

Management of the Risks Related to Chronic Occupational Exposure to Cadmium and its Compounds (2018 revision)

Issue	Date	Main changes
2018 Issue	07/2018	Incorporation of feed-back from members in several sections New section on how to check compliance with an OEL Lowering of Cd-B action levels Update on use of microprotein results
2013 Issue	11/2013	Incorporation of OEL and BLV limit values from SCOEL 2010 Recommendation Incorporation of extensive guidance on plant cleanliness and industrial hygiene
2006 issue	02/2006	Extensive rewriting based on Cd/CdO RAR findings Incorporation the main components of the applicable Swedish regulation
1996 issue	05/1996	Initial publication

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1 Purpose

The purpose of this document is to supply guidance to occupational medical doctors and management of plants in which cadmium (Cd) and/or hazardous cadmium compounds are being processed, manufactured, transformed, incorporated into articles or recycled, with the purpose of bringing Cd exposure of all employees at a level which ensures an adequate control of risks to workers.

This guidance presents a set of measures which, if properly implemented, will ensure that the work environment meets both the Occupational Exposure Limit (OEL) of 4 µg Cd/m³ (respirable fraction) to protect against local effects (to the lungs) and the Biological Limit Value (BLV) of Cd in urine (Cd-U) = 2 µg Cd/g creatinine to protect against systemic effects (kidney tubular damage).

Both values have been recommended by the Scientific Committee on Occupational Exposure Limits (SCOEL) in 2010¹. These values have been further confirmed by SCOEL in 2017².

It is expected that these limit values will be incorporated into EU law by means of an amendment to directive 98/24/EC or 2004/37/EC. Once adopted, these levels must be transposed into the national legislations of the EU Member States and will become binding on employers.

2 Structure

This Industry Guidance rests on three pillars:

1. Ensure plant cleanliness,
2. Implement collective and individual hygiene procedures,
3. Conduct medical surveillance of exposed workers, including bio-monitoring of both urinary cadmium (Cd-U) and blood cadmium (Cd-B), as a safety net to detect any issue arising in pillars (1) and (2) before any adverse effect is likely to arise.

To achieve the best results, these three pillars need to be implemented concurrently.

Should equipment changes be conducted, preference should be given to equipment designs which address cleanliness performance at the onset of equipment startup, over a stepwise improvement process, which may not be able to reach the desired performance.

Should hygiene policies need to be reinforced; this can only be implemented in a stepwise, progressive manner, to ensure proper buy-in by employees and true long term behavioral changes.

Strengthened medical surveillance should be implemented swiftly; but needs to take into consideration the ability of a plant to reassign workers to non-exposed positions.

¹ See "SCOEL Recommendation 136" www.ec.europa.eu/social/BlobServlet?docId=3803&langId=en

² See "SCOEL Opinion 336": <https://circabc.europa.eu/sd/a/13cad802-1f3c-40c0-bce4-6838cf5fc4ff/OPIN-336%20Cadmium%20and%20its%20inorganic%20compounds.pdf>

3 Ensuring plant cleanliness

Plant cleanliness, in the frame of the hierarchy of controls, whether it is (a) ensuring inner air quality or (b) eliminating cadmium deposit on surfaces, is the foundation of any chemical risk management program.

3.1 Ensuring workplace air quality

3.1.1 *Selecting the workplace OEL*

Until a few years ago, complying with the national OEL (be it binding or guidance) was the mandatory or voluntary strategy in countries where such an OEL did exist.

However, in 2010 SCOEL gave its view as to what the EU-wide health-based OEL should be. Although as of today, EU institutions have not yet acted on this by adopting a legislative instrument, the Cadmium REACH Consortium and lead registrants of Cd and Cd compounds brought this proposed OEL forward as the Derived No Effect Level (DNEL) in the REACH registration dossiers of these substances.

For this reason, this DNEL has become legally binding on Producers and Downstream Users.

The DNEL of the cadmium and compounds REACH registration dossiers is **4 µg/m³ (respirable fraction)**.

