MANAGEMENT OF MERCURY CONTAMINATED SITES

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Euro Chlor

Euro Chlor is the European federation that represents the producers of chlorine and its primary derivatives.

Euro Chlor is working to:

- improve awareness and understanding of the contribution that chlorine chemistry has made to the thousands of products, which have improved our health, nutrition, standard of living and quality of life;
- maintain open and timely dialogue with regulators, politicians, scientists, the media and other interested stakeholders in the debate on chlorine;
- ensure our industry contributes actively to any public, regulatory or scientific debate and provides balanced and objective science-based information to help answer questions about chlorine and its derivatives;
- promote the best safety, health and environmental practices in the manufacture, handling and use of chlor-alkali products in order to assist our members in achieving continuous improvements (*Responsible Care).*

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Prior to 1990, Euro Chlor's technical activities took place under the name BITC (Bureau International Technique du Chlore). References to BITC documents may be assumed to be to Euro Chlor documents.

RESPONSIBLE CARE IN ACTION

Chlorine is essential in the chemical industry and consequently there is a need for chlorine to be produced, stored, transported and used. The chlorine industry has co-operated over many years to ensure the well-being of its employees, local communities and the wider environment. This document is one in a series which the European producers, acting through Euro Chlor, have drawn up to promote continuous improvement in the general standards of health, safety and the environment associated with chlorine manufacture in the spirit of *Responsible Care.*

The voluntary recommendations, techniques and standards presented in these documents are based on the experiences and best practices adopted by member companies of Euro Chlor at their date of issue. They can be taken into account in full or partly, whenever companies decide it individually, in the operation of existing processes and in the design of new installations. They are in no way intended as a substitute for the relevant national or international regulations which should be fully complied with.

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This document has been drawn up by the Environmental Protection Working Group to whom all suggestions concerning possible revision should be addressed through the offices of Euro Chlor.

Summary of the Main Modifications in this version

Section	Nature
All	Reorganisation of some chapters and elimination of not industrially applicable methods
All	The word “remediation” has been replaced by the more general “risk management measures”

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FOREWORD

This document aims to give a state of the art of the management of mercury contaminated sites, showing which items have to be developed and/or confirmed in the practice. As actions are in progress in Europe and in North America (see USEPA study in ref. 1), this document will be periodically updated based on gained expertise. Nevertheless, it does not preclude that other techniques in development could be tried in industrial sites and give satisfactory results.

It must be emphasized that the purpose of this document is not the creation of a contaminated site management guide, but that of providing managers with a relevant and updated review of techniques and trends in site characterisation, risk assessment and subsequent site management, including monitoring and risk management measures. Thereby the reader will encounter a useful toolbox from which to select, with the aid of qualified environmental professionals, and attending to specific local, regional and national regulations, the techniques and technologies which best suit each individual site, and which will undoubtedly be modulated by socio-economic and political considerations.

To protect workers' health, it is necessary to control exposure to mercury. For more detailed information about workers protection in case of exposure to mercury, it is advised to consult Euro Chlor document ***HEALTH 2 - Code of Practice: Control of Worker Exposure to Mercury in the Chlor-Alkali Industry*** (ref. 2)***.***

1 BACKGROUND

In Europe, about 30% of chlorine was still produced by the mercury process at the beginning of 2012. At some stage in the future, and in agreement with the Euro Chlor commitment, mercury cell chlor-alkali plants will be decommissioned by 2020 at the latest.

Efficient better technical measures and provisions against soil contamination from spills and leaks and waste disposal in a safe and traceable manner are available. Nevertheless, this has not always been the case in the past and, in some cases, historical mercury contamination in the subsoil is present. Additionally to the production unit area, consideration should also be taken for possible old and badly recognised (and investigated) waste landfills that may have occurred on some sites.

As far as contamination through atmospheric deposition is concerned, previous studies (Ref. 3 and 4), have shown that the levels of contamination within site limits are often rather low (generally less than 10 ppm) and limited to the superficial topsoil (~30 cm) in the surroundings of the mercury cells. This pathway is usually not expected to impact the groundwater quality, but should be confirmed case by case.

Moreover, experience has shown that concentration of mercury in the top soil 500 meters downwind from the cell room is typically less than 300 ppb and is usually of no concern (ref. 5), but also in this case the local situation should be assessed.

