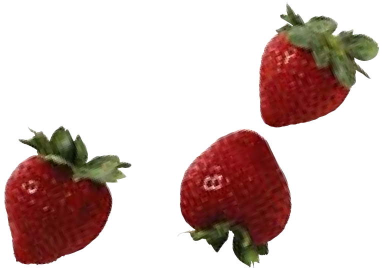
METALS

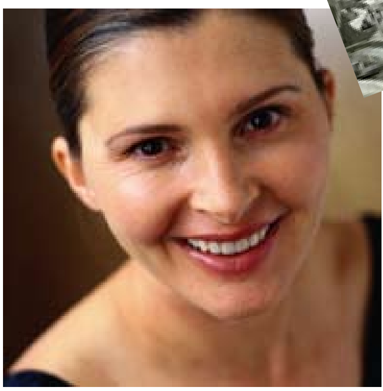
– in Society and in the Environment

Metals

– A natural part of life.

Metals play a role in our lives in many ways. Ever since the Bronze Age people have made use of metals for their unique properties such as strength and durability.





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METALS – good or bad?

Of around one hundred known elements eighty are metals. Two of the four most common elements, iron and aluminium, are metals. Metals thus occur naturally in large quantities throughout our environment.

Some are essential for life

Many metals, such as iron, zinc, copper and chrome, fulfil essential functions in every living organism. For all elements essential to life, and not only metals, there exists an optimal dose. If human beings or organisms receive too little of an element, deficiency symptoms can arise. With an overdose, even of useful elements, poisoning can occur. Human beings, animals and plants have, over millions of years, developed systems in order to regulate the uptake and secretion of essential metals.

In the case of several common metals, such as aluminium, tin and lead, scientists have not found any biological function. They are however used in household products and construction. Use of some metals that in certain forms are hazardous to both health and the environment, has significantly decreased during recent years. A marked example of this is that it is no longer possible to purchase leaded petrol in Sweden.

New knowledge for better decisions

In order to make wise decisions that are beneficial to our society, our health and the environment knowledge is required. New research is providing an improved basis for decision making.

Scientists have for example in recent years developed methods that take into consideration the fact that metals occur and appear in many different forms in the environment and that only some of these cause damage. In the past, assessments of environmental effects were based mainly on the total content of metals in for example water, sediment and soil samples. We now know that the total content gives only limited information.

Balancing risk and benefit

Lead as an additive in petrol has been phased out in most countries but cars still have lead in their batteries. This is partly because there is no good alternative to lead batteries and partly because the risks associated with this use of lead are negligible. Everyone knows that petrol is both an inflammable and poisonous mixture of chemicals. Nonetheless cars are allowed to drive around with tanks full of petrol. This is due to our modern society depending upon petrol and that we judge the risks involved with the handling of petrol to be acceptable. Both these examples illustrate that an assessment of the use of various substances must take many different aspects into consideration such as for example services provided, possible alternatives, the properties of the substance and its management.

METALS in our everyday lives

Metals are a natural part of our lives. Metals exist in many of the products and applications that we use every day.

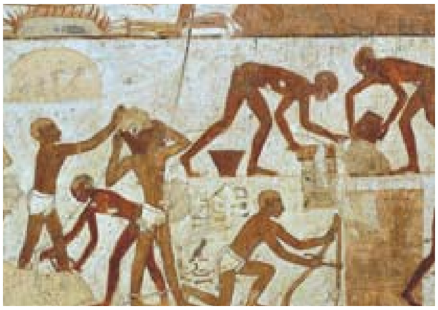
We come across metals in our everyday lives in many different forms. In the electric alarm clock and toothbrush there is copper, in the coffee machine we are very likely to find resistors made of aluminium-coated iron wire, the kitchen sink is often made of stainless steel while the water pipes are likely to be made of copper. In grocery packaging metal foil is often used as it has no taste or smell. In the freezer we find shelves of aluminium and in the freezer's compressor, copper wire. When we leave the house we may see painted plate roofs that are often, beneath the paint, coated in zinc that gives improved protection against corrosion. At the bus stop it is likely that the shelter will be an aluminium/glass construction while the protective rail at the road side is often manufactured of zinccoated steel tubing.

The list of 'everyday metals' is very long. Metals are not only included in many of the everyday articles that surround us but are also a requirement for the manufacture of most other materials and products that people use. Without steel we would not have modern pharmaceuticals or newspapers. Optical lenses and CDs are pressed in steel forms, milk is chilled in steel containers, and the list goes on.

Often metals are chosen for their durability and long useful life. In certain applications metals are used because of their effectiveness in conducting heat and electric current. In many cases there is simply no functional alternative.

A good material today and in the future

Many years of experience in using metals means that today there is a lot of knowledge concerning how metals can be used and tailored in order to become optimal materials. Modern metals can be made lighter and stronger. This knowledge contributes towards saving natural resources



YEAR

2500 BC

Already in the time of the pharaohs iron was being melted in Egypt. Copper and bronze we used regularly some thousand years earlier.

