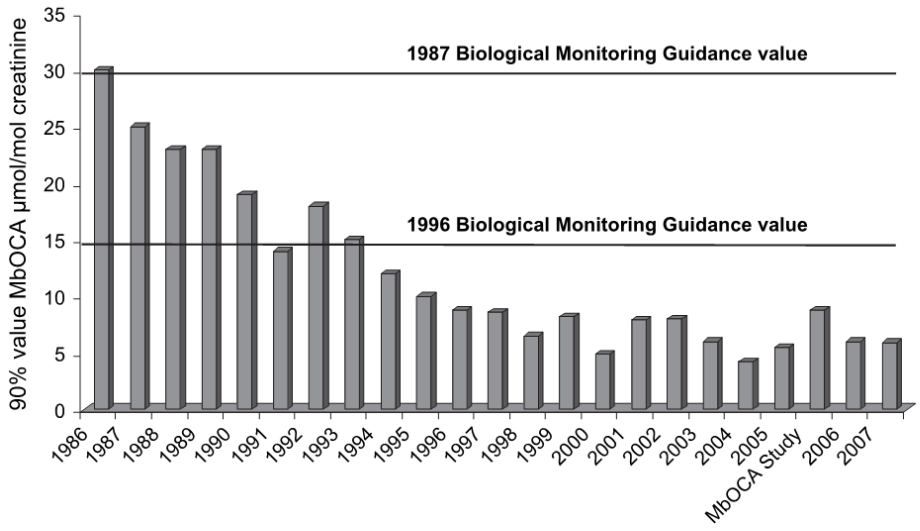


Figure 3.5: The 90th percentile values for urinary MOCA in the UK. Each bar is the 90th percentile of MOCA data from 136 to 1495 urine samples from workers in 15–30 companies each year. Data from the MOCA study (Cocker et al., 2009) are included in the 90th percentile for 2005 and 2006 along with data from additional samples received in those years. In 1987, HSE (UK) had a biological action limit for MOCA of 30 µmol /mol. This was reduced to 15 µmol/mol and became a Biological Monitoring Guidance Value (BMGV) in 1996.

Source: Cocker et al., 2009, reproduced with courtesy of Occupational & Environmental Medicine

Robert et al. (2001) reported on the trend in urinary concentration in workers from three polyurethane manufacturers in France. The data are shown in the table below. The author's note that the higher concentration witnessed in 1996 compared with 1982 in company A, demonstrate the need to constantly improve the working conditions and keep workstations free from any MOCA contamination and maintain a good personal hygiene and clothing standard.

Table 3-11: Development in occupational exposure to MOCA in three companies in France			
	Year	Number of workers	Urinary MOCA concentrations, µg/L
Company A	1982 1984 1996	13 14 11	53 236 85
Company B	1982 1984 1996	11 12 11	156 25 11
Company C	1982 1984 1996	11 13 11	77 34 74
Source: Robert et al. 2001			

3.5.4 Summary and conclusion

Exposure concentrations

The only comprehensive dataset available on exposure concentrations in the workplace air is the data obtained in the UK in 2005/2006.

The highest levels were found for workers undertaking manual processes which are supported by modelling results from the application for authorisation. The dataset is 12 years old and most of the companies used at that time manual processes. According to the application today most companies use the automatic process. On the other hand, most MS have higher OELs than applied in the UK and the companies would be less forced to reduce the exposure levels. New data from Australia shows significantly lower levels than reported in the UK 2005/2006 survey.

It is on this basis deemed that extrapolation of the UK 2005/2006 survey to the supply chain of the applicant would probably not underestimate the current exposure concentration. The data from personal sampling and static sampling were not significantly different and the pooled dataset will be applied. The distribution will be applied on the total number of direct exposed workers of 350 at EU level (from section 3.4).

Table 3-12: Distribution of workers by exposure concentration					
	< 1 µg/m³	1-1.5 µg/m³	1.5-5 µg/m³	5-10 µg/m³	10-15 µg/m³
Number of workers - UK survey *	183	12	11	0	2
Percentage *	88%	6%	5%	0%	1%
Number of workers at EU level **	308	20	19	0	3
*Sources: * Cocker et al., 2009 **RPA/COWI*					

For the further data processing all data below the detection limit will be set at half detection limit of 1 µg/m³ i.e. 0.5 µg/m³.

Urinary concentrations

For the subsequent estimation of the current, past and future current burden of disease based on urinary concentration an arithmetic mean value of urinary levels in mol/mol creatinine is used. As the exposure risk relationship (ERR) is linear without threshold, only the mean value is needed for calculation of the burden.

As for the exposure concentrations, the best dataset is available from the UK, and as mentioned above, these data are considered to be representative for the companies in the supply chain of the applicant for authorisation.

For the 2005/2006 survey, a mean value for the 40 out of 78 samples above the detection limit is reported to be 3.2 µmol/mol creatinine. If the analyses below the LOD is set at half the LOD (0.4/2 µmol/mol creatinine) a geometric mean value for entire dataset can be estimated at 1.8 µmol/mol creatinine. IOM (2011) estimated, on the basis of the same dataset using Monte Carlo modelling for the data below the detection limit, a mean value for the dataset at 2.3 µmol/mol creatinine. The median is reported to be 3.2 µmol/mol creatinine.

For the surveys from 2008 and 2011 no mean value were reported but the median values were in both surveys reported at 1.6 µmol/mol creatinine i.e. about half the value in the 2005/2006 survey and the mean value is likely also significantly lower. The median values reported for the application for authorisation for the 9 companies reporting on the median, ranged from 0 to 10.3 µmol/mol creatinine with an average value of 3.2 (not a mathematically correctly derived median but a simple average of reported median µmol/mol creatinine).

Based on the available data a mean value of 2 µmol/mol creatinine (range 1 - 3 µmol/mol creatinine) is set as the most likely value and used for the calculation of the current burden of disease.

3.6 Current Risk Management Measures (RMMs)

The objective of this subtask is to map the risk management measures (RMM) currently in place to comply with the obligations of the CMD to minimise exposure to carcinogenic/mutagenic chemical agents, and to determine what RMMs are currently used to achieve different exposure concentrations (both 8-hr and 15 minute averages).

A wide range of RMMs have been considered, reflecting the hierarchy of RMMs in the CMD, see below. Data have been collected both through literature review and consultation.

Table 3-13: Hierarchy of measures to be applied by the employers, as listed in the CMD

Type of measure	Measures specified in the CMD
Reducing the quantities of the chemical agents used (substitution and material reduction)	(a) limitation of the quantities of a carcinogen or mutagen at the place of work;
Reducing the number of workers exposed	(b) keeping as low as possible the number of workers exposed or likely to be exposed;
Reducing the concentration of the chemical agents at the workplace	(c) design of work processes and engineering control measures so as to avoid or minimise the release of carcinogens or mutagens into the place of work;
	(d) evacuation of carcinogens or mutagens at source, local extraction system or general ventilation, all such methods to be appropriate and compatible with the need to protect public health and the environment;

Table 3-13: Hierarchy of measures to be applied by the employers, as listed in the CMD	
Type of measure	**Measures specified in the CMD**
	(e) use of existing appropriate procedures for the measurement of carcinogens or mutagens, in particular for the early detection of abnormal exposures resulting from an unforeseeable event or an accident;
	(f) application of suitable working procedures and methods;
Reducing the exposure of workers by protective measures	(g) collective protection measures and/or, where exposure cannot be avoided by other means, individual protection measures;
	(h) hygiene measures, in particular regular cleaning of floors, walls and other surfaces;
	(i) information for workers;
	(j) demarcation of risk areas and use of adequate warning and safety signs including 'no smoking' signs in areas where workers are exposed or likely to be exposed to carcinogens or mutagens;
	(k) drawing up plans to deal with emergencies likely to result in abnormally high exposure;
Other measures	(l) means for safe storage, handling and transportation, in particular by using sealed and clearly and visibly labelled containers.

Data on RMMs applied by the downstream users of the applicant for authorisation is shown in Table 3-14

Table 3-14: Current RMMs as reported												
Sector/ application	1 Substitute/ reduce	2 Reduce workers	3 Reduce ambient concentration			4. Reduce worker exposure		Best practice				Possible to reduce further?
			3a Reduce concentration by process design	3b Reduce concentration by control equipment	3c Reduce concentration: detect problems	4a Collective	4b PPE	Comments	Lowest 8hr TWA achieved?	Which application did this apply to?	Which measures were used?	
Plastics industry - polyurethane elastomers	Substitution has taken place by many former users, but the application does not consider it feasible for current downstream users	Yes - change to automatic process	Yes - machine moulders reported to use glove boxes for loading of MOCA	Yes - LEV and general ventilation reported by both automatic and manual moulders	Yes- Surface swype tests, biological monitoring	Yes - training in proper use of PPE, biological monitoring	Yes - all workers wear gloves, improved use of gloves, full RPE in high-exposure situations	Best practice is advice by RAC (2017) in case authorisations is granted	New data from Australia demonstrates that levels can be kept below 0.3 µg/m^3 (Skanker et al., 2017)	Both manual and automatic	Extensive use of LEV	Not reported
Sources: Current RMM from application for authorisation (REACHLaw, 2016b); best practice based on section 3.8.												

3.7 Voluntary industry initiatives

In the UK, the British Rubber & Polyurethane Products Association and the Health and Safety Executive have jointly published a guide on safe use of MOCA to their members (BRPPA/HSE, year not indicated).

Furthermore, in the UK in 2000, the former British Rubber Manufacturers Association (BRMA) in co-operation with the RAPRA Ltd. published a document entitled "Code of Practice for the use of MbOCA in the manufacture of polyurethane elastomers".

No other voluntary industry initiatives and Social Partner Agreements at European or national level with the aim of reducing the use of or exposure to MOCA have been identified.

3.8 Best practice

RAC recommendation

According to RAC (2017), RAC has proposed a stringent set of conditions in case the authorisation would be granted, which can be considered best practice. These conditions aim for:

- A higher degree of automation and containment of the process.
- Better extraction of process emissions.
- Improved cleaning and maintenance procedures.
- Improved overall occupational hygiene measures and proper training and supervision of the workers.

Furthermore, in order to improve the exposure assessment and ensure the success of the previous conditions, RAC recommend that twice yearly biomonitoring programmes must be in place accompanied by testing for possible surface contamination, complemented with air monitoring and, when appropriate, measurements of skin contamination.

Best practice recommended by industry organisations and authorities

Best practice in the use of MOCA has been addressed in a number of publications from industry associations and authorities, among these the British Rubber & Polyurethane Products Association and the Health and Safety Executive (BRPPA/HSE, year not indicated) and the former British Rubber Manufacturers Association in cooperation with the RAPRA Ltd. (BRMA, 2000).

According to the applicant for authorisation, many companies use the "MOCA safe use guidance for the castable polyurethane industry" prepared by the Polyurethane Manufacturing Association (PMA) in the USA (PMA, 2010).

The RAC opinion on the application for authorisation and the conditions proposed are still not published. However, it must be expected that if authorisation is granted, it will be followed by conditions for the use which will result in occupational exposure concentrations across the EU which are at a level or lower than the concentrations use for the modelling of occupational exposure in this study.

Reducing the quantities of the chemical agents used (substitution and material reduction)

The only way to reduce the quantities of the chemical used is to replace it with alternatives as described in section 3.12.

Reducing the concentration of the chemical agents at the workplace

As mentioned above, RAC consider a higher degree of automation and containment of the process and better extraction of process emissions is key elements for reduce of the spreading of the MOCA in the workplace.

LEV (Local exhaust ventilation) - LEV on machinery is not addressed specifically in the guidelines. A survey of MOCA in Australia, demonstrating low exposure levels, notes that it was reiterated to the employers and workers that the melting and mixing tasks should always be conducted under a fume hood extraction and to have adequate natural ventilation in MOCA work areas to maintain such low exposures and that maintenance of such exhaust systems was also emphasized. The results demonstrate that levels can be kept below 0.3 µg/m^3 by the applied measures (Skanker et al., 2017).

Transfer of MOCA to the smelter - A high degree of containment when emptying the MOCA from the drums is to use a ventilated glove box where the plastic bags with MOCA inside the transport drums are opened inside the box and MOCA is automatically transferred into the smelter. An example is described below.

The process is described as follows by a downstream user for the stakeholder consultation for the application for authorisation: "*MOCA, is introduced to the plant in a sealed bag, in a cardboard drum. To process it, the chemical is transferred to a sealed hopper, with a circular opening similar in diameter to that of the open cardboard container. A rubber seal surrounds the orifice, ensuring a tight fit. After the drum has been attached to the side of the hopper, the internal doors can be opened, with the aid of the viewing window at the front. The bag can be opened inside the closed chamber. Internal non detachable gloves, allow this step without opening the compartment. The gloves are EN374 approved, the operator also wears protective glasses EN166, a half mask EN140, with P3 particulate filters, in addition to gas/vapour filters, and overalls*."

