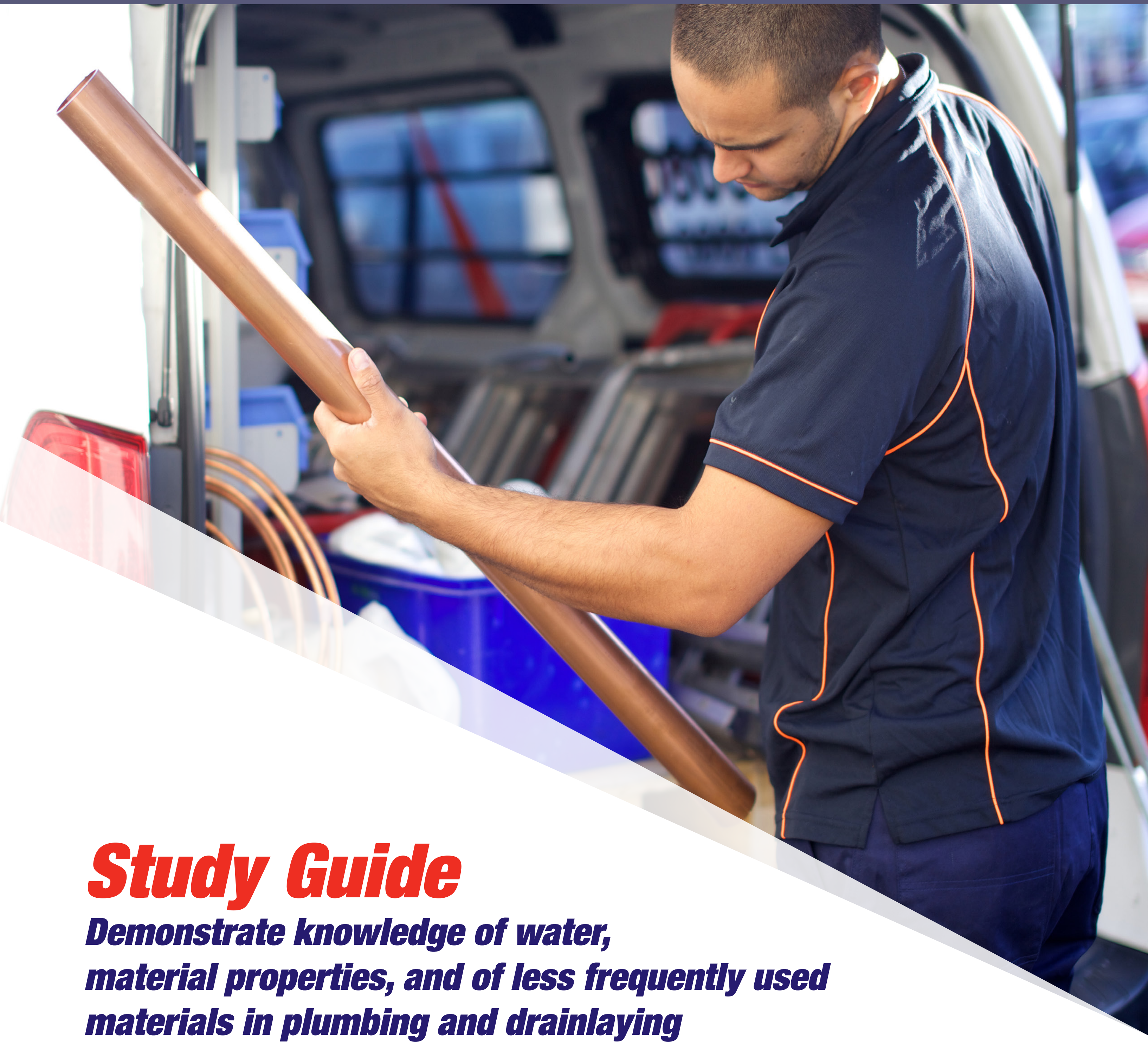


Study Guide

Demonstrate knowledge of water, material properties, and of less frequently used materials in plumbing and drainlaying

30616 | Version 1 | Level 3 | Credits 3

Trainee Name

Grow by growing others

skills.

Unit Standard 30616

People credited with this unit standard are able to demonstrate knowledge of:

- water in relation to plumbing and drainlaying
- compatibility and protection considerations of materials used in plumbing and drainlaying
- properties of less frequently used materials in plumbing and drainlaying
- the application of less frequently used materials used in plumbing and drainlaying

The best way to use this Study Guide is:

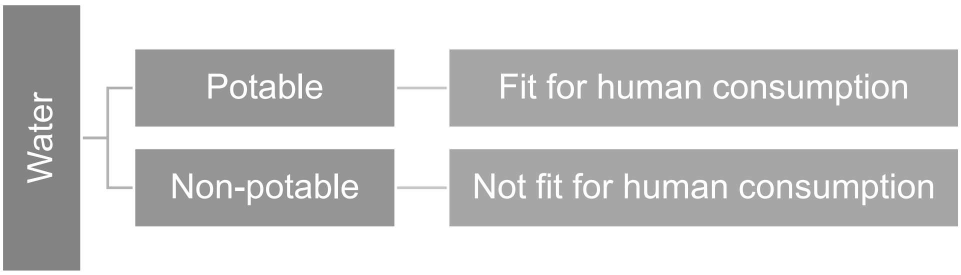
1. Read through the following information step by step.
2. Where other resources are mentioned (such as websites), find those and read them as well.