100 BC

Metals are durable materials. Coins, tools, jewellery and weapons still exist after several thousand years.

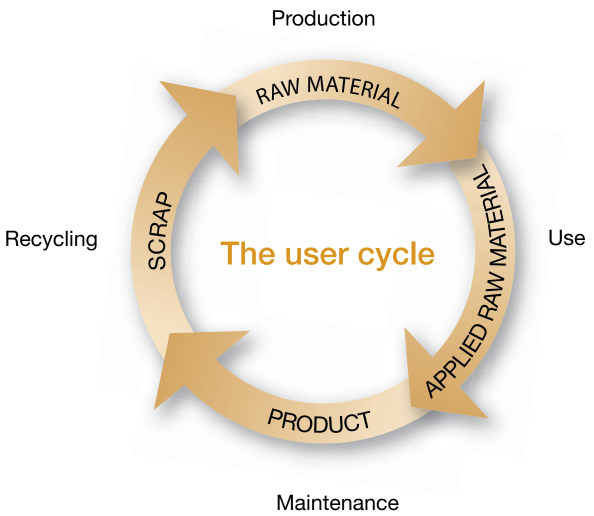
The 13th century

A share certificate from the world's oldest private limited company, Stora Kopparberg, Sweden. The mining of copper in Falun continued for around one thousand years before being phased out in 1992.

through a smaller amount of material giving the same function or the same amount of material giving increased benefits. New durable alloys can be used for applications that weigh less than before while at the same time being both stronger and more durable.

Can always be recycled

Metals are often not consumed during use and can usually be recycled. They can be melted down to either raw materi-als or semi-manufactured for use in the manufacture of new products. As metal scrap is often valuable the extent of recycling is great.

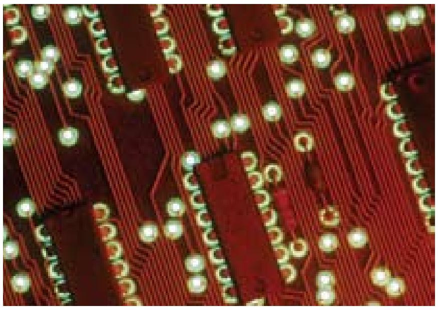


At recycling centres it is possible, following the shredding of collected materials, to use different methods to further separate the different types of material. Steel scrap that is magnetic is sorted with the help of large magnets. Metal scrap can be recycled even if it is made up of different alloys or if the surface is coated with another metal, paint or plastic. Recycled metals still retain their original properties.

Steel is the world's most recycled construction material and approximately forty percent of all steel production is based on recycled scrap. Steel products often have a very long useful life, e. g. many very old steel bridges are still in use. For that reason there is a shortage of scrap and the constant growth in infrastructure will have to be based on primary production of iron ore. The same applies to many other metals that are used in applications with a long useful life.

The 19th century

During the industrial revolution of the eighteenth and nineteenth centuries the use of metals increased. New methods for their extraction and processing increased the amount of metals that could be used to improve transportation through for example railways and new types of bridges.

