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EXECUTIVE SUMMARY OF THE STATUS REPORT ON THE MANAGEMENT OF BY-PRODUCTS/RESIDUES CONTAINING HEAVY METALS AND/OR PERSISTENT ORGANIC POLLUTANTS

Prepared by the Task Force in collaboration with the secretariat */

1. This executive summary was prepared at an editorial meeting of the Task Force held in Rome from 7 - 9 March 2001. It is based on a draft document prepared by Environment Canada.

*/ This document has not been formally edited.

I. INTRODUCTION

2. At its sixteenth session, the Executive Body established a Task Force on the Management of By-products and Residues Containing Heavy Metals and Persistent Organic Pollutants (POPs). Its objective was to prepare a state-of-the-art report on the management and use of by-products/residues containing primarily heavy metals and persistent organic pollutants generated by different combustion and industrial processes, including incineration and other control techniques. The report should have an executive summary and include conclusions and draft recommendation and, where appropriate, proposals to modify or to extend control techniques under the existing protocols to the Convention. Based on the output of the Task Force's work, conclusions and action-oriented recommendations including proposals to modify or to extend control techniques for managing in an integrated manner by-products, mainly HMs and POPs, will be drawn-up for consideration by the Working Group on Strategies.

3. The Task Force built on earlier work conducted by the Task Force on By-products Utilization and Waste Management from Fuel Treatment and Combustion (1986-91) and the Task Force on By-product Utilization from Stationary Installations (1991-96), and their respective Status Reports. The Task Force, led by Austria, held four meetings (Salzburg, Brussels, Ottawa and Zagreb) and one editorial conference (Frascati/Rome). Experts from Austria, Belgium, Canada, Croatia, the Czech Republic, Denmark, Hungary, Italy, the Slovak Republic and Slovenia attended meetings of the Task Force. Members of the UNECE secretariat were also in attendance. The work of the Task Force was supported by the Union of the Electricity Industry (EURELECTRIC), who hosted the meeting in Brussels and Euro Chloro Federation (representing the Western European Chlorine industry), who supported the writing of the chlor-alkali chapter.

4. The Task Force addressed the management of by-products and residues from the following industrial sectors: waste incineration; co-incineration; thermal electric power production; small-scale firing energy production; iron and steel production; aluminium production; copper, lead and zinc production; pulp and paper production; oil refineries; and chlor-alkali electrolysis. Information on these sectors was collected and reviewed. A questionnaire for most of the sectors was prepared and distributed to Parties, requesting information on the management of the by-products and residues from these sectors.

5. The Status Report summarizes the findings of the Task Force. It describes how the by-products and residues of the selected industrial sectors are currently being managed and what constitutes the "state of the art". There are chapters on each sector, background information, legal instruments, conclusions and recommendations. Responses to the questionnaires are summarized in tables towards the end of each sectoral chapter.

6. The recommended practices suggested may be used by sector facilities, regulatory agencies and the general public as sources of technical and policy guidance in the development and implementation of environmental protection practices and requirements. However, interpretations of the recommendations should be undertaken in consultation with the appropriate regulatory authorities and stakeholders. All legal requirements must be met, and the recommendations do not remove obligations to comply with all local, national or international requirements or agreements.

II. DEFINITIONS

7. The following definitions are used in this Status Report:

"Waste prevention": Measures that prevent the generation of waste at source;
"Waste minimization": Measures that reduce the waste at the source (i.e. waste prevention), and environmentally-sound recycling and recovery [US-EPA];
"Recovery": Comprises all measures for recycling and re-use of waste and recovery of energy;
"Recycling": Measures that use specific waste fractions as a secondary source of raw materials;
"Re-utilization or re-use": The successive use of residues by subsequent users;
"By-products": Materials directly produced from a process as secondary products for use (e.g. sulphuric acid from acid plants at base metal smelters, gypsum from some flue gas desulphurization systems);
"Residues": Materials which are discarded from industrial processes for disposal without further use, or which are recovered for further use;
"Wastes": Wastes may include materials that are discarded for disposal with or without the possibility of resource recovery;

Note: The definitions of "Residues" and "Wastes" are similar and used interchangeably in the Report."Residues" takes into account the secondary (residual) nature of these materials derived by processes, and focuses on the use or non-use of the material."Wastes" takes into account considerations of the Basel Convention, and the European Union Council Directive on Wastes, 91/156/EEC.

