Physical and Chemical Properties, Usage, and Environmental Behaviour

Physical and Chemical Properties of Mercury

Physical Properties of Mercury Element

- Atomic number: 80 — Next to Gold (79)
- Atomic weight: 200.59
- Melting point: -38.8 °C
- Boiling point: 356 °C
- Specific gravity: 13.6 at 0 °C
- Thermal conductivity: 8.3 W/m°C
- Saturated vapour concentration: 13.2 mg/m^3 at 20 °C — High vapour pressure
- Abundance in Earth's crust: 0.05 - 0.08 ppm — Similar to Silver
- Emission spectrum at ultra-violet band: 254 nm (UV-C)
- Forming amalgam with many metallic elements

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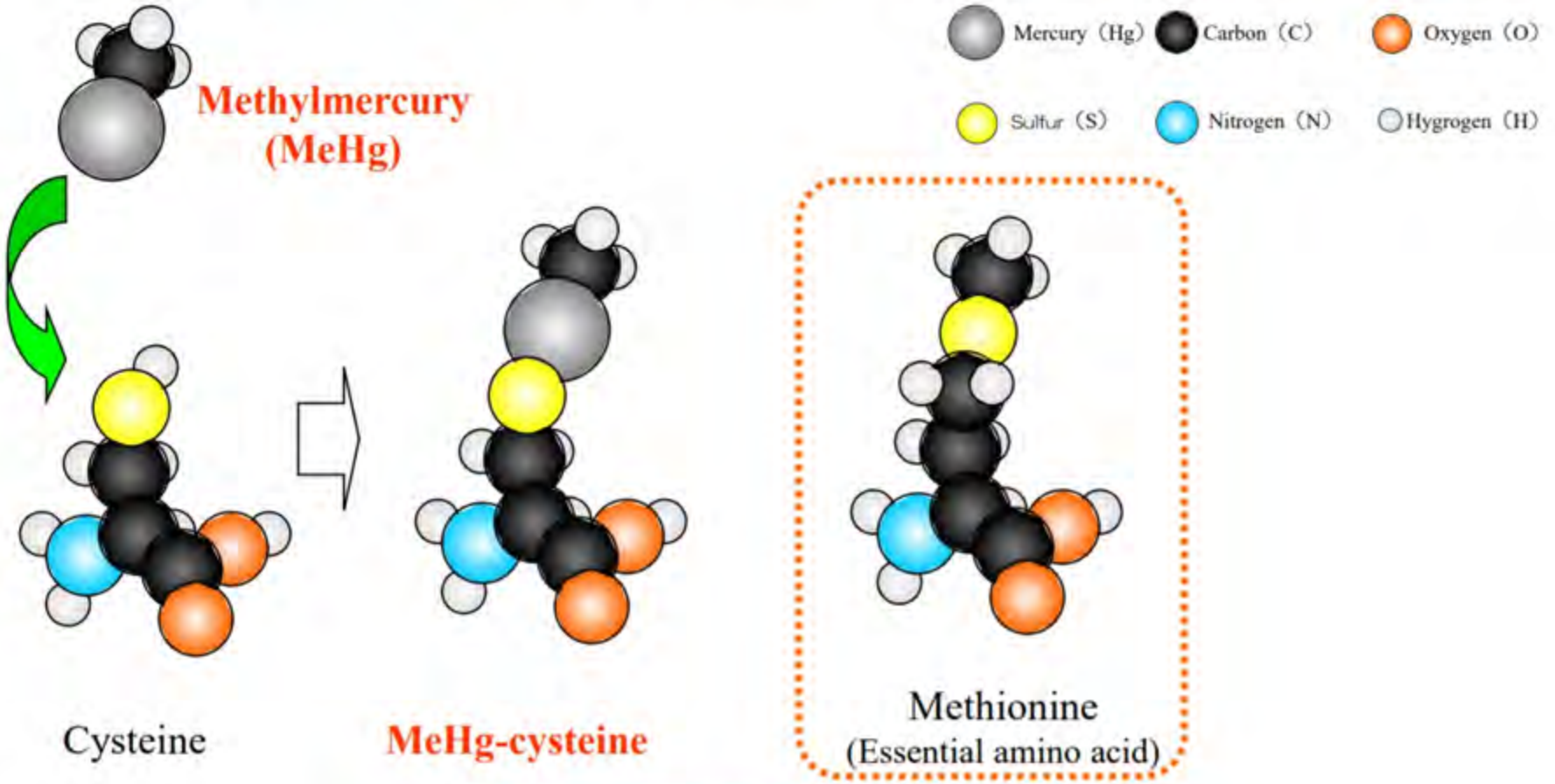
Physical and Chemical Properties, Usage, and Environmental Behaviours

Physical and Chemical Properties of Mercury

Mechanism of Methylmercury Assimilation



Amino-acid transportation mechanism

Human tissues (protein)

Source: Japan, National Institute for Minamata Disease (2013). Mercury and health V4.1.