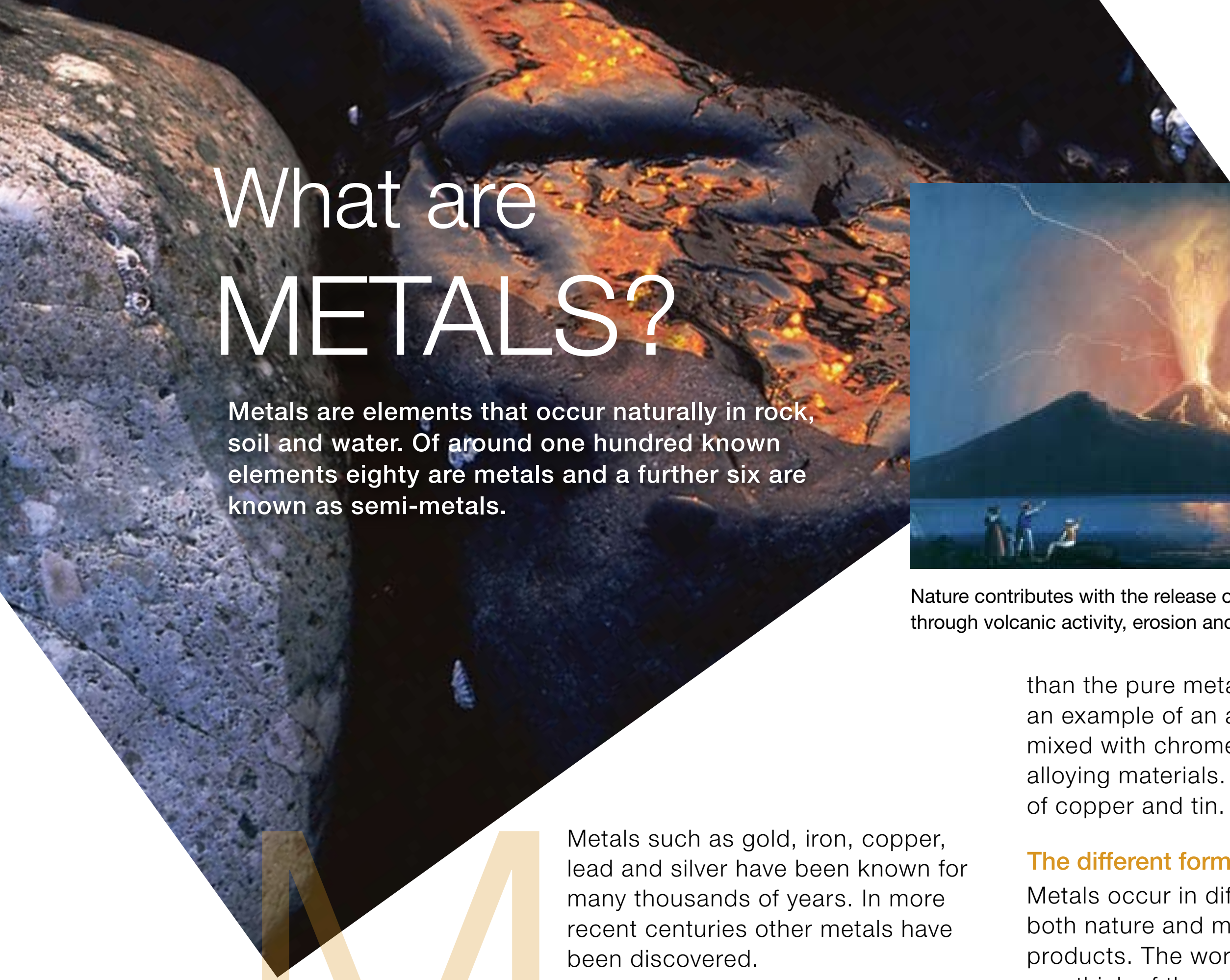


The 20th century

During the twentieth century society was revolutionised by electricity. Both the production of electricity and its use in for example motors, radios, TVs, computers and mobile telephones was based on metals, mainly the conductive properties of copper. More recently 'new metals' and alloys have contributed to developments within fields such as medicine and information technology – everything from dental implants to microchips.

The 21st century

Metals are the basis for many high technology products such as for example the artificial hip joint above. Extra strong steel makes cars safer and lighter. Metals are still being used for design and decoration.



What are METALS?

Metals are elements that occur naturally in rock, soil and water. Of around one hundred known elements eighty are metals and a further six are known as semi-metals.

Nature contributes with the release of large amounts of metals through volcanic activity, erosion and other processes.

Metals such as gold, iron, copper, lead and silver have been known for many thousands of years. In more recent centuries other metals have been discovered.

Aluminium and iron are two of the four most common elements in the earth's crust. Gold, silver and platinum are on the other hand very scarce, which in combination with their unique properties makes them both desired and valuable.

The natural concentration of metals in bedrock varies widely

The natural occurrence of metals in rock varies a great deal. In most places the content is very low but in others the content is so high that it is technically and economically feasible to extract the metal. In areas where the rock is rich in metals the soil cover also contains higher levels of metals. These natural variations also cause a change in the flora. Dissolved metals also occur in sea water, though in very low concentrations.

By mixing a metal with another metal or with a non-metal, an alloy is created with different properties than the pure metal. Stainless steel is an example of an alloy where iron is mixed with chrome, nickel and other alloying materials. Bronze is an alloy of copper and tin.

The different forms of metal

Metals occur in different forms in both nature and manufactured products. The word "metal" makes one think of the pure and solid form, but iron for example can be found in steel, iron tablets and as water soluble salts in water purifying chemicals.

All materials, even those thought of as resistant, are vulnerable to attack from surrounding elements, mainly from oxygen and the moisture in the air. Iron rusts and copper becomes coated with verdigris. This is also known as corrosion and is part of a natural process whereby metals constantly endeavour to return to their most stable state as a mineral.
A mineral is a solid material that is created by natural processes.

Did you know that…

…the definition of heavy metal has nothing whatsoever to do with hazard or environmental properties but merely means that a metal has a heavy weight for its volume (i.e. density >4.5g/cm^3) and that most metals are therefore "heavy"?