"Wastes for disposal": Residues that are discarded for disposal without re-use (e.g. coal fly ash from boilers which is land-filled);

"Wastes for recovery": Residues that are managed for direct re-use, reclamation, recycling, energy utilisation or similar alternative uses (e.g. coal fly ash from boilers used in cement);

"Residues for Disposal": Residues disposed of without use, in an environmentally sound manner;

"Residues for recovery": Residues that are recovered for use, in an environmentally sound manner;

"Co-incineration": The use of waste as a regular or additional fuel in a facility whose main purpose is the generation of energy or production of material products;

"Environmentally sound management": Taking all practical steps to ensure that residues and wastes are managed in a manner that will protect human health and the environment against the adverse effects which may result from such residues and wastes;

8. Key principles of sustainable waste management should include:

Prevention principle: waste generation should be minimized and prevented where possible;
Precautionary principle: potential problems should be anticipated on the basis of state of the art or best available technology (BAT);
Producer responsibility and polluter pays principle: those who generate the waste or contaminate the environment should pay the full costs of their actions; and
Proximity principle: waste should be disposed of as closely as possible to where it is generated and where adequate treatment is available.

III. WASTE INCINERATION

9. The types of wastes incinerated in UNECE countries include solid household waste, medical wastes, hazardous wastes and residual wastes. Energy can be recovered from waste incineration, thus lowering fossil fuel consumption that in turn can reduce emissions of greenhouse gases. There are several technologies for waste incineration, including grate firing, rotary kiln with afterburner chamber, and various types of fluidised bed. Use of these technologies can minimize residues containing harmful contaminants, when operated under optimal conditions. Waste incinerators are equipped with flue gas cleaning systems. Examples for flue gas cleaning systems are selective non-catalytic reduction, selective catalytic reduction, de-dusting devices, dry flue gas cleaning systems, quasi-dry flue gas cleaning systems, wet flue gas cleaning systems, and/or fixed bed reactors using activated carbon. The choice of incineration technology and flue gas cleaning system will depend on the nature of the waste and on regulatory conditions.

10. Solid residues from incineration include bottom ash, boiler ash, and filter dust/fly ash. The amount and composition of the residues is dependent on the composition of the wastes fed to the incinerator, the firing technique, and the gas cleaning system used. In terms of volume, bottom ash is the most significant residue generated. The solid residues are mostly composed of a matrix consisting of various silicates and oxides of silicon, aluminium, calcium, magnesium, sodium, and potassium. However, it also contains organic and inorganic substances that can pose a risk to

the environment, including heavy metals such as cadmium, mercury and lead, and POPs such as polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Methods to reduce the potential hazards associated with solid residues include: solidification, physical separation, scrubbing of bottom ash or filter dust/fly ash, low temperature and incineration processes, and melting, sintering, vitrification and plasma processes.

11. Ferrous metals from the bottom ash can be recovered. Some countries use the remaining material for road aggregates, fill, admixture in soil stabilization, masonry bricks, cement replacement material, daily cover in landfills, wind and sound barriers, or as dams in areas with suitable hydrology. In bottom ash the concentrations of harmful substances are less concentrated than in fly ash. However, the bottom ash must be stabilized in an aging process before use and the surface must be covered with a layer of a material with very low permeability.

12. Fly ash and other residues from gas cleaning systems are usually classified as hazardous waste because they contain high levels of heavy metals and POPs. In general, they are not suitable for any sort of recovery because of environmental and health concerns, as well as engineering and economic considerations. Furthermore, fly ash and other residues from gas cleaning must be treated before disposal to ensure that harmful components are immobilized or destroyed. Also, techniques are available to separate heavy metals from fly ash. In some cases, the packing of void volumes in mines with residues can be interpreted as re-use, if this prevents potential hazards such as subsidence or break down of a mine.

13. To protect the environment and human health, long-term chemical analysis of ash residues from waste incineration is needed before full-scale ash re-use is permitted. The disposal of filter dust and other contaminated residues should only be permitted in special landfills, underground dumps, or special areas of conventional landfill sites.

IV. CO-INCINERATION

14. Co-incineration is the use of waste as an additional fuel to generate energy or material products. It is gaining popularity because conventional fossil fuels are becoming increasingly expensive and generate carbon dioxide (greenhouse gas), and in many countries waste disposal options are limited. Several industrial sectors use co-incineration including the cement industry, power plants and firing installations, the pulp and paper industry, iron and steel production, the non-ferrous metal industry, and the chemical industry.

15. Many types of wastes can be used for co-incineration including plastics, used tyres,

sewage sludge and other residues from water treatment, residues and rejects from the pulp and paper industry, residues from wood processing, waste oil/petrol coke, and solvents. Waste fractions for co-incineration should be available in sufficient quantities and be homogenous, easily available, easy and safe to handle, and economically advantageous to use. Household waste should be excluded from co-incineration because it is not homogenous, does not have a stable calorific value, and contains varying numbers and amounts of contaminants.