Contents

Water

Types of water in plumbing or drainlaying

Working in plumbing or drainlaying industries involves being able to identify the various types of water you may come in contact with. Generally, they can be divided into two main groups, potable and non-potable.



Potable water

Potable water is water that is fit for human consumption.

In New Zealand the public water supply is provided by the network utility operator. In rural areas it can be supplied by bores and wells, rainwater or tanker.

If supplied from a reticulated public water supply or provided by tanker, it must meet the Heath (Drinking Water) Amendment Act 2007 which ensures that all public water supplies are safe and palatable for the consumer.

The network utility operator will supply water as far as each property's boundary isolation valve. At this point, it is the responsibility of the plumber to provide water to every outlet within the property without reducing the quality of the water.

When supplied from bores, wells or rainwater for a private supply, it can be difficult to maintain the quality of the water. Chemicals, organic matter or organisms may be present, and it may require further treatment to improve the quality.

Quality of water

Potable water for domestic use should fulfil the following conditions and be:

- practically colourless, clear, sparkling and free from sediment
- pleasant to taste and odourless
- soft to touch, dissolve soap easily and contain only small amounts of mineral matter (if any)
- free of organic matter
- free of organisms that may cause disease

Appearance

Ideally, water should be colourless, but when viewed at depth even pure water will appear slightly blue. The presence of organic matter within surface water varies the colour of water from green to yellow or brown.

Turbid water is water which is not clear due to the presence of organic matter particles or solids suspended in the water. Although turbid water is not visually pleasant, it may still be suitable for consumption.

Turbidity in surface waters often varies due to recent weather conditions. For example turbidity levels will increase with wet weather and decrease with dry weather.

Underground water sources should supply clear colourless water as all impurities are filtered out as water flows through the earth.

Flavour and odour

Water taste can vary from region to region due to a number of factors. For example, bore water may contain ammonia or nitrates, whereas iron and calcium may be found in surface water.

As well as the source of the water, the treatment used by the regional water treatment facility to reduce impurities to acceptable levels can change the taste of the water. The network utility operator may choose from a variety of treatments such as settlement, aeration, ultra-violet treatment, as well as chemical additives, to treat the raw water.

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Oxygen depletion can change water flavour too, leaving it flat and insipid. This can occur if there is organic matter present, as the oxygen is required for decomposition. Oxygen is also lost when water is required to be boiled.

The taste of oxygen depleted water can be enhanced by aeration. This can be achieved by vigorously shaking a vessel of water or using aerators (which double as filters) on taps.

Odours, while possibly unpleasant, are not always hazardous to a person’s health. Odours develop as a result of organic growth in surface waters and from stagnation in well water. The process of chlorination may often leave a smell in the water.

Water and heat

Water is the most abundant substance on earth, and the only one that can be naturally found in all three states of matter (solid, liquid, or gas). As with all substances, the effect of temperature and pressure alters the structure or bonding of its molecules.

Materials change between the different states, as their temperature is raised or lowered. This is because the level of heat in a material determines how active the atoms and molecules are and this determines if their forces of attraction are strong enough to keep them together.

At ordinary temperatures and pressures, water expands when heated and contracts when cooled. This is because the molecules move further apart, or closer together. Because the molecules move apart when heated, it takes less of them to fill the same volume. This results in the volume becoming lighter, or less dense.

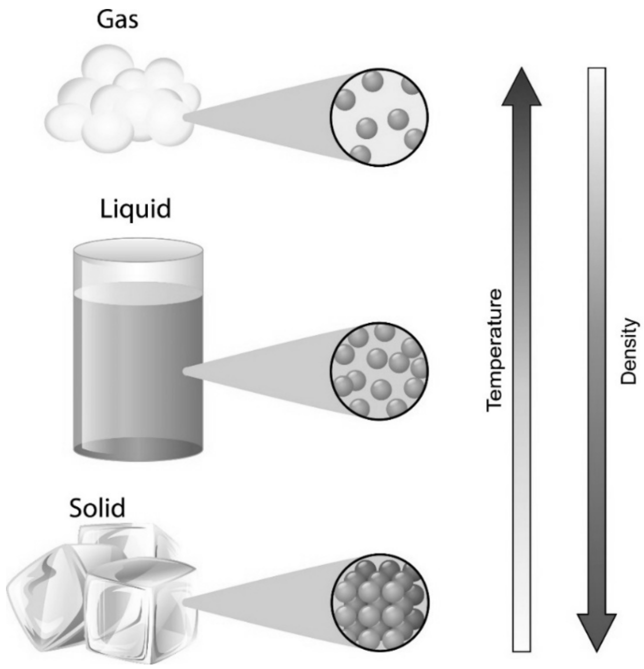
When water is at 4°C it is at its densest or "heaviest", and starts to form a gas at 100°C at its "lightest". For this reason, when heating a volume of water, the hottest water will move to the top, and the cooler water to the bottom of a vessel or container.

Specific heat capacity is the heat energy applied to a substance to raise its temperature e.g. the amount of heat required to raise 1kg of water at 4°C through 1°C temperature rise is 4.2 Kj.

When water has a temperature of below 0°C it becomes a solid (ice). If heat is continuously applied to ice, it increases in temperature until it gets to 0°C, which is when it starts to melt. Adding more heat at this point doesn't initially raise the temperature, as the energy from the heat breaks the molecular bonds holding it together, turning it into water.