Some common properties of metals

- They have a metallic shine
- They conduct heat and electricity well
- They are malleable and ductile

During the two days of the eruption in 1991 of the volcano Pinatubo in the Philippines there was released:

- 10 billion tons of magma
- 20 million tons of sulphur dioxides
- 2 million tons of zinc
- 1 million tons of copper
- 550,000 tons of chrome
- 300,000 tons of nickel
- 100,000 tons of lead
- 10,000 tons of arsenic
- 5,500 tons of cadmium
- 800 tons of mercury

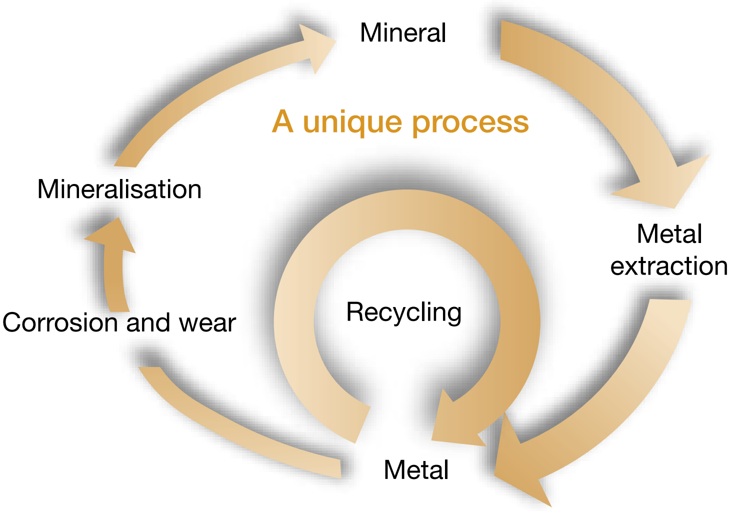
Source: Swedish Geological Survey (SGU).

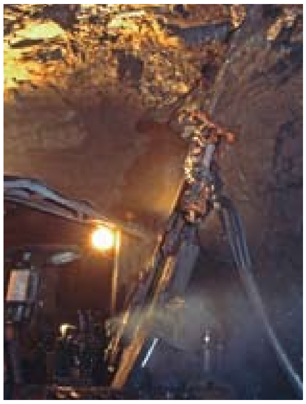
The natural cycle of metals

Metal rich minerals (ores) are mined from underground or opencast mines and processed into metals that are later used in many different products and applications. Many applications lead to a certain amount of wear and tear or corrosion, releasing metals. The metals released are relatively quickly bound in soil or lake sediment where mineralisation can take place. The majority of the metals in use can however be collected and recycled.

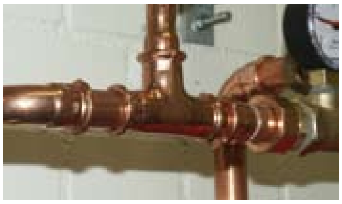
Metals exist as minerals and are a natural part of our environment. Metals are not degradable but instead endeavour to return to their original mineral state.

Metals return to nature through rust and wear.