16. Co-incineration facilities should meet the same emission criteria and have the same monitoring systems as other types of waste incineration facilities, meet certain criteria for process technology, and provide adequate product quality. Before co-incineration is considered, there should always be a comparison on an ecological basis with alternative means for the recovery or re-use of the waste. Toxic substances should be separated through pre-treatment or by flue gas cleaning and careful handling of the solid residues. Co-incineration requires continuous monitoring and control. In cement plants, the high flame temperature almost completely destroys PCDD/Fs, PAHs and PCBs. Nevertheless, the possibility of PCDD/F de-novo synthesis should be taken into account. The behaviour of heavy metals in co-incineration depends on their volatility. Highly volatile substances such as mercury, selenium, and thallium and to some extent cadmium are emitted with the flue gas if no appropriate flue gas cleaning devices (e. g. activated carbon) are installed. Heavy metals of lower volatility are separated with the fly ash or are enriched in internal and external cycles in rotary kilns of the cement industry.

17. Other major parameters that may influence residue characteristics and process technology are the concentration of alkalis, chlorides and chlorinated compounds (as a precursor for PCDD/F formation), the calorific value and the ash content (e. g. sewage sludge) of waste fractions.

V. THERMAL ELECTRIC POWER PRODUCTION

18. Major residues and by-products from thermal power plants include bottom ash, boiler slag, fly ash, gypsum from flue gas desulphurization (FGD) by wet limestone scrubbing, residues from wet, dry and semi-dry FGD, sulphur, sulphuric acid and liquid sulphur dioxide from desulphurization using the Wellman-Lord process, spent catalyst from selective catalytic reduction, residues from fluidized bed incineration and Integrated Gasification Combine Cycle (IGCC) systems, residues from water and effluent treatment and others. Approximately 55 million tonnes of coal combustion by-products and residues were generated from thermal power plants in the European Union in 1999.

19. The characteristics of the residues and by-products from thermal power plants are determined by a variety of factors including the type and composition of the fuel, the combustion

system and conditions, the FGD system used, the de-NO_X system used, and the storage and possible processing of the ash. There are several different types of thermal power plants including coal- and oil-fired power plants, natural gas fired power plants, coal-fired fluidized bed combustion, and gasification systems. In some cases, biomass fuels are used.

20. Residues and by-products from thermal power plants contain heavy metals, POPs, and trace levels of some natural radioactive compounds. Bottom ash contains non-volatile heavy metals, while semi-volatile and volatile ones can be found in the fly ash or flue gas. PCDD/Fs can be formed after the combustion process when flue gas cools on solid surfaces, although this can be prevented by optimizing combustion and flue gas cleaning conditions. The production of residues from thermal power plants can be minimized by the choice and preparation of fuel, and by ensuring the optimal functioning of the combustion system and the flue gas cleaning system.

21. Ashes from thermal power plants may be re-used in a variety of ways, although ashes from different combustion systems and different fuels have different characteristics and properties, making them more or less suitable for different uses. The predominant use of ash from thermal power plants is in the construction industry. Ashes that are not suitable for use in the construction industry can be processed by blending, sieving, grinding, carbon burn-out, electrostatic separation, magnetic removal and chemical treatment to enhance their potential usefulness in other industries.

22. Bottom ash, which is relatively inert, may be used as construction material in some countries. Fly ash, which represents the largest residue fraction, is commonly used as an additive in the manufacture of cement and concrete. In some countries other possible uses include engineered fill material or a soil substitute to construct embankments and dykes, grouts and roads and the manufacture of lightweight aggregates, cenopheres and zeolites. Approximately 48% of fly ash from coal-fired power plants (total production 37 million tonnes in 1999) is re-used in the European Union.

23. Gypsum from FGD can be used by the gypsum or cement industry as a substitute for natural gypsum.

VI. SMALL-SCALE FIRING INSTALLATIONS (BIOMASS AND OIL)

24. This section addresses small scale firing installations (100 kW_{th} to 5 MW_{th}) that use biomass or oil. It does not address domestic firing because the ash is usually disposed of with household waste. The combustion of biomass constitutes about 3% of the primary energy consumption in the 15 European Union Member States and is increasing, resulting in increased

production of biomass (wood) ash. Furthermore, biomass generates more ash than oil, and ash from biomass has higher concentrations of heavy metals, PAHs and PCDD/Fs.