This heat energy is referred to as latent. The same thing happens when water reaches 100°C, latent heat energy turns it into gas (steam).

As water cools, its heat energy can be transferred through conduction, convection or radiation.



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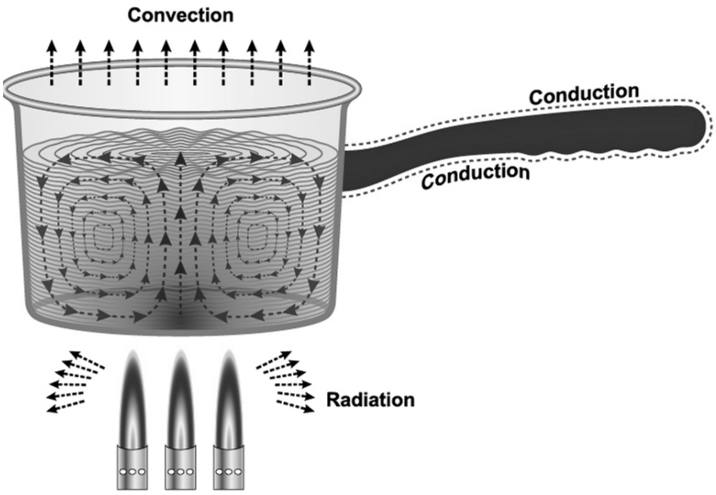
- **conduction** is energy transfer through solid materials; for example, heat traveling through a metal bar
- **convection** only occurs in liquids or gases. This is the movement of a less dense liquid or gas upwards, such as hot water in a cylinder, or hot gases in a flue.
- **radiant** heat is transmitted through space, for example the sun's rays passing through the vacuum of space, or the heat felt from standing in front of an open fire.



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Non-potable water

Non-potable water can come from a variety of sources, such as rivers, stormwater run-offs, or recycled water. Although it is not deemed fit for human consumption, it can still be used for industrial and agricultural applications, irrigation and domestic use such as toilet flushing.

Foul water

The New Zealand Building Code G13 Foul Water defines “foul water” as being the discharge from any sanitary fixture or sanitary appliance. Foul water can be broken down into two groups:

- greywater and
- blackwater.

Greywater

Greywater is any domestic wastewater produced from baths, showers, hand basins and in some cases, from laundries. It excludes sewage and water from kitchens because it contains fats.

Recycled greywater

With proper treatment, greywater can be recycled and put to good use. These uses include water for laundry and toilet flushing, and also irrigation of plants. The nutrients in the greywater (such as phosphorus and nitrogen) provide an excellent food source.

Like all wastewater, greywater is likely to contain suspended solids, be cloudy in appearance and possibly have an odour. Before re-use it needs to be filtered and treated, as it can be harmful or infectious. When used for irrigation it is recommended for below ground systems only (not sprinkler systems).

Re-use of greywater can reduce the usage of fresh water in a house and provide a source of water for garden irrigation during dry periods. In rural areas, it can provide a reduction in water entering an on-site effluent disposal system. Because of the health risks involved in collecting and storing grey water, a building consent is required to install such a system.

Blackwater

Blackwater is water from kitchens and toilets, and in some cases laundries. It can contain chemicals, fats and organic materials from kitchens, and faecal matter from toilets. As with all foul water it may have odours, be cloudy in appearance and be highly infectious.

Unlike greywater, it cannot be reused due to the organic or faecal loading and so needs to be disposed of into the council sewer or an onsite effluent disposal system.

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Water quality variation in NZ

Water hardness is caused by minerals such as calcium and magnesium in water. The source of the water has a large impact on if it is hard or soft – rainwater tends to be soft, whereas water from the ground can contain minerals making it hard.

The Drinking – Water Standards for New Zealand 2005 (Revised 2088) gives a scale of hardness that ranges from soft through to very hard. For example, water from the Rotorua District Council is mainly classed as soft, whereas water in some Gisborne areas is classed as hard.

While hard water is safe to drink, it can be aesthetically unattractive. Hard water also makes it difficult to lather up soap and the minerals form a residue that makes it harder to rinse items. It may also cause white chalky scale or water spots on glass and stainless steel. In the long term, hard water can cause scale to develop on the inside of pipes.

Other variations in water quality relate to additions made to water. Some councils/territorial authorities, such as Rotorua Lakes Council, add chlorine to water supplies to disinfect it. Others, such as the Auckland, Gisborne, and Dunedin Councils add fluoride to the water to prevent tooth decay.

Materials

Why are material properties important?

Plumbers and drainlayers need to understand why the materials we handle every day behave the way they do. It will also help us to select and install products in a way that will best suit the application.

How a product behaves in its application depends on a variety of factors, including:

- what it is made of (the materials used)
- how it has been made
- how it has been installed
- the stresses it will be subjected to when it is in use
- the environment in which it has been installed.

A product is chosen for a particular task due to the properties or characteristics of the materials it is made of. The properties of a material relate to the way it is or behaves in certain situations.

Material properties

Every material has a variety of properties that may make it more or less suitable for a particular application or purpose. The most important factor when deciding which material to use is its durability, i.e. it will last for a suitable length of time before failing for any reason, in its normal use.

If there is a range of possible materials that are suitable given their durability, a choice can then be made based on a variety of other factors such as the:

- cost of the material
- cost of manufacturing
- cost of installation
- availability of the product
- and/or personal preference.

