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International Cadmium Association

Management of the Risks Related to Chronic Occupational Exposure to Cadmium and its Compounds

2024 revision

Issue	Date	Main changes
2024 Issue	10/2024	Incorporation of binding OEL values applicable in the EU. Update on literature. Incorporation of additional guidance on plant cleanliness and industrial hygiene.
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.

Contents

Word of the Chairman

Welcome to this latest update of the ICdA Guidance on Risk Management to control Occupational Exposure to Cadmium and its compounds.

First published in 1996 after expert collaboration between Eurometaux and ICdA, it has since been revised and improved in the intervening period into this 5th version. **Members have been attentively implementing this Guidance throughout this period** with many of the risk management improvements resulting from the regular ICdA Health and Safety Committee meetings in which Members share and discuss their best practice developments.

Contributing to this process has also been a series of **unique voluntary Observatory programmes** – an anonymized annual data gathering from Member on air monitoring values, cadmium in blood and urine of workers, and emissions to air and water from our plants.

Data is collated and reviewed by Members with independent expert Academic support. As a result, this enables the industry to monitor the progress resulting from the implementation of the measures recommended in the Guidance. **The results have been very significant with notable decreasing trends observed for all metrics**. This drives even more ambitious goals for exposure control to meet current or anticipated Regulatory targets and importantly maintain workers exposure in the identified safe 'green zone'.

We expect all plants and their management teams to implement the changes and measures detailed herein, thereby ensuring a successful Integrated Risk Management system.

Dr Howard Winbow

Chairman of the International Cadmium Association

1 Purpose

The International Cadmium Association (ICdA) is supporting the cadmium industry on the Environmental, Health and Sustainability fronts with programs aiming at assessing and reducing cadmium exposure of workers and risks to the environment. Uses of cadmium and its compounds are very strictly regulated, managed and controlled with several of these applications being critical for the success of the clean energy and digital transition or have no substitute[1].

The goal of this document is to provide guidance to professionals involved in the reduction of risks to workers from exposure to cadmium (Cd) and/or hazardous cadmium compounds in industrial settings in which these substances are processed, manufactured, transformed, incorporated into articles or recycled. The target audience consists of occupational medical doctors, EHS professionals, process design teams as well as plant management.

This guidance presents a set of measures which, if properly implemented, will ensure that the work environment meets local or jurisdictional worker safety and occupational exposure control requirements.

More specifically, it will enable the most demanding, precautionary EU binding Occupational Exposure Limit (OEL) for CMR Cd substances[2] and the industry voluntary Biological Limit Value (BLV) of Cd in urine to be met.

The urinary Biological Limit Value (BLV) has been recommended by the EU Scientific Committee on Occupational Exposure Limits (SCOEL) in 2010[3] and reconfirmed by SCOEL in 2017[4].

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 biomonitoring 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; such a process 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 https://www.cadmium.org/
[2] At the latest by July 11th, 2027; See DIRECTIVE (EU) 2019/983: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0983
[3] See "SCOEL/SUM/136" https://www.ser.nl/api/Mfiles/DownloadFirstDocument?Id=23df5574-775a-4cb1-877c-c762031225fc
[4] See "SCOEL/OPIN/336" NB – re-confirmation that a combination of an OEL of 4ug/m³ Cd Respirable fraction together with a BLV of 2 µg Cd/g creatinine in urine as being protective for workers, is embedded in the text on page 10:
https://echa.europa.eu/documents/10162/35144386/182_cadmium_and_its_inorganic_compounds_oel_en.pdf/19700d5a-2c65-1827-15ca-463f612096fb?t=1699953898709

3 Ensuring plant cleanliness

Plant cleanliness, in the frame of the hierarchy of controls, whether it is (a) ensuring workplace 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

Most regions in the world have a Cd OEL in place for worker protection - a position which is supported by ICdA. It is important to note that the OEL developed per country or jurisdiction may have different legal status (e.g. binding, indicative or recommended), different numerical values and may cover different dust fractions (inhalable, thoracic, respirable). Furthermore, in some jurisdictions, a distinction is made between cadmium compounds based on their classification - most notably for non-CMR Cadmium Pigments.

- **With this in mind, if the facility under consideration is located in a jurisdiction where specific OELs are set,** the plant shall comply with those relevant OELs.

- **In the EU,** a binding OEL value has been set **for CMR classified Cd substances** in Directive 2019/983/EU published in June 2019, in which a two-step process is detailed:
  - Step 1:
    - The directive requires that a binding OEL of **4 µg/m3** (inhalable fraction) be set in all EU Member States by July 11th, 2021,
    - For those EU Member States that implement, on the date of the entry into force of this Directive, a biomonitoring system with a urinary BLV not exceeding 2 µg Cd/g creatinine in urine, the binding OEL of **4 µg/m3** applies to the respirable fraction shall be set by the same date,
  - Step 2: On July 11th, 2027 at the latest, all EU Member States shall set a binding OEL of **1 µg/m3** (inhalable fraction).