The price of the glove box including feeder per product line is reported for this study to be €15,000-20,000.

This procedure is applicable for transfer of MOCA into the melter in automatic processes.

For manual processes, the PMA guidelines specifies that "*Where MOCA is used in the manufacture of relatively small products and parts, often utilizing a "hand-casting" procedure, a closed transfer method can be used to transfer the MOCA pellets from the drum to a dispenser for weighing and melting small quantities of the chemical. Two principal closed transfer systems include vacuum transfer systems which are commercially available, or gravity feed systems in conjunction with MOCA shipping drums which incorporate a spout dispenser as a part of the blow mold inner liner in the drum. Manual transfer of MOCA from the shipping drum to a melter in an enclosed MOCA transfer area, with reliance upon personal protective equipment and clothing to avoid employee exposure, or glove boxes, have also been used to control employee exposure*".

Spills - the BRPPA/HSE guidelines advice regarding spills:

- Take care to avoid splashing when handling MOCA.

- Clean any spillages/splashes immediately to avoid the spread to others or other areas. Use HEPA filtered vacuums for cleaning up loose solids. Have a periodic routine clean of all surfaces where there is potential for contamination spread.

- Use decontamination solvents to clean liquid spills or splashes.

Spills would typically only be as issue in the manual process where the MOCA is not handled in a closed box.

Reducing the exposure of workers by protective measures

Skin protection - As the dermal route is the main exposure route, much attention is focused on the proper use of gloves. The use of gloves is the basic measure, apparently used in all workplaces, whereas the correct use of gloves should ensure that MOCA on the gloves does not cross contaminate all surfaces and indirectly expose a larger group of workers in the companies. The measures proposed do not necessarily result in any costs to the companies, but concern good working hygiene.

The BRPPA/HSE guidelines advise workers to always protect the skin from contact by (partly citation):

- Use gloves impervious to MOCA in addition to any other gloves worn for heat or other protection; inner nitrile gloves or inner cotton liners with outer terry gloves are recommended.

- Replace contaminated gloves or clothing as necessary to avoid skin contact.

- When removing gloves always follow the guidelines to avoid contamination e.g. remove inside out [the guidelines shows the procedures to follow in order to avoid that MOCA at the surface of the gloves contaminate the skin when taken off].

- Dispose of contaminated items in the hazardous waste bins, not on the table or floor.

- Wear long sleeved tops / jackets or coveralls and have them cleaned regularly.

- Remove all PPE correctly when leaving the area and wash hands thoroughly before eating, drinking or smoking.

- Avoid cross contamination.

- Thoroughly wash contaminated skin immediately.

- Report any incidences of contamination, however small, to your supervisor.

Eye protection - the BRPPA/HSE guidelines advises to always wear eye protection.

Reduce inhalation - The BRPPA/HSE guidelines do not mention the use of respirators. According to the PMA guidelines "*employees working in MOCA areas customarily are not required to use respirators, since the recommended exposure levels are not exceeded. However, processors may, for certain operations in castable polyurethane processing, desire to instruct employees to use respirators even though the air concentrations of MOCA are not expected to exceed the recommended levels. Such use may be prescribed as an added precaution to avoid MOCA exposure, particularly in activities or operations involving a potential for exposure to accumulated MOCA particulates, such as equipment maintenance or clean-up of a MOCA spill*."

As indicated by the modelled exposure levels during maintenance and clean up described in Section 3.5, relatively high exposure levels can be reached by maintenance operations and use of respirators should be considered as best practice during these operations.

Monitoring - According to the PMA guidelines, a MOCA urinalysis testing program is recommended for those employees who work in areas of potential MOCA exposure, including areas where MOCA surface contamination is expected.

According to the BRMA/RAPRA (1999) guidelines, employees exposed to MOCA in the course of their work, in addition to the keeping of a Health Surveillance Record, should also undergo the regime of routine biological testing. In summary these recommendations are: a six monthly review of the medical history and biological monitoring (the measurement of MOCA in urine samples) carried out at regular intervals. These levels should not exceed the UK Benchmark Guidance Value of 15 µmol/mol of creatinine. It is also recommended that bi-annual exfoliative urine cytology is carried out.

Other measures - The PMA guidelines specify detailed training programmes for the workers involved in all parts of the processes.

3.9 Standard monitoring methods/tools

Procedures for monitoring of contaminants in the workplace are established by the national working environment authorities. The guidelines would typically make reference to European standards to be used for the monitoring.

As an example, in Denmark, the Danish Working Environment Authority specifies requirements to occupational hygiene measurements in the guideline: At-Vejledning D-7.2-2 "Arbejdshygiejniske dokumentationsmålinger" [Occupational hygiene documentation][7]. The guidelines define the documentation that concerns:

- The workplace air content of gases, vapours, dust and other particulate pollutants from substances and materials.
- The concentration of harmful substances or their metabolites in biological fluids.
- The extent of biochemical changes in biological fluids.

3.9.1 Monitoring of substances in workplace air

As concerns the monitoring of substances in workplace air, the guidelines make reference to two European standards:

- EN 482:2012+A1:2015: "Workplace exposure. General requirements for the performance of procedures for the measurement of chemical agents."
- EN 689:1995: "Workplace atmospheres - Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy."

[7] See https://arbejdstilsynet.dk/da/regler/at-vejledninger/a/d-7-2-arbejdshygiejniske-dokumentationsmaalinger

The latter is under revision and available as a draft: "DSF/prEN 689: Workplace exposure - Measurement of exposure by inhalation to chemical agents - Strategy for testing compliance with occupational exposure limit values".

EN 482:2012+A1:2015 specifies general requirements for the performance of procedures for the determination of the concentration of chemical agents in workplace atmospheres as required by the Chemical Agents Directive 98/24/EC. The requirements given apply to all measuring procedures, irrespective of the physical form of the chemical agent (gas, vapour, airborne particles), the sampling method and the analytical method used and is applicable to all steps measuring procedures with separate sampling and analysis steps, and direct-reading devices.

EN 689:1995 provides guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy. The standard refers to the latest update of EN 482 as concern the general requirements for the performance of procedures for the measurement of chemical agents. The standard describes the monitoring strategy consisting of two phases:

- An occupational exposure assessment where the exposure is compared with the OEL.
- Periodic measurements to regularly check if exposure conditions have changes.

Analytical methods for MOCA in workplace air

The Gestis database[8] does not include any description of methods for determination of MOCA in the workplace air and no ISO or CEN standards are available for the analysis of this substance.

The MDHS 75/2 and OSHA method ORG-71 methods described below with practical limit of quantification of 0.2 and 0.44 µg/m³ (depending on sample volume), respectively, are applicable for compliance control of an OELV of 5 µg/m³.

MDHS 75/2 - A method is available from the Health and Safety Executive in the UK which has been used e.g. for the surveys of MOCA in workplace air in the UK: MDHS 75/2 "Aromatic amines in air and on surfaces - Laboratory method using pumped acid coated filters, moistened swabs and HPLC"[9]. The procedure describes the determination of time-weighted average concentrations of aromatic amines in air and the identification of amine contamination on surfaces. The procedure is suitable for a range of aromatic amines including MOCA. In summary, a measured volume of air is drawn through an acid-coated glass fibre filter and, if required, a sorbent back-up tube in series to trap aromatic amines with significant vapour pressure (not required for MDA, MOCA and aniline). After sampling, the filters are desorbed in sodium hydroxide solution and the sorbent tube in methanol. The resultant solutions are analysed by HPLC with UV (ultraviolet radiation) detection.

The LOQ for a 10-litre air sample is reported to be 0.2 µg/m³. For air samples, the overall uncertainty for this measurement procedure is less than 25%.

OSHA method ORG-71 - By the method of the United States Department of Labor 14 (OSHA method ORG-71- July 1989) *"samples are collected closed-face by drawing known volumes of air through sampling devices consisting of three-piece cassettes, each containing two sulfuric acid-treated glass fiber filters separated by a spacer. The sample filters are transferred to separate glass vials containing 2 mL*

[8] See http://www.dguv.de/ifa/gestis/gestis-analysenverfahren-fuer-chemische-stoffe/index-2.jsp

[9] HPLC: High Pressure Liquid Chromatography

of deionized water within 10 h after sampling. Quantitation is performed by analyzing the heptafluorobutyric acid anhydride derivatives of the amines by gas chromatography using an electron capture detector".[10] The limit of quantification (LOQ) is reported to be 0.44 µg/m³ with a recommended air volume of 100 L at 1 L/min.

Jeżewska and Buszewski (2011) describe a new method for the determination of MOCA using high-performance liquid chromatography with diode array detector. MOCA was sampled from workplace air and derivatised before determination using 3,5-dinitrobenzoyl chloride. The determination was carried out in the reverse-phase system (mobile phase: acetonitrile: water) using an Ultra C18 column (Restek, Bellefonte, PA, US). The measurement range was 2–40 µg/m^3 for a 100 dm^3 air sample. Limit of detection is reported 7.9 ng/m^3 and LOQ is 23.8 ng/m^3 (0.023 µg/m^3).

BGI 505-38E - The method recommended for occupational hygiene monitoring in Germany, BGI 505-38E11, is based on GC-FID analysis (Gas Chromatography – Flame Ionization Detector). The method has with an air sample of 140 L a reported LOQ of 40 µg/m^3.

Conclusions

The MDHS 75/2, applied in the UK, has a reported LOQ of 0.2 µg/m³, which is more than ten times below the lowest OELV assessed in this report of 5 µg/m³.

3.9.2 Monitoring of MOCA in biological samples

According to SCOEL 2013, for biological monitoring of MOCA exposure, total MOCA (free and conjugated MOCA) can be determined in the urine. Analytical methods typically applied include high-performance liquid chromatography (HPLC) coupled with ultraviolet or electrochemical detection, or gas chromatography (GC) connected with mass spectrometric detection.

Is has been found that MOCA is mostly excreted as labile glucuronide and acetyl conjugates, which can break down forming free MOCA during sample storage, thus affecting the final levels of free MOCA in the sample. Therefore, it is recommended to pre-treat samples to take into account these labile conjugates (Cocker et al., 1988, Cocker et al., 1990 as cited by SCOEL, 2013).

A method described by Cocker et al. (1990) involves heat hydrolysis of labile conjugates followed by solid-phase extraction into 90% acetonitrile, with separation of MOCA by reverse-phase HPLC and electrochemical detection. The detection limit of this method was reported as 10 nmol/L (~ 3 µg/L) (Cocker et al 2009 as cited by SCOEL, 2013).

According to SCOEL (2013), alkaline hydrolysis has also been used for the measurement of total MOCA in urine samples. Robert et al. (1999a) used a method involving stabilisation of MOCA by sulphamic acid followed by alkaline hydrolysis at 80 °C, a single isooctane extraction and HPLC analysis, either with UV or electrochemical detection. The detection limit of this method was reported to be 1 µg/L (UV detection) and 0.1 µg/L (electrochemical detection) (3.745 nmol/L and 0.37 nmol/L, respectively) (Robert et al 1999a as cited by SCOEL, 2013).

[10] See https://www.osha.gov/dts/sltc/methods/organic/org071/org071.html

[11] Available at: http://onlinelibrary.wiley.com/doi/10.1002/3527600418.am10114e0007/pdf, accessed October 2017.

3.10 Relevance of REACH Restrictions or Authorisation

3.10.1 Summary of REACH Registration and Authorisation

Registration

MOCA is registered in quantities of 1,000-10,000 t/year. The substance is registered by a joint registration by the following five companies:

- Chemical Inspection & Regulation Service Limited Unit 1 Ardee Business Park, Hale Street Co. Louth Ardee Ireland
- K-I Chemical Europe S.A./N.V. Avenue Louise 326, Box3 1050 Brussels Belgium
- LANXESS Sales Europe B.V. Ankerweg 18 1041AT Amsterdam Netherlands
- Limburgse Urethane Castings NV Slakweidestraat 18 B-3630 Maasmechelen Belgium
- REACHLaw Oy Vänrikinkuja 3 JK 21 02600 Espoo Finland (applicant for authorisation)

According to the Annex XV report (ECHA, 2011a), no manufacturing sites have been identified within the EU. According to information collected from industry for the Annex XV report, the import of MOCA into the EU was within the range of 1,000 to 10,000 tonnes for 2010 and the net volume used within the EU was in the same range (ECHA, 2011a).

Authorisation

MOCA is subject to authorisation under REACH with a sunset date of 22 November 2017.

ECHA has received only one application for authorisation for MOCA (REACHLaw Ltd, 2016a,b) covering its industrial use as a curing agent/chain extender in cast polyurethane elastomer production. The total import is reported to be approximately 500 t/year, used at about 89 potential sites in the EU. Detailed information is available on the uses and sectors from this authorisation application.