Physical properties

Physical properties are the properties of a material that can be observed or measured without changing the composition of the material. For example:

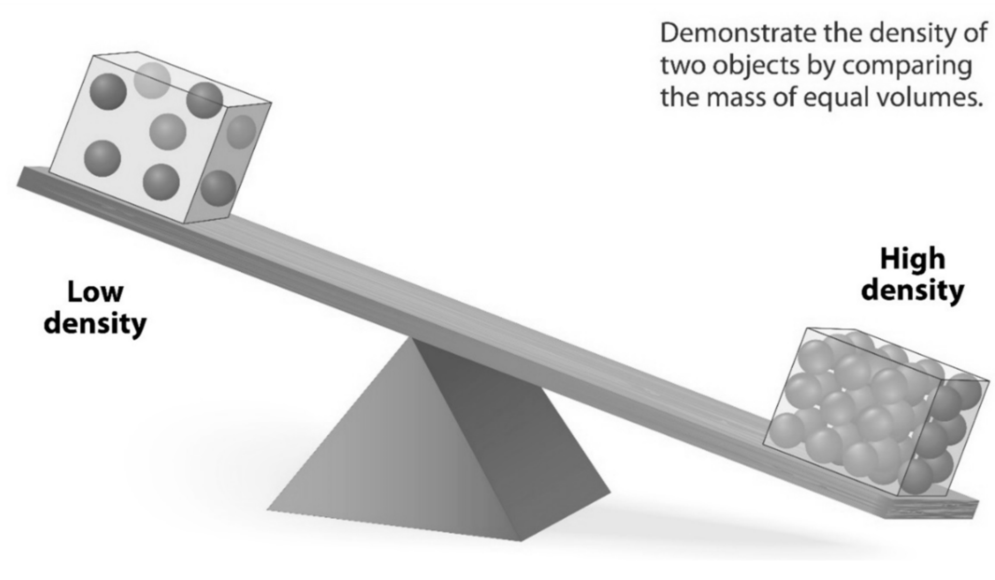
- colour and smell
- hardness
- density
- thermal properties (freezing, melting and boiling points)
- electrical properties
- mechanical properties
- conductivity
- or whether the material is porous or solid

Density and weight

As discussed in 'Water and Heat', a material's density is a measure of its mass and how tightly the atoms and molecules are 'packed' together. The higher the density of a material, the heavier it is. Water is taken as the standard measure – one litre of clean water has a mass of one kilogram. Lead for example is 11.3 times heavier than water of the same volume.

Density becomes an issue in construction when the load of the product needs to be supported. For example, if a roof material weighs more, or is denser than the framing that supports it, then the framing will need to be stronger. If a pipe is denser than another, its brackets will need to be stronger and may need to be installed closer together.

Heavy materials also require greater care when it comes to lifting, therefore if there is a choice between similar materials or products, the less dense material or product would normally be chosen.



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Thermal properties

Thermal properties relate to how materials react to temperature change. There are several different measures.