3.1.2 *Getting to compliance*

To comply with this OEL/DNEL, equipment upgrade may be required and should include, inter alia, a combination of the following measures:

- *Conduct, at plant level or workshop level, air flow studies.* These should cover heating and ventilation issues to understand the air flows,
- *Install or enhance Local Exhaust Ventilation systems (LEV)³.* This encompasses the following steps:
 - *Create plant wide piping, connected to negative pressure ventilation, along with adequate filtration* before air is released to the outside atmosphere,
 - *Place machinery within negative pressure enclosures* where feasible,
 - *Conduct local adequate air flow studies before new equipment is installed* to ensure adequate air speed is obtained at the opening of each suction head,
 - *Install, when and where appropriate, suction heads in places where cadmium emissions occur* (this should be preferred over the development of a plant-wide air circulation system, which is known to be both less effective and costlier).

In cases where it is impossible to maintain exposure at all time below the OEL, or during maintenance work with risk of elevated high? exposure, respiratory protection devices with adequate efficiency levels⁴ shall be worn. It is of utmost importance that specific procedures (beyond the scope of this

³ For Guidance on LEV in English, see <http://www.hse.gov.uk/pubns/books/hsg258.htm>
For Guidance on LEV in French, see <http://www.inrs.fr/media.html?refINRS=ED%20695>

⁴ For European standards on respiratory equipment, see EN 143
For a Guidance in English, see <http://www.hse.gov.uk/pubns/books/hsg53.htm>
For a Guidance in French, see <http://www.inrs.fr/media.html?refINRS=ED%206106>

document) be developed with a view to ensure proper use (including fit test) and handling of such devices.

3.1.3 *Checking compliance with the OEL*

Compliance with this OEL must be checked at least on a yearly basis and every time a significant workplace layout change is implemented. Air sampling should always be conducted directly on workers with the use of portable measurement equipment. Static measurements should be conducted mainly to assess the performance of LEV around an equipment.

Methodologies, standards such as EN 689, and, in some member States, regulations provide a framework to ensure that measurement campaigns are conducted properly, in a cost-effective way.

These define the concept of Same Exposure Groups (SEG) and recommend the use of a statistical methodology based on a log-normal distribution of measurements and the calculation high level percentile (typically 90th or 95th) along with a confidence interval (typically 70%) to check whether the exposure data captured shows compliance with the OEL with a high level of confidence.

Software and worksheets have been developed (such as the OCdAIR template developed by ICdA) to assist EHS personnel to conduct a proper statistical analysis of air measurement results.

3.2 Eliminating Cd deposits on all surfaces

This involves the usual, but sometimes overlooked, requirement that floors, structures, machines, change rooms be kept tidy, to ensure that cadmium containing dust deposited onto surfaces cannot be remobilized by air movements into the working environment nor picked up by physical contacts.

In practical terms, adequate equipment and proper routines need to be set up to ensure these goals are achieved.

These routines should include, inter alia:

- *Choosing the floor coating color which helps spot any deposits* (choose a floor coating color which contrasts with the Cd compound being controlled),
- *Acquiring floor scrubbers, and putting in place the adequate cleaning routines* (preferably involving water spraying to avoid remobilization of dust to air),
- *Setting up negative pressure piping* with permanent/moveable click-on suction hoses,
- *Implementing regular routine addressing structure clean-up,*
- *Developing machine clean-up routines* as part of the shift ending procedure.
- *Proper handling of contaminated defective equipment,* which includes cleaning or isolating it before it is sent for repair to the workshop

4 Reinforcing collective and personal hygiene procedures, including training

Even with the strictest adherence to adequate plant cleanliness practice, small particles can still be emitted at the workplace. It is known that once the inhalation route is placed under control through compliance with workplace air quality requirements (compliance with the OEL/DNEL), the ingestion route may become the predominant route of Cd intake into the organism.

To limit this intake, plants must develop and implement proper hygiene procedures, both at collective and individual level.