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Physical and Chemical Properties, Usage, and Environmental Behaviours

Physical and Chemical Properties of Mercury

Exposures, Symptoms and Treatments

	Elemental Mercury	Inorganic Mercury	Methylmercury
Exposure pathway	Inhalation (75-85 %), ingestion (0.01 % or less).	Ingestion (5-10 % or less), dermal (not expected to be high).	Ingestion (90 % or more).
Behaviour and fate	Unoxidized form passes through blood-brain barrier (diffusion). Gradually oxidized to divalent inorganic mercury.	Excreted in urine.	Passes through blood-brain and placenta barrier (amino acid transportation). Gradually oxidized to divalent inorganic mercury.
Symptom	Respiratory distress. Central nervous system effects: tremor, personality change, tooth pain, excessive salivation. Referred to as 'mad-hatter's disease.	Corrosion in digestive tract: vomiting, chest pain, abdominal pain, and bloody diarrhoea. Kidney damage. Renal insufficiency.	Central nervous system effects: sensory nerve dysfunction, ataxia, and constriction of visual field. Fetal: non-specific cerebral palsy-like features.
Treatment	Stimulation of mercury excretion.	Gastric lavage, excretion with chelating agent.	No effective treatment.

Source: Japan Public Health Association (2001). Preventive Measures against Environmental Mercury Pollution and Its Health Effects.

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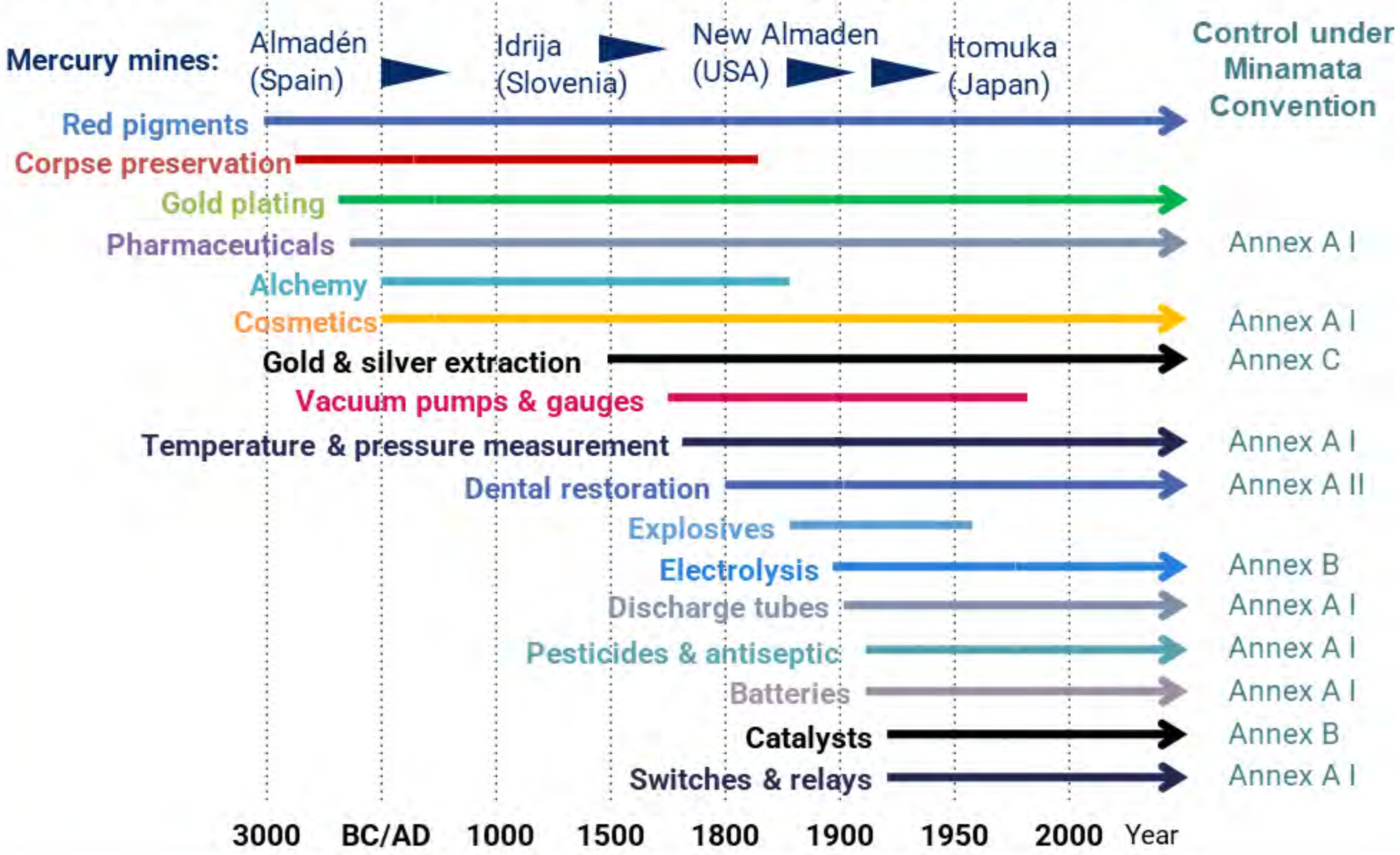
Mercury Products and Uses