For the preparation of the application, a questionnaire was undertaken by the applicant in order to gather information on operational conditions, RMM, PPE and possible measurements conducted at the sites using MOCA. Questionnaires were sent to moulders and distributors. In total, 20 moulders companies, representing 65% of the tonnage imported to EU, responded. Total number of employees in these companies was 892. Information provided in the following sections with reference to the application for authorisation is largely based on this survey (REACHLaw Ltd, 2016a,b).

The authorisation has not yet been granted, but the users within this supply chain can continue to use MOCA until a decision is published. The opinion of RAC to the applications has still not been published.

The following description of applications focuses on those covered by the application for authorisation as all other uses will cease before the sunset data.

3.10.2 Potential exposure not covered by REACH

The draft background document for MOCA developed in the context of ECHA's fourth Recommendation for the inclusion of chemical agents in Annex XIV[12] (as well as the Annex XV dossier for the chemical agents), discusses in detail the possible use as intermediate. The background document reached the conclusion that it is dependent on the exact application of MOCA and comes to the following conclusion for two main applications (text extracted from the background document):

- The main use of MOCA as a curing agent cannot be regarded as a use as intermediate. According to the ECHA guidance on intermediates, a chemical agent should not be regarded as intermediate as soon as the main aim of the chemical process is not to manufacture another chemical agent, but rather to achieve another function, specific property, or a chemical reaction as an integrated part of producing articles (semi-finished or finished).

- A further minor use of the chemical agent is as a monomer in the manufacture of a prepolymer. This might be considered as a use of MOCA as an intermediate, as the outcome are prepolymer flakes without defined shape and further additives determine the properties of the final polymer.

The application for authorisation does not mention the use as intermediate as this would be excluded from the requirements. According to REACHLaw (2017), it is the company's understanding that the system providers, who are supplied with MOCA from the manufacturer in China, may perform the minor intermediate use and then supply it to the moulders. However, in general MOCA is more often supplied as is, with the prepolymer (diol and isocyanate) being supplied separately. The PU reaction (MOCA + prepolymer) is then performed on-site by the moulders.

It has not been possible to find any information on the use of MOCA for manufacture of prepolymers or any marketing of MOCA-containing prepolymers. All available information describes that MOCA is reacted with the prepolymer by the moulders.

3.11 Market analysis

The overall market for polyurethane elastomers has been described by Amec Foster Wheeler for Chemtura in a report prepared in the context of REACH authorisation (Corden and Tyrer, 2017). Chemtura is, as mentioned, a former supplier of MOCA-based polyurethane systems and supplier of alternatives to MOCA-based systems.

According to the report, Chemtura estimates the sales of cast polyurethane in Europe of around 33,000 tonnes per year (expressed as prepolymer plus curative).

The moulders of polyurethane elastomers are as described elsewhere, typically micro-, small- or medium-sized companies which are specialised in the manufacture of a large number of different parts which are used by other companies in the manufacture of articles. The moulders typically serve a large number of customers and provide a large number of articles. A company consulted by Corden and Tyrer (2017) estimated that they had manufactured 10,000 unique articles in the last 10 years. Final

[12] Draft background document for 2,2'-dichloro-4,4'-methylenedianiline (MOCA). Document developed in the context of ECHA's fourth Recommendation for the inclusion of chemical agents in Annex XIV. ECHA 20 June 2012.

components/articles are manufactured from cast polyurethane elastomers derived from reacting a 'prepolymer' with a 'curative'.

The number of companies providing MOCA for polyurethane systems and polyurethane moulders are listed in the table below.

Table 3-15: MOCA - Number of companies		
Sector	**Group**	**Number of companies**
Plastics industry, chemicals sector	Suppliers of the polyurethane sector	5
Plastics industry	Polyurethane moulders	89 (best estimate but it is noted that the maximum is less than 120)
Laboratories	Research and commercial laboratories	Not investigated
Source: based on REACHLaw (2016a)		

Typical isocyanate prepolymers, which account for 90% or more of European prepolymer sales, include those based on TDI (toluene diisocyanate), LFTDI (low free toluene diisocyanate), MDI (methylene diphenyl diisocyanate) and LFMDI (low free methylene diphenyl diisocyanate).

Typical curatives which account for 95% or more of European curative sales include MOCA, DMTDA (better known as Ethacure® 3006), BDO (1,4-Butanediol) and HQEE. More specialised curatives include M-CDEA (4,4-methylenebis-3-(chloro-2,6-diethyl)-aniline) and Addolink ® 1604 HW.

The European cast polyurethane industry by polyurethane system technology is according to Chemtura divided as follows (Corden and Tyrer, 2017):

- LFTDI & TDI systems/MOCA: 17%
- LFTDI & TDI systems/non-MOCA: 17%
- MDI/ 1,4 butanediol systems: 18%
- Quasi MDI / 1,4 butanediol systems: 32%
- Speciality (LFMDI and others): 16%

The LFTDI & TDI systems/MOCA today thus only account for about 17% of the total market.

During the last decade the industry in Europa has moved away from the MOCA-based system. This is also indicated in the application for authorisation which notes that "*of those moulders who responded to the survey, 90% had tested at least one alternative to MOCA. 45% have already moved part of their business away from MOCA, while only 20% of companies still use MOCA exclusively*"(Corden and Tyrer, 2017).

According to Chemtura, the distribution between the different systems varies in Europe and in competitor countries. MOCA remains the most important curing agent for cast polyurethane on the global market and it accounts for around 70% of the sales in North America and Australia, and around 85% in Asia (Corden and Tyrer, 2017). According to Chemtura, the European cast polyurethane industry had similarly high penetration of MOCA several decades ago, illustrating the ongoing move away from

the use of MOCA to alternatives such as DMTDA and BDO initially, and more recently to LFMDI pre-polymer/HQEE (Corden and Tyrer, 2017).

China is the largest global polyurethane elastomer market, representing half of global demand as shown in the figure below.

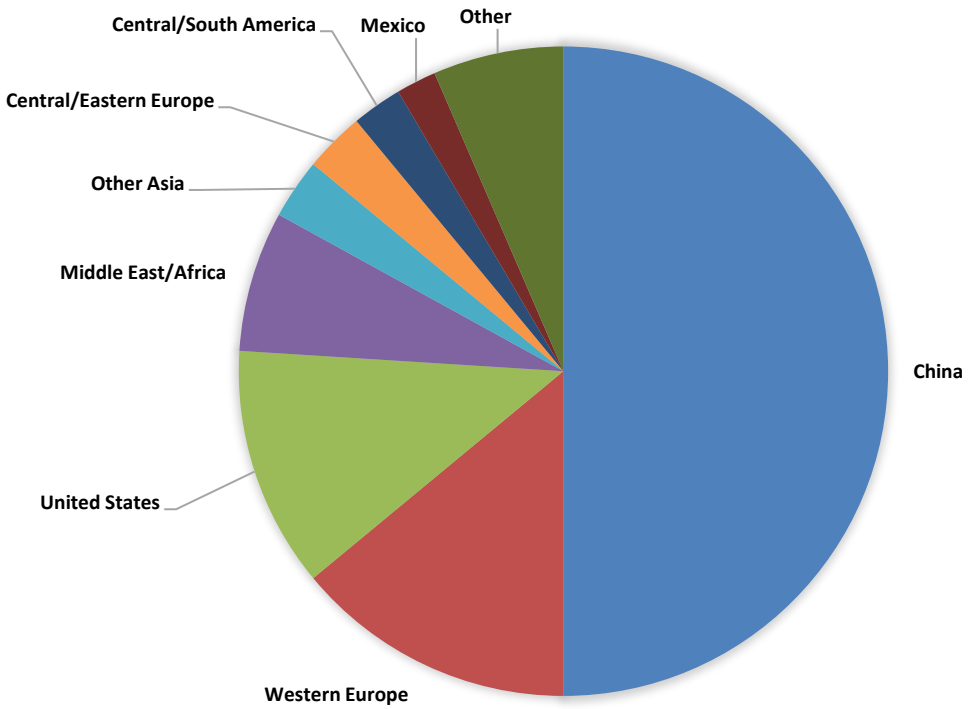


Figure 3.6: Global consumption of polyurethane elastomers.
Source: IHS, 2017

3.12 Alternatives

A number of alternatives to polyurethane systems with MOCA exists.

The assessment of alternatives is highly relevant in the context of authorisation, whereas substitution would likely not be the measure to be taken in order to meet an OEL at a level of 5 µg/m^3 which is the lowest in any MS in the EU today. As aforementioned, most companies are unlikely to have significant difficulties in complying such a level with the current RMMs and a shift to alternatives would not be a cost-efficient option.

As mentioned in the section on market analysis, the LFTDI & TDI systems with MOCA account for 17% of the market today and many companies have already replaced MOCA for some of the production or for the entire production.

Examples of costs estimates for companies which have already replaced MOCA are provided in Corden and Tyrer (2017) but in the published report the actual costs have, for confidentiality reasons, been withheld.

In order to illustrate the possible costs, the experience of a small company with approximately 25 employees in Northern Europe manufacturing polyurethane elastomers, contacted as part of the stakeholder consultation for this study, are briefly described. Until recently MOCA-based elastomers represented 70% of the production volume. During the last years the company has substituted MOCA in all its production in order to phase out MOCA before the sunset date of 22 November 2017. Many of the company's products are used in the aviation and offshore sectors where the products need to meet strict specifications. For these applications, the challenge has been to obtain the right hardness and that the material was more difficult to machine by the customers in particular. The replacement has been done in close cooperation with the customers. The costs of substituting MOCA can be summarised as:

- Investment in new ovens and machinery: ~ €550,000
- R&D (Research & Development): ~ 1 man-year in the company; ~ 1-2 man-years by the customers
- The price of the new hardener systems is 4 times the price of MOCA
- The price of the final elastomer products is approximately +20% compared to products based on MOCA
- The energy consumption has increased due to higher processing temperatures

In comparison to this, the company 10-15 years ago invested in a system for automatic feeding of MOCA, where the packaging with MOCA is opened and emptied in a closed, ventilated glove-box and automatically sucked into the oven which minimises the potentially exposure of the workers (described under best practice). The company has two of such boxes at a cost (2017 value) of €15,000-20,000 each.

The application for authorisation summarises possible alternatives as follows:

- A like-for-like substitution of MOCA within a TDI system; those most commonly cited by moulders in the questionnaire were shortlisted as the preferred TDI based alternatives. These were dimethyl thiotoluene diamine (DMTDA) (80%); M-CDEA (48%) and; 3,5-Diamino-4-chlorobenzoacid isobutyl ester (26%).
- The use of another system entirely, e.g. an MDI based system which does not use MOCA. 85% of respondents stated that they had tested, or currently use, an MDI system.

The application assesses the pros and cons for a number of alternatives. The detailed cost-benefit analysis is confidential, but the assessment mention that according to the moulders, relocation costs would be from €250,000 to €3 million per company. Furthermore the alternatives are more expensive and would imply at least a 15% increase in the cost of the final product. These estimates are quite well in accordance with the example above.

Responses to the application from three providers of alternatives, BASF Polyurethanes GmbH, Chemtura, and Albemarle, however, questions the comparison.

Corden and Tyrer (2017) in a report for Chemtura, a manufacturer of alternative systems, provide a detailed description of the substitution process and substitution costs of a number of companies that have changed to Chemtura's alternatives (detailed costs estimate is confidential).

According to the report, there are two main existing MOCA-based systems, one based on TDI prepolymer and another based on LFTDI prepolymer. The cost implications of switching to the alterative system differ between the two. For the technical details please consult the report and the description in the applications for authorisation.

According to the report some of the alternatives (LFMDI prepolymer/HQEE) can be used without a need to change equipment. Some other alternatives (e.g. MDI prepolymer/BDO) require changes to processing equipment, such as the use of a new pump in meter-mix machines. Concerning raw material costs, the alternatives are more expensive than TDI prepolymer/MOCA. Prices range from about two times the costs of MOCA for DMTDA and HQEE up to 11 times the price of MOCA for other listed curatives. However, the full assessment of costs (R&D, capital investments, and higher raw materials prices) and benefit (savings with regard to monitoring costs, PPE and LEV savings, etc.) is as previously mentioned not included in the report.

Corden and Tyrer (2017) report that consultation with three companies who have successfully switched to LFMDI prepolymer/HQEE, indicates that the costs incurred by those who have undertaken the transition has not affected the final product price.

3.13 Current and future burden of disease

No published data on the current burden of disease have been identified.

3.13.1 Input data for calculation of disease burden

Parameters for calculation of current, past and future burden of disease are shown in Table 3-16.