Historically, the soil of an electrolysis unit can have been contaminated by mercury in different main forms:

- elemental metallic mercury
- ionic mercury (II) chloride (from bine leaks)
- solid mercury sulphide (from handling of liquid effluent treatments precipitates)

Additionally, this mercury can have evolved into forms like other inorganic salts (sulphates …) and organo-mercury compounds.

This paper deals only with subsoil contamination resulting from spills, leaks, waste disposal and not with the indirect pathway of soil contamination through atmospheric deposition.

Management of mercury contaminated sites will have to satisfy three main driving forces, according to the sustainability concept:

- Protection of human health and environment
- Responsible Care programme of the chemical industry
- Economics: an economic evaluation of the different possible solutions has to be set up to select the most cost effective and sustainable solution.

This document is a general framework for the management of mercury contaminated sites. It is based on the three following points in order to support the decision making.

1.1 Define the current situation and the future use/development of the site

Knowing the historical, actual and any planned future use of the site is necessary in order to develop relevant scenarios to be taken into account when evaluating the risk. This implies the development of a robust site specific conceptual model.

1.2 Assess the risk associated with the contamination

In general, risk assessment consists in the determination of the potential consequence of a situation, and the probability that these consequences could occur.

In the context of contaminated land, a contamination (source) may represent a danger (toxicity, radioactivity, pathogenicity…). For any receptor (human, environmental), the probability of exposure to the danger represents the risk. In the case of chemical contamination, there must be an exposure pathway (link from the substance to the receptor) in order for a risk to occur.

At chlor-alkali plants, this means identifying

- the source (mercury concentration, localisation/-depth …)
- the pathway (exposure through vapour phase, groundwater, surface water migration …)
- the receptors (workers, residents, ecosystem …)

1.3 Decide the actions to be taken in case of risk

The risk management strives to break the link mentioned above by:

- source control, removing the source or reducing the danger (toxicity, exposure) associated with the contaminant (e.g. changing the speciation for metals)
- pathway/exposure control: barriers or cut off screens (capping, containment, immobilisation …)
- receptors control: restriction of use.

Monitoring provides verification as to whether the objectives of the actions taken are met.

To our understanding a risk management/fit for purpose approach, as stated in the CLARINET-NICOLE statement, will give the best results in terms of risk reduction, environmental merit and financial impact (see http://www.nicole.org/publications/NICOLEjoint2.PDF). This approach was incorporated in the Commission proposal for the directive 2006/0086 (ref. 6) on contaminated soils management, but the Council decided to temporarily put in hold the decision process (progress report 7100/19 of March 2010).

The activities to be undertaken during these steps are site specific and dependent on such issues as pollution intensity and extent, local hydrogeology, presence of potentially threatened targets.

There are a range of existing tools which may be directly applied to mercury contaminated sites, others may need some adaptations and some may be not widely applicable at present. New techniques may need to be developed to ensure cost effective management.

Sharing resources, experiences and cooperative development of techniques would be the first step in setting up an efficient, cost effective management of mercury contaminated sites.

2 SITE CHARACTERISATION

The site characterisation is dealing also with the exposure scenarios and includes three major steps with the following objectives:

- *Desk study*: to identify, from the available data (including historical, actual and future use of the site), all relevant potential sources, pathways and receptors scenarios for a specific site, and then using conceptual models and a preliminary hazard assessment to select the relevant scenarios and to eliminate the implausible ones.

- *Screening survey*: to assess the presence of contaminated areas using rapid and cost effective screening methods.
- *Confirmation survey:* when contaminated areas are identified in the screening survey, to quantify their extent.

In some cases, other data could be required (e.g., to perform a detailed risk assessment) and further characterisation may be necessary.

Due to the physico-chemical properties of metallic mercury, care must be taken when carrying out engineering work during the characterisation of the site to avoid the formation of preferential pathways or the mobilisation of contamination:

- It is important to take into account the “nugget effect” of looking for tiny beads of elemental mercury in building structures and geological media
- Separated phase (mercury droplets) tend to sink down the profile during soil sampling (liquid state, hydrophobicity, superficial tension and high density)
- Metallic mercury droplets render the contamination highly heterogeneous at a very small scale, making representative sampling very difficult
- Volatility of the metallic phase should not be overlooked (losses, health and safety issues).