4.1 At collective level, plants need to develop several actions:

Amongst such actions, the following should be noted:

- *Conduct initial training on Cd related risks:* how to mitigate it, the importance of complying with rules and policies,
- *Conduct refresher training on these issues on a regular basis:* preferably yearly,
- *Set up triple compartment locker-rooms:* with separate change rooms for the city clothes side and the work clothes side, separated by a shower section,
- *Have employer supplied work clothes:* with adequate frequency of supply of clean clothes (from weekly to daily depending on the area), considering the differing requirements of male and female employees as well as the specific requirements for the different seasons of the year,
- *This should also include company supplied laundry service:* so that dirty clothes do not find their way into the home of employees. The selected laundry service should have adequate waste water treatment systems in place to avoid the uncontrolled release of contaminants in the sewage system.

4.2 Focus on initial training:

A worker hired for or moved to a Cd exposed position should be mentored by another worker with seniority in a similarly exposed position with a good track record of compliance with Hygiene procedures. It is recommended that this mentoring program extends over at least one year.

During this mentoring period, a newly hired or newly assigned worker should undergo several biomarker measurements at a reduced interval (typically every quarter or every semester) to identify any increase of Cd-B with a view to ensure proper hygiene procedures are properly adopted by this “new” worker. Alternatively, a record of continuous increase of Cd-B could be a deciding factor in a decision to not confirm this worker in this exposed position.

This mentoring program is to be conducted in addition, and not as a replacement, to the formal training described in the previous paragraph.

4.3 At individual level: several requirements need to be implemented:

Amongst these requirements, the following should be noted:

- *Comply with the above mentioned collective hygiene procedures,*
- *Take a shower after the end of each shift:* this requires that an adequate number of showers is made available, so as not to discourage employees from showering,
- *Only smoke, snack and drink in designated areas,* these activities must not occur within work areas,
- *Wash one’s hands before meals, snacks and breaks, and remove one’s top clothes before meals* so that no dust can fall onto the plate,

- *An encouragement to stop smoking, biting nails and to avoid growing facial hair, these are habits which lead to the transfer of cadmium through the mouth into the digestive system,*
- *Store all personal objects (keys, cell phone, cigarette packs...) in dedicated lockers outside of the work area.*

5 Strengthening medical surveillance

If all procedures indicated above are properly implemented, risks of Cd adverse effects are controlled.

However, since Cd is a cumulative toxicant, even at relatively low levels of accumulation, occasional uptakes (due to either equipment malfunction or procedural non-compliance) can be a source of Cd accumulation for workers. This accumulation may in turn create a risk.

It is therefore necessary to install complementary medical measures for the control of risks such as:

- The identification of a preexisting condition (e.g. existing kidney condition...) which renders the worker unfit to Cd exposure,
- The identification of individuals who, in spite of general measures taken, continue to accumulate Cd in the body. This is detected in an early stage by proper monitoring of biomarkers of Cd exposure. By following these parameters, possible (subclinical) changes of biomarkers can be identified.

5.1 Identification of employees covered

All employees under a risk of exposure to Cd, whether on a permanent basis or on an occasional basis throughout their work day, are to be identified by plant management and the occupational medical doctor to undergo strengthened medical surveillance. Furthermore, the strengthened medical surveillance of employees who have been exposed to Cd and been subsequently removed from exposure for medical reasons needs to be continued.

5.2 “Exposure biomarkers” and their uses

Cd-B is a biomarker which is influenced both by total exposure (integrated over 20 years) and recent exposure (over the past 3 months), both from ingestion and inhalation. However, the variation of CdB over two consecutive dates, if less than a year apart, reflects recent exposure, and its sensitivity to recent exposure, in both directions (up or down), is quite high.

Cd-B should therefore be used to detect an equipment dysfunction or a poor implementation of hygiene policies which happened over the past 3 months.

Cd-U is a biomarker which reflects total exposure of the worker over a period of 20 years. It integrates both ingestion and inhalation. There is a direct proportion between urinary clearance of Cd and Cd load in the kidney, which above certain levels may induce tubular dysfunction.

Cd half-life in the kidney is approximately 20 years. Therefore, Cd-U varies quite slowly over time.

Cd-U should therefore be used to assess whether an exposed worker’s total exposure brings him to a situation in which his risk to develop a tubular dysfunction is increased compared to a non-exposed worker.