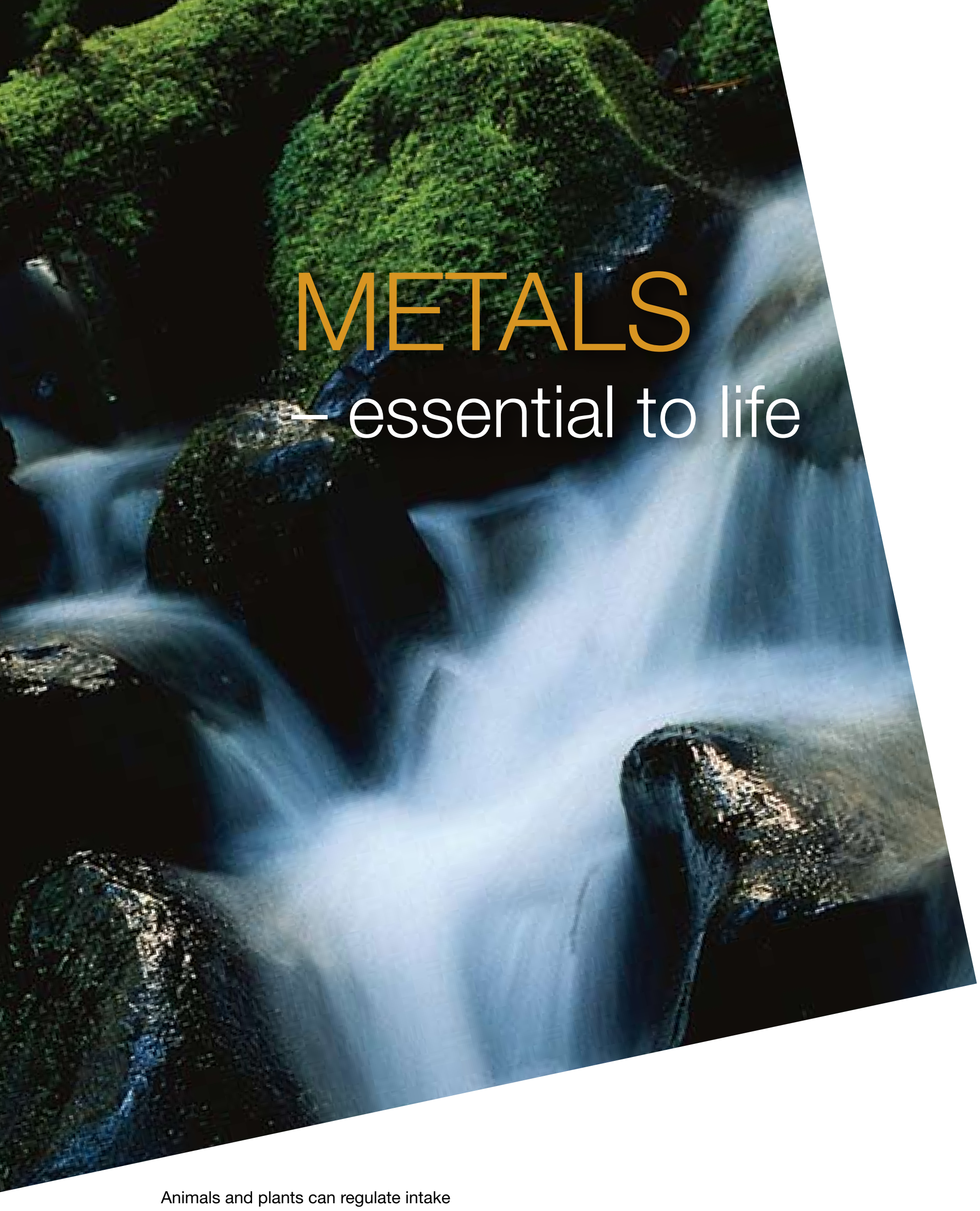


Metals are extracted at underground and opencast mines.



The extracted metals are used either in a pure form or as alloys in many objects that we use every day.

METALS – essential to life



Animals and plants can regulate intake and secretion of metals.

The human body is comprised mainly of hydrogen, oxygen, carbon and nitrogen as well as, mainly in the skeleton, calcium. Elements such as copper, iron and zinc also occur. Even though the quantities of these elements are small they are vital for all biological life as well as for all living organisms.

Iron is, among other things, necessary in order for the body to be able to produce red blood cells. It has been known for a very long time that iron is important for the formation of blood. The importance of zinc for the body's proteins was not established until the 1960s. As a comparison the level of zinc in human blood is two thousand times higher than the levels in Swedish waterways. The fact that copper was important to life was noticed as early as the end of the 1920s, but it is only in more recent years that the key role of copper in many biological processes in the body was established.

Organisms regulate the level

In the case of elements necessary for life there is an optimum interval, a wholesome level that organisms regulate through their metabolism.

In the case of most elements, including metals, concentrations that are too high can cause direct damage to health and the environment. In order to be able to assess and manage these effects, risk assessments are carried out.

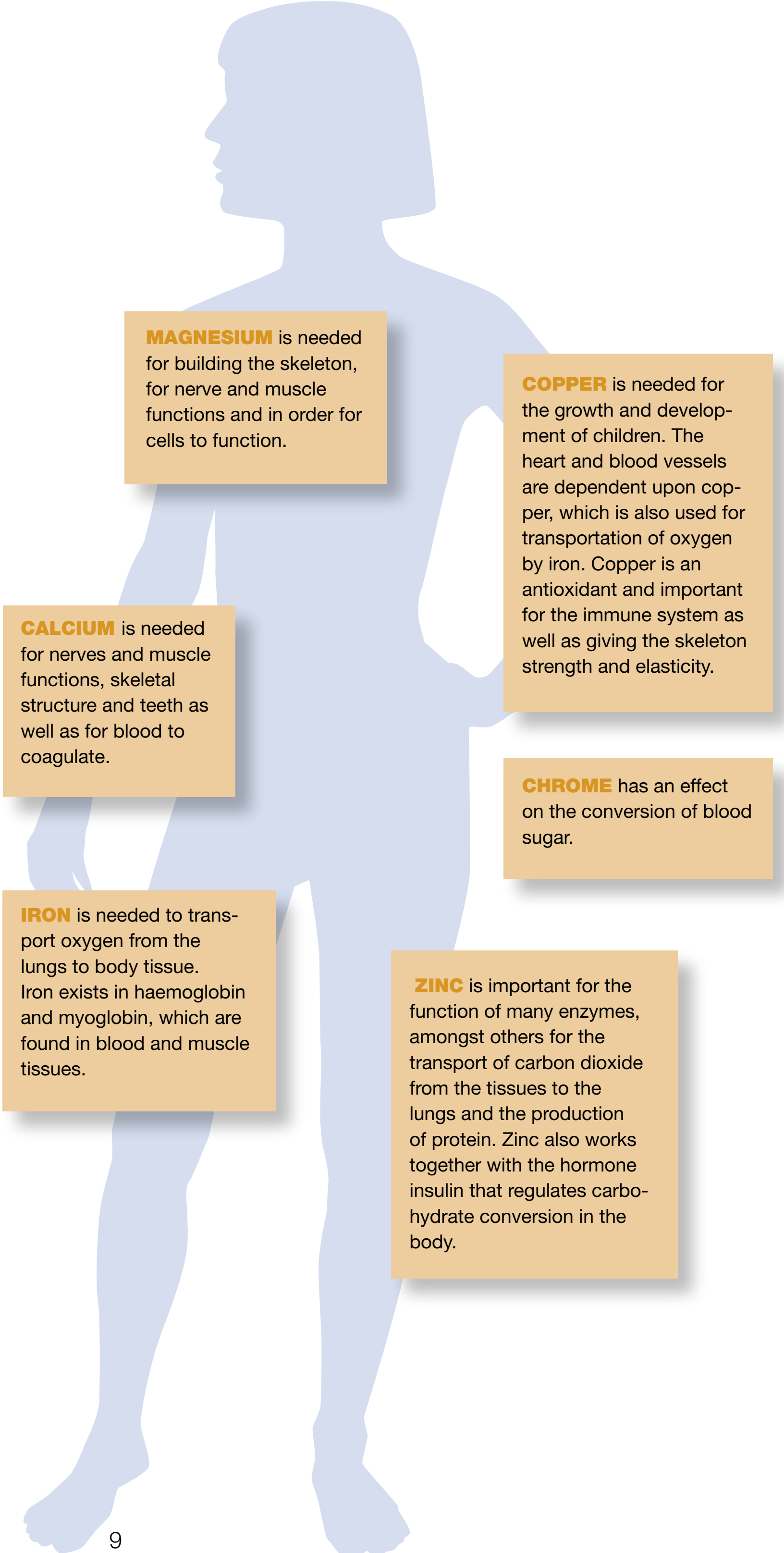
When issuing recommendations or standards for health and the environment for elements vital to life, consideration must be given to both the risk of poisoning and symptoms of deficiency. With regard for example to copper and human health, the World Health Organisation (WHO) has stated that copper deficiency from a global perspective is a relatively common problem while examples of copper poisoning are hard to find.