Historical Mercury Supply and Use



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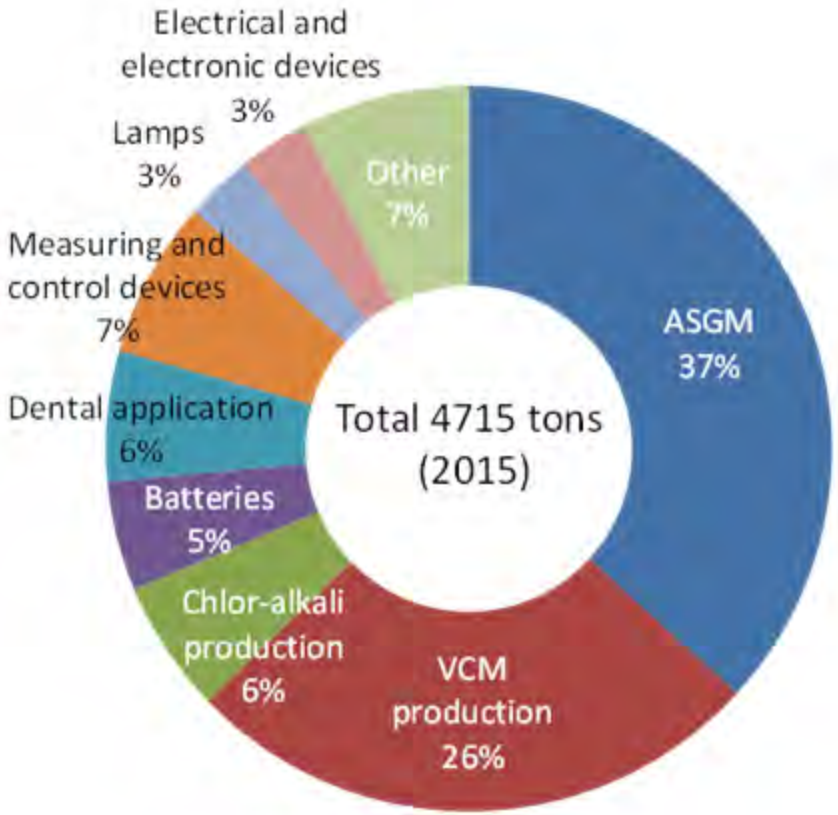
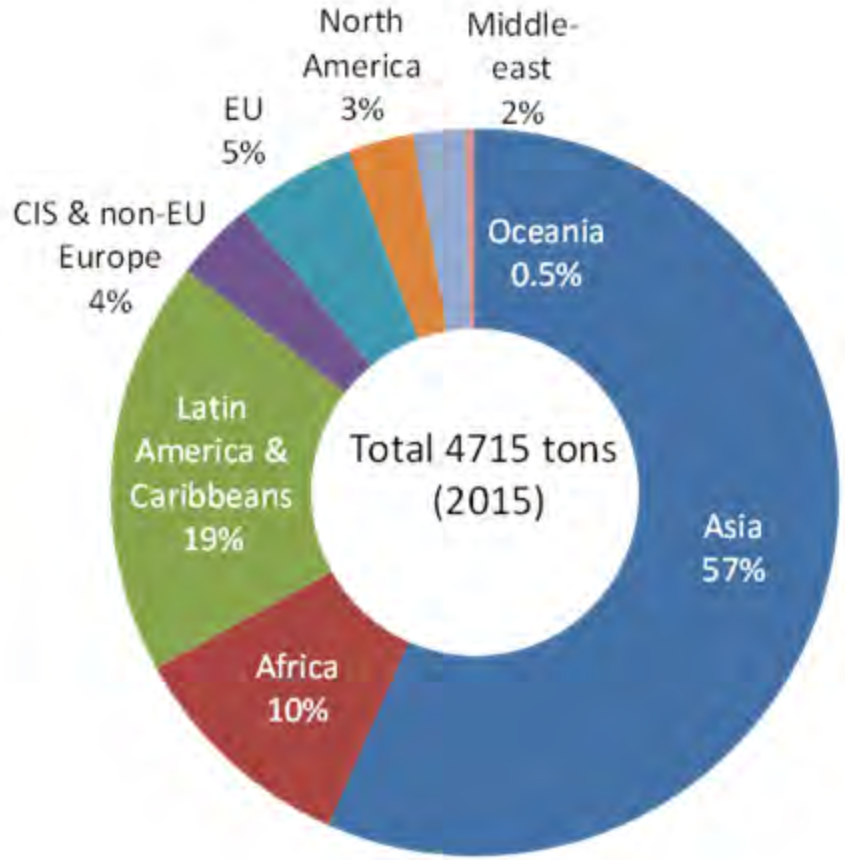
Physical and Chemical Properties, Usage, and Environmental Behaviours

