

The Science of Chemical Safety
Essential Toxicology - 5

Management of Potentially Toxic Substances

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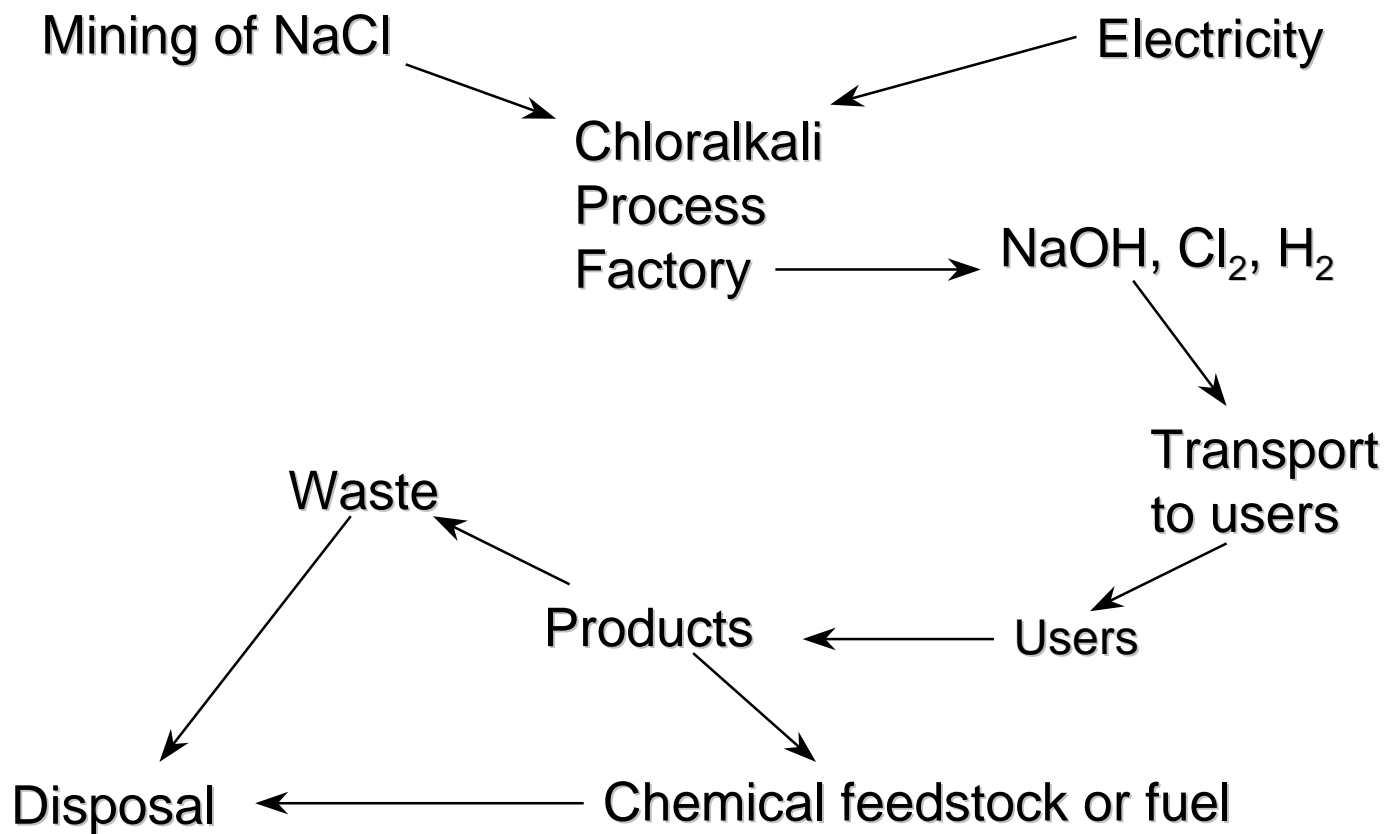
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Management of Toxic Substances

- Management of a chemical must be from the “cradle to the grave”, sometimes called “life cycle” management
 - This implies that managers must consider the possible impact of raw materials, transport, processing, use, and disposal of waste after the chemical has been used
 - After manufacture, the majority of chemicals are used outside the chemical industry, in other industries, in agriculture, in the home, and in laboratories for research, analysis and for the teaching of students.
 - Thus all of us have a responsibility for handling chemicals safely and must consider our part in the “life cycle” of a chemical and its safe use and disposal