25. Three size fractions of ash are produced during biomass (wood) combustion: bottom (grate) ash, cyclone ash, and filter-fly ash. These fractions differ in their chemical composition, and neither coarse nor fine fly ash should be used as fertilizer. Bottom (grate) ash is rich in nutrients and less contaminated with heavy metals and PAHs than cyclone ash or filter-fly ash. Cyclone ash from natural wood combustion should only be re-used as fertilizer if low contamination is determined. Filter-fly ash contain the highest levels of contaminants. Before management or disposal, biomass ash should be stabilized to minimize dust and corrosivity problems by adding water and agglomeration. Three methods have been studied to agglomerate ash: self-hardening, granulation, and pelletizing.

26. Filter-fly ash from untreated, natural wood should not be used in this way because it contains higher levels of heavy metals and PCDD/Fs. Similarly, ash from treated waste wood or residue wood should not be applied as fertilizer because of the levels of contaminants it contains. Coarse ash should not be applied in forests unless an analysis of the ash is conducted and there is an identified need for a fertilizer, based upon an individual-stand fertilizing diagnosis. If a need is identified, an application of 2 tonnes of ash/ha in 30 years or 3 tonnes of ash/ha in 50 years may be considered.

27. Other ash that should not be used as fertilizer, includes filter-fly ash from the combustion of untreated, natural wood, and any ash from the combustion of treated, waste or residue wood. These may be re-used industrially. Factors to be considered in the industrial re-use of ash includes: their levels of heavy metals, the unique chemical and physical properties of the ash, the amount of ash required, the need for a homogenous ash composition over a long time period, and the acceptance of the industry and local population. Biomass ash that cannot be used as fertilizer or by industry require disposal in landfill. Because of its high water solubility, high pH value, and high hydrocarbon content, this ash must often be treated and disposed of in special landfill sites, unless it is converted into inert material.

VII. IRON AND STEEL PRODUCTION

28. The main processes in iron and steel production are coking, sintering, pelletizing, pig iron production/hot metal production, steel production, and continuous casting and rolling mill processes. Integrated iron and steel production results in about 450-500 kg of residues and by-products per tonne of crude steel produced. Of this, more than 375 kg/tonne is slag and approximately 60 – 65 kg/tonne is dust and sludge from flue gas cleaning and scale. Estimates of

residues generated from iron and steel production in the UNECE member states range from 81.2 – 126.9 million tonnes of slag per year.

29. Production of residues and by-products can be minimized by optimizing existing production facilities and using new technologies. Ways of optimizing existing facilities include reducing emissions from coke production and consumption, recycling by-products and residues into certain sintering processes. These use the new top layer sinter process for residues with a high oil content (up to 3%), the AIRFINE process for gas cleaning in sinter and pellet plants, the emission optimised sintering (EOS) process for reducing emissions from sinter plants, fabric filters to remove PCDD/Fs in sinter plants, and the Lurgi Thyssen (LT) process for flue gas cooling and cleaning, energy recovery, and dust recycling. New technological approaches for minimizing residues and by-products include direct reduction processes for iron (such as the MIDREX, HyL and FIOR processes) and smelting reduction processes (such as the COREX process) that pre-reduce iron ore and then reduce it again in a liquid stage.

30. Approximately 86% of all residues and by-products can be recycled internally and externally, although they should be pre-treated. There are several processes for preparing dust, sludge and scale for internal recycling, although some are still at a developmental stage. They include the hot briquetting process, recirculating converter sludge , integrated recycling of sludge into the LD (Linz – Donawitz) converter, de-oiling mill scale in an indirect heated rotary kiln, using a hydrocyclone on the sludge from the blast furnace gas cleaning system, the Carbofer process (of blowing a mixture of electric arc furnace dust, coal dust and lime into an electric arc furnace), and the circulating fluidised bed process (which is a treatment for fine residues with a middle-zinc content).

31. Slag from blast furnaces can be used externally in road construction, in cement production, as a building material, for road grit and for special products. The possible uses depend on the exact type of slag. Some slag is recycled to the blast furnace and a small amount is landfilled. Steel slag (from electric arc furnaces) can be re-used in the iron-making process, or as a building material, but care should be taken if steel slag is used as a building material because it is not constant in volume and because of its free lime content. In addition, the elutants may need to be characterized because of potentially high levels of heavy metals. Slag from electric arc furnaces contains less free lime and may be used in road construction and hydraulic engineering.

32. Fabric filter dust from electric arc furnaces contains heavy metals (such as zinc and lead) and PCDD/Fs and is considered as hazardous waste in some UNECE countries. Processes for the re-use of dust, sludge and mill scale include: the INMETCO process (to produce sponge iron and recover non-ferrous metals); recycling melting furnace technology (which produces semi-steel

from pre-treated wastes, scrap, hot metal, direct reduced iron or pig iron); the Waelz process (for conditioning dust from steel production in electric arc furnaces with high zinc content); the CONTOP process (for zinc containing wastes); and hydrometallurgical processes.