Therefore standard tools for site characterisation may not be suited for mercury contamination. However, there are a number of technologies that have been employed with varying levels of success. For the three steps presented above, the following tables highlight what is available and what developments/adaptations are needed (shaded) to be applicable to mercury contamination.

2.1 Desk Study

	Comments	Status
Existing protocols and good practice manuals	Underground structures have to be localised Special attention is needed for sewer and buried pipes as potential secondary point sources Past waste management (areas concerned) and maintenance practices should not be forgotten	Applicable to Hg contaminated sites

Areas with potentially mercury contaminations in soil and in groundwater can basically be summarised as follows:

- The production areas, and especially those of the cell room and other particular units (e.g. waste handling and retorting, maintenance …), can be highly contaminated
- The areas surrounding the production zone can be contaminated as well by cross contamination
- The walls, floors and structures of the cell room (e.g. concrete, bricks and wood), and their surface covering, can be contaminated by absorbed mercury
- The metallic structures and tanks can be contaminated by absorbed mercury in their superficial layer
- Sludge contaminated with mercury can accumulate in open and underground sewers
- The groundwater can be contaminated.

Even if in some parts of the process mercury can be found in ionic form (historical leaks of brine for example), it is mostly present as metallic component (Hg^0); nevertheless the pH and Redox potential of the soil can also influence the chemical form of the mercury; oxidising conditions can stabilise the ionic forms (Hg^{2+}), while slightly reducing conditions can favour the transformation of ionic and organic mercury into its metallic form. This form can be converted biologically into the toxic alkylate forms, representing usually less than 1% of the total, but potentially relevant in some scenarios due to their volatility and solubility into water.

2.2 Screening Survey

The screening survey should consider the characterisation of the geology, hydrology and hydrogeology as well as the nature and distribution of any potential contamination.

2.2.1 Soil gas survey

A soil gas survey measures the vapour content in the unsaturated soil. It can only be applied to detect metallic mercury but the effectiveness depends strongly of the permeability of the soil. **The method would not detect contamination by mercuric or mercurous salts (difficult to detect as much less volatile), possibly overlooking area with presence of mobile mercuric ions that could present a risk for underlying groundwater**.

	Comments
Soil gas survey	Potentially applicable to metallic mercury contamination (volatility of Hg°) On site measurement possible (rapidity) Measurement possible over a significantly greater volume than with discrete soil sampling Fast and low cost but validation is needed for Hg (for mercuric soils and metallic mercury)

2.2.2 Geophysical methods

Geophysical methods work by measuring contrast of the measured physical parameter (electrical resistivity, gravitational field, sound …).The sensitivity is limited by the presence of underground structures (e.g. foundations/sewers). It works well for groundwater, geological layers and buried metals, but the sensitivity is too low for many environmental applications, in particular in the case of mercury contamination because of

- The relative low level of contamination
- The high heterogeneity of the contamination
- The presence of interfering factor on the industrial sites such as buried cables, pipes and co-contamination.

	Comments
Geophysical methods (electrical resistivity, electromagnetic, georadar and gravimetric methods)	Non-intrusive, global Each tool has its own limits Measurement possible over a significant greater volume than with discrete soil sampling Need to use a number of techniques in conjunction with other more traditional methods Interferences with pipes cables, chloride co-contamination

2.2.3 X-ray fluorescence

X-ray fluorescence is a rapid method for the determination of chemical elements in a matrix. In the portable format, it has been applied to screening solid matrix for heavy metals. The sensitivity of the method varies; for mercury it is rather low compared to the environmental standards (limits). It can be used for the identification of hot spots (highly polluted areas). XRF scans a very small section of the sample, so it is inherently unsuitable for determining the average mercury content of raw coarse, heterogeneous material in the field. Such material must be homogenised (e.g. by grinding of a representative sample) before a useful quantitative measurement can be made.

	Comments
Portable X-ray fluorescence	Rapid, low cost, on-site measurement Poor sensitivity (detection limit~25 ppm total Hg) Useful for screening hot spots Measurement possible over a significant greater volume than with discrete soil sampling Small window area of the instruments means that the effective area surveyed by each scan is very small. Areas scanned are typically 1 cm^2 and scan to a maximum depth of 2 mm.