Mercury Products and Uses

Global Mercury Uses





Source: UNEP (2017). Global mercury supply, trade and demand.

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Physical and Chemical Properties, Usage, and Environmental Behaviours

Mercury Products and Uses

Use of Elemental Mercury

Measuring Devices

Type	Theory / Principle	Application	Remarks
Measuring devices	❑ High density liquid.	❑ Manometer (pressure in system, facility, etc.). ❑ Barometer (atmospheric pressure). ❑ Sphygmomanometer (blood pressure).	❑ No electric supply required. ❑ No equivalent alternative for high temperature devices. ❑ Extensively used for measuring blood pressure.
Measuring devices	❑ Liquid in wide temperature range. ❑ High thermal conductivity.	❑ Thermometer (temperature). ❑ Hygrometer (wet bulb, relative humidity).	❑ No electric supply required. ❑ Quick response. ❑ No equivalent alternative for high temperature devices.

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Discharge Tubes

Type	Theory / Principle	Application	Remarks
Discharge tubes	❑ Electric valve effect.	❑ Mercury arc rectifier (rectifying high voltage AC to DC).	❑ Large power supply capacity for industries requiring DC. ❑ Largely replaced by power semiconductors.
Discharge tubes	❑ Emitting UV-C (254 nm).	❑ Neon lamp (signage, display). ❑ Fluorescent lamp (lighting). ❑ High pressure discharge lamp (projection, lighting, headlamp of vehicle). ❑ Low pressure mercury vapour lamp (disinfection).	❑ No filament in bulb, long life. ❑ UV-C emitting efficiency is higher than LED.

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Switches, Relays, Batteries

Type	Theory / Principle	Application	Remarks
Switches and relays	❑ Electrically conductive liquid. ❑ Wetting effect on the contact surface.	❑ Tilt switch/alarm (activating lights for boot lids of vehicle). ❑ Acceleration censor (anti-lock braking systems). ❑ Mercury-wetted relay.	❑ Low resistance and no chattering at contact surface. ❑ Allows high frequency switching.
Electric conductors	❑ Electrically conductive liquid	❑ Slip ring (360° rotation)	❑ Brushless contact.
Batteries	❑ Hydrogen overpotential.	❑ Button cell (preventing hydrogen gas generation at zinc anode).	❑ Lithium coin cell does not use water; thus no mercury is added.