EU plants shall take the necessary actions to comply with both steps when they become applicable.

- **In the absence of specific local mandatory OEL requirements for CMR classified Cd substances**, ICdA recommends its members to comply with the limit values legislated under the second bullet point of step 1 of EU Directive 2019/983/EU, which is the combination of an OEL of 4 µg/m3 (respirable fraction) with a BLV of urinary cadmium of 2 µg/g creatinine.

- **For non-CMR Cd compounds** such as Cd pigments, CdTe and CdSe which are **not classified for adverse CMR effects**, facilities involved in the manufacture or use of said compounds shall refer to local specific OEL limits. Where significant volumes are handled it is also advised to have biomonitoring in place as a precautionary measure as detailed in section 5.4.

3.1.2 Getting to compliance

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

- Do local air sampling to identify sources of cadmium emissions,
- 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)[5]. 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 Cd processing 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 cadmium exposure, respiratory protection devices with adequate efficiency levels[6] shall be worn. It is of utmost importance that specific procedures (beyond the scope of this 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 tightness of enclosures or the performance of LEV around an equipment in which cadmium or cadmium compounds are processed.

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

These frameworks define the concept of Similar Exposure Groups (SEG) and recommend the use of a statistical methodology based on a log-normal distribution of measurements to assess compliance.

For each SEG, the calculation of the 90th or the 95th percentile of the measurements conducted on workers of that SEG throughout the year must be conducted, possibly along with a confidence interval (typically 70%). For each SEG, it is that calculated representative exposure value which must be assessed against the applicable OEL to check for compliance.

A plant is deemed fully compliant with the applicable OEL when each one of the SEG specific calculated values is below the OEL.

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 campaigns.

[5] 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
[6] 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

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 neither 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 position where there is a risk of Cd exposure 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. This should happen in a space outside of the room where the break is taken to avoid contamination of this designated area,
- 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.
- Use airflow type of respiratory protection for workers with facial hair, facial hair has negative impact on tightness of most protection.
- Store all personal objects (keys, cell phone, cigarette packs…) in dedicated lockers outside of the work area. Pick up these items only after washing hands and face.

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 workday, 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

5.2.1 Cadmium in blood: Cd-B

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 Cd-B 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.

Increase of Cd-B value of one worker in a SEG while no increase for other workers in the same SEG might be an indication of insufficient respect of personal hygiene measures rather than an increased cadmium concentration in workplace air. An increase of Cd-B for multiple workers in a given SEG is an indication of a probable general increase of exposure to cadmium.

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.

5.2.2 Cadmium in urine: Cd-U

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, after cessation of exposure Cd-U drops quite slowly over time. When exposed to cadmium, Cd-U also increases slowly. 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 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 5 µg Cd/g creatinine.

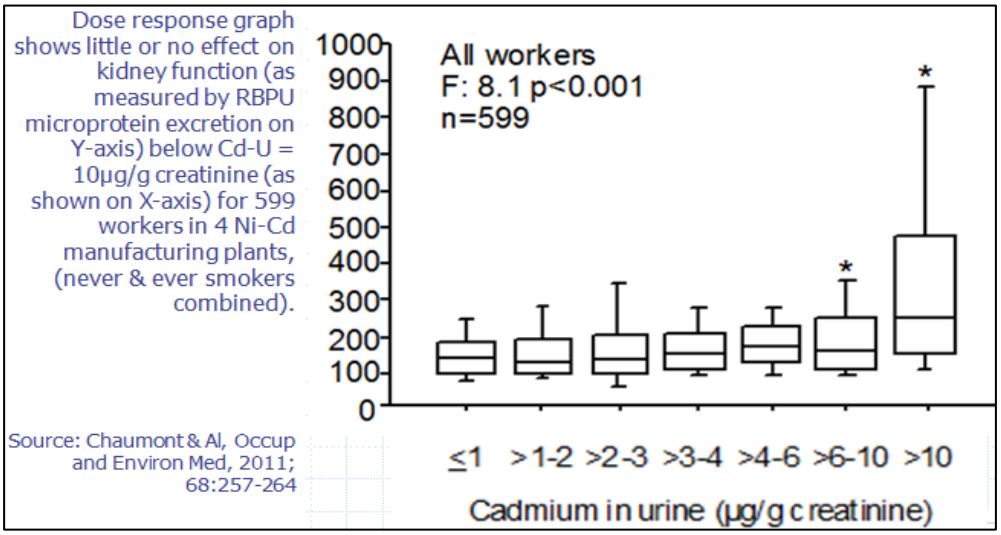

Figure 1. Urinary RBP (effect biomarker) as a function of Cd in urine (exposure biomarker, adapted from Chaumont et al 2011.)

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 (α_1-microglobulin, also called protein HC)
- β_2-microglobulin (β_2-M)

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

β_2-M 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.

Table 1 shows the guideline used to interpret the levels of microprotein excretion.

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.e.* 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 nephropahy 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.)