2.2.4 Other methods

Some field screening techniques are available but have not been validated for mercury contamination or, in their present state of development, show serious limitations like a lack of sensitivity with regards to the environmental standards.

For metallic mercury, a screening technique like camera mounted push probe still needs development and confirmation.

2.3 Confirmation Survey

It is necessary to confirm the results of the screening survey.

At assumed hot spots, careful test pits could be preferred to drilling with speciation of the mercury compounds.

Groundwater should also be monitored (e.g. flow direction, volume and content) during this phase.

	Comments	Status
Sampling protocol and strategy	Existing norms and guidelines for soil and water (ref. 7) Care should be taken to avoid creation of pathways for contamination	Sampling : adaptation needed to take into account metallic Hg droplets in soil (nugget effect) Strategy has to be adapted in function of the heterogeneity of underground and contamination
Hg total assay	Existing norms for soil and water (ref. 8, 9 and 10)	Care must be taken in handling samples containing humic/uric acids
Hg speciation	No established norm	Methyl-Hg : debate over the protocols in the scientific literature (ref. 11 and 12) Other forms : work done in the scientific community (ref. 13)

In conclusions, tools already exist to characterise a site but, due to the physico-chemical properties of mercury, case and site specific strategies are needed to improve the reliability of the characterisation of mercury contaminated sites.

3 SITE RISK ASSESSMENT

Risk assessment is carried out with the objective of assessing the risk posed by the mercury contaminated soil for receptors over time and space and for the specific land use. In some cases, food chain and eco-toxicity issues must be taken into account.

If mercury contamination of groundwater is suspected, attention must be given to the possible toxic effects of abstracted groundwater and to conformance with the EQS (environment quality standards) if groundwater discharges into a controlled water body.

Current models (ref. 14) used for risk assessment give a picture of the risk over space at a specific point in time (now) and assume steady state. They generally use total concentration input data and assume fixed coefficients for real impact on the receptor (human or environment). Neither site specific speciation nor substance specific bioavailability data are taken into account in the models, although the bioavailable fraction of the contaminant in the soil is a central concept in risk assessment. It can be defined (ref. 15) as "… the fraction of a compound in a matrix that, when released from the matrix, can be absorbed by an organism. This absorbed compound is then available to cause a biological effect."

To our knowledge, no model can estimate the evolution of the risk over time. Risk could evolve due to change of the mobility of mercury (speciation, precipitation, adsorption and volatility) over time. If the site or surrounding use changes, the risk evaluation may need to be reviewed.

To establish a high degree of confidence in the results generated during the risk assessment, consideration should be given to the use of experienced professionals/academics for peer review. The basis of selection is also their awareness of such issues as European and local legislations.

	Comments	Status
Risk calculation/ models	Models account for some speciation / bioavailability effect but not necessarily from site specific data TDI values provided by WHO	Selection of existing models is country specific Models are not Hg specific Based on total concentrations, no prediction of the evolution of the risk over time

	Comments	Status
Bioavailability	Important parameter in risk assessment Biosensor for Hg and methyl-Hg could be developed	Norms exists: Soil quality - requirements and guidance for the selection and application of methods for the assessment of bioavailability of contaminants in soil and soil materials - ISO 17402:2008
Leaching test/mobility	Existing leaching test for waste Soil and sediment are considered as sinks for heavy metals including Hg Sediments are identified as a major compartment where speciation reactions which are significant for risk assessment occur	ISO norm for soil (ref. 16) Significant amount of data for mobility evaluation in the literature : adsorption coefficients on soil, humic material, sediments for ionic Hg and methyl Hg (ref. 17 and 18)

In conclusion, models for risk assessment are available, but their applicability to mercury contaminated sites must be critically reviewed in the light of the available data on toxicity, speciation and mobility of mercury. Sensitivity analysis should be considered when assessing the parameters used within the risk assessment.

4 SITE MANAGEMENT

Site management options will be defined according to the defined future use of the site and the results of the risk assessment. Options include:

- *Risk management measures* with the objective of limiting the risk at an acceptable level to the receptors for the intended use of the land
- *Monitoring* with the objective of judging the contamination risk evolution over time and space (e.g. air and groundwater).