The WHO even mentions that zinc deficiency is one of the most common causes of ill health in the developing countries.

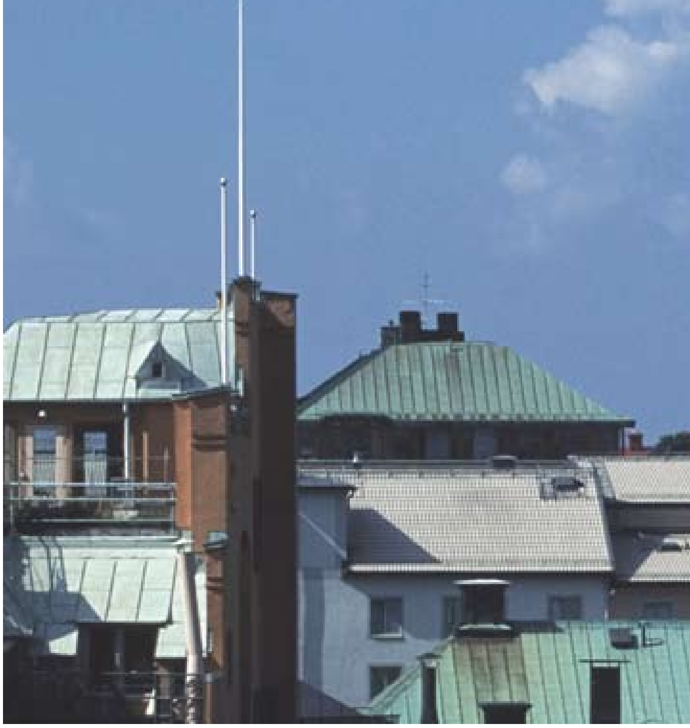
Many aspects to a correct risk analysis

An analysis of the risks involved in the use of metals requires the existence of reliable information on the amount and flow of metals in society and nature. Furthermore, knowledge of the metal's properties, behaviour and effects in the environment is required. It is not enough to investigate the total quantity and concentration of the metal.

6 COMMON METALS that are essential for humans. Some exist in the body in grams, such as iron and zinc, while the majority exist in milligram quantities. As a rule the metals vital to life, the so called essential metals, occur in nature in relatively high levels.



The air quality in Stockholm has greatly improved over the last twenty years. This has led to a decrease in the amount of metal being released from roofs.



THE FLOW OF METAL
From society to the environment

Metals are a natural feature of today's society and their use has increased from year to year. Scientists know that today the majority of the metal products in use have a minute effect on the environment. Nonetheless, to a certain degree a flow of metal from products to the environment does occur. It is therefore important to know whether this risks causing a negative effect on human health or the environment.

Material flow analysis is a technique that can be used to measure the extent to which the use of metals leads to their unwanted dispersal into the environment. By mapping the entire lifecycle of a metal, from extraction to use and recycling, risks of dispersion can be identified and evaluated. In that way the environmental aspects of the use of the metals can be assessed. Material analysis can be used for limited geographic areas, an entire country and even for an entire continent.