Sodium Chloride From “Cradle to Grave”



Prevention

- It is always easier, less costly, and far less damaging to both human health and the environment, to prevent a toxic release rather than try to contain, compensate for, or clean up after a release of pollutants

Heavy Chemicals

- When the term *heavy chemical* is used in the chemical industry, it refers to the magnitude of production
 - In other words, a heavy chemical is one that is used to a large extent, and is manufactured on a very large scale.
 - There is thus always the possibility of a heavy chemical causing great harm.
- Let us consider the manufacture of a heavy chemical and the potential hazards that each step might produce, both environmentally, and for the average person

Chlorine and Caustic Soda - 1

- Chlorine and caustic soda are both heavy chemicals which are starting materials in many manufacturing processes
- They are the products of electrolysis of sodium chloride solution
- Industrially this is carried out on a massive scale by the electrolysis of brine, a concentrated solution of sodium chloride

Chlorine and Caustic Soda - 2

- Chlorine is a lung irritant which can cause death by suffocation following exposure to high concentrations
 - The effects of low exposure concentrations, though unpleasant, are completely reversible
- Sodium hydroxide, because of its reactivity, causes immediate damage to any living organism with which it comes in contact
 - It is classified for labelling as corrosive and not as toxic

Dose-Effect Relationship for Exposure to Chlorine

- Detectable smell 3 air ppmv
- Threshold of lung irritation 15 air ppmv
- Threshold for coughing 30 air ppmv
- 30 Minute level causing irreversible damage 60 air ppmv
- Concentration causing death 1000 air ppmv

- ppmv = parts per million by volume

Mining Sodium Chloride

- Brine is produced from naturally occurring sodium chloride, which must be mined and transported to the site of the electrolysis plant.
- Sodium chloride is not usually considered toxic but excessive amounts in soil destroy its fertility (salination)
 - Salination is a major cause of loss of farming land worldwide