4.1 Risk Management Measures

Risk can be mitigated by acting on any of the three elements of the risk chain or by a combination of those:

- At the level of the hazard, by source control (i.e. reducing the amount of dangerous substances or by transforming the form of the element to obtain a less dangerous one).
- At the level of the pathway transfers, by cutting of the linkage to the receptor (i.e. containment of the source).

- At the level of the receptor, by controlling use of the land so that receptors will not be exposed to the hazardous substance.

4.1.1 Hazard Reduction Measures (source control)

It must be noted that different possible mercury contaminated soil treatment methods have been published, but the majority has only been applied at laboratory or pilot scale and only a few on industrial scale.

There was also sometimes a confusion introduced between waste/sludge (more homogeneous) and soil treatment, the last one being characterised by:

- very random distribution of the contamination (for metallic mercury)
- unknown mercury compounds types present
- large inhomogeneity of the substrate
- unknown chemical characteristics of the soil
- presence of underground voids and structures

Two modes of hazard reduction measures can be considered:

- In situ treatment which is performed without excavation of the soil
- On site and off site treatments applied after excavation of the contaminated soil

Soil treatment operations are time consuming and expensive. Generally, they are focused on hot spots. Excavations are technically difficult in the presence of underground structures (e.g. pipes and foundations), under buildings and for deeper contaminations, especially in the presence of an aquifer. Excavation techniques could lead to create additional pathways/cross contaminations with further downwards mobilisation/migration of the metallic mercury. They require very strict measures to protect workers and environment against exposure to the contaminants.

Additionally, these techniques can create the risk of dispersing the contamination into the environment. Where such potential risks exist, very careful work (e.g. handwork) might be recommended for digging and removing underground pipes and structures.

	Comments
Thermal treatment (ref. 19 and 20)	On site or off site treatment after excavation Gaseous effluents to be treated Classical high temperature (>800°C) or lower T° (<500) + partial vacuum Impacts on the mechanical properties of the ground, load bearing capacity Impacts on underground services (gas, electric etc.) May affect the leaching potential Health/hygiene issues to be monitored at units

	Comments
In situ thermal treatment (ref. 21 and 22)	Electrical heating/vapour extraction; the treatment is technically very sophisticated. Potential mobilisation of mercury vapours and health/hygiene issues to be monitored around operating units Applied for organics
Physical treatment Dry and wet classification (ref. 19 and 20)	On site or off site treatment after excavation If Hg contamination is associated with the fine fraction ⇒ reduction in volume and mass of the residue to be disposed or treated Applicable to soil with low fine and organic matter content Health and safety issue not to be overlooked during excavation and treatment (Hg vapours, contaminated dust)
Hydro-metallurgical extraction	On site or off site treatment after excavation Extraction with chemicals Technically feasible only for small quantities considering the enclosure and filter system required.
Electro-remediation (ref. 23 and 24)	Applicable in situ or on/off site after excavation Need for an extracting solution (oxidant/complexing agent) Little in situ data; the electro-osmotic flow may yield to a significant risk of uncontrolled migration of the leaching solution Applicability in heterogeneous soil (layer of varying conductivity)? Applicability on industrial site with lots of conductive material in the soil (pipes, wires)? Results of pilots studies with questionable success
Immobilisation inertisation	For excavated material and waste Does not avoid the cost of disposal
	In situ application : precipitation as sulphur compounds of soluble mercury or immobilisation with hydraulic binder No long term experience (behaviour of immobilised form).
Chemical extraction	Difficult to apply due to the heterogeneous contamination
Disposal without treatment	Available for landfill and mines

In conclusion, commercial solutions exist for hazard reduction on excavated materials (on/off site). They rely on dry and wet classification, on thermal desorption, on (underground) disposal or a combination thereof. The major limitations to their use are their relatively high cost and slow process, without considering the problems related to the excavation itself.

Where site configuration requires in situ techniques for hazard reduction, only immobilisation/stabilisation is currently commercially available.

4.1.2 Pathway Cut off

Containment techniques apply equally to mercury contamination as to any contamination. The principle is the cut-off of the exposure pathways. Possible techniques include

- hydraulic containment (pump & treat) where the exposure route is via the aquifer
- mechanical containment that is typically an in situ method covering:
    - horizontal capping to minimise migration either through evaporation or leaching by rainfall
    - vertical low permeability barrier installed in the subsurface to minimise/eliminate migration via groundwater flow

In some cases, limitations or geotechnical restrictions for future land use could arise from the existence of underground structures.