Dispersion from nature and people

Nature itself contributes a large amount of the metals in circulation in the environment. Globally the natural flow of a large number of metals, for example from volcanic activity and erosion, is noticeably greater than that from human activity. An average sized Swedish river transports every year over ten tons of metal to the sea due to natural weathering and leaching from bedrock. In a city such as Stockholm, the disperal of metals

from human use originates mainly from traffic (brake pads, tyres, road surfaces, railway lines and conductor rails), buildings (water pipes and roofs) and various galvanised materials.

Dispersion from Stockholm's roofs

An example of an issue that has been the subject of much research is how much metal can be released from the surface of an outdoor roof and the effect this metal can have on the environment. The Division of Corrosion Science at the Royal Institute of Technology (KTH) in Stockholm has been studying zinc, copper and stainless steel roofing materials since 1995 under conditions representative for Stockholm.

When it rains the substances that are created through the corrosion of the roof surface are released. The amount of metal that can be released depends, among other things, on a number of different factors such as the amount of air pollution, the chemical composition and pH of the rain as well as the length and intensity of the rainfall.

The rain water that leaves the surface of the roof and travels through pipes and the water drainage system contains metals in different forms, for example as metal ions or metal compounds bound to particles.

Metal ions will bind themselves to other materials

The copper and zinc that exists in the run off water leaving the edge of the roof consists mainly of free ions. Scientists at KTH found through their research that once water had percolated through soil or had been in contact with concrete or limestone the total metal content in the water had decreased by 96 to 99.8 percent. The majority of metals bond very quickly on contact with the soil and the metals that remain in the water have a low bioavailability.

Metals have been used throughout history to beautify the human environment.

THE EFFECT
depends on quantity and form

In order for people and the environment to absorb metals they must be in a so called bioavailable form. You cannot eat nails in order to have a reliable supply of wholesome iron. The iron must be part of particular chemical compounds in order for the body to be able to assimilate any substantial amount.

Bioavailability

Bioavailability is a concept that indicates how accessible an element, for example a metal, is for plants, animals and people. It is the form in which the metal occurs that decides the bioavailability of the metal and therefore the risk of negative effects. Also for an organism to be able to assimilate the metals it needs, the metals must be in a bioavailable form.

In the case of many metals, free ions are the most bioavailable form. If for example zinc forms part of a compound it is not as accessible as it would be if it occurred as zinc ion. For a metal to occur in ionic form it has to be chemically dissolved, for example, by water.

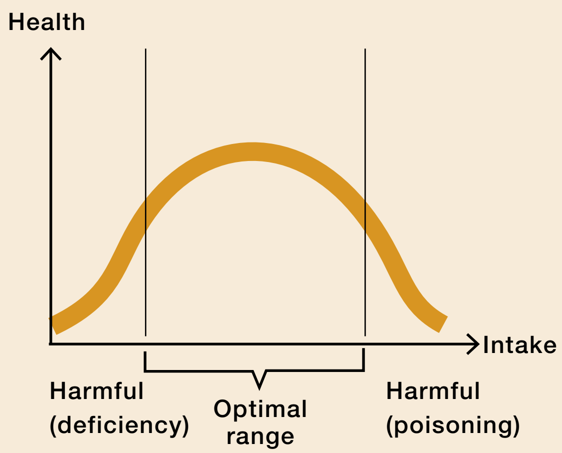
How can the effect of metals in the environment be assessed?

There are various methods for assessing the level of bioavailability and therefore the level of potentially harmful metals in the environment. For analysis of the content of bottom sediment or sludge the so called SEM/AVS-method, is a useful tool. When an assessment needs to be made of the effect on water the BLM-method is used instead. Both methods are the result of the latest research in the field. Method development is nevertheless constantly ongoing and increasingly effective methods are being tried and tested.

How can potential risks be assessed?

In order to make a realistic assessment of the bioavailable forms of a certain metal, consideration must be taken of the local conditions in the field. For example the water's pH, hardness and natural background concentrations. Furthermore these conditions vary throughout the year. As far as possible, field studies should be carried out over a long period of time. Short term investigations based on addition of metal to the environment or laboratory studies are often not sufficiently reliable.

With the help of mathematical models such as BLM the distribution and content of various forms of metal can be predicted. On the basis of these, an analysis of the risk of harmful effects, given the local environmental conditions, can be made.



The useful range of intake

For an organism insufficient intake of an essential metal can be harmful, leading to symptoms of deficiency, while intake that is too high can lead to toxic effects. In a range between the two there is a non-damaging and even beneficial concentration that is required for normal function. The border between 'beneficial' and 'harmful', varies for different species and individuals.

Bioavailability in sediment is measured in samples from the lake bottom.

ASSESSING BIOAVAILABILITY IN BOTTOM SEDIMENT – “SEM/AVS”

Metals in sediments are often bound as metal sulphides with very low solubility and are therefore not bioavailable. If sediment is treated with hydrochloric acid many of the metal sulphides can be dissolved. They then release both metals (SEM: ‘simultaneously extracted metals’) and sulphides (AVS: ‘acid-volatile sulphides’). The quantity of metals and sulphides in the acid can then be measured.