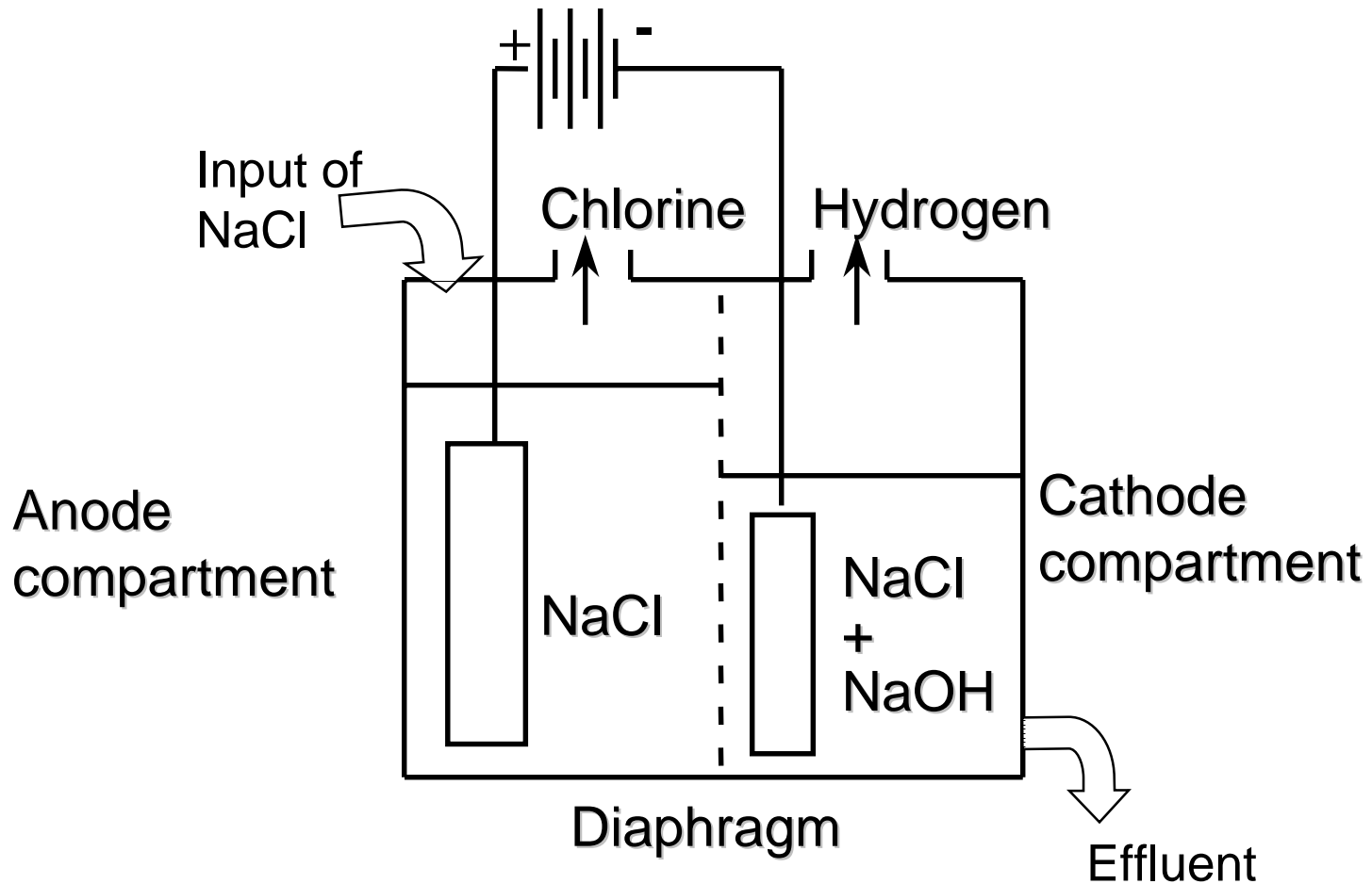
Mine Tailings

- Mining is hazardous, for the environment as well as for miners
- Mine tailings often contain metals which can be leached out into nearby water with resultant damage to organisms which live in the water or drink it: there may also be cyanide which has been used as a metal extractant and arsenic from metal ore as arsenide, arsenite or arsenate
 - serious spillages of tailings have occurred recently in Guyana, Spain and Romania.

Transport

- Transport of bulk chemicals is hazardous.
 - There may be accidents and spillage which may cause local problems or may have a widespread effect if a water supply or the air is contaminated.
- Combustion of fossil fuels by the transporting vehicle causes air pollution (see earlier)
- Extraction and manufacture of fossil fuels causes environmental damage and hazards of fire and explosion
 - People who are exposed to components of the fuel or the products of combustion may suffer health damage

A diaphragm electrolytic chlor-alkali cell



Hazards of Chloralkali Manufacture - 1

- The electrolytic process is usually carried out at 100°C because of the greater conductivity of ionic solutions at higher temperatures: there is a potential for scalding as well as the direct chemical hazard
- Sodium chloride is recovered by concentrating the solution by evaporation; it crystallises out and sodium hydroxide stays in solution: again, there is a potential for scalding as well as the direct chemical hazard

Hazards of Chloralkali Manufacture - 2

- Sodium hydroxide is corrosive
- Hydrogen gas is formed at the cathode; it is an important byproduct of the process; hydrogen is highly explosive with a high rate of diffusion
- The electrolytic process and the generation of steam in order to carry it out at 100°C require a high electrical input, which in turn involves the management of the toxic substances in the manufacture of electricity

Hazards of Chloralkali Manufacture - 3

- Fossil fuel and nuclear power plants producing electricity may both contaminate air and/or water.
- As heavy chemicals, chlorine and sodium hydroxide are raw commercial products, sold to other manufacturers, or transferred to other parts of the manufacturer's plant, to be used in further chemical processes; there is always the risk of leakage in such transfer