VIII. ALUMINIUM PRODUCTION

33. Primary production of aluminium takes place through the electrolysis of aluminium oxide (alumina), which in turn is produced by refining bauxite. Secondary aluminium production recycles aluminium by using different types of aluminium scrap as the raw material. The annual aluminium production in the EU in 1996 was 3.96 million tonnes, of which 44% was secondary aluminium production. For primary aluminium production, anode pre-bake technology is considered the “state of the art”. In secondary production, scrap and aluminium containing residues are sorted, processed and re-smelted. Other metals can be recovered by further recycling of residues into other metallurgical processes. In secondary smelters, salt usage and the production of salt slag can be minimised by pre-treating the scrap. To limit dross accumulation, only materials with a minimum of adhering oxide should be used in smelting furnaces operated without salt.

34. “State-of-the-art” flue gas cleaning consists of fabric filters and dry sorption processes, or alternatively injection flow processes. Heavy metals are separated together with the dust. By-products and residues from the aluminium industry include red mud, dross, filter dust, refractory lining, salt slag, and spent pot liner. Most of these may be re-used. Red mud from bauxite refining is usually landfilled. Dross is generated in primary and secondary aluminium production and may contain heavy metals including cadmium and lead. Dross should be recycled internally or externally, rather than being landfilled. After milling or sieving, the coarse fraction can be re-used in secondary production and the fine fraction can be processed with salt slag. In some UNECE countries, dross is considered a hazardous waste.

35. Filter dust can contain heavy metals, such as cadmium and lead, as well as PCDD/Fs and is often considered as a hazardous waste. Most filter dusts are landfilled, although this is not considered to be the “state of the art”. Possible ways of using and managing filter dust include: a desulphurizing agent for the steel industry; decontamination by heat treatment; low temperature treatment and possible treatment in a salt slag recovery plant; re-use in the melting furnace; and decontamination by extraction. The generation of used refractory lining is unavoidable, but the shift from primary to secondary aluminium production will reduce the amount produced. Salt slag can be re-used after solution crystallization processes, although most is currently recycled externally. Spent pot lining can be re-used in pyrometallurgical furnaces or for cryolite production. Use in the cement industry is possible.

IX. COPPER, LEAD AND ZINC PRODUCTION

36. Primary and secondary copper, lead and zinc production can result in the emission of heavy metals such as cadmium, lead, and mercury, and chlorinated hydrocarbons including PCDD/Fs. A priority should be to avoid and minimize the production of residues and wastes containing these pollutants. Many by-products and residues can be re-used, recovered or recycled including slag, drosses and skimmings, collected dusts, leach residues, sulphuric acid, mercury, spent furnace linings and refractories, sludges, and polypropylene from lead production. Depending on its metal content, slag can be cleaned to recover remaining metals of value. Cleaned slags can be re-used in other industrial sectors. Drosses and skimmings usually contain high levels of metals and may therefore be returned to the smelter to recover the metal content. Most dusts from copper production are recycled internally to the smelter, sent for re-use at other production facilities, or sent for the recovery of zinc, lead or other constituents. Dusts that are not recycled or recovered are disposed of. Dusts from lead production may be recycled to the sinter machine, or to the smelter furnace or kiln after being pelletized or agglomerated.

37. Leach residues from copper or zinc ores are usually disposed of in on-site waste and residue areas or in tailings ponds. New techniques can stabilize and immobilize the residues. Process gases containing sufficient concentrations of sulphur dioxide are cleaned to remove dust and volatile metals, such as mercury, and then converted to sulphuric acid, which may be used in the plant or sold commercially. Depending on the process used to remove the mercury, it may be returned to the mercury removal process, stored, or used as a feed material for mercury production. Spent furnace linings and refractories are treated in smelters to form relatively inert slag or are disposed of in landfills. Sludges from wastewater treatment plants and wet air pollution control technologies are filtered or de-watered. Depending on the characteristics of the residue the remaining residues are either returned to the smelter or landfilled. Anode slimes from refineries may be sent for the recovery of precious and valuable metals. Polypropylene materials from battery feedstock in secondary lead production are separated and sent for recycling. PCDD/Fs can be produced during primary and secondary metals production. They condense on small particulate matter and collected dusts. Most collected dusts and sludges from air pollution control equipment are returned to the smelting or sintering processes. Collected dusts and sludges which cannot be recycled or recovered are disposed of.