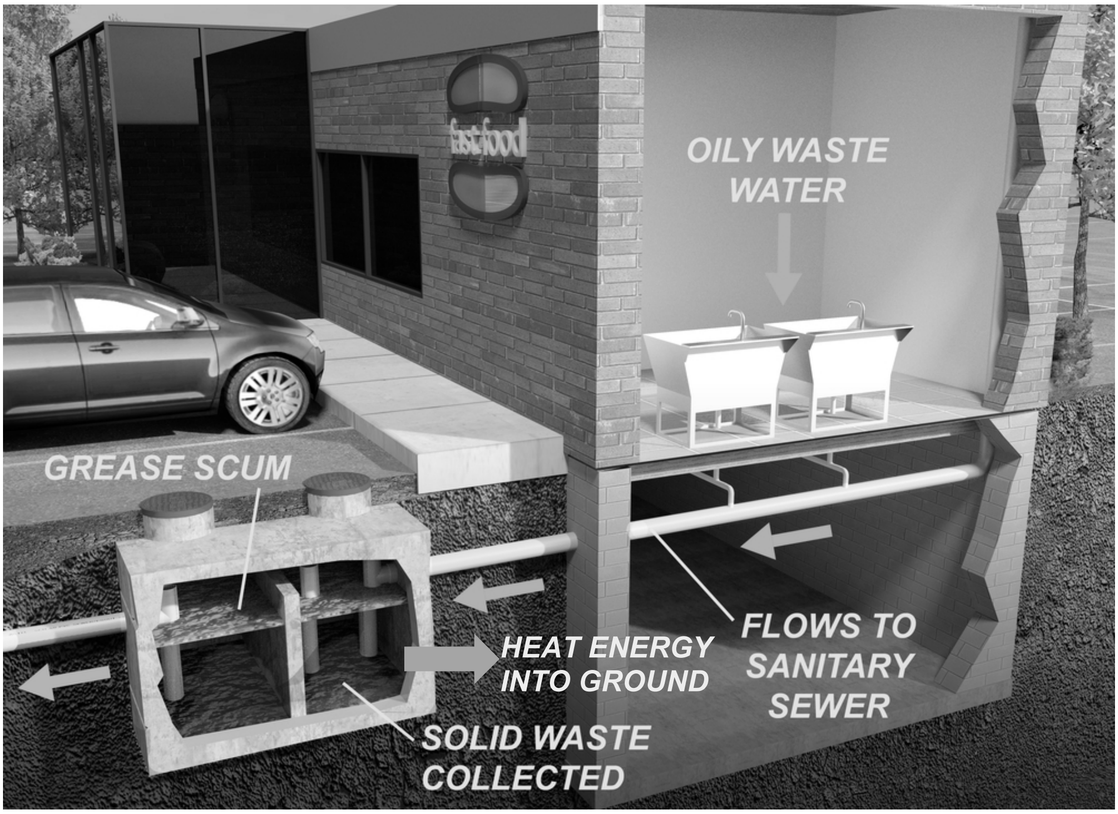
Melting and boiling points

Materials have differing melting and boiling points, which are the point when the material changes state. As mentioned previously, water changes state at 0°C and again at 100°C. Lead changes from solid to liquid at 327°C and steel changes state at 1371°C.

Plumbers and drainlayers will normally work with solid materials, but the materials used must reflect their use. When installing pipes conveying fluids, consideration has to be given to the temperature that a material can withstand as high temperatures can place stress on piping materials and systems.

In extreme cases excess heat can cause materials to fail, which is important when melting materials, or trying to avoid melting them. For example, PVC begins changing state and distorting at 92°C so hot water discharging into a drainage system can damage pipes and fittings. The system may require cooling or transfer of the heat energy into the ground or atmosphere by passing through an interceptor trap designed for it.

Interceptor trap



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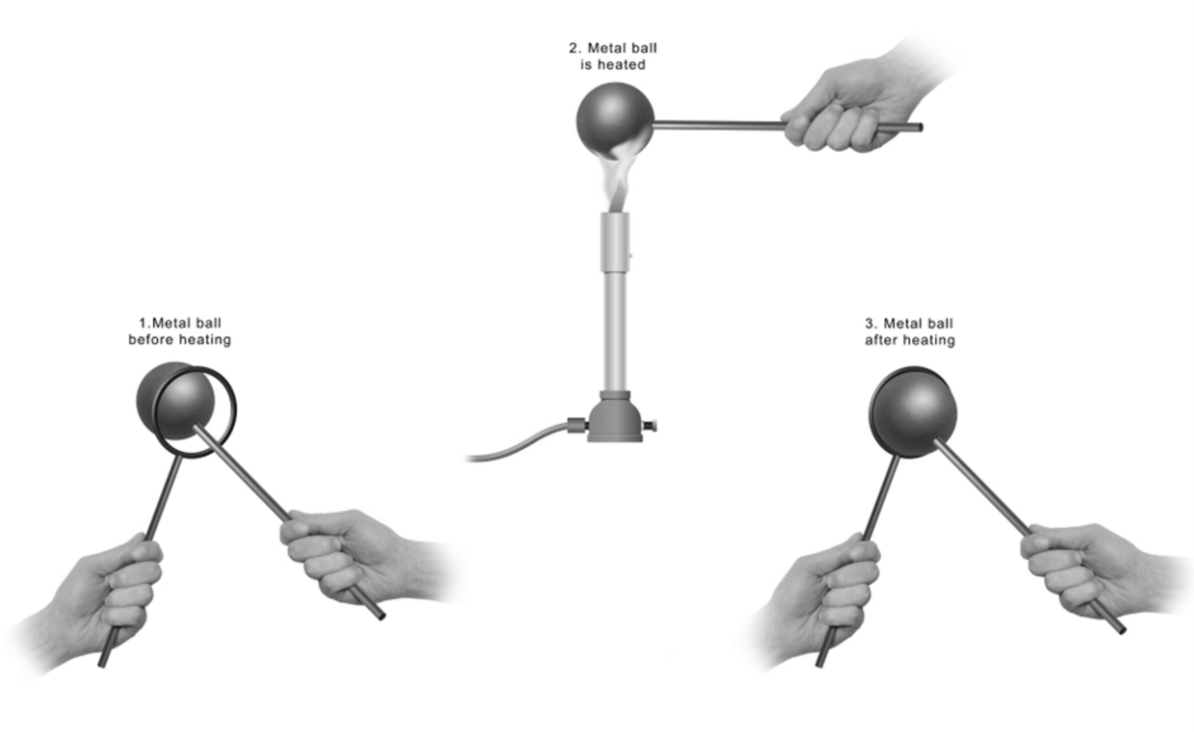
Interceptor traps allow heat from the wastewater to be transferred to the ground. This allows the waste to cool enough to go into a PVC pipe without distorting it. The metal traps are a good conductor of heat from the hot wastewater through to the ground.

Thermal expansion

Materials also expand and contract at different rates when they are heated or cooled. These rates are called coefficient of linear expansion, and each material differs in how it responds.



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Usually for plumbers or drainlayers the consideration is how much the length of a pipe will increase as it is heated.

Tables are available which give the coefficient for different materials. In most cases the increase is very small, however large temperature changes over long lengths of pipe can put very strong forces on the pipework. Allowances can be made for the material to expand freely to prevent stress being exerted on the material or the structure.

Thermal conductivity transfer

Thermal conductivity is a measure of how well heat moves through a material. It is relevant when looking for the transfer of energy in heat exchange systems, or for preventing heat loss or gain with insulation.

Mechanical properties

The mechanical properties of a material characterise how it will behave when force is applied to it, which is important when it comes to material selection. For example, a pipe must withstand the pressure of the liquid inside it without bursting. It will also need to be strong enough, if it is buried, to support the load of the soil and not be damaged through contact with other materials.