4.1.3 Measures at Receptor Level

It encompasses simple measures such as restricting the use or, if necessary, fencing and prohibiting access to the contaminated body (land, aquifer...); they should be used immediately and, in some cases, these restrictions can be limited in time.

4.2 Monitoring

4.2.1 Vapour monitoring

Consideration should be given to the end use of the site and if necessary vapour monitoring, to assess the likelihood of vapour emissions from contaminated ground into buildings.

4.2.2 Groundwater monitoring

The sampling strategy and analysis protocols must be specific to the monitoring required for each specific receptor as defined by the risk assessment. The frequency of the monitoring requirements will depend on the amount of knowledge of the long-term behaviour of the contamination.

	Comments	Status
Sampling strategy	General protocol existing	To be developed specifically for Hg; work on going (ref. 25)
Analysis	General methods exist for total mercury	Soil Quality ISO 16772 – 2004 Water Quality ISO 17852 - 2006

In conclusion, general tools already exist and specific approaches for mercury are currently being further developed.

5 HEALTH AND SAFETY

For all the activities related to mercury and contaminated materials or soils it is necessary to follow the guidance in the ***Env Prot 3 – Guideline for Decommissioning of Mercury Chlor-Alkali Plants*** publication (ref. 26) about health protection and safety, request the use of suitable clothes and monitor the mercury exposure of workers.

6 BREF FOR THE CHLOR-ALKALI MANUFACTURING INDUSTRY

This document published in December 2000 gives information for the treatment of mercury containing wastes. The general recommendation about the treatment is related with the mercury content of the waste, selecting distillation, when possible, for high concentrations, and landfills for the others. It contains a review of all the European legislation for mercury containing wastes at the moment of redaction (1999).

The update of the BREF document has started in 2009 and the first draft has been published end of 2011; it contains a more elaborated chapter on site remediation.

7 SUMMARY

To manage mercury contaminated soils as a result of historical spills, leaks or waste disposal, the following steps must be considered:

- Inventory
- Site characterisation (historical and current)
- Detailed site specific conceptual model
- Exposure scenarios (current and future)
- Targeted risk assessment

- Site management (monitoring, risk management measures, etc.)

The future use of the site should be a guide in defining the measures to be taken.

The activities to be undertaken during these steps depend on the site specificities (pollution intensity and extent, hydrogeology, exposure pathway risks, potentially threatened targets etc.).

There is a range of existing tools (e.g. norms and guidance on characterisation, sampling and analysis, geo-modelling …) which may be applied, and some of them may need to be adapted to the specificity of mercury. A technico-economic evaluation of the different possible solutions has to be set up due to the fact that some tools could be unsustainable or not yet practically proven.

Regarding site characterisation, tools already exist but, due to the physico-chemical properties of mercury, specific tools are needed to improve the reliability of the characterisation of mercury contaminated sites.

For targeted risk assessment, models are available but their applicability to mercury contaminated sites must be critically reviewed in the light of the available data on toxicity, speciation and mobility of mercury.

For site monitoring, general tools already exist and specific approaches for mercury are currently being developed.

Regarding risk management measures, solutions exist at the level of

- Hazard reduction on excavated materials (on or off site). They rely on dry and wet classification, on thermal desorption, on (underground) disposal or a combination thereof. The major limitation to their use is their relatively high cost and lack of sustainability (cf. problems related to excavation). Where sites configuration requires in situ techniques for hazard reduction, only immobilisation/stabilisation is currently commercially available.
- Pathway transfers, i.e. containment techniques.
- Receptors, via restriction of use.

In synthesis, the following points should be kept in mind:

- disconnection of pathways should be considered as first choice
- as excavation might create more problems (cross-contaminations, further pathways) as it solves, remediation -if required- should focus only on the hot spots, if needed
- foundations should only be touched very carefully to reduce disturbances and risk of vertical migration of the mercury.