Hazards of Chloralkali

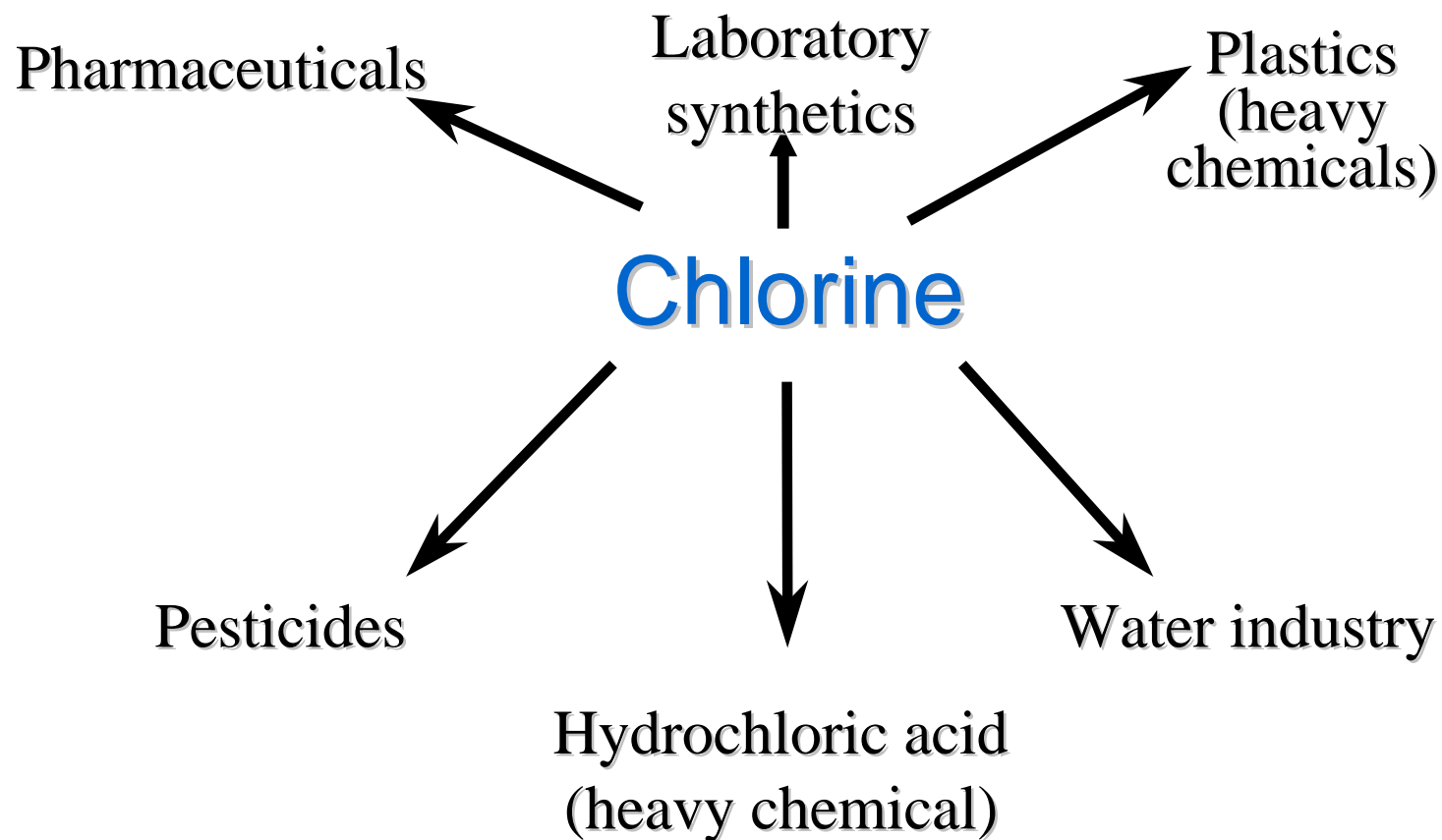
Manufacture - 4

- As a chlorinating agent, chlorine is used in the production of drugs, in the production of pesticides, and in the plastics industry where plastics themselves are heavy chemicals; again there is risk of leakage of chlorine
- Chlorine is used as a bactericide in the water industry and may react with organic chemicals in the water to give potentially toxic derivatives; low concentrations mean that these are rarely a significant problem