A range of different properties that relate to mechanical situations are described below.

Strength

The strength of a material is a measure of its ability to withstand stresses or loads. These loads can be applied in a variety of different ways.

Tensile strength

Tensile strength refers to the ability of a material to resist stretching or pulling apart. Stretching can be applied by pulling from both ends. In a pipe tensile strength is the ability to resist stretching in the internal part of the pipe (under pressure).

A bike tube is a good example of a material with poor tensile strength - when pulled from both sides it stretches easily and as pressure increases internally the rubber stretches to fill the tyre.

When describing a material's overall strength properties it is usually tensile strength that is being referred to. It influences installation as materials should be able to contract with temperature change, without placing too much tension along the length of the material.

A material should also be supported at regular intervals to prevent bending and should be strong enough to withstand the pressure of the liquids inside them.

Compressive strength

Compressive strength is the ability to resist crushing or squashing. This is especially important for drainlaying, as pipes are buried and may suffer compressive loads from backfill and vehicles.

Shear strength

Shear strength is the ability to resist tearing. This happens when loads are concentrated across a material in opposite directions. For example, a suspended pipe will have shear force near its supporting brackets, as the weight of the pipe and its contents pulls against the force of the bracket holding it up.

Torsional strength

Torsional strength is the ability to resist twisting such as the screwing actions when materials are being joined together. Weaker materials may fail if too much force is applied.

Stainless steel square drive screws for example, have poor torsional strength and can snap off easily compared to zinc plated steel ones which resist the torsional action better.

Stiffness

It is important to note that all materials, regardless of their strength, deform under load.

For small loads this is not noticeable, but for larger loads this can be measured. In plumbing and drainlaying the aim is to keep the stress on a material within its elastic limits. This means that if the load is removed, the material will return to its original shape. This is referred to as the 'stiffness' of the material.

Brittleness and plastic deformation

Each material has an elastic range and, if overloaded, plastic deformation takes place, which means that the internal structure of the material has begun to break down and when the load is removed it won't return to its original shape.

Brittle materials such as glass do not plastically deform, they tend to 'shatter' when they fail. Materials that do plastically deform are called 'ductile' or 'malleable', which means they can be drawn into lengths or flattened out without breaking.

Toughness

Toughness is another desirable property for a material to have. It means that the material can sustain minor damage, like abrasions and small cracks or cuts, without seriously affecting its strength. The structure of the material distributes the load around the weakness instead of concentrating it at the point of damage, leading to failure.

Malleable or ductile materials are generally tougher than brittle ones.

Hardness

The hardness of a material is its resistance to indentation, marking and scratching. Hard materials are used as abrasives for grinding and for cutting softer ones. Softer materials may need protection from harder ones in situations such as backfilling a trench over pipework.

Work hardening and annealing

Working or deforming metals at low temperatures can increase their strength and hardness. This distortion of the crystal structure puts tension in it, and also dramatically reduces its ductility. This may be desirable if a material is too weak in its 'natural' form for an application.

Ductility can be returned, and strength and hardness reduced, by annealing the metal. Annealing involves a process of heating the material above its recrystallisation temperature, which is below its melting point. This allows the crystals to realign, releasing the inbuilt tension.

Chemical properties

Most materials tend to chemically react and have to be processed in order to make them useable for construction purposes. It is important that in their application they don't react with their environment and lose the properties they have been manufactured with. We will look at chemical characteristics and corrosion later.

Materials used in Plumbing and Drainlaying

Metals

Aluminium

In the plumbing and drainlaying industries aluminium is mainly found in roof sheeting, flashing and drainage applications due to its low density and corrosion resistant properties.

It is lightweight, ductile and malleable. It is often pre-painted. It is also used in reflective foil insulation products, and in composite piping systems laminated between layers of plastic. The aluminium in this application provides strength and is impermeable to gas.

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Copper

Copper's durability and workability make it a popular material especially for plumbers, where it is mainly used in pipe form for water, and some sanitary applications.

In sheet form it is occasionally used for roofing in corrosive environments, or where durability is an important requirement. Its thermal conductivity makes it ideal for heat exchangers such as in refrigeration, air conditioning, boilers and solar collectors.

In installation, consideration needs to be given to its high rate of lineal expansion, and the reduction of tensile strength that takes place when annealing the pipe. This occurs during the brazing of fittings and the formation of bends.

Brass

Brass is the common name for the alloy made primarily from copper and zinc and a small amount of lead. Brass varies in colour from reddish to light yellow as the proportion of copper is decreased.

Brass is harder than copper or zinc, and because of its relatively low melting point is easily cast into shapes and machined for manufacture into valves and plumbing fittings (which are often plated). It can be subject to degradation due to the zinc reacting with lime, calcium or water containing high levels of chlorine, so should not be used in situations where high levels of these chemicals may be present.

Bronze

Bronze is one of the earlier metal alloys, originally made up of copper and tin. It is both strong and malleable, meaning it would not crack as easily as something like iron. Bronze now has other metals added to it, and has a higher level of lead than brass.

When using bronze fittings for water supplies, the lead content should be checked as it may not be permitted. It is preferred for marine applications over brass as the tin content is more resistant to saltwater degradation than the zinc content in brass.