8 REFERENCES

1. Treatment Technologies for Mercury in soil, Waste and Water, US EPA August 2007

2. ***HEALTH 2 - Code of Practice: Control of Worker Exposure to Mercury in the Chlor-Alkali Industry***

3. Mercury in plants, soil and atmosphere near a chlor-alkali complex, B.E. Maserti, R. Ferrara, Water, Air, Soil Pollution; 1991, 56, 1: 15-20

4. Estimating distribution and retention of mercury in three different soils contaminated by emissions from chlor-alkali plants, part 1 - H. Biester and al. - Elsevier, The Science of the Total Environment 284 (2002) 177-189. Binding and mobility of mercury in soils contaminated by emissions from chlor-alkali plants - H. Biester and al. - The Science of the Total Environment 284 (2002) 191-203

5. Euro Chlor Risk Assessment, Mercury - Local Scenario (internal document)

6. Proposal for a Directive … establishing a framework for the protection of soil … (2006/0086)

7. Different ASTM Standards related to environmental site characterisation package

8. EN 1483: 2007 - Water quality – Determination of mercury (Atomic absorption spectrometry – method after digestion with permanganate peroxodisulphate)

9. ISO 5666: 1999 - Water quality – Determination of mercury (Flameless atomic absorption spectrometry - method after pre-treatment with ultraviolet radiation and method after digestion with bromine)

10. ISO 11466: 1995 - Soil quality – Extraction of trace elements soluble in aqua regia

11. Artifact formation of methyl mercury during aqueous distillation and alternative techniques for the extraction of methyl mercury from environmental samples. Fresenius J. Anal. Chem. ; 1997, 358: 371-377

12. Determination of artifactual formation of monomethylmercury (CH_3Hg^+) in environmental samples using stable Hg^{2+} isotopes with ICP-MS detection: calculation of contents applying species specific isotope addition - Fresenius J. Anal. Chem. ; 1997, 358: 363-370

13. Determination of mercury binding forms in contaminated soils: mercury pyrolysis versus sequential extractions - Environ. Sci. Technol.; 1997, 31: 233-239

14. Mercury study report to Congress - Volume III: An assessment of exposure from anthropogenic mercury emissions in the United States - EPA-452/R-96-001c, April 1996

15. Environmental distribution and transformation of mercury compounds - Crit. Rev. Environ. Sci. Technol.; 1996, 26: 1-43

16. ISO/TS 21268-2: 2007 - Soil quality - Leaching procedures for subsequent chemical and eco-toxicological testing of soil and soil materials - Part 2: Batch test using a liquid to solid ratio of 10 l/kg dry matter

17. Adsorption/desorption isotherms of Hg(II) by soil - Soil Sci. 1997, 162: 35-45

18. Effects of pH, chloride and calcium (II) on adsorption of monomethylmercury by soils - Environ. Toxicol. Chem.; 1997, 16: 2457-2462

19. Remediation of the Marktredwitz chemical factory – First experiences of a large-scale washing and distillation plant for mercury contaminated sites in Bavaria F. Defregger - Contaminated Soil, 1995 vol.2, pp.903-910

20. Remediation of mercury-contaminated soils – Development and testing of technologies - Topical Report, May 1992 – December 1994. Gas Research Institute (GRI-94/0402) North Dakota Univ. Grand Forks 1995

21. Destroying PCBs in soil at a dragstrip – In situ - Environ. Technol. 1997, 7(5):

22. Geosafe Corporation – In situ vitrification - SITE Technology Profile – Demonstration Programme- EPA/540/R-97/502 , December 1996 pp. 78-79

23. Lockheed Martin Missiles and space Co. and Geokinetics International, Inc. – Electrokinetic remediation process – - SITE Technology Profile – Demonstration Programme- EPA/540/R-97/502 , December 1996 pp. 200-201

24. Electrokinetic remediation of mercury-contaminated soils using iodine/iodide lixiviant - Environ. Sci. Technol. 1996, 30: 1933-1938

25. Sites et sols pollués – Réalisation d'une surveillance - Cas du mercure historique dans les sols - Syndicat des Halogénés et Dérivés, 1999

26. ***Env. Prot. 3 - Guideline for Decommissioning of Mercury Chlor Alkali Plants***

Some additional information is available on the two following websites:

http://www.nicole.org/

http://www.umweltbundesamt.at/en/clarinet

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