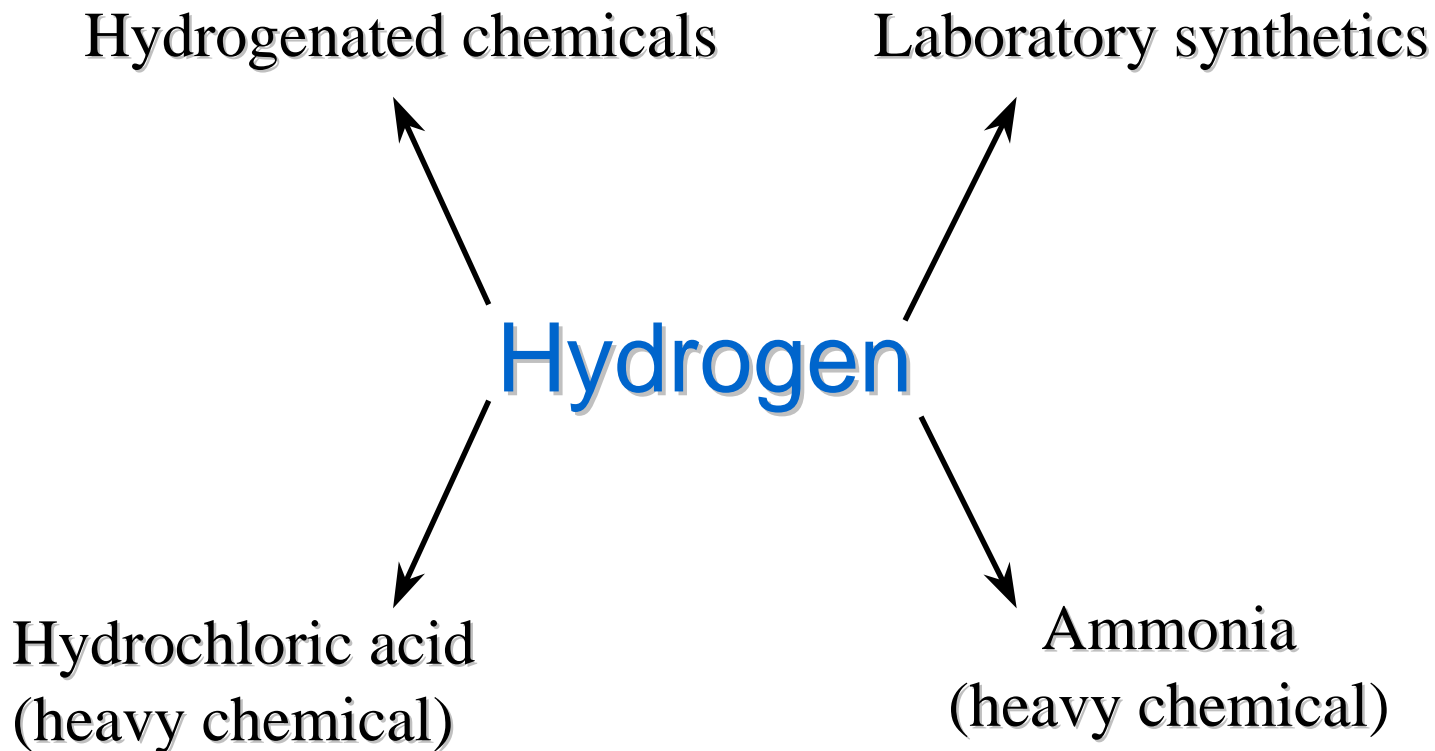
Hazards of Chloralkali Manufacture - 5

- Chlorine may be combined with hydrogen (from the electrolyte process) in the production of hydrochloric acid, another heavy chemical with corrosive properties

Uses of Chlorine



Uses of Hydrogen



The Laboratory and the Home - 1

- Chlorine and sodium hydroxide are also laboratory reagents and hazardous in use
- In the home, chlorine is present in bleaching agents; addition of dilute acid will cause chlorine to be released into the air
- Sodium hydroxide is used as a drain deblocker
- Similar corrosive strong alkaline reagents may be present in dishwasher detergents.

The Laboratory and the Home - 2

- Particular care must be taken to ensure that any household chemical is kept well out of the reach of children, preferably in a locked cupboard
- Bleaching agents, pesticides etc. must never be transferred to inappropriate containers such as soft drink bottles.

Waste - 1

- Within the chemical industry, disposal of “waste” chemicals is a major problem and one that is subject to legislation in all countries and to very strict legislation in many
- Domestically, there are very few restrictions on disposal because such restrictions would be difficult, if not impossible, to legislate and most chemicals at a domestic level do not pose a major hazard to the individual
- BUT - the management of domestic waste in bulk on a global level is a major problem

Waste - 2

- The processing of sewage and the collection and disposal of solid domestic waste becomes more and more difficult as the population increases
- Both sewage and domestic solid waste consist of chemicals in the broadest sense; some of them are highly toxic, for example - drugs and pesticides, and some will react with others to give highly toxic products

Waste - 3

- Making the public more aware of these problems is done at the present time partly through hazard warnings on the packaging of commodities
- There are certain things that carry clear and very explicit labels with warnings about the process of disposal, for example - domestic batteries and packages of hazardous substances

Typical domestic battery label with disposal warning

- LR1 1.5V
 - E90 MN9100 AM5 4001
- **GUARANTEE: ENERGIZER** batteries are guaranteed against any manufacturing defects. Should any device be damaged by these batteries, we will repair or replace it, except in case of misuse.
- **WARNING** Insert correctly (+/-), do not recharge, **do not dispose in fire or open, do not mix with used or other battery type, may explode, leak and cause damage**