Table 3-16: Input data for calculation of cases at baseline and target OEL at current, future and past exposures

Parameter	Unit	Value		
Exposure				
Exposure concentrations in the workplace	µg/m³		Average	Boundaries
		Band 1	0.5	0 - 1
		Band 2	1.25	1 – 1.5
		Band 3	3.25	1.5 – 5
		Band 4	10	5 – 15
Exposure concentrations, urinary concentration	µmol/mol creatinine	2		
Target OELV	µg/m³	5 ; 10; 20		
Target % compliance with OELV	%	100		
MS OELs	µg/m³	See Table 3-1		
Exposure concentration trend - future	% p.a.	-1%		
Exposure concentration trend - past	% p.a.	-4%		
Exposed workforce				
Total exposed workforce	No.	350		
Distribution of workers per concentration band	No.	Band 1	308	
		Band 2	21	

Table 3-16: Input data for calculation of cases at baseline and target OEL at current, future and past exposures			
Parameter	**Unit**	**Value**	
		Band 3	18
		Band 4	4
Workforce trend - future	% p.a.	0	
Workforce trend - past	% p.a.	-3	
Health endpoints			
ERR	/µg/m³ /µmol/mol creatinine	9.65×10^{-6} 3.28×10^{-6}	
Effect threshold	µg/m³	0	
Latency period	a	20	
Mortality rate	%	80	
Time periods			
Period for baseline cases	a	50	
Future period	a	60	
Past period	a	50	

Exposure concentrations are derived from the only comprehensive dataset available, which is data obtained in the UK in 2005/2006 as described in section 3.5.4. The highest levels were found for workers undertaking manual processes which are supported by modelling results from the application for authorisation. The dataset is 12 years old and most of the companies at that time used manual processes. According to the application for authorisation, most companies use the automatic process today. On the other hand, most MS have higher OELs than applied in the UK and the companies in those MS would be less forced to reduce the exposure levels as compared to companies in the UK. New data from Australia shows levels 10 times lower than reported in the UK 2005/2006 survey. As workers use respiratory protection equipment (RPE) for the work processes with highest workplace air concentrations, the measured concentration represents a "worst case". The data have not been modified to reflect the use of RPE.

On this basis, it is deemed that extrapolation of the UK 2005/2006 survey to the supply chain of the applicant would probably not underestimate the current exposure concentration. The data from personal sampling and static sampling in the UK survey were not significantly different and the pooled dataset has been applied. All samples below the LOQ of < 1 µg/m^3 is by the estimates set at half the LOQ i.e. at 0.5 µg/m^3. The highest measured or modelled concentration of 15 µg/m^3 is set as the upper limit.

For the alternative estimations of the number of cases based on biological values, a mean value of a 2 µmol/mol creatinine (see section 3.5.2) is used.

The trend in exposure concentration in the past is set at -4% p.a. for a past period of time of 40 years (corresponding to an exposure level in 1988 at three times today's level). According to the experience from the UK the average urinary MOCA concentration decreased during the 1980's and the beginning of the 1990's and then levelled off. As the main exposure route is the dermal route, the trend in urinary MOCA levels, however, cannot be used directly as an indication for the trend in workplace air concentrations. According to information obtained from the stakeholder consultation, it is more common today to use RPE than it was 20 years ago (but the estimates do not take use RPE into account), and furthermore, the automatic processes with lower workplace concentrations account for a major part today compared to 20 years ago.

The exposed workforce in the EU is estimated at 350 directly exposed by inhalation at the levels used for the calculations as described in section 3.4. In addition, workers potentially indirectly exposed by the dermal route is estimated at 1,200. These are not included in the estimate. The distribution between the different exposure bands are based on data from the same UK survey as the exposure concentrations. The workforce trend in the past is set at -3% p.a. reflecting the general trend in the use of MOCA in the industry. No trend in workforce is assumed for the future.

No data are available on the distribution of the workers by MS. According to the survey undertaken for the application for authorisation, moulders within the supply chain of the applicant are located in Belgium, Denmark, France, Italy, Ireland, Greece, Hungary, Portugal, Spain, the Netherlands, and the United Kingdom. Overall, the distribution between MS is of minor importance for the assessment and the workforce has in the absence of specific data been distributed between these MS on a population basis.

The Exposure Risk Relationship (ERR) for cancer from occupational exposure to MOCA is 9.65 x 10^{-6} per µg/m^3 for air concentration and 3.28 x 10-6 per µmol/mol creatinine for the biological concentrations as described in section 2.4.5.

3.13.2 Current burden of disease

The current burden of disease has been estimated using the data in the preceding sections. As shown, the number of cases are about 0.001 per year using both methods of calculation.

Table 3-17: Current burden of disease due to past exposure

Endpoint	Number of cases in 2017 based on past exposure
Cancer (based on workplace concentration)	0.0005
Cancer (based on urinary concentration)	0.0005

The estimates presented above only relate to the sectors where exposure to MOCA currently occurs and do not represent the total burden of possible past occupational exposure to MOCA. The total burden from all past occupational exposure to MOCA would require consideration of sectors where occupational exposure no longer takes place and which are not relevant to the problem definition for this Impact Assessment.

These figures are far below the previous estimates by IOM (2011) who based on biological monitoring data estimated that in 2010 there would be about 3 deaths (eight registrations) from bladder cancer that might be attributable to past exposure to MOCA.

The estimates made by IOM (2011) were based on the following assumptions:

- Exposed workforce: 2,500; of these 1,400 in high exposure industries (compared to a high exposure workforce of 350 in the current assessment)
- Average exposure: 2.3 µmol/mol creatinine (for all exposed)
- Trend in MOCA exposure: - 7.9%
- Trend in exposed workforce: 0

The approach used by IOM was, as discussed in section 2.4.2, based on human data and thus different from the approach used in this study. The results are not readily comparable.

3.13.3 Future burden of disease

The number of cases cancer expected to occur in the future is given below for a workforce of 350. These estimates are based on the assumption that the number of workers exposed to MOCA and the associated exposure concentrations will remain unchanged.

Table 3-18: Baseline burden of disease – constant workforce				
Endpoint	Number of cases over 40 years	Number of cases over 60 years	Monetary value PV 60 years	
			Static discount rate	Declining discount rate
Lung cancer	0.0021	0.0036	3,000 EUR	3,000 EUR

3.13.4 Summary and conclusion on the baseline scenario

A summary of the baseline scenario results is shown in Table 3-19.

The model calculations show that a very low number (<< 1 over 60 years) of cancer cases can be expected at current exposure levels. Exposure is not expected to change in the future. The monetary values caused by current and future cancer cases are regarded as negligible, around 3,000 EUR over the 60 year period.

The baseline scenario therefore demonstrates that occupational exposure to MOCA if authorisation is granted is well controlled and exposure concentrations does not give rise to primary concern.

Table 3-19: MOCA - Summary of the baseline burden of disease	
Carcinogen	4,4'-Methylene-bis(2-chloroaniline) MOCA
Classification	Carc. 1B
Key sectors used	Plastics sector, polyurethane elastomer production
Types of health effect caused	Lung cancer, bladder cancer
No. of exp. workers	350
Change in exposure levels	Past - 4% Future -1%
Change number of exposed workers	Past - 3% Future 0%
Period for estimation	50 years
Current disease burden (CDB) no. of cancer cases in 2017 based on previous 50 years exposure	0.0005
Future disease burden (FDB) no. of cancer cases	0.0021 (40 years) 0.0036 (60 years)
Current disease burden (CDB) - no. of other adverse health effect cases in	No effects assessed

Table 3-19: MOCA - Summary of the baseline burden of disease	
2017 based on previous 50 years exposure	
Future disease burden (FDB) - no. of other adverse health effect cases, over 60 years	No effects assessed
Exp. no. of deaths (FDB) cancer, 60 years	0.0017 (40 years) 0.0019 (60 years)
Exp. no. of deaths (FDB) from other adverse health effects, 60 years	No effects assessed
Monetary value FDB cancer, 60 years, static discount rate*	€3000
Monetary value FDB, other adverse health effects, 60 years, static discount rate	No effects assessed
CDB - Current disease burden; FDB - Future Disease Burden * Method 1 - See section 4.2.	

4 Benefits of the measures under consideration

4.1 Introduction

This section comprises the following subsections:

- Section 4.2: Summary of the assessment framework
- Section 4.3: Avoided cases of ill health
- Section 4.4: Benefits to workers & families
- Section 4.5: Benefits to employers
- Section 4.6: Benefits to the public sector
- Section 4.7: Aggregated benefits & sensitivity analysis

4.2 Summary of the assessment framework

4.2.1 Summary of the key features of the model

The benefits of the potential measures to reduce worker exposure equal the costs of avoided cases of ill health. The model developed to estimate these costs relative to the baseline takes into account the cost categories set out in the table below.

Table 4-1: The benefits framework

Category	Cost	Notes
Direct	Healthcare	Cost of medical treatment, including hospitalisation, surgery, consultations, radiation therapy, chemotherapy/immunotherapy, etc.
	Informal care[13]	Opportunity cost of unpaid care (i.e. the monetary value of the working and/or leisure time that relatives or friends provide to those with cancer)
	Cost for employers (e.g. liability insurance)	Cost to employers due to insurance payments and absence from work
Indirect	Mortality – productivity loss	The economic loss to society due to premature death
	Morbidity – lost working days	Loss of earnings and output due to absence from work due to illness or treatment
Intangible	Approach 1 WTP[14]: Mortality	A monetary value of the impact on quality of life of affected workers
	Approach 1 WTP: Morbidity	
	Approach 2 DALY: Mortality	
	Approach 2 DALY: Morbidity	

[13] A decision has been taken to include informal care costs in this analysis even though some elements of these costs may also have been included in individuals' willingness to pay values to avoid a future case of ill health. This decision may result in an overestimate of the benefits as generated by this study.

[14] WTP: Willingness to pay; DALY: Disability adjusted life years

The total avoided cost of ill health is calculated using the following two methods:

Method 1: Ctotal= Ch+Ci+Cp+Cvsl+Cvsm

Method 2: Ctotal= Ch+Ci+Cp+Cl+Cdaly

The abbreviations are explained below.

Table 4-2: Overview of cost categories

Category	Code	Cost
Direct	*Ch*	Healthcare
	Ci	Informal care
	Ce	Total cost to an employer
Indirect	*Cp*	Productivity loss due to mortality
	Cl	Lost earnings due to morbidity
Intangible	*Cvsl*	Value of statistical life
	Cvsm	Value of cancer morbidity/value of statistical morbidity
	Cdaly	Value of DALYs

Ce is not considered in the totals under both Method 1 and 2 to avoid double-counting. *Cl* is not considered under Method 1 since *Cvsl* may already include these costs.

The outputs of the model include:

- The number of new cases for each health endpoint assigned to a specific year in the 60 year assessment period;
- The Present Value (PV) of the direct, indirect, and intangible costs of each case.

Two key scenarios are modelled for the exposed workforce. These are:

- **ExW-Constant:** Workforce remains unchanged over 40 years (the same individuals, no replacement of workers afflicted by ill health), the whole workforce is replaced in year 41 with these individuals remaining in the exposed workforce over the next 40 years. This scenario does not take into account either the natural turnover of workers changing jobs or the turnover due to the ill health caused by exposure to the relevant chemical agents.
- **ExW-Turnover**: This assumes that there is a turnover of 5% per year (although this is lower than the turnover ratios in the published literature and Eurostat which are typically derived at the level of individual companies rather than sectors, a ratio of 5% is deemed appropriate to account for the fact that some workers may continue to work in the same sector and continue to be exposed). This means that the whole workforce is replaced every 20 years and no worker is exposed for the full 40 year period (this is modelled here as a group of workers being exposed for a 20 year period, followed by another group of workers exposed over the subsequent 20 years). This increases the number of cases for non-cancer endpoints. The turnover caused by treatment or early retirement due to the conditions considered in this report has not been modelled.

A detailed overview of the key features of the model for the estimation of the benefits and the assumptions underpinning it are set out in the methodology report.

4.2.2 Relevant health endpoints for MOCA

For MOCA compounds, the benefits (i.e. changes in the costs caused by ill health) have been quantified for one health endpoint: lung cancer.

4.2.3 Summary of the key assumptions for MOCA

Onset of the disease

The time of diagnosis of the cases calculated over an average working life is determined taking into account the minimum and maximum time required to develop the condition (MinEx and MaxEx) and the distribution of new cases between these two points in time, combined with the latency period with which the effects are diagnosed.

The MinEx and MaxEx for lung cancer are summarised below.

Table 4-3: Minimum & maximum exposure duration to develop a condition (MinEx & MaxEx)

Endpoint	MinEx (years)	MaxEx (years)
Lung cancer	2	40

Notes:
MinEx *The minimum exposure duration required to develop the endpoint*
MaxEx *The time required for all workers at risk to develop the endpoint*

For lung cancer, it is assumed that no risk (i.e. not incidence but risk since incidence is delayed due to latency) arises until MinEx has expired. Subsequently, it is assumed that the distribution of risk is linear, i.e. 0% of the excess risk arises in year 2 and 100% of the excess risk arises by year 40.