Normal: $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

Abnormal: $Zn + 2H_2O \rightarrow Zn^{2+} + 2OH^- + H_2\uparrow$

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Other Purposes

Type	Theory / Principle	Application	Remarks
Vacuum pumps	❑ High density liquid ❑ Air induction	❑ Mercury column pump ❑ Mercury rotary pump ❑ Mercury diffusion pump	❑ Replaced with oil-based fluid.
Balancers	❑ High density liquid	❑ Wheel balancer ❑ Trim and heel controller (submarine)	❑ Non-mercury (solid) balancers are available.
Laboratory instruments	❑ High surface tension	❑ Porosimeter	❑ Used to analyse porosity of material surfaces.
Fluid bearings	❑ High density liquid	❑ Lighthouse rotation unit	❑ Floating Fresnel lens.
Mirrors	❑ Liquid with high reflectance	❑ Liquid zenith telescope	❑ Rotating mirror to form paraboloid mirrors.
Propellants	❑ Easy ionization	❑ Ion thruster (satellites)	❑ Replaced by xenon.

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Use of Amalgam

Dental Treatment, Surface Treatment

Type	Theory / Principle	Application	Remarks
Dental treatment	❑ Gradually hardening after mixing.	❑ Dental cavity restoration (filling silver tin amalgam into dental cavities).	❑ No electric supply required. ❑ Mercury waste is released into drainage. ❑ Mercury is gradually vapourised in the mouth.
Surface treatment	❑ Gradually hardening after mixing.	❑ Mirror (tin amalgam forms the reflective surfaces)	❑ Replaced by silver mirror reaction.

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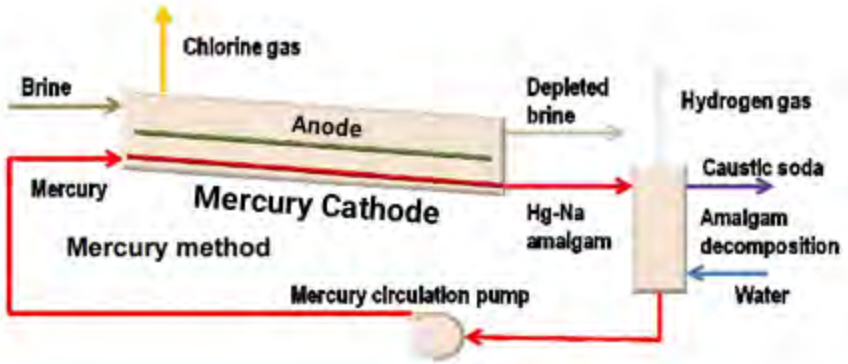
Gold/Silver Extraction/Plating

Type	Theory / Principle	Application	Remarks
Gold/ silver industry	❑ Absorption of metallic elements. ❑ Low boiling point.	❑ Gold/silver extraction (predominantly used for ASGM). ❑ Gold plating (gold amalgam is smeared on metallic surface and then heated).	❑ Workers are exposed to mercury vapour. ❑ Cyanide method is an alternative for extraction but requires higher management skill.

- Cupellation method (lead)
  - Invented in ancient (the BC era) Mesopotamian.
- The amalgamation method
  - Invented in the 16th century to cope with large demand in Latin America.
- The cyanide method
  - Invented in late the 19th century.

Electrolysis

Type	Theory / Principle	Application	Remarks
Electrolysis	❑ Absorption of metallic elements.	❑ Chlor-alkali production (separating sodium from brine after electrolysis) .	❑ Ion exchange membrane process is an alternative with a higher energy efficiency.



Anode

$2Cl^- \rightarrow Cl_2\uparrow + 2e^-$

Cathode

$2Na^+ + 2e^- + Hg \rightarrow 2Na\text{-}Hg$

Decomposer

$2Na\text{-}Hg + H_2O \rightarrow 2Na^+ + 2OH^- + H_2\uparrow + Hg$

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Physical and Chemical Properties, Usage, and Environmental Behaviours

Use of Amalgam

Special Applications, Amalgam Trouble

Type	Theory / Principle	Application	Remarks
Measuring devices	❑ Low temperature alloy.	❑ Low temperature thermometer.	❑ Melting temperature of thallium amalgam is -60 °C.
Oil and gas (problematic)	❑ Creating unwanted amalgam.	❑ Aluminium equipment (eroding surface of equipment) ❑ Palladium catalyst (inactivating the catalytic function).	❑ Mercury removal process should be installed in the system.