Bronze has a rough, porous exterior with small cavities in the surface that are formed when it is cast. However, bronze alloys with select additives can hold a polish and are not as abrasive. Bronze has many benefits, including high ductility (resists cracking), corrosion resistance, and low cost.

Lead

Lead is a pure metal with the chemical symbol Pb which comes from its latin name plumbum (which is where the word plumbing came from).

It is a heavy metal, being denser than most others and is soft and malleable, easily worked from sheet form into flashings and roofing components. However, it should not be used in contact with aluminium or zincalume.

Lead also rapidly forms a protective oxide layer that makes it corrosion resistant. However, this layer can be slowly dissolved by water, and enter the water supply. Lead is a toxic substance that accumulates in the body and can cause damage to the nervous system, kidneys, and cause blood and brain disorders. Lead affects young children in particular, and it can also affect pregnancy.

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For these reasons, lead is generally being removed from the environment.

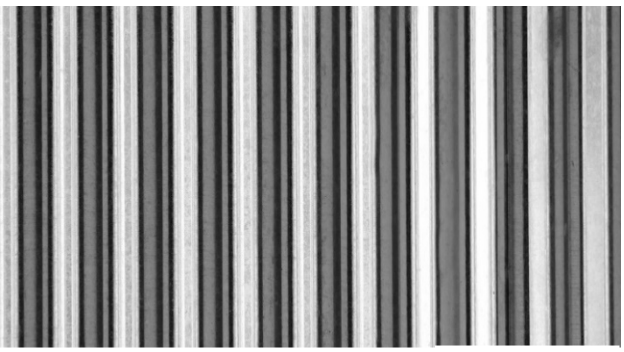
Paint is now lead free, and soft solder for water supply has to be less than 0.1% lead.

Lead should not be used in roofing flashings or gutter solders, especially when the water is collected for domestic use. Working with lead is an obvious occupational hazard and guidelines on material safety data sheets (MSDS) should be followed.

Zinc

A zinc coating can be used in roofing applications (e.g. zincalume corrugated iron). Pure zinc is not commonly used as a roof covering as it is not strong enough to support itself in sheet form.

Zinc is an alternative to lead as a flashing material and is suitable for downpipes and guttering.



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Ferrous alloys

Ferrous alloys are iron based compounds, for example cast iron. In plumbing and gasfitting installations, mild steels are used the most due to their lower cost and reduced need for hardness and wear resistance. In roofing products, some medium carbon steels are occasionally used.

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Galvanised mild steel piping is no longer used for drinking water applications or below ground. Black mild steel (BMS) is used for pipes in heating applications.

Steel is also used extensively in structural situations such as brackets and fixings, and in gratings and covers for pits and chambers.

Alloy steels such as stainless steel

Alloy steels contain greater quantities of different alloys than the plain carbon steels, and are made for a wide variety of reasons including improving strength, hardness and wearing properties. The alloys include aluminium, cobalt, copper, chromium, nickel, niobium, molybdenum, phosphorus, titanium, tungsten and vanadium.

Stainless steel

The stainless steel group, which has the main alloy of chromium with concentrations of chromium ranging between 10 and 25 per cent is used the most in plumbing. Stainless steel is resistant to high temperatures and is chemical resistant. Stainless steels are corrosion resistant for the same reasons that non-metals are. A very thin, hard layer of chromium oxide forms on the surface of the material, protecting it from further attack.

The different chromium concentrations give different grades of protection; however, the chromium can react with galvanised unpainted steel or zinc roofing components. It is used in a variety of products where corrosion resistance is required. The most common application is in fixtures, such as kitchen sinks and laundry tubs, but it also has applications in piping and pumping systems and is useful in a variety of joining systems.

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Cast irons

Cast irons are formed by casting the molten mixture of iron into a finished shape; for pipes this is done in a spinning mould, the centrifugal force keeping the liquid to the outside until it solidifies. This economic method of manufacture has been used for a long time, and produces a product quite different to steel, with cast irons being generally more brittle, harder and more corrosion resistant than steel.

Cast iron has been commonly used for casting baths, gratings and lids. In its pipe form, it has been used for gas and water and conduction. It was also used extensively for sewer stack work.

It is difficult to work due to its brittle nature and subject to corrosion in some environments. For example, it would not be suitable in a highly corrosive environment such as a neutralising interceptor trap.

Ductile and malleable irons

Grey irons have been, and still are, used for sanitary piping systems and cast products such as baths, pit covers and grates. The increased toughness of ductile irons has seen them replace the grey cast iron water mains.

Polymers

Thermoplastics

These plastics make up the majority of polymers used in the trade, and have been progressively replacing metal and ceramic piping systems in lower temperature applications. The different types have similar mechanical and chemical properties.

Polyethylene

Also known as polythene this is the simplest polymer chain based on the ethylene monomer. It comes in several forms depending on the extent of polymerisation, the length of the molecular chains, and the extent of branching, which can be controlled to manage properties. High Density Polyethylene (HDPE) has the simplest form with minimal branches, allowing the molecules to be packed tightly together. This makes it more rigid and temperature resistant than lower density polyethylenes, making it suitable for sanitary and heated water applications. The lower density pipes can only be used in cold-water applications.

Another form of polyethylene is made when cross-linking is introduced to PE-X, making the material more elastomeric in nature and capable of handling heated water applications. Pex pipe is another, widely used form of piping in current use. It is also cross linked with aluminium to make PEX/AL “PEXAL” another common heating, water and gas piping product widely used.