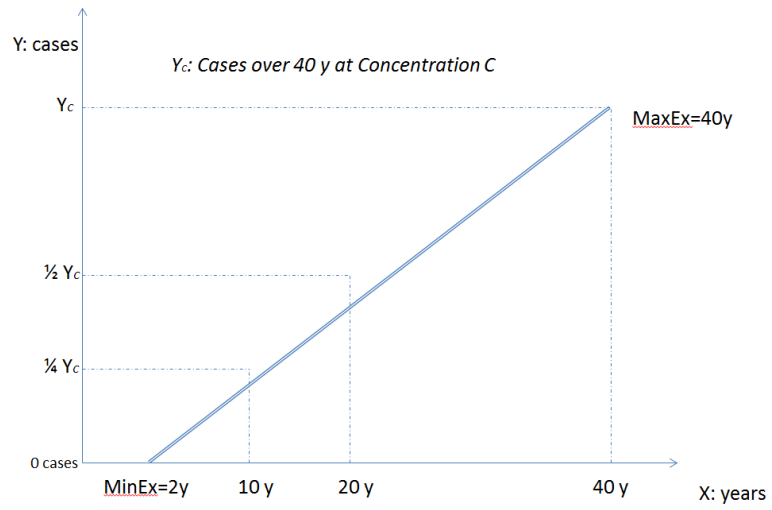


Figure 4.1: Lung cancer risk – distribution over time

For lung cancer, a latency period of 10 years is used in this study. Although longer latency periods are often estimated for lung cancer, a short latency period is used to be protective to workers and ensure

that relevant cancer cases are assessed within the 60 year assessment period for this study. However, with the method still some cancer cases will arise after the 60 years assessment period.

The effects of the disease

The key assumptions used for the modelling of the benefits from reduced exposure to MOCA are summarised below. For a detailed explanation of the model and the assumptions, please refer to the methodology report.

The key inputs and assumptions include:

- Treatment periods;
- fatality rates;
- treatment cost;
- values for the Willingness to Pay (WTP) to avoid cases of fatal and non-fatal cancer and elevated protein urea; and
- disability weights for the relevant endpoints.

Treatment period

The treatment periods used in the model are given below. The end of the treatment period signifies either a fatal or illness-free outcome.

Table 4-4: Treatment period	
Endpoint	**Treatment period (years)**
Cancer	5

Mortality rate

The mortality rates used in the model are given below.

Table 4-5: Fatality rates (MoR)	
Endpoint	**MoR (years)**
Cancer - lung	80%

Willingness to Pay (WTP) values

The WTP values for a case of fatal and non-fatal cancer are €4,100,000 and €420,000; this is in line with the approach taken across all the reports produced under this contract, see the methodology report for details.

Disability weights

The disability weights used are summarised below.

Table 4-6: Disability weights collated in European Burden of Disease study (2015)		
Type of cancer	**Stage of disease**	**Disability Weight**
Lung cancer	Disseminated	0.515

Summary

Table 4-7: Unit costs		
Category	**Cost**	**Lung cancer**
Direct	Healthcare	€7,000/year
	Informal care	€3,000/year
	Cost for employers	€12,000/case
Indirect	Mortality – productivity loss	€5,000/year
	Morbidity – lost working days	€1,000/year
Intangible	Approach 1 WTP: Mortality	€4,100,000/case
	Approach 1 WTP: Morbidity	€420,000/case
	Approach 2 DALY: Morbidity	Value of a DALY: €100,000
* Estimated as proportional to healthcare costs: 3/7 ratio based on cancer healthcare and informal care costs. ** Estimated as proportional to healthcare costs: 1/7 ratio based on the costs of cancer healthcare and lost working days.		

4.3 Avoided cases of ill health (cancer and non-cancer)

This subtask will involve the following steps:

- Distribution of workers across exposure concentrations (can be taken from the baseline)
- Estimation of avoided cases of ill health at different OELV levels (as well as for STEL and skin notation)

Establishing an OELV

The outputs of the cancer case calculations are shown in for three different reference OELVs: 5, 10 and 20 µg/m³. The basis for the calculations is the model based on workplace concentrations. As described in section 3.13.2, calculations based on biomonitoring data comes to similar results.

The results show that the number of cases would not significantly be affected by establishing an OEL at 5, 10, or 20 µg/m³ because only a few workers are exposed at these levels.

Table 4-8: Cases of lung cancer for each reference OELV		
Reference OELV (inhalable fraction)	**Lung cancer**	
	40 years	**60 years**
Baseline	0.0021	0.0036
5 µg/m³	0.0020	0.0034
10 µg/m³	0.0021	0.0036
20 µg/m³	0.0021	0.0036

For the calculations based on the urinary exposure concentrations, the figures are nearly identical with the estimates based on workplace concentrations above; the differences being within the uncertainties on the estimates.

Establishing a skin notation

As indicated in the Commission's impact assessment, "*The main positive effect of establishing a skin notation is that employers should thereby be alerted that a considerable part of the 'body burden' is the result of the uptake via the skin, and that biological monitoring would, if possible, be a valuable additional tool to ensure that adequate risk management measures are in place.*" (COM, 2017) Furthermore, MOCA is supplied in the EU bearing hazard warnings relating to dermal exposure and as a result of these hazard classifications employers should already be taking steps to manage risks to workers by avoiding dermal exposure.

The applicant for authorisation indicates in a response to the stakeholder consultation: "*In relation to glove use, all respondents to our surveys indicated that they used gloves either for all operations involving MOCA or for specific WCSs where the likelihood of MOCA contact was high (this is especially true for machine moulders whose systems are closed).*"

As indicated under "Best practice" in section 3.8, use of gloves does not necessarily provide the optimal protection if the workers are not aware of how to use them correctly and avoid contamination of the hands when they are removed, and avoid contamination of surfaces which consequently contaminate other workers. For this reason, biomonitoring and measurements of skin and surface contamination are tools which can be used to monitor if gloves and other PPE are used correctly and by all workers who may be dermally exposed to the MOCA.

A skin notation may have some impact on the burden of disease by increasing the focus on the dermal route, but this has not been possible to quantify in terms of reduced number of cancer cases.

4.4 Benefits to workers & families

The benefits (avoided costs of ill health) for workers and their families are calculated using the two methods summarised below. These equal the cost of ill health under the baseline scenario, less the cost of ill health following the introduction of an OELV.

Table 4-9: Benefits for workers and their families (avoided cost of ill health)		
Stakeholder group	**Costs**	**Method of summation**
Workers/family	Ci, Cl, Cvsl, Cvcm, Cdaly	Method 1: *CtotalWorker&Family=Ci+Cvsl+Cvcm* Method 2: *CtotalWorker&Family=Ci+Cl+Cdaly*

The benefits of each reference OELV are summarised in the tables below.

Table 4-10: Benefits to WORKERS & FAMILIES (reference OELVs vs baseline), lung cancer, constant workforce			
Reference point (inhalable)	***5 µg/m³***	***10 µg/m³***	***20 µg/m³***
Method 1	€140	0	0
Method 2	€130	0	0
Method 1 relies on WTP values for morbidity; Method 2 relies on monetised DALYs.			

It is only for the OELV of 5 µg/m³ that there will be a benefit. Given the very limited effects, this benefit is estimated between €130 and €140 over a 60 year period. The figure of €140 will be used further in the cost benefit assessment.

4.5 Benefits to the public sector

The benefits (avoided costs of ill health) for the public sector are calculated using the method summarised below.

Table 4-11: Benefits to the PUBLIC SECTOR (avoided cost of ill health)		
Stakeholder group	**Costs**	**Method of summation**
Governments	Ch, part of Cp (loss of tax revenue), part of Cl (loss of tax revenue)	*CtotalGov=Ch+0.2(Cp+Cl)*[15]

The benefits of each reference OELV are summarised below.

Table 4-12: Benefits to PUBLIC SECTOR (reference OELVs vs baseline), lung cancer, constant workforce			
Reference point (inhalable)	***5 µg/m³***	***10 µg/m³***	***20 µg/m³***
Governments	€2	0	0

4.6 Benefits to employers

The benefits (avoided costs of ill health) accrued by employers are calculated using the method summarised below.

Table 4-13: Benefits to EMPLOYERS (avoided cost of ill health)		
Stakeholder group	**Costs**	**Method of summation**
Employers	Ce, Cp	*CtotalEmployer=Ce+0.8*Cp*

The benefits of each reference OELV are summarised below.

Table 4-14: Benefits to EMPLOYERS (reference OELVs vs baseline), lung cancer, constant workforce			
Reference point (inhalable)	***5 µg/m³***	***10 µg/m³***	***20 µg/m³***
Employers	€1	0	0

[15] Assumes 20% tax.

4.7 Aggregated benefits & sensitivity analysis

4.7.1 Aggregated benefits

Based on the estimations of benefit presented in the previous sectors, it is estimated that the aggregated benefits of establishing the OELVs at the three assessed levels will be negligible. Only for the OELV of 5 µg/m³, there is a very small benefit in the order of €133-143 EUR over a 60 year period. The figure of €143 will be used further in the cost benefit assessment.

Table 4-15: Total benefits over 60 years of avoided ill health (baseline and reference OELVs), lung cancer, constant workforce

Reference point (inhalable)	*5 µg/m³*	*10 µg/m³*	*20 µg/m³*
Method 1	143	0	0
Method 2	133	0	0
Method 1 relies on WTP values for morbidity; Method 2 relies on monetised DALYs.			

4.7.2 Sensitivity analysis

Exposure levels

The conclusions are drawn on the basis that the current levels of exposure are typically below the lowest of the OELs assessed and consequently the estimates are not very sensitive to the number of exposed workers, or to the relationship between exposure and effects (EER) and to the costs of cancer cases. The uncertainty is consequently mainly related to the estimated exposure levels.

As RAC suggests a number of best practice measures should be required in case an authorisation is granted, it is deemed to be very certain that the exposure levels would in the future be below 5 µg/m³, which is the lowest of the assessed OELVs.

Toxicological parameters

The benefits of establishing an OELV for MOCA only slightly depend on the toxicological parameters (ERR), as derived in Section 2.4 of this report. However, those parameters include some uncertainties, because of the completeness of endpoints, and because of the selected slope of the ERR (effects and severity in higher doses compared to lower doses).

The assessment does not include other types of cancer than lung cancer (e.g. bladder cancer) and does not take oral and dermal exposure into account. It will consequently underestimate the actual number of cases. Furthermore, cancer cases due to exposure during the 60 years assessment period that will arise after the assessment period is not taken into account which would result in an underestimation of the long-term benefits of avoided cases.

The risk analysis for lung cancer is based on the key studies reported in Section 2.3.3. However, classification of MOCA is based on animal data and uncertainties of interspecies extrapolation have to be acknowledged. Actually, the slope of the ERR is rather uncertain, because RAC (2017) indicated that exposure given as air concentration and MOCA excretion in urine are poorly correlated.

For aromatic amines, other risk assessments assume that other cancer sites (i.e., bladder cancer) are more relevant than lung cancer. An assessment by IOM has not been adopted here, as this was linked to (uncertain) human data. Based on the results of a study on workers (Dost et al., 2009), IOM (2011) used a risk estimate of 3.28 (95 % CI 0.40-11.81) for the incidence of bladder cancer for "high" exposure to MOCA. The risk estimate for the "low" exposure was set to 1 by IOM. It must be noted that the observed SRR was not significantly increased and that there were no exposure data in the baseline study of Dost et al. (2009). Furthermore, setting the risk estimate to one for the "low" exposure is equivalent to assuming a threshold for the carcinogenic effect of MOCA, a genotoxic carcinogen. Thus, quantitative data from other studies provide a higher or lower relative risk (standard risk ratio) and cancer site compared to lung cancer. Therefore no conclusions in the shift of the slope for the ERR (all cancer sites vs. most significant cancer site) can be provided in this sensitivity analysis. Moreover, there exists no adequate methodology to discriminate the occurrence of multiple cancers in identical persons or the additive occurrence of cancers in different persons (hence, additional ´cancer cases, if more cancer sites are considered). Therefore a quantitative sensitivity analysis is not feasible, but it may be concluded that the reference to only lung cancers tends to underestimate total number of cancer cases to be expected after occupational exposure to MOCA.

Very few data are available regarding non-carcinogenic toxic effects of MOCA. Single case studies report “mild burning sensation” after accidental occupational aerosol exposure. In occupationally exposed humans, haematuria has been described with no further details, but otherwise, even after long-term occupational exposure, no non-neoplastic chronic effects. In the carcinogenicity study with dogs, increased activities of transaminases in serum were noted during the first and last two years of treatment (Section 2.3.4) for reference on non-cancer effects). Non-cancer endpoints have not been selected for this assessment, because the studies often do not provide a dose response relationship validated for the occupational exposure scenario and because those studies are not equally analysed for reliability. Consequently, a quantitative sensitivity analysis is not feasible, but it may be concluded that the reference to only cancer effects tends to underestimate total number of cases of disease to be expected after occupational exposure to MOCA.