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Use of Mercury Compounds

Pigments and Colours

Compound	Theory / Principle	Application	Remarks
Mercury sulphide/ cinnabar	❑ Low solubility and stable chemical form. ❑ Reddish colour.	❑ Red pigment (vermillion refined from cinnabar or synthesised from mercury and sulphur).	❑ Iron oxide (brownish red ochre) and lead oxide (bright orange red) have also been used.
Mercury (II) iodide	❑ Thermo-chromism	❑ Thermochromic paint	❑ Alters crystal structure at certain temperature.

Cosmetics

Compound	Theory / Principle	Application	Remarks
Mercury sulphide/ cinnabar	❑ Reddish colour.	❑ Bodypainting (ancient indigenous custom).	❑ Iron oxide (brownish red ochre) have also been used.
Mercury (I) chloride / calomel	❑ White colour.	❑ White face powder.	❑ Lead white (lead poisoning), talc (contaminated with asbestos).
Ammoniated (II) mercury	❑ Bleaching effect.	❑ Skin whitening cream (bleaching melamine).	❑ Widely used in developing countries.

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Biocides, Preservatives

Compound	Theory / Principle	Application	Remarks
Phenyl-mercury	❑ Bactericidal & fungicidal actions.	❑ Fungicide (seed dressing against rice blight). ❑ Preservative (for latex paint, pulp & paper).	❑ Widely used in paddy fields.
Mercury (II) chloride	❑ Bactericidal & fungicidal actions.	❑ Fungicide (wood preservation, seed dressing). ❑ Preservative (pulp & paper).	
Mercury (II) oxide (Red)	❑ Biocidal action.	❑ Antifouling ship paint for ship's bottom.	❑ Replaced with copper-based ship paint.
Thiomersal	❑ Bactericidal action.	❑ Preservative (vaccines and eye area cosmetics).	❑ Vaccines can be stored at normal temperatures.

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Pharmaceutical

Compound	Theory / Principle	Application	Remarks
Mercury (I) chloride / calomel	❑ Bactericidal & fungicidal actions.	❑ Pharmaceuticals (syphilis).	
Merbromin	❑ Inhibition of bacterial growth.	❑ Mercurochrome (topical antiseptic for minor wounds).	❑ Less absorbed from skin surface.
Mercury (II) iodide	❑ Inhibition of bacterial growth.	❑ Topical antiseptic ointment.	
Ammoniated (II) mercury	❑ Inhibition of bacterial growth.	❑ Topical antiseptic ointment.	

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Catalysts

Compound	Theory / Principle	Application	Remarks
Mercury (II) chloride	❑ Forming intermediate with acetylene.	❑ Catalyst (vinyl chloride monomer production).	
Mercury (II) sulphate	❑ Forming intermediate with acetylene.	❑ Catalyst (acetaldehyde production).	❑ Acetylene-based acetaldehyde production has been replaced with ethylene-based system.
Phenyl-mercury	❑ Initiating polymerization reaction	❑ Latent catalyst (polyurethane elastomer)	

VCM

$CH{\equiv}CH + HgCl_2 + HCl \rightarrow CHHgCl{=}CHCl + HCl \rightarrow CH2{=}CHCl + HgCl_2$

Acetaldehyde

$CH{\equiv}CH + HgSO_4 + H_2O \rightarrow CHHg{=}CHOH^+ + H^+ + SO4^{2-} \rightarrow CH_2{=}CHOH + HgSO_4$

$CH_2{=}CHOH \rightleftarrows CH_3CHO$

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Batteries

Compound	Theory / Principle	Application	Remarks
Mercury (II) oxide (Red)	❑ Forming liquid mercury once reduced.	❑ Mercury cell battery (cathode).	❑ Mercury cell has been replaced with non-mercury alternatives.
Mercury (II) sulphate	❑ Forming liquid mercury once reduced.	❑ Weston standard cell (producing highly stable voltage for calibration).	

Other Purposes

Compound	Theory / Principle	Application	Remarks
Mercury (II) nitrate	❑ Fulling fur	❑ Carroting (preparation of felt)	❑ Extensively used for hat making in the 19th century.
Mercury (II) fulminate	❑ Explosiveness	❑ Detonation cap (blasting dynamite, bullet cartridge)	❑ Replaced by DDNP.
Mercury (II) chloride	❑ Reducing silver halide (photo) ❑ Water solubility	❑ Push-processing for photo ❑ Standard solution (mercury analysis)	
Mercury (I) chloride / calomel	❑ Stable electrode potential	❑ Saturated calomel electrode	❑ Silver chloride reference electrode is an alternative.
Mercury sulphide	❑ Low solubility and stable chemical form.	❑ Waste mercury (stabilisation for final disposal).	