To ensure good correction for urine dilution, and ensure this indicator is meaningful, this biomarker needs to be standardized by means of a creatinine measurement.

Figure 1. Urinary RBP as a function of Cd in urine (adapted from Chaumont et al 2011).

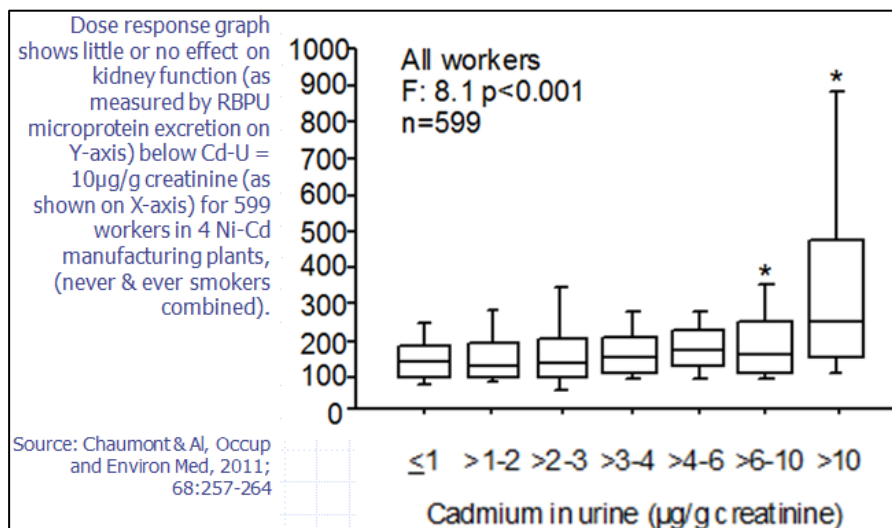


Figure 1 indicates that no degradation of the kidney tubular reabsorption (as measured by urinary Retinol Binding Protein (RBP)) function occurs if Cd in urine is maintained below the 5 to 10 µg Cd/g creatinine level

5.3 “Effect biomarkers” and their uses

To measure the decrease of tubular reabsorption in the kidneys, the urinary clearance of one amongst several proteins is measured.

The most commonly used proteins for this purpose are:

- Retinol binding protein (RBP)
- Alpha 1 microglobulin (α1 microglobulin, also called protein HC)
- Beta 2 microglobulin (β2M)

In table 1 is the guideline used to interpret the levels of microprotein excretion.

Table 1. Interpretation of elevated values of urinary β₂-microglobulin (β₂-M) and retinol-binding protein (RBP) induced by occupational or environmental exposure to Cd

β ₂ -M or RBP in urine (µg/g creatinine)	Significance
< 300	Normal value
300 - 1,000	Incipient Cd tubulopathy (possibility of some reversal after removal of exposure if urinary Cd is not too high <i>i.e.</i> below 20 µg/g cr)
1,000-10,000	Irreversible tubular proteinuria that may accelerate the decline of glomerular filtration rate with age. At this stage glomerular filtration rate is normal or slightly impaired.
>10,000	Overt Cd nephropathy usually associated with a decreased glomerular filtration rate

Modified from Ref. 4

Source table 1: Bernard A. Cadmium & its adverse effects on human health. Indian J Med Res. 2008; 128(4):557-64. Review. (Ref 4: Bernard A. Renal dysfunction induced by cadmium: biomarkers of critical effects. Biometals 2004; 17: 519-23.)

Due to both its specificity and its stability, use of RBP should be preferred.

B2M is unstable at low pH and is also influenced by other elements like chronic inflammation, liver diseases, acute viral infection and is therefore a less reliable indicator.