38. Residues for disposal from zinc production include leach residues (iron-based solids) due to heavy metal content and potential leaching of metals, slags from copper and lead production that cannot be re-used, collected dusts and sludges from air pollution control equipment that are

not internally recycled or sent for metal recovery, mercury-containing sludges and compounds, and spent furnace linings and refractories.

X. PULP AND PAPER PRODUCTION

39. The pulp and paper industry is characterized by four major processes: chemical pulping (Kraft- or sulphate pulping, sulphite pulping), mechanical and chemi-mechanical pulping, recycled fibre processing, and paper-making and related processes. The chemical pulping process produces several residues including inorganic sludge (dregs and lime mud), bark and wood residues, sludge from effluent treatment (inorganic material, fibres and biological sludge), dust from boilers and furnaces, rejects (mainly sand) from wood-handling processes, and ash and miscellaneous material. By-products and residues from mechanical and chemi-mechanical pulping include bark and wood residues, fibre rejects, ash from energy production, and excess sludge from external biological wastewater treatment. In recycled fibre processing, the major by-products and residues include rejects with no recycling potential that are landfilled or incinerated, and wastewater and sludge from wastewater treatment. By-products and residues from paper-making and related processes include rejects from stock preparation, and sludge from water treatment. In addition, wastewater, waste heat and atmospheric emissions are generated by all four processes.

40. The by-products and residues from the pulp and paper industry are managed using several approaches including landfilling, incineration, use in cement plants and brickworks, agricultural use and composting, anaerobic treatment, recycling, and others. Incineration is usually favoured for materials with a high organic content and a high calorific value, such as bark, wood and some types of sludges. Dewatering is usually required prior to incineration. Incineration technologies include rotary kiln, multiple hearth, grate firing, fluidised bed, and combined techniques (pyrolysis and combustion). Some pulp and paper by-products and residues can be re-used by other industries.

41. In some countries, some sludges from primary paper manufacturing are especially suitable for use as a fuel in cement plants or in the brick-making industry provided that emissions of air pollutants do not increase and the properties of the product are not negatively influenced. De-inking sludges and sludges from recovered paper processing are not normally used in cement plants and brick-making because of their contamination with heavy metals, organo-chlorine and other toxic compounds. In some countries sludges from chemical-mechanical, mechanical and/or biological wastewater treatment are used in agriculture. Residues are either landfilled or incinerated. Ash from fluidized bed combustion are used in the cement and brick industry.

Wood waste from chipboard production can be recycled for use as a cat litter adsorbent, in asphalt mixing, in flower pot manufacturing, and in the production of moulded egg cartons.

XI. OIL REFINERIES

42. The refining of crude oil generates solid, liquid and gaseous pollutants. Oil refining processes can be divided into separation processes and conversion processes. The by-products from separation processes include naphthenic acids, refinery gas, and “asphaltite”. Associated wastes include: caustic; sediments and sludges; cleaning residues; scales and rust; and used alkanolamines. The by-products from conversion processes include: C3 - C4 paraffins; hydrogen; sulphur; hydrogen sulphide; methane; benzene rich fraction; refinery (fuel) gases; clarified oil; and cycle oil. Associated wastes include: spent acid; residues and gum; caustic; mercury; products from FGD; catalyst fines and particulates from electrostatic precipitators; slurries and sludges; coke; glassy slag; wastewater; phenols; tar and heavy metal concentrate; and soot.

43. There are several techniques that can be used to minimize the production of residues and wastes, including “cleaner technologies” such as: reverse osmosis for water treatment; process modifications such as minimizing spills and leaks by using mechanical seals and special valves; changing feed quality by using feeds with lower levels of sulphur and heavy metals; additives such as antifouling additives; and reducing waste volume by incineration and other approaches. However, secondary processes, such as FGD and water and effluent treatment, are necessary to reduce emissions to air, water, and soil.

44. Most remaining by-products can be re-used internally. For example, off-specification products can be re-processed by distillation; spent lubricant and refinery gas can be used as fuels; slurry and refinery waste streams from the fluidized catalytic cracking process can be used as a feed or for generating energy; flare gas can be recovered and used as fuel; and catalysts can be regenerated and re-used. Others can be re-used externally. For example, waste lubricants can be re-refined and re-used; spent caustic can be used in the paper industry; by-products from FGD can be processed to yield gypsum, fertilizer and basic compounds used by the chemical industry, such as sulphur dioxide, sulphuric acid, ammonium sulphate and sulphur; calcium fluoride (from alkylation plants) can be used in the steel industry; and spent catalysts can be recovered or used in the cement industry. Remaining wastes should be pre-treated before landfilling, by dewatering, solidification, and/or stabilization.