Prior Informed Consent (PIC)

- The United Nations “Code of Conduct” for chemical safety includes provisions for “prior informed consent” (PIC)
- PIC is a procedure by which no substance which has been banned or severely restricted in any industrialised country, can be exported to another country without its prior agreement following consideration of all the information which led to the ban or restriction in the first place, in the country of origin

Joint Meeting on Pesticide Residues

- Countries which do not have a well developed pesticide registration and review framework may make use of evaluations performed by the Joint Meeting of Pesticide Residues (JMPR) for the use of pesticides in agriculture.
- The JMPR operates under the auspices of the World Health Organization and the Food and Agriculture Organization and establishes levels of pesticide residues that may be consumed on a daily basis by humans, for a lifetime, without appreciable risk; for each a Tolerable Daily Intake (see earlier) is calculated

Guidance on Safe Use of Chemicals

- Guidance in safe use of chemicals has been included in law in many countries, for example, the Control of Substances Hazardous to Health (COSHH) regulations in the United Kingdom under the Health and Safety at Work Act (1974).
- Guidance in safe use of chemicals is given on Material Safety Data Sheets from chemical manufacturers and on International Chemical Safety Cards prepared jointly by the Commission of the European Communities, and the International Programme on Chemical Safety

International Chemical Safety Cards

- Information available:
 - Flammability; prevention of fire
 - Spillage treatment; storage
 - Packaging / labelling
 - Risk and safety phrases giving danger warnings and guidance on safe use
 - Physical properties
 - Toxicity, inhalation, ingestion, skin, eye
 - Symptoms and treatment; occupational exposure levels
 - Environmental data

Self Assessment - 5.1

True or False?

- Life cycle (cradle to the grave) management of chemicals covers everything from their production to their final disposal - see slide 2
- Sodium chloride is a harmless substance - see slide 9
- Chlorine attacks the lungs but the effects are reversible at low doses- see slide 7

Self Assessment - 5.2

True or false?

- Mine tailings are a not a major source of environmental contamination- see slide 10
- Transport of chemicals adds to air pollution and may lead to accidental chemical releases- see slide 11
- Electrolysis of chemical solutions can release hydrogen which is explosive; electrolysis requires electricity generation and electricity generation may cause environmental pollution- see slide 14

Self Assessment - 5.3

True or false?

- In the home, chlorine may be released from bleaching agents - see slide 20
- Labels often have useful information on safe use of chemicals - see slide 24,25
- Prior Informed Consent (PIC) should ensure that importing countries have adequate information to assess the dangers of chemicals to be imported - see slide 26

Self Assessment - 5.4

True or false?

- The Joint Meeting on Pesticide Residues (JMPR) assesses pesticide residues in the environment and determines TDI's - see slide 27
- Guidance on safe use of chemicals is given in Material Safety Data Sheets (prepared by industry) and in ICSC (International Chemical Safety Cards prepared by the International Programme on Chemical Safety and the European Commission) - see slides 28 and 29

Self Assessment - 5.1

Checklist

- Life cycle (cradle to the grave) management of chemicals covers everything from their production to their final disposal - **True**
- Sodium chloride is a harmless substance - **False**
- Chlorine attacks the lungs but the effects are reversible at low doses - **True**

Self Assessment - 5.2

Checklist

- Mine tailings are a not a major source of environmental metal contamination - **False**
- Transporting chemicals adds to air pollution and the danger of accidental chemical releases - **True**
- Electrolysis of aqueous solutions can release hydrogen which is explosive; electrolysis requires electricity generation and electricity generation may cause environmental pollution - **True**

Self Assessment - 5.3

Checklist

- In the home, chlorine may be released from bleaching agents - **True**
- Labels often have useful information on safe use of chemicals - **True**
- Prior Informed Consent (PIC) should ensure that importing countries have adequate information to assess the dangers of chemicals to be imported - **True**

Self Assessment - 5.4

Checklist

- The Joint Meeting on Pesticide Residues (JMPR) assesses pesticide residues in the environment and determines TDI's - **True**
- Guidance on safe use of chemicals is given in Material Safety Data Sheets (MSDS - prepared by industry) and in International Chemical Safety Cards (ICSC - prepared by the International Programme on Chemical Safety and the European Commission) - **True**