By comparing the amount of metal (SEM) with the amount of sulphides (AVS) it is possible to create a picture of the bioavailability of the metal. A large amount of metal in proportion to the amount of sulphides indicates that there are metals in the sediment that are not bound to sulphides. If the quantity of metal is on the other hand less than the quantity of sulphides, that is to say the SEM/AVS quotient is less than one, it is clear that the metals in the sediment mainly exist bound as metal sulphides and are therefore not bioavailable.

The method does not take into consideration exposure via food intake.

The effects of metals on fish and other aquatic organisms are assessed.

ASSESSING THE POSSIBLE EFFECTS ON AQUATIC ORGANISMS – ”BLM”

With the help of the recently developed ‘BLM’ (biotic ligand-model) it is possible to assess the effects of metals such as copper, nickel, silver and zinc on water organisms such as fish, daphnia and algae. Effects are caused by, for example, metal ions accumulating in the tissue or organs of fish. In order for such an accumulation to take place the metal ions must first be absorbed from the water, which occurs through the metal ion binding to a particular place (biotic ligand) on a fish’s organs, usually the gills.

By taking into consideration, among other things, the hardness, pH, concentration of particles and of complexing agents in the water, the concentration of metals actually bound to the organ can be calculated and the toxicity of the metals in different types of water predicted. Very simply, this model gives a theoretical explanation to previous observations of metal behaviour in nature.

Learning from HISTORY

The Falun copper mine has released more metals and acidifying substances to the environment than anywhere else in Sweden. A thousand years of mining have led to approximately six million tons of sulphur dioxide being released into the air and probably between a half and one million tons of copper, lead, zinc and cadmium being released into the surrounding woodland and watercourses. Throughout the entire lifespan of the Falun copper mine it produced large quantities of mine waste and slag from smelting. These emissions have had an obvious effect on the environment.

By studying the environment around Falun important lessons can be learned about how nature has been affected by the large scale discharge of sulphur dioxide and metals. The effects in the environment around Falun copper mine are still clearly visible today.

Today mining operations in Sweden are regulated by many laws and regulations. Mining operations and metal extraction must take the environment extensively into consideration. Even before starting a new mine, plans are required for its decommissioning. An extensive monitoring programme is required in order to measure discharges and any effects on the environment. These requirements also applied to the last decade of the Falun copper mine until it was closed at the beginning of the 1990s.

Three possible reasons for the recovery of the environment in Falun

- Significant quantities of the metals are bound in forms that are not bioavailable.
- The balance between ‘essential’ and ‘harmful’ metals is favourable.
- Certain plants successfully adapted to the high metal content of the local soils during the long period that the mine was in operation.

Despite the environmental effects in Falun being dramatic there are positive signs. There is confidence that the land around Falun has to a large degree managed to recover during the latter half of the twentieth century. The vegetation that was absent from the mining area has begun to return since discharges to the area were discontinued.

How has the environment around the Falun copper mine been able to begin to recover? There seem to be at least three reasons. The first is that most of the metals in the mine surroundings are bound in forms that are not bioavailable. The second is that the balance between 'essential' and 'harmful' metals seems to be favourable. The third is that certain plants have adapted to the high metal content of the local soils over the long time that the mine was in operation.

The environmental history around the Falun copper mine can be used to improve our understanding of how natural ecosystems react to the long term discharge of metals and sulphur as well as how they are capable of recovering once the discharge has ended. This is a source of knowledge on complicated environmental issues.

A thousand years of mining operations caused vegetation to disappear completely from the area around Stora Kopparberg's mine. Today the environment around the mine has slowly but surely begun to recover. Greenery encroaches on the Creuz head frame. The mine is now a historical monument and world heritage site.

Image from: Dalarnas museum

Links to where you can find more information

www.kimab.com
Institute of Corrosion and Metal Research

www.corrosionscience.se
KTH Department of Corrosion Studies

www.ivl.se
IVL Swedish Environmental Institute

www.sgu.se
The Geological Survey of Sweden

www.kopparberget.com
The Kopparberget World Heritage Centre in Falun

www.copperinfo.org
The International Copper Association

www.nickel-institute.org
The Nickel Institute

www.worldsteel.org
The International Iron and Steel Institute

www.icdachromium.com
The International Chromium Development Association

www.iza.com
The International Zinc Association

Literature where you can find more information

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The Environmental History of the Falun mine
Lennart Lindeström, published by Stiftelsen Stora Kopparberget (2003).
ISBN 91-631-3536-1

Zinc in Society and in the Environment
L. Landner and L. Lindeström (1996).
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Copper in Society and in the Environment
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2nd rev.ed. (English edition) 1999.
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MITF
Metall Information

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www.jernkontoret.se

Nordic Galvanizers
www.nordicgalvanizers.com

The Swedish Plastics and Chemicals Federation
www.plastkemiforetagen.se

Scandinavian Copper Development Association, SCDA
www.scda.com

SveMin
Swedish Association of Mines, Mineral and Metal Producers
www.svemin.se