5 Costs of the measures under consideration

5.1 Introduction

This section comprises the following subsections:

- Section 5.2: The cost framework
- Section 5.3: OELVs – compliance and administrative costs for companies
- Section 5.4: OELVs – indirect costs for companies
- Section 5.5: STELs or skin notation - compliance and administrative costs for companies
- Section 5.6: STELs or skin notation - indirect costs for companies
- Section 5.7: OELVs, STELs, skin notation – costs for public authorities
- Section 5.8: Aggregated costs & sensitivity analysis

5.2 The cost framework

5.2.1 Summary of the cost assessment framework

The first step in estimating the economic impacts of introducing a new OELV for MOCA was the development of a cost framework describing the different cost components (direct, indirect and intangible; one-off versus recurring) and the determination of the assessment period.

In line with the more general impact assessment requirements of BR Tool #19, this first involved determining which of the potentially relevant impacts are expected to be significant and should thus be subject to a detailed cost assessment.

Taking into account the direct and indirect behavioural changes as well as potential ultimate impacts, the most relevant impacts were selected on the basis of the following factors:

- The relevance of the impact within the intervention logic;
- The absolute magnitude of the expected impacts;
- The relative size of expected impacts for specific stakeholders (such as impacts which may be small in absolute terms but may be particularly significant to specific types of companies, regions, sectors, etc.); and
- The importance of the impacts for Commission horizontal objectives and policies.

The table below summarises the impact categories that could be significant and that are thus assessed in this report, together with the relevant questions considered in this section (costs for companies and public authorities) and the next section (impacts on competitiveness etc.).

Table 5-1: Assessment of the most significant economic impact categories	
Impact category	**Key impacts**
Operating costs and conduct of business	• Will it impose additional adjustment, compliance or transaction costs on businesses? • Does it impact on the investment cycle? • Will it entail the withdrawal of certain products from the market? • Will it lead to new or the closing down of businesses? • Are some products or businesses treated differently from others in a comparable situation?
Administrative burdens on businesses	• Does it affect the nature of information obligations placed on businesses?
Trade and investment flows	• How will the option affect exports and imports out of and into the EU? Will imported products be treated differently to domestic goods? • How will investment flows be affected and the trade in services? • Will the option affect regulatory convergence with third countries? Have international standards and common regulatory approaches been considered?
Public authorities	• Does the option have budgetary consequences for public authorities at different levels of government (EU own resources, national, regional, local), both immediately and in the long run? • Does it bring additional governmental administrative burden? • Does the option require the creation of new or restructuring of existing public authorities?
Consumers and households	• Does the option affect the prices consumers pay for goods and services? • Does it have an impact on the quality or safety of the goods/services consumers receive? • Does it affect consumer choice, trust or protection? • Does it have an impact on the availability or sustainability of consumer goods and services?
Specific regions or sectors	• Does the option have significant effects on certain sectors? • Will it have a specific impact on certain regions, for instance in terms of jobs created or lost? • Is there a single Member State, region or sector which is disproportionately affected (so-called “outlier” impact)?
Source: BR Tool #19	

The costs assessed in this section, together with an indication of which stakeholders are likely to be affected, are presented below.

Table 5-2: Cost impacts on different stakeholders						
Type of cost		Citizens	Consumers	Workers	Enterprises	Public authorities
Direct	Compliance costs				✓	✓
Indirect	Product choice/price					
Enforcement	Measurements & inspections				✓	✓
Notes: *Considered in Section 6 Market effects.						

These costs are assessed below qualitatively and considering the small impacts only quantitatively for the most significant impacts.

5.3 OELVs – compliance and administrative costs for companies relative to the baseline

5.3.1 Current level of actual exposure in the companies

The current level of actual exposures in the companies is shown below. In total the number of exposed workers is estimated at 350 in 89 companies with a total of approximately 1,526 employees. All moulders in the supply chain of the applicant are surveyed as micro- (< 10 employee; 20%), small (10-50 employee; 65%) or medium (50-250 employee; 15%) sized enterprises in the application for authorisation.

No data demonstrating any differences in exposure concentrations depending on the size of the companies have been identified.

Table 5-3: Distribution of workers by exposure concentration					
	< 1 µg/m³	1-1.5 µg/m³	1.5-5 µg/m³	5-10 µg/m³	10-15 µg/m³
Percentage	88%	6%	5%	0%	1%
Number of workers at EU level	308	20	19	0	3

5.3.2 Marginal abatement cost curves

As RAC suggests a number of best practice measures should be required in case the authorisation is granted, it is estimated to be very certain that the exposure levels in the future would be below 5 µg/m³, which is the lowest of the assessed OELVs. Establishing the OEL is consequently considered not to have any impacts on the companies apart from the measurement costs discussed in section 5.3.4.

A marginal abatement cost curve has consequently not been established.

5.3.3 Sector/use-specific cost curves

Sector/use-specific cost curves have not been established.

5.3.4 Measurement costs

Potentially, the most significant costs for the companies would be the costs of monitoring of exposure concentrations to demonstrate compliance with the OELV.

As discussed in section 3.8, RAC has recommended, in case authorisation is granted, that twice yearly biomonitoring programmes must be in place, accompanied by testing for possible surface contamination and to some extent complemented with air monitoring. To what extent biomonitoring and monitoring of workplace concentrations will be required is not known but based on conditions for other substances subject to authorisation, it is likely that biomonitoring will be required. As an example, the Commission Implementing Decision granting an authorisation for some uses of lead sulfochromate yellow and of lead chromate molybdate sulphate red, requires that the authorisation holder's downstream users, when requested to do so, provide the competent authorities of the Member States data from regular air monitoring of chromium, obtained in accordance with Article 6(4) of Directive 98/24/EC (EC, 2016).

To what extent the costs of monitoring of workplace concentrations should be allocated to the impacts of the authorisation requirements or establishing an OELV is not clear. As the dermal route is the major route of exposure, it seems to be more common practice that biomonitoring is used for regular monitoring of exposure and measurements of workplace concentrations are done only once or on an irregular basis. One explanation for this may, however, be that the OELs in many MS have been far above the actual levels and consequently regular monitoring of workplace concentrations has not been required.

An example of a typical monitoring programme is shown in the table below. It is assumed that the campaign consists of a total of 10 samples. The planning and sampling is done in accordance with national guidelines making reference to the European standards EN 482:2012+A1:2015 and DS/EN 689. The number of samples is derived from a survey of occupational exposure to MOCA in the UK, where 4 personal samples and 6 stationary samples were taken in each company on average. The costs are based on the salary of an EHS consultant undertaking planning and sampling and the costs of analyses of MOCA in Denmark (but analysed in a laboratory outside Denmark). The costs for Denmark are estimated at €11,900; of these 47% are the costs of analysis.

For other countries, the salary costs would be different, whereas the costs of analysis is assumed to be the same as these are standard analyses usually done by international laboratories.

The total number of companies in the supply chain are estimated to be 89. For this analysis it is assumed that roughly 23% are placed in the UK and Ireland (with an existing OEL of 5 µg/m^3) which will not be impacted of an OELV at 5 µg/m^3 or higher. It will be assumed that the remaining companies will be required to undertake one monitoring programme to demonstrate compliance. The costs will depend on the salary rates of the EHS consultant and in MS with lower salary rates, the costs of analysis will make up the majority of the costs. The costs have been calculated for Denmark, the UK, Lithuania, Poland and Slovenia (general model for all substances assessed in this project). The number of companies in the supply chain have been allocated between the different countries with Denmark being used as an indicator of costs for companies in Denmark, Belgium and the Netherlands, whereas Slovenia (€7,630) has been used as an indicator for Greece, Hungary, Portugal and Spain. The total costs are on this basis estimated at €701,000.

Table 5-4: Costs of a monitoring campaign for MOCA - example with 8 samples, Danish wages			
Activity	**Units**	**Unit costs, EUR**	**Total costs, EUR**
Number of samples	10		
Planning, man-hours	6	120	720
Execution, man-hours	34	120	4,080
Reporting, man-hours	7.5	120	900
Rent of equipment, first day	5	80	400
Rent of equipment, subsequent days	5	40	200
Analysis *	10	560	5,600
Total costs			11,900
* Price provided by International laboratory, the LOQ is 0.53* with a total sample air volume of 240 L sampled over a period of 5h. Filter cartridge with two glass fibre filters treated with H_2SO_4.			

5.3.5 The total cost curve

Total cost curve has not been established as the direct cost of complying with the OELVs are considered insignificant.

5.3.6 Sum of all compliance costs

The sum of all compliance costs is estimated at €701,000.

5.4 OELVs, skin notation – indirect costs for companies

The indirect costs for companies are considered insignificant.

According to the applicant for authorisation, gloves are already used by all downstream users. Furthermore, RAC has suggested the use of gloves to be a requirement in case the authorisation is granted. Consequently, no costs for purchase of gloves are expected from a skin notation.

5.5 OELVs, STELs, skin notation – costs for public authorities

The impacts on public authorities, mainly at the national level but in some Member States also at the regional level, are expected to relate to:

- The cost of adapting national legislation and procedures to the new OELV (where the Member State is above the OELV); and
- The enforcement of the new OEL.

It is not expected that there will be a significant cost to national authorities in the Member States which already have an OEL for MOCA.[16] Member States where this is not the case may incur a one-off cost for changing their legislation and a recurring cost of increased enforcement. Thus, although the specific OELV level will determine whether a Member State needs to revise legislation, the transposition and implementation costs are unlikely to depend on the specific values so there will only be a

[16] Some Member States may carry out Impact Assessments on the transposition of EU legislation but this cost is not considered here.

cost difference between the baseline scenario and scenarios where a new OEL is introduced in a Member State.

In addition, the cost of legislative change will only be incurred once, regardless of whether one or several chemical agents are covered, and whether an OELV or also a STEL and/or skin notation is introduced.

5.5.1 Cost of transposition

Should an OELV be implemented, EU Member States would incur costs arising from the need to transpose the relevant changes into national legislation. In practice, the exact costs would depend on the specific changes agreed in the final version of the Directive and the regulatory model used in each country to implement the Directive (i.e. the number of departments involved in transposition or implementing the Directive). These costs are therefore likely to vary significantly between Member States (for example, Sweden is obliged to carry out an impact assessment on new EU legislation; it is expected that this may not be the case in some Member States).

Of the 28 EU Member States, research carried out for this study has confirmed that 16 have an OEL for MOCA. There is no information with regard to a MOCA OEL for the following Member States and this study thus assumes that they do not have an OEL: Bulgaria, Cyprus, Czech Republic, Estonia, Germany, Hungary, Italy, Latvia, Lithuania, Luxembourg, and Malta. It is thus assumed that these twelve Member States would incur costs for transposing an OELV introduced under the CMD.

Specific data on the costs of transposition of EU legislation by Member States and their relevant departments/ministries are not readily available. As noted in RPA (2012)[17], one UK impact assessment states that *"the costs of amending current regulations to implement a Directive are thought to be around £700,000"* (around €900,000 in €2017). Although no details are given on the basis for this calculation, it is expected that these costs relate to a rather substantial legislative change and would include those costs of making (e.g. preparing an impact assessment, drafting a substantial bill and presenting the legislation before parliament), printing and publishing the legislation. This estimate is significantly higher than the cost estimated in UK Department for Transport (2011) which notes that *"a combination of legal and technical resources as well as policy advisors are usually required to implement such a change, costing approximately £15,687 per amendment"* (approximately €20,000 in €2017).

Considering that all Member States have transposed the CMD which already contains a number of OELVs, it appears more likely that the cost of transposing an additional OELV would be closer to the low-end estimate. However, it is also appears that there has been a general trend towards increased impact assessment in the Member States (see, for example, RPA 2015[18]), which suggests that the costs would likely be higher than €20,000. In the case of MOCA, which is used for one application only by a few companies in each Member State, and which use requires authorisation it is assumed that the costs of transposition is relatively low. Furthermore, MOCA is currently used only in two of the MS without an existing OEL: Hungary and Italy. This study thus takes €20,000 per Member State as an

[17] RPA (2012): Ex-Post Evaluation and Impact Assessment Study on Enhancing the Implementation of the Internal Market Legislation Relating to Motor Vehicles, http://www.rpaltd.co.uk/documents/J746_MotorVehicleLegislation_FinalReport_publ.pdf

[18] RPA (2015): Study on the potential of impact assessments to support environmental goals in the context of the European Semester, available at http://ec.europa.eu/environment/integration/green_semester/pdf/J856.pdf

approximation of the general order of magnitude of the applicable transposition costs but the costs may be significantly lower in some of the MS.