XII. CHLOR-ALKALI ELECTROLYSIS

45. The main chlor-alkali electrolysis processes are the mercury cell process, the membrane process and the diaphragm process. The mercury cell process generates mercury emissions to air, as well as waste water and other wastes. The membrane process does not use mercury and therefore do not generate mercury containing residues. Annex III of the Heavy Metals Protocol states that existing mercury cell chlor-alkali plants should be phased out as soon as practicable, with the objective of phasing them out completely by 2010.

46. The main potential sources of mercury-containing wastes in a mercury cell plant are the caustic soda filter residue; the hydrogen gas filter residue; sludge from brine filtration; sludge from the inlet box flushing water; sludge from rinsing water to cell room; sludge from the wastewater treatment unit; exhaust gas cleaning filter residue; material from cells; graphite from amalgam decomposers; and sludges from storage tanks. Chlorine and caustic soda may contain mercury, which may be released from them. Proven techniques for the treatment of mercury-containing wastes include mechanical/physical processes, such as brushing and ultrasonic vibration; water treatment; chemical treatment, using hypochlorite, chlorinated brine, or solutions of hydrogen peroxide; and distillation. In general, the mercury content in the waste can be reduced to less than 50 mg/kg. Mercury can be recovered from caustic treatment residues, hydrogen and waste gas treatment when using chemical processes, water treatment sludges, the mercury distillation unit, and the area for handling mercury-contaminated parts. When decommissioning mercury cell plants, measures should be taken to minimize environmental releases of mercury during decommissioning and after shut down. This includes careful management of construction waste from demolished buildings, because of their high mercury content.

XIII. LEGAL INSTRUMENTS

47. The most important international agreement on waste management is the 1989 Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (the Basel Convention). The Basel Convention, which entered into force in 1992, prohibits countries from allowing wastes to be exported to countries that do not consent to receiving such shipments, or where the exporting country believes that the wastes will not be managed in an environmentally-sound manner. In the EU, there are several Council Directives and Regulations on the management of waste. Individual countries within the UNECE region have different legal instruments, as well as different programs and policies, for managing industrial by-products and residues.

XIV. GENERAL CONCLUSIONS AND RECOMMENDATIONS

A. General Conclusions

48. The Task Force concludes the following:

(a) All of the industrial sectors examined generate by-products and residues that may contain heavy metals and/or POPs. Most of the sectors involve thermal processes and flue gas cleaning systems that generate slags, bottom ashes, sludges, fly ashes and dusts containing heavy metals and POPs. Incineration and other thermal processes can result in the formation of PCDD/Fs;

(b) The production of by-products and residues containing heavy metals and POPs can be minimized through using “state-of-the-art” process technologies and flue gas cleaning systems, using raw materials and fuels with low levels of contaminants, and ensuring optimal operating conditions at all times;

(c) Internal recycling of residues is widely practised. Within many of the sectors examined, residues are recycled internally to production processes. For example, many residues from iron and steel production, copper, lead and zinc production, and oil refineries are recycled internally. Technical and environmental considerations may limit the extent of internal recycling of residues;

(d) There are opportunities for the external utilization of many residue types. For example, some types of bottom ash are used in the construction industry or in engineering projects in some countries;

(e) Factors influence whether or not residues are re-used in other industries including their homogeneity, the amounts available, and economic feasibility (which includes the cost of final disposal). If residues are not recovered, they may be disposed of in landfill sites;

(f) In some cases, by-products and residues are treated before being re-used or disposed of. Treatment can include the recovery of metals for use in ferrous or non-ferrous industries, dewatering of liquid or semi-liquid by-products or residues, processing to make the by-products and residues marketable (e.g. by sieving, blending, grinding). Treatment of wastes before disposal includes stabilization and immobilization to prevent leaching of heavy metals and soluble materials and/or destruction of POPs;

(g) Disposed waste with organic or biological content generates green-house and other gases;

(h) Collected dust and fly ash from several of the industrial sectors examined contain high levels of heavy metals and/or POPs, and are typically classified as hazardous wastes. There are few opportunities to re-use these residues, unless they are recycled into production processes. They can require stabilization and immobilization before disposal in special landfill sites, special designated areas of landfill sites or other environmentally-appropriate sites;

(i) The main driving force to promote waste minimization and maximize the use of by-products and residues are economic concerns and regulatory requirements. Only if “undesired behaviour” becomes more expensive or prohibited, will industry users behave in the desired way;

(j) Legal instruments are a crucial pre-requisite to environmentally-sound waste management on a national and an international level;

(k) The classification of hazardous and non-hazardous wastes is not consistent in different UNECE countries. Similarly, regulations on the treatment of residues are not consistent;

(l) Information on residues and by-products provided by different UNECE countries varies widely in terms of detail and availability;

(m) There is a need for standards concerning the classification and environmentally-sound treatment of waste, the leaching protocols and for management practices.