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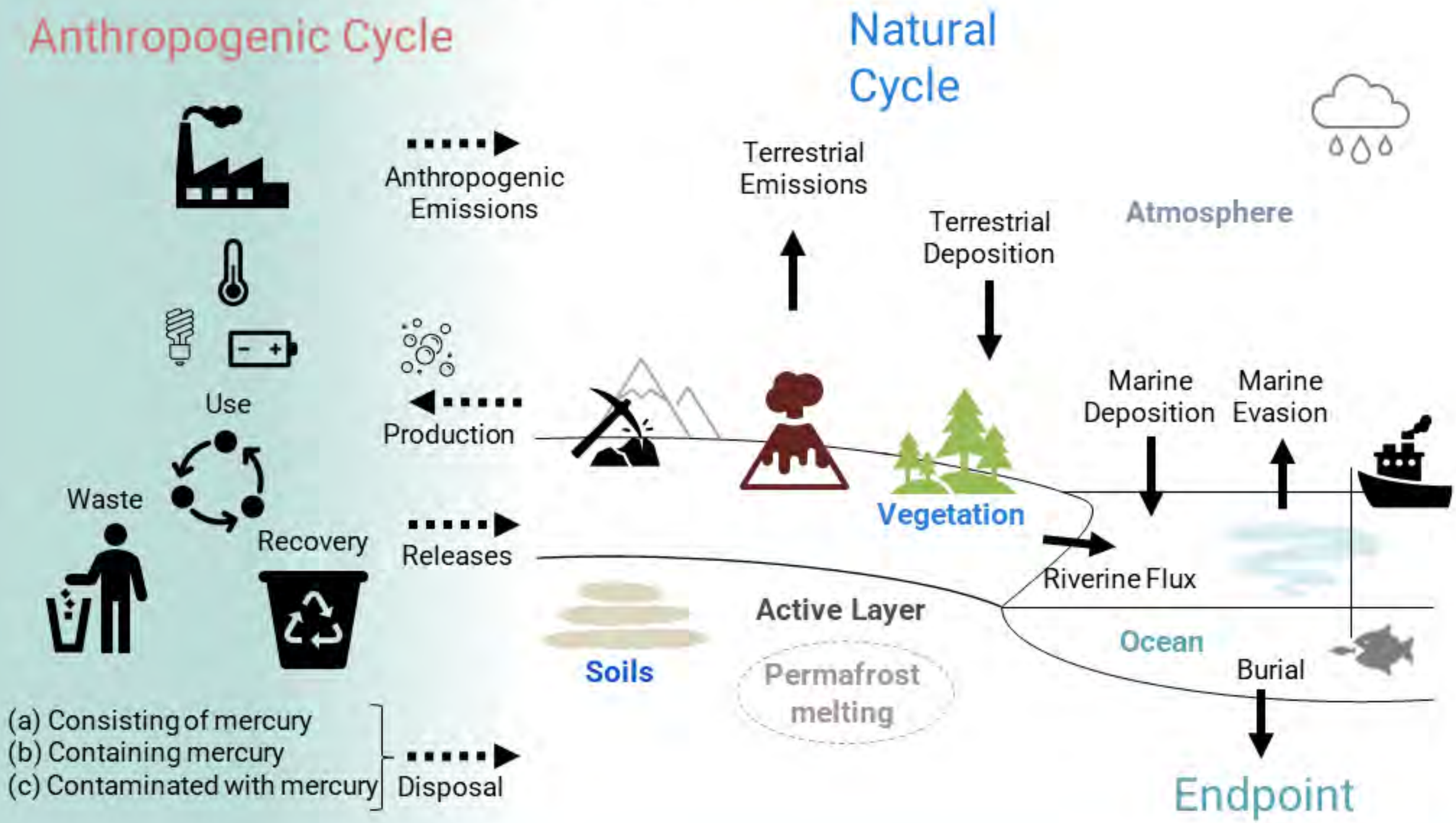
The Global Mercury Cycle and Emissions