Table 5-5: Transposition costs		
Member States with no OEL	**Transposition cost per Member State**	**Total cost across the EU**
Member States: Bulgaria, Cyprus, Czech Republic, Estonia, Germany, Hungary, Italy, Latvia, Lithuania, Luxembourg, and Malta	€20,000	€240,000

It is assumed that for Member States that already have an OEL for MOCA, the change to a different value (in case the OEL were to be higher than the OELV) would entail no significant costs.

5.5.2 Enforcement costs

The enforcement costs depend on the number of companies that will be covered by the OELV. In principle, national authorities are supposed to inspect companies already as they have the general obligation to protect workers. However, there could be an additional cost due to the need to ensure compliance with the new rules. Such enforcement costs depend on the inspection regime in each country and they are not estimated in this study.

5.6 Aggregated costs & sensitivity analysis

5.6.1 Aggregated costs

The aggregated costs of establishing the OELV is estimated at €941,000 over the next 60 years. The costs will be the same for all three assessed reference values.

As the costs are expected to be incurred at the first year of implementation, the costs do not need to be discounted and the total costs correspond to an average of approximately €15,700 p.a. The average costs per company affected (excl. companies in the UK and Ireland) will on average be €169 p.a. These costs are not assessed to have any significant impacts on competitiveness of the companies.

Table 5-6: Sum of all costs for the reference OELVs (PV CAPEX and OPEX over 60 years)			
Cost	**5 µg/m³**	**10 µg/m³**	**20 µg/m³**
Compliance costs for companies	€701,000	€701,000	€701,000
Costs for public authorities	€240,000	€240,000	€240,000
Total across all sectors	€941,000	€941,000	€941,000

5.6.2 Sensitivity analysis

The estimate is sensitive to the assumption that monitoring of the workplace concentration will be required in all MS. In some MS the enforcement may be limited to requiring biomonitoring and implementation of certain RMMs specified in the Commission Implementing Decision for granting the authorisation. As the dermal route is the major route of exposure it is likely that some MS would not require monitoring of workplace concentrations and the total costs could be significantly lower. On

the other hand, in some MS, the authorities may require that the workplace air concentration is measured regularly and in this case the total costs over the next 60 years would be higher.

MOCA is currently used only in two of the MS without an existing OEL: Hungary and Italy. The average transposition costs of the 12 MS without an existing OEL is estimated at €20,000 per MS as an approximation of the general order of magnitude of the applicable transposition costs. However, the costs in some of the MS without any known use of MOCA may be significantly lower.

6 Market effects

This section comprises the following subsections:

- Section 6.1: Impact on research and innovation
- Section 6.2: Impact on the single market
- Section 6.3: Impact on competitiveness
- Section 6.4: Impact on employment

The following assessment concerns Scenario 2: Authorisation is granted and the users in the supply chain of the applicant continue to use the substance for production of polyurethane elastomers.

6.1 Research and innovation

Establishing one of the reference OELVs is assessed not to have any impact on research and innovation. The main driver for research and innovation in the sector is that the substance is subject to authorisation.

6.2 Single market

6.2.1 Competition

Establishing one of the reference OELVs is assessed not to have any significant impact on competition. The costs of monitoring are so small that the economic impact on each company will be negligible.

6.2.2 Consumers

Establishing the reference OELVs is assessed not to have any significant impact on consumers. The components of polyurethane elastomers are mainly used in industry and transportation. In consumer products they would typically take up a small part of the final articles e.g. rollers in printers, and the small costs of monitoring in the industry are not considered to have any significant impact on the prices of the final consumer products.

6.2.3 Internal market

Establishing one of the reference OELVs is assessed to have minor impact on the internal market by establishing a more level playing field. The ratio of highest OEL/lowest OEL ratio is currently 44 and would be reduced to "no difference", 1 or 4 by introducing an OELV at 5, 10 and 20 µg/m^3, respectively.

6.3 Competitiveness of EU businesses

Establishing the reference OELVs is assessed not to have any significant impact on the competiveness of EU businesses.

6.4 Employment

Establishing the reference OELVs is assessed not to have any impact on employment.

7 Environmental impacts

This section comprises the following subsections:

- Section 7.1: PBT screening
- Section 7.2: Current environmental levels in relation to hazard data
- Section 7.3: Humans via the environment
- Section 7.4: Conclusion

7.1 PBT screening

4,4'-methylenebis(2-chloroaniline) (MOCA) is very toxic to environmental organisms (Classification H400, H410). The aquatic and terrestrial PNEC (predicted no-effect concentration) were derived to be 0.095 µg/L (assessment factor 100) and 7 µg/kg soil dry weight (equilibrium partitioning method), respectively. It is not PBT (Persistent (P), Bioaccumulative (B) and Toxic (T)), but details were not provided (ECHA Dissemination, 2017, as of November 2017). The PBT assessment was reported in detail in an Annex XV dossier (ECHA, 2011c), where it is stated that it would meet the persistent or very persistent criteria and the T criterion is fulfilled according to Annex XIII, but the substance does not meet the numerical B criterion. In conclusion, the substance is not PBT. In line with these assessment results, according to ATSDR (1994) the BCF (Bioconcentration Factor) for aquatic organisms was estimated to be 5.75 and thus very low. However, roots of plants grown in contaminated soil were shown to absorb MOCA into the outer root surface (could not be rinsed off). However, it was not distributed throughout the plant. Based on these results, a potential for food chain bioaccumulation was suggested. Also the Annex XV dossier mentioned above states that the public could be exposed to MOCA in contaminated areas via consumption of root crops grown in MOCA contaminated soil.

If released to air, an estimated vapour pressure of 3.9×10^{-6} mm Hg (0.00052 Pa) at 25 °C indicates MOCA will exist in both the vapour and particulate phases in the atmosphere. MOCA in the vapour-phase will be degraded in the atmosphere by reaction with hydroxyl radicals (photodegradation). The half-life for this reaction in air is estimated to be 5.0 h. MOCA in the particulate phase will be removed from the atmosphere by wet or dry deposition. If released to soil, MOCA is not expected to be mobile based upon an estimated K_{oc} of 5,700. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 1.1×10^{-11} atm m^3/mole. Hydrolysis is not expected based on a hydrolysis half-life of >800 years at pH 7 and 25 °C (NLM, 2017).

7.2 Current environmental levels in relation to hazard data

Environmental concentrations are only reported for an extensive environmental contamination surrounding a MOCA plant in Adrian, MI, USA. Levels up to several mg/kg were found in gardens and community recreation areas. Concentrations in sediment samples collected from the lagoon used by the MOCA plant mentioned above ranged from 1,600 to 3,800 mg/kg dry weight. Effluent water from the lagoon had a concentration of 250 µg/L, deep-well water from under the plant had a concentration of 1.5 µg/L, and surface runoff water contained 1 µg/L (IARC, 2010). Background measurement data are not available.

From the given aquatic and terrestrial PNEC of 95 ng/L (freshwater), 9.5 ng/L (marine water) and 7 µg/kg soil dry weight, there is some concern that this PNEC may be reached or exceeded, in specific pollution scenarios. However, there are no suitable background data to assess ubiquitous ratios of hazard versus concentrations relevant for environmental media.

7.3 Current environmental exposure – sources and impact

Vaporous MOCA emitted by industry into air is rapidly photodegraded and not expected to remain in the environment for longer periods, in contrast to particulate emissions. Once deposited, MOCA is not considered mobile due to its high KOC (partition coefficient between organic carbon and water).

7.4 Humans via the environment

There is no known significant contamination of food or drinking water with MOCA to be considered.

7.5 Conclusion

Considering

- The PT properties of MOCA (not B);
- The uncertain toxicological relevance of environmental burden to aquatic or terrestrial species (exposure /PNEC ratio);
- The significant contribution of industrial air emissions to the total emission and;
- A negligible human exposure via the environment,

the environmental impact of MOCA is regarded as “moderate”.

Furthermore, as establishing an OELV is assessed to have no significant impact on the amount of MOCA released from processes, the environmental impact of establishing an OELV is considered to be negligible.

8 Distribution of the impacts

The impacts identified under the previous tasks will be broken down by stakeholder type and a systematic analysis of who will bear the costs and accrue the benefits will be provided.

This section comprises the following subsections:

- Section 8.1: Businesses
- Section 8.2: SMEs
- Section 8.3: Workers
- Section 8.4: Consumers
- Section 8.5: Taxpayers/public authorities
- Section 8.6: Specific Member States/regions
- Section 8.7: Different timeframes for costs and benefits

8.1 Businesses

The major impact of establishing the different OELVs is estimated to be on business where the compliance costs for companies is estimated at €701,000 for monitoring. The costs for each company is estimated at €7,630 to €11,900.

According to the socioeconomic analysis of the application for authorisation, the moulders have a median number of 23 employees (REACHLaw, 2016a). The application does not provide information on turnover per company. Corden and Tyrer (2017) provide estimates on turnover per company (moulders using MOCA) from three different sources at €2.5 million to €4.6 million. Using these figures, the one-off costs of monitoring of €7,630 to €11,900 per company would correspond to 0.2-0.5% of turnover the first year and be insignificant over a 60-years period.

8.2 SMEs

All moulders are in the application for authorisation surveyed as micro (20%), small (65%) or medium (15%) sized enterprises. The estimated costs of compliance will depend on the size of the companies, as the main costs is estimated to be costs of monitoring i.e. the costs for micro companies with a few workers to monitor will be smaller than the costs for medium sized companies with more workers.

8.3 Workers

The impact on consumers of the different OELVs is considered to be insignificant and not further assessed.

8.4 Consumers

The impact on consumers of the different OELVs is considered to be insignificant and not further assessed.

8.5 Taxpayers/public authorities

The costs for public authorities is considered mainly to be the costs of transposition which is estimated at a total one-off sum of €240,000.

Other impact on taxpayers/public authorities of the different OELVs is considered to be insignificant and not further assessed.

8.6 Specific Member States/regions

13 MS have an OEL larger than the lowest assessed OELV of 5 µg/m³ (Austria, Belgium, Denmark, Finland, France, Greece, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia and Spain) and 11 MS do not have an OEL (Bulgaria, Cyprus, Czech Republic, Estonia, Germany, Hungary, Italy, Latvia, Lithuania, Luxembourg and Malta). Only three MS (Ireland, United Kingdom and Croatia) have an OEL corresponding to the lowest assessed OELV of 5 µg/m³.

Table 8-1: MS with OELs higher than assessed levels

OELV µg/m³	Member States where current limits are higher or the MS do not have an OEL covering the compounds within the scope	% of MS above reference OELV or without OEL	Notes regarding national limits
5	AT, BE, DK, FI, FR, EL, NL, PL, PT, RO, SK, SI, ES BU, CY, CZ, EE, DE, HU, IT, LV, LT, LU, MT	86%	-
10	AT, BE, DK, FI, FR, EL, NL, PL, PT, RO, SK, SI, ES BU, CY, CZ, EE, DE, HU, IT, LV, LT, LU, MT	86%	-
20	BE, DK, FI, FR, EL, NL, PT, RO, ES BU, CY, CZ, EE, DE, HU, IT, LV, LT, LU, MT	71%	-

The number of companies in each of the MS is not reported.

According to the survey undertaken for the application for authorisation, users of MOCA are located in Belgium, Denmark, France, Italy, Ireland, Greece, Hungary, Portugal, Spain, the Netherlands, and the United Kingdom.

Companies in the United Kingdom and Ireland will not be impacted as the lowest of the assessed OELVs are already in force in these MS. Theoretically, the companies in these two MS would consequently have a competitive advantage, however, the impact of the different OELVs on companies in specific Member States/regions is considered to be insignificant and not further assessed.

The Member States without an existing OEL are considered to have costs of transposition of a new OELV for MOCA. Notably, of these countries, MOCA is currently used only in Hungary and Italy.

Table 8-2: MS with companies using MOCA and with OELs higher than assessed levels			
OELV µg/m³	**Companies located in MS where current limits are higher or the MS do not have an OEL covering the compounds within the scope**	**% of MS with companies using MOCA above reference OELV or without OEL**	**Notes regarding national limits**
5	BE, DK, FR, EL, NL, PT, ES HU, IT	82%	-
10	BE, DK, FR, EL, NL, PT, ES HU, IT	82%	-
20	BE, DK, FR, EL, NL, PT, ES HU, IT	82%	-

8.7 Different timeframes for costs and benefits

All costs are allocated to the first year of implementation and the costs in the first year would be significantly higher than the benefits.

9 Conclusions

This section comprises the following subsections:

- Section 9.1: Cost-benefit assessment (CBA)
- Section 9.2: Multi-criteria analysis (MCA)

After the REACH Annex XIV sunset day of 22 November 2017, MOCA is used only by the downstream users in the supply chain of the only applicant for authorisation. No use as intermediate has been identified. The authorisation has still not been granted.