Sector-specific conclusions are included in each sector chapter.

B. General Recommendations

49. These general recommendations for the management of by-products and residues containing heavy metals and persistent organic pollutants take into account the recommendations in each sector chapter. They also build on recommendations made in 1996 by the Task Force on By-Product Utilization from Stationary Installations (EB.AIR/WG.6/R.32). Sector-specific recommendations are included in each sector chapter. General principles to avoid the generation of wastes include using: the “best available techniques” (BAT) which prevent and minimize pollution; a combination of goal setting, performance feedback, and rewards for plant production employees to reduce the rate of rejection of the final product; feedstocks that contain lower levels of impurities; appropriately sized and designed flue gas cleaning systems; and processes that have lower energy requirements.

50. Waste prevention:

(a) Waste prevention should have priority over waste recovery (which includes recycling and re-use of waste and recovery of energy) and disposal;

(b) The generation of wastes should be minimized as much as possible. To achieve this minimization producers should:

- (i) use “state-of-the-art” processes that generate fewer wastes, effluents and emissions, are more energy efficient, and allow for the capture of emissions and effluents;
- (ii) equip plants with “state-of-the-art” gas cleaning systems;
- (iii) optimize process and gas-cleaning technologies and ensure optimal operating conditions;

(iv) use less hazardous materials as raw materials and fuels;

(v) further optimize primary and secondary process technologies.

(c) Processes should be further developed that produce as small amounts of residues as possible with better material properties in energy efficient processes.

51. Waste re-use, recycling and recovery:

(a) Waste re-use and recycling should be encouraged as much as possible because they allow the recovery of resources, either as materials, or in the form of energy;

(b) Waste re-use and recycling may be facilitated by collecting different waste fractions separately;

(c) Internal re-use and recycling of wastes should be promoted as a means of reducing the use of raw materials and fuels. However the internal re-use and recycling of wastes should not increase a plant's emissions;

(d) Economic incentives and regulatory approaches should be developed to promote the re-use and recycling of residues and wastes, including alternative use of residues and their external utilization where it is technically and environmentally sound to do so;

(e) Residues and by-products should be tested to ensure that they are not environmentally harmful and are suitable for re-use, before being sold or re-used by another industry. This includes testing for the potential leaching of contaminants and, if appropriate, testing to determine the strength of the material, and its long-term chemical and physical stability;

(f) In general, heavy metals should be recycled as far as technically and economically possible in an environmentally-sound manner;

(g) Where the residues can not be recycled internally, efforts should be made to recover any metal or other substance of value from the residue before alternate use or disposal.

52. Waste storage and disposal:

(a) Separate collection of waste fractions at source and, if necessary, intermediate storage of wastes should be made to make appropriate handling of remaining waste products possible;

(b) All wastes that cannot be otherwise re-used or recycled should be disposed of in an environmentally-sound manner, to prevent odour and the contamination of air, surface water, groundwater, and soil;

(c) Waste should be managed in such a way that greenhouse gases are minimized as far as technically and economically possible in an environmental-sound manner;

(d) Heavy metals in wastes should be immobilized to prevent leaching and release into the environment;

(e) POPs in wastes should be destroyed to prevent their release into the environment;

(f) Disposal sites should be reclaimed for future beneficial uses.

53. Air pollution control measures:

(a) Pollution prevention should have priority over pollution control;

(b) Emissions from all processes should be controlled/minimized by well-designed and properly operated pollution control equipment/systems;

(c) Plants that treat wastes should be equipped with effective gas cleaning systems according to BAT to minimize emissions of dust, heavy metals, dioxins and furans and other gases.

54. Legal Instruments:

(a) For ecological and economic reasons, legal instruments for by-product and residue management should be harmonized within the UNECE region.

(b) Internationally acceptable protocols for the classification of by-products, residues and wastes, should be further developed and adopted, including associated leaching tests and other protocols;

(c) Definitions for by-products, residues and wastes and types of treatment (e.g. recovery, disposal) should be further developed, adopted and harmonised within the UNECE Region;

(d) Pollution prevention strategies, such as cleaner production should be further developed and adopted.

55. Recommendations for Further Action:

(a) Technical annexes on the management of by-products and residues should be prepared under the 1998 Protocol on Heavy Metals and 1998 Protocol on POPs for review by the Parties.

(b) A state-of-the-art report about life-cycle analyses should be elaborated under the 1998 Protocol on Heavy Metals and the 1998 Protocol on POPs, for review by the Parties.