Global Mercury Cycling



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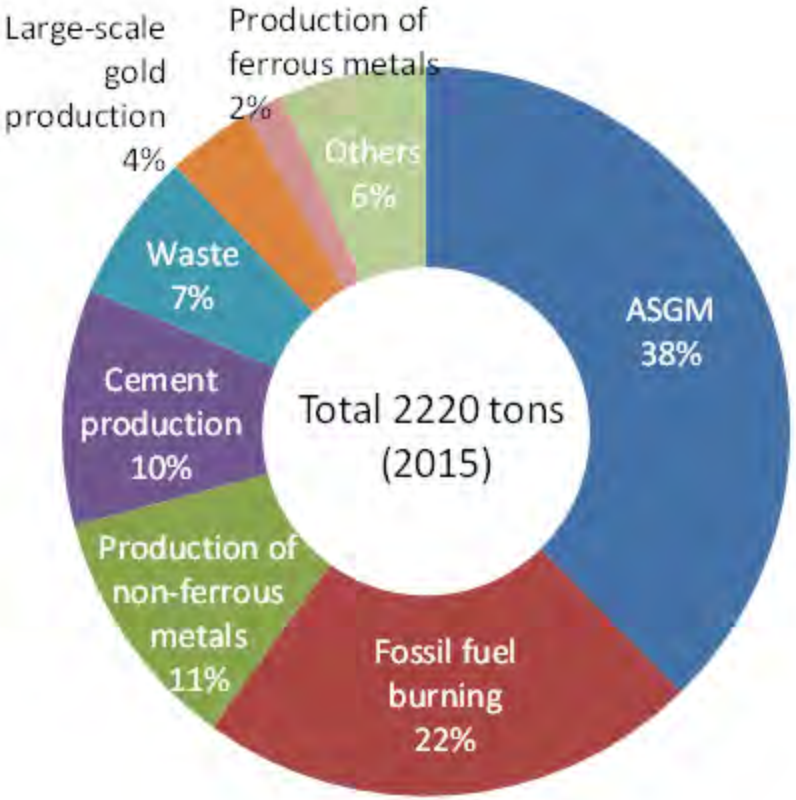
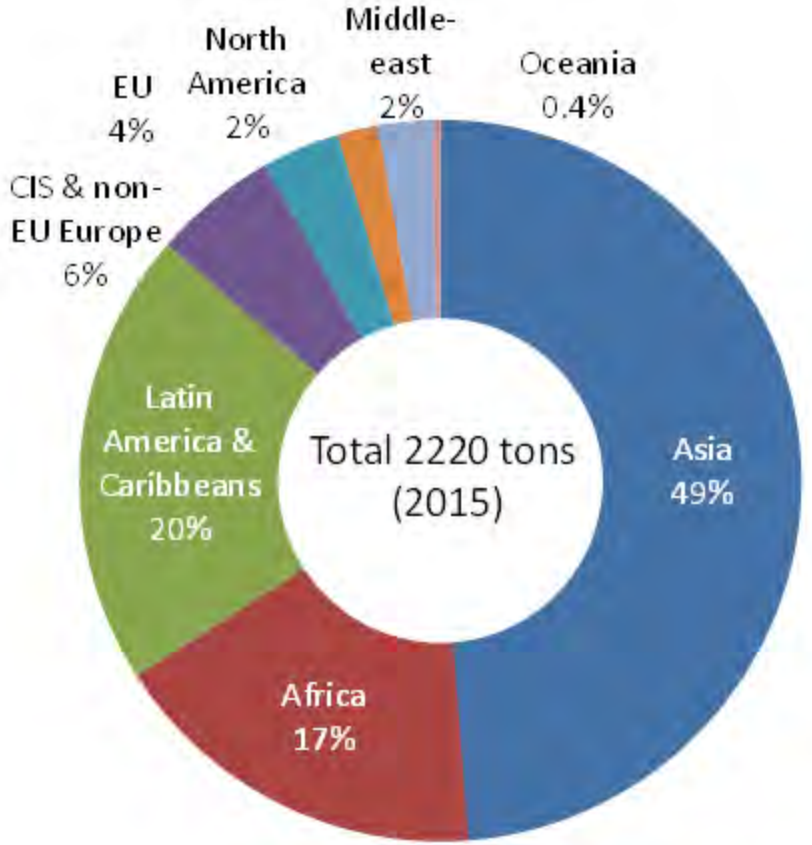
Physical and Chemical Properties, Usage, and Environmental Behaviours

Global Mercury Cycle and Emissions

Global Mercury Emissions





Source: UNEP (2019). Global mercury assessment 2018.

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Physical and Chemical Properties, Usage, and Environmental Behaviours

Global Mercury Cycle and Emissions