5.4 Using “exposure biomarkers” to conduct preventive medical surveillance

5.4.1 *Using Cd-U:*

- **Cd-U $\leq 2 \mu\text{g Cd/g creatinine}$** [$2 \mu\text{g Cd/g creatinine}$ is a conservative threshold (and action level) based on general population studies (**green zone**, see Figure 2)]:
 - general medical follow-up is conducted along with regular measures of the exposure indicators Cd-U, Cd-B. Use of the subclinical effect biomarker (urinary protein excretion measurement) can be introduced,
 - no further special action is required beyond proper implementation of the general hygiene procedures and medical surveillance.
- **$2 \mu\text{g Cd/g creatinine} < \text{Cd-U} \leq 5 \mu\text{g Cd/g creatinine}$** [$5 \mu\text{g Cd/g creatinine}$ is a 2nd threshold (and action level) based on studies at the workplace (**orange zone**, see Figure 2)]:
 - general medical follow-up is conducted along with regular measures of the exposure indicators Cd-U, Cd-B and the subclinical effect biomarker (urinary protein excretion measurement),
 - and a detailed analysis of the related workplace (by plant maintenance) along with an assessment of collective (by area supervisor) and individual hygiene procedures implementation, including training are conducted (by occupational doctor).
- **Cd-U $> 5 \mu\text{g Cd/g creatinine}$** (**red zone**, see Figure 2):
 - worker is removed from Cd exposure, bio-monitoring is to be continued.

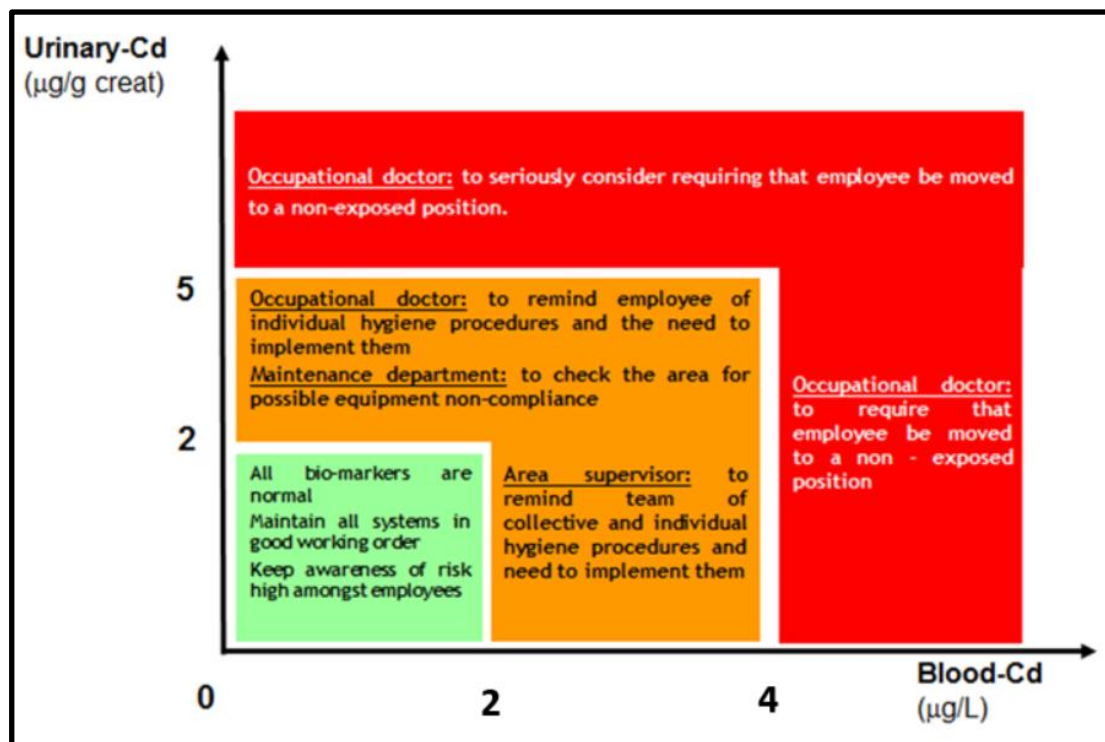
5.4.2 *Using Cd-B:*

As indicated under 5.2., Cd-B is function of both the Cd body burden (and as such, partially proportional to Cd-U) and of recent exposure.