Two scenarios have been considered:

- **Scenario 1:** Authorisation is not granted. The use of MOCA discontinues. Consequently, there will be o benefits of establishing an OELV is

- **Scenario 2:** Authorisation is granted. The use of MOCA continues by the users of MOCA in the supply chain of the applicant under the conditions set for authorisation at least during the review period. As these conditions are still not set, the estimates have been based on the conditions described in the application for authorisation.

The following cost-benefit assessment concern Scenario 2.

9.1 Cost-benefit assessment (CBA)

9.1.1 Overview of the costs and benefits relative to the baseline of the reference OELVs

Reference OELV A: 5 µg/m³

The costs and benefits estimated in this report for Reference OELV A: 5 µg/m³ are summarised in the tables below.

Table 9-1: Overview of the benefits (reference OELV A: 5 µg/m³)		
Description	**Amount for 60 year with a declining discount rate**	**Comments**
Direct benefits		
Reduced number of cancer cases	€3	Benefits to workers and their families, public sector and employers
Indirect benefits		
Reduced number of cancer cases	≈ €0	Benefits to employers and public sector
Intangible benefits		
Reduced number of cancer cases	€140	Benefits to workers and their families

Table 9-2: Overview of the costs (Reference OELV A: 5 µg/m³)							
		Citizens/consumers		Businesses		Administrations	
		One-off	Recurrent	One-off	Recurrent	One-off	Recurrent
Establishing an OELV	Direct costs	-	-	€701,000	-	€240,000	-
	Indirect costs	-	-	-	-	-	-

Reference OELV B: 10 µg/m³ and Reference OELV C: 20 µg/m³

The costs and benefits estimated in this report for Reference OELV B: 10 µg/m³ and Reference OELV C: 20 µg/m³ are summarised in the tables below.

Table 9-3: Overview of the benefits (reference OELV B: 10 µg/m³ and reference OELV C: 20 µg/m³)		
Description	**Amount for 60 year with a declining discount rate**	**Comments**
Direct benefits		
Reduced number of cancer cases	0	Benefits to workers and their families, public sector and employers
Indirect benefits		
Indirect benefits	0	Benefits to employers and public sector
Intangible benefits		
Intangible benefits	0	Benefits to workers and their families

9.1.2 CBA for the reference OELVs

The overall costs and benefits relative to the baseline of establishing an OELV at the three different reference levels are shown in Table 9-4 and Figure 9.1. For all OELVs, the benefits are much lower than the estimated costs.

Table 9-4: Summary of monetised costs and benefits relative to the baseline		
Reference OELV	**PV benefits over 60 years (€2017)**	**PV costs over 60 years (€2017)**
A: 5 µg/m³	€143	€941,000
B: 10 µg/m³	0	€941,000
C: 20 µg/m³	0	€941,000
Monetised costs and benefits	*Avoided lung cancer vis-à-vis the baseline*	*Monitoring* *Transposition*
Significant non-monetised costs and benefits	*No significant benefits*	*No significant costs*

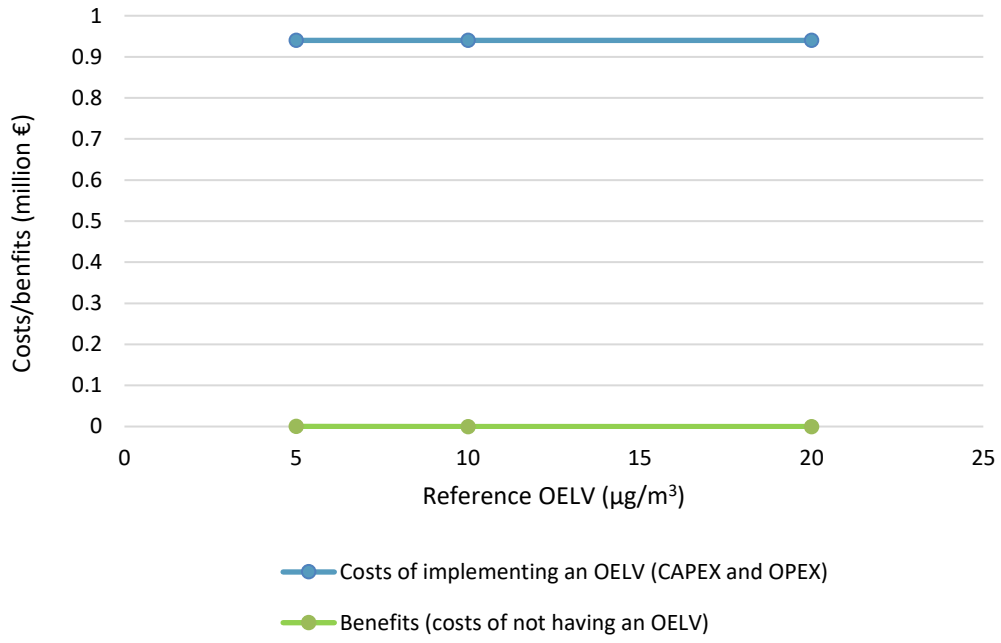


Figure 9.1: Costs/benefits of establishing an OELV for MOCA for all sectors in the EU. Estimated costs (CAPEX AND OPEX) for 60 year and benefits (costs of not having an OELV) for a static baseline with a declining discount rate (all reletive to the baseline). Scenario 2.

9.2 Multi-criteria analysis (MCA)

The multi-criteria analysis indicating impacts and stakeholders affected is summarised in Table 9-5.

The summary concerns Scenario 2: Authorisation is granted. No MCA is prepared for Scenario 1: Authorisation is not granted and the use of MOCA will discontinue.

Table 9-5: MOCA. Multi-criteria analysis, Scenario 2

Impact	Stakeholders affected	Reference OELV A 5 µg/m³	Reference OELV B 10 µg/m³	Reference OELV C 20 µg/m³
Economic impacts				
Compliance costs	Companies exposing their workers	€0.7 million	€0.7 million	€0.7 million
Increased business	RMM suppliers	No impact	No impact	No impact
Enforcement costs	Public sector	€0.2 million	€0.2 million	€0.2 million
Benefits from reduced ill health	Employers	No impact	No impact	No impact
	Public sector	No impact	No impact	No impact
Single-market: competition		No impact	No impact	No impact
Single-market: consumers		No impact	No impact	No impact

Table 9-5: MOCA. Multi-criteria analysis, Scenario 2				
Impact	**Stakeholders affected**	**Reference OELV A 5 µg/m³**	**Reference OELV B 10 µg/m³**	**Reference OELV C 20 µg/m³**
Single-market: internal market	Companies. Positive impact of level playing field	Reduction of highest OEL/lowest OEL ratio from 44 to "no difference"	Reduction of highest OEL/lowest OEL ratio from 44 to 2	Reduction of highest OEL/lowest OEL ratio from 44 to 4
International competitiveness		No impact	No impact	No impact
SMEs	Companies	All impacted companies are micro-sized or SME – cost of monitoring could affect the smallest companies disproportionally, but monitoring costs are not significant		
Specific MS/regions	Public sector (MS with higher or without an OEL):	AT, BE, BU, CZ, CY, DK, EE, EL, ES, DE, FI, FR, HU, IT, LV, LT, LU, MT NL, PL, PT, RO, SK, SI	AT, BE, BU, CZ, CY, DK, EE, EL, ES, DE, FI, FR, HU, IT, LV, LT, LU, MT NL, PL, PT, RO, SK, SI	BE, BU, CZ, CY, DK, EE, EL, ES, DE, FI, FR, HU, IT, LV, LT, LU, MT NL, PT, RO
	Companies (in MS with higher or without an OEL)	BE, DK, FR, EL, NL, PT, ES, HU, IT	BE, DK, FR, EL, NL, PT, ES, HU, IT	BE, DK, FR, EL, NL, PT, ES, HU, IT
Social impacts				
Ill-health avoided, lung cancer	Workers & families	€143	Insignificant	Insignificant
Other health points, exposure pathways	Workers & families	Dermal exposure		
Employment	Workers	No impact	No impact	No impact
Environmental impacts				
Environmental releases		No impact	No impact	No impact
Recycling – loss of business*	Recycling companies	No impact	No impact	No impact
Recycling – durability of consumer goods*, etc.		No impact	No impact	No impact
+ small positive impact; - small negative impact; * MOCA is transformed by the use and not present at any significant concentration in recycled articles. Furthermore, for polyurethane elastomers, like other thermosets, energy recovery is currently the only recovery pathway.				

10 Sensitivity analysis

Benefits - The conclusions are drawn on the basis that the current levels of exposure are typically below the lowest of the OELs assessed and consequently the estimates are not sensitive to the number of exposed workers, or to the relationship between exposure and effects and the costs of cancer cases. The uncertainty is consequently related to the estimated exposure levels.

As RAC suggests a number of best practice measures should be required in case an authorisation is granted, it is estimated to be very certain that the exposure levels would in the future be below 5 $\mu g/m^3$, which is the lowest of the assessed OELVs.

The assessment does not include other types of cancer than lung cancer (e.g. bladder cancer) and does not take oral and dermal exposure into account. It will consequently underestimate the actual number of cases. Furthermore, cancer cases due to exposure during the 60 years assessment period that will arise after the assessment period is not taken into account which would result in an underestimation of the long-term benefits of avoided cases. As the number of cases is very small it is estimated that the benefits would still be well below the costs even if more cancers and cases that will arise after the assessment period.

Costs - The estimate is sensitive to the assumption that monitoring of the workplace concentration will be required in all MS. In some MS the enforcement may be limited to requiring implementation of certain RMMs specified in the Commission Implementing Decision for granting the authorisation and biomonitoring. As the dermal route is the major exposure route it is likely that some MS would not require monitoring of workplace concentrations and the total costs could be significantly lower. The conditions suggested by RAC in case authorisation is granted focus on frequent biomonitoring as the method to demonstrate that workers are not exposed at an unacceptable level. However, in some MS, the authorities may require that the workplace air concentration is measured regularly and in this case the total costs over the next 60 years would be higher.

MOCA is currently only used in two of the MS without an existing OEL: Hungary and Italy. The average transposition costs of the 12 MS without an existing OEL is estimated at €20,000 per Member State as an approximation of the general order of magnitude of the applicable transposition costs. However, the costs in some of the MS without any known use of MOCA may be significantly lower.

Conclusion - Even the costs of establishing the OEL may be overestimated, it is considered to be very certain that the costs exceed the benefits.

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Annex 1 Summary of consultation responses

ECHA has received an application for authorisation for MOCA from one company only: REACHLaw Ltd, Finland in its legal capacity as only representative of Suzhou Xiangyuan Special Fine Chemical Co., Ltd. After the sunset date of 22 November 2017, MOCA may only be used in the EU by the estimated 89 companies in the supply chain of the applicant. Detailed information is available on the uses and sectors from the authorisation application. Through the consultation process REACHLaw Ltd has requested various information not provided in the application.

The approach for the stakeholder consultation was to request the applicant for authorisation to distribute the questionnaire down through the supply chain. No answers were obtained from the downstream users. An explanation may be that a quite similar questionnaire was distributed to downstream uses as part of the preparation of the applications. For this purpose, a questionnaire was undertaken by the applicant in order to gather information on operational conditions, RMM, PPE and possible measurements of workplace concentrations conducted at the sites using MOCA. Questionnaires were sent to moulders and distributors. In total, 20 moulders companies, representing 65% of the tonnage imported to EU, responded. The results of this questionnaire is reported in the applications for authorisation and used in the current report. Furthermore, extensive information on uses is available from the comments to the applications from competitor companies to the applicant. These comments represent a second view to the information provided in the application; in particularly with regard to availability of alternatives.

Another explanation for the missing responses to the questionnaire is that the companies did not expect to be significantly impacted; which is confirmed by the current assessment.

As part of the general stakeholder consultation under the contract, requests have been distributed to relevant industry associations on European level including European Rubber Chemicals Association (ERCA), European Di-isocyanate & Polyol Producers Association (ISOPA), European Rubber Manufacturers Association (BLIC) and European Plastics Converters (EUPC). Furthermore, a number of national associations for plastics and rubber were contacted. No responses were received.

In order to obtain more specific information from companies and national industry associations, the national plastics/rubber associations in Denmark, UK and Germany were contacted by phone and interviews were undertaken with two companies using MOCA; one outside the supply chain (using MOCA until the sunset date) and one within the supply chain. The organisations and companies confirmed information from the application for authorisation.

Considering the comprehensive information available in the application for authorisation and comments to this, as well as in the literature as compared to most other applications of substances under this contract, further interviews and site visits were not prioritised. There were a relatively small number of questionnaire responses, interviews and site visits for MOCA due to its limited use and the fact that companies would not be challenged by the assessed OELVs.

Responses to consultation relevant to MOCA:

Table A11-1: Number of responses relevant to MOCA	
Questionnaire responses	1
Interviews	3
Site visits	0
Total	**4**

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