Toxic metals (A2)

Some metals, especially certain heavy metals (eg. mercury and lead) can have serious health effects even though they may occur only in small amounts in the environment.

Heavy metals or their ions can accumulate in the food chain as one organism feeds on another.

For example:

plankton (microscopic organisms in the sea) → shrimps → fish → man

increasing concentration of heavy metal in the organism

Eventually the metal ions build up to toxic levels in organisms higher up the food chain.

Living organisms can concentrate metals by:

- precipitating insoluble salts of the metal in their bodies.
- concentrating ions, especially organometallic ions, eg. CH_3Hg^+; many of these are soluble in fats and are easily absorbed by organisms higher up the food chain.

Metal ions can interfere with enzyme function by disrupting —SH or —S—S— groups involved in maintaining the tertiary structure of proteins.

Metal ions such as Li^{+}, Ca^{2+}, Pb^{2+} and Hg^{+} can also disrupt van der Waals' forces.

In extreme cases this can result in loss of protein tertiary structure and loss of enzyme function.

The way in which heavy metals accumulate in the environment varies from metal to metal.

Mercury

Symptoms of mercury poisoning include loss of muscle coordination and mental functions.

Mercury can enter the food chain by a number of routes:

- waste water from factories using mercury in industrial processes, e.g. old processes for making sodium hydroxide.
- mercury-based fungicides used to spray crops wash off into rivers.
- mercury compounds used to treat wood wash off into rivers.

Some micro-organisms can convert mercury salts into organomercury compounds which are taken up by organisms in the water then follow the food chain and eventually end up in humans.

Lead

The uptake of lead by humans has harmful effects on the nervous system, including the brain (particularly in children)

Lead can enter the environment in a number of ways:

- Lead used in old water pipes can be taken into the body when water is used for drinking.
- Lead compounds in some paints can get into the air we breathe.
- Lead compounds from car exhausts can settle on fruit and vegetables and be taken in when they are eaten.

  Pollution levels from this source are falling as the use of lead-free petrol increases.

Exercise

Explain how traces of a heavy metal such as mercury can accumulate progressively up the food chain.

Workings

Mercury in low concentrations in seawater is concentrated by small microscopic sea creatures (plankton) or directly by shellfish.
It is further concentrated by other organisms when they feed off the first consumers in the food chain.
For example, shrimps or fish feed off plankton.
Humans might eat the shellfish or fish and concentrate the mercury even more.
In each case, the mercury is not got rid of from the body.
It accumulates in organs especially in fats.

Exercise

State two ways by which mercury can enter the environment.

Workings

Mercury can enter water from industrial processes such as making sodium hydroxide, from fungicides sprayed on crops 'running off' the land into streams or from chemicals used to treat timber.

Exercise

How do heavy metal ions affect the structure and function of enzymes?

Workings

Heavy metal ions react with –SH groups in enzymes and they react with ionic groups.
This may result in loss of tertiary structure of the enzyme (denaturation).
The active site is no longer in the correct shape to accept the substrate and the enzyme will not function.
They act as non-competitive inhibitors.
Some may bind directly to an –SH group at the active site and thereby inhibit the enzyme directly.
Heavy metal ions such as Hg^{+} break disulfide bridges, which keep the polypeptide chain in the correct position and therefore cause enzyme denaturation.

Exercise

Write an equation to show the reaction of Hg^+ ions with an —S–S— bridge in a polypeptide chain.

Workings

$$R-S-S-R + 2Hg^+ \longrightarrow R-S-Hg + Hg-S-R$$

R: represents one or more polypeptide chains.