Table 1. Interpretation of elevated values of urinary β_2-microglobulin (β_2-M) and retinol binding protein (RBP) induced by occupational or environmental exposure to Cd

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5.4 Using "exposure biomarkers" to conduct preventive medical surveillance

5.4.1 Using Cd-U:

- **Cd-U =< 2 µg Cd/g creatinine** [2 µg 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 µg Cd /g creatinine < Cd-U =<5 µg Cd/g creatinine [5 µg 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 µg Cd/g creatinine (red zone, see Figure 2):**
    - worker is removed from Cd exposure, biomonitoring 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 µg Cd/L or the exceedance of the first action level of 2 µg 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 µg Cd/L or the exceedance of the second action level of 4 µg Cd/L triggers the removal of the worker from exposure.**

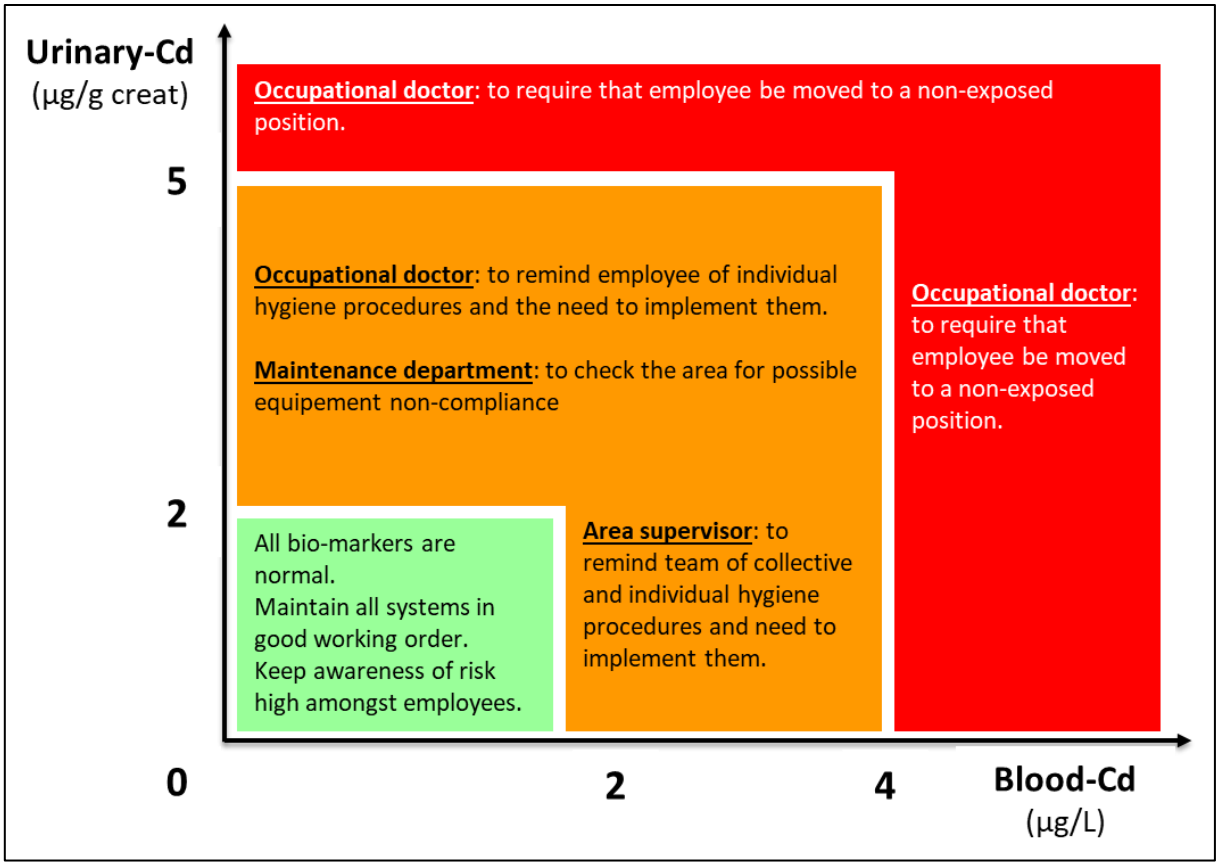

Figure 2. Decision diagram

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 (RPB) and for beta-2 microglobulin (β_2-M) or 700 µg/mmol creatinine (=6200 µg/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 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 report on a yearly basis the status of the several Similar 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
CMR Carcinogenic Mutagenic Reprotoxic
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
SEG Similar Exposure Group

9 References

1. Bernard A (2004). Renal dysfunction induced by cadmium: biomarkers of critical effects. Biometals, 17: 519-23.
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4. Lombaert, N.; Gilles, M.; Verougstraete, V. Cadmium Monitoring at the Workplace: Effectiveness of a Combination of Air and Biomonitoring. Toxics 2023, 11, 354. https://doi.org/10.3390/toxics11040354
5. Directive EU 2019/983 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work.
6. European standard EN 143- Respiratory protective devices - Particle filter - Requirements, testing, marking
7. 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.
8. 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.

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