Cd-B is used as a complementary biomarker mainly to identify recent accumulation (approximately within the preceding 3 months window). Cd-B is evaluated as follows:

- **A rapid increase of Cd-B towards $2 \mu\text{g Cd/L}$ or the exceedance of the first action level of $2 \mu\text{g Cd/L}$** triggers a detailed analysis of the related workplace (by plant maintenance) along with an assessment of collective (by area supervisor) and individual hygiene procedures implementation, including training (by occupational doctor),
- **A rapid increase of Cd-B towards $4 \mu\text{g Cd/L}$ or the exceedance of the second action level of $4 \mu\text{g Cd/L}$** triggers the removal of the worker from exposure.

Figure 2. Decision diagram:



5.5 Using effect biomarkers (β 2-M, RBP or protein HC):

Workers whose effect biomarker is exceeding the reference value or shows a consistent pattern of increase, which may lead to approaching the reference value of 300 for retinol binding protein (RBP) and for beta-2 microglobulin (β 2-MG) or 700 μ g/mmol creatinine (=6200 μ g/g creatinine) for alpha-1 microglobulin (α 1-microglobulin or protein HC) should be given greater attention during their occupational medical visits.

6 Practical considerations

This Cd occupational risk management program and its medical surveillance compartment have been progressively implemented and strengthened in the EU Cd industry over the last decades. Workers that have been exposed to Cd at earlier stages of their implementation must have their situation reviewed by the supervising occupational doctor on a case by case basis.

Moreover, the health professional in charge of medical surveillance should also consider all factors, both work related and external (such as smoking habits, diet, possible health conditions...) when assessing a worker's situation.

7 Exposure observatories: OCdBIO and OCdAIR

In order to monitor industry progress in worker protection, members of ICdA commit to report to the Association anonymized exposure data.

These results are consolidated at industry level with the purpose of generating a complete picture of worker exposure.

7.1 Biomonitoring observatory: OCdBIO

Members of the Association are expected to report on a yearly basis the distribution Cd-U and Cd-B values of workers who are being bio-monitored as decided by each plant occupational doctor. This anonymous data is aggregated at industry level and communicated back to members as consolidated data.

7.2 Air exposure observatory: OCdAIR

Members of the Association are expected to report on a yearly basis the status of the several Same Exposure Groups (SEG) that have been set up to track compliance of air exposure with the OEL. This anonymous data is aggregated at industry level and communicated back to members as consolidated data.

7.3 Purpose of these observatories

The aggregated data is used for the following purposes:

- Assess progress of the whole industry over time,
- Allow each member to benchmark its individual results relative to the whole industry,
- Communicate data to regulators as the need may arise.

8 Glossary

BLV Biological Limit Value

Cd-B Cadmium concentration in blood

Cd-U Cadmium concentration in urine

DNEL Derived No Effect Level

LEV Local Exhaust Ventilation systems

OEL Occupational Exposure Limit

RAR Risk Assessment Report

RBP Retinol Binding Protein

SCOEL Scientific Committee on Occupational Exposure Limits

9 References:

Bernard A (2004). Renal dysfunction induced by cadmium: biomarkers of critical effects. *Biometals*, 17: 519-23.

Bernard A. (2008) Cadmium & its adverse effects on human health. *Indian J Med Res.*, 128(4):557-64. Review.

Chaumont A, De Winter F, Dumont X, Haufroid V and Bernard A (2011). The threshold level of urinary cadmium associated with an increased urinary excretion of retinol-binding protein and β 2-microglobulin: a re-assessment in a large cohort of nickel-cadmium battery workers. *Occupational and environmental medicine*, 68(4):257-264.

Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

Directive 2004/37/EC of 29 April 2004 on the on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (Sixth individual Directive within the meaning of Article 16(1) of Council Directive 89/391/EEC)

European standard EN 143- Respiratory protective devices - Particle filter - Requirements, testing, marking

Scientific Expert Group on Occupational Exposure Limits (SCOEL) (2010). Recommendation from the scientific expert group on occupational exposure limits for cadmium and its inorganic compounds. SCOEL/SUM/136.

Scientific Expert Group on Occupational Exposure Limits (SCOEL) (2017). Opinion from the scientific expert group on occupational exposure limits for cadmium and its inorganic compounds. SCOEL/OPIN/336.