Polyvinyl chloride (PVC)

PVC is based on another simple monomer and is one of the most extensively used plastics with uses in both sanitary and water applications in the plumbing industry. PVC is naturally rigid and has a tensile strength of around 50–70 MPa. It is quite often softened with plasticisers leading the original product to be called unplasticised PVC.

More recently the products modified PVC (PVC-M) and oriented PVC (PVC-O) have become approved materials for use in both sanitary and water supply applications. Both these products increase the strength and toughness of PVC. PVC-M does this by the addition of chlorinated polyethylene in concentrations up to 6 per cent, while PVC-O achieves it by stretching the material at higher temperatures in the manufacturing process.

Polypropylene

Polypropylene's methyl (CH3) group makes this material stronger and stiffer than polyethylene, thus enabling its use in sanitary and heated water applications. Polypropylene can also be combined with the ethylene monomer to produce the 'random copolymer' polypropylene-ethylene (PP-R or EPM), which improves its impact resistance, but reduces strength marginally.

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Polybutylene (PB) and acrylonitrile butadiene styrene (ABS)

These two thermoplastics have more complex structures, being made from a combination of different monomers. They are approved for use in sanitary, water and heated water services due to their properties.

Polycarbonate

Polycarbonate is a strong, tough, transparent polymer that can maintain its properties at 100°C. It is used for transparent roof sheeting as well as safety and bullet proof glass.

Thermosetting plastics

The rigidity and brittleness of thermosetting plastics make them a less common material within the plumbing industry.

Two-part epoxy resins are used as joining compounds, but it is in composite form with fibreglass that thermosets become more useful, due to increased strength and toughness. Depending on the amount of fibre, and its orientation, tensile strength can be improved from as low as 50 MPa to in excess of 1000 MPa. Orientation means its placement within the fibreglass structure, i.e. horizontal woven, criss cross or diagonal woven. Each provides a different bond strength as required per application.

These composites are called glass reinforced plastics (GRP) and are used for moulded products such as arrestors, separators and baths, but can also be used in sanitary, stormwater, water and heated water piping systems.

As well as epoxies, there are also phenolic, polyester, and vinyl ester thermosetting plastics.

Other materials

Vitrified clay pipe (VCP)

Also known as earthenware pipe, VCPs are used for sanitary and stormwater drainage applications but have now been largely replaced by polymer alternatives which are less brittle.

VCP pipes are, however, very durable and are still preferred in certain applications.

Vitreous china

Ceramics are still dominant in fixtures such as toilets and basins, where their smooth hard surfaces allow them to be easily maintained and blend in with the tiled wall and floor finishes.

Glass

Glass is one of the most corrosion resistant materials available, which makes it especially suitable for conveyance of fluids containing chemicals and acids such as in laboratories or industrial plumbing.

It has poor conductivity and is resistant to abrasion but is extremely fragile and brittle, so should not be used in an area where physical damage may occur.

It is often used for sanitary plumbing systems in hospitals and requires mechanical jointing methods such as clamps and gaskets.

Summary of Material Compatibility

The following table is adapted from the NZ Metal Roof and Wall Cladding Code of Practice 2012 published by the NZ Metal Roofing Manufacturers Inc.

○ Suitable
⊙ Suitable but may stain
● Use with caution
× Not suitable

		Aluminium	Pre-painted aluminium	AZ coated steel	Zinc coated steel	Pre-painted AZ steel	Zinc	Copper/Brass	Stainless steel	Lead	Plastics/glass	Concrete & plaster - wet	Concrete & plaster - dry	CCA treated timber
Aluminium	Contact with	○	○	○	○	○	○	×	○	×	○	×	●	×
	Runoff onto	○	○	○	×	○	×	○	○	○	○	⊙	⊙	○
Pre-painted aluminium	Contact with	○	○	○	○	○	○	×	○	×	○	●	○	×
	Runoff onto	○	○	○	×	○	×	○	○	○	○	○	○	○
AZ coated steel	Contact with	○	○	○	○	○	○	×	●	×	○	×	○	×
	Runoff onto	○	○	○	×	○	×	○	○	○	○	⊙	⊙	○
Zinc coated steel	Contact with	○	○	○	○	○	○	×	●	○	○	○	○	×
	Runoff onto	○	○	○	○	○	○	○	○	○	○	⊙	⊙	○
Pre-painted AZ steel	Contact with	○	○	○	○	○	○	×	●	×	○	×	○	×
	Runoff onto	○	○	○	×	○	×	○	○	○	○	○	○	○
Zinc	Contact with	○	○	○	○	○	○	×	●	○	○	×	○	×
	Runoff onto	○	○	○	○	○	○	○	○	○	○	⊙	⊙	○
Copper/Brass	Contact with	×	×	×	×	×	×	○	●	●	⊙	⊙	○	○
	Runoff onto	×	×	×	×	×	×	○	○	●	⊙	⊙	○	○
Stainless steel	Contact with	●	●	●	●	●	●	○	○	○	○	○	○	○
	Runoff onto	○	○	○	×	○	×	○	○	○	○	○	○	○
Lead	Contact with	×	×	×	○	×	○	●	○	○	○	○	○	×
	Runoff onto	●	×	×	○	×	○	○	○	○	×	⊙	⊙	○
Plastics/glass	Contact with	○	○	○	●	○	●	⊙	○	○	○	●	○	○
	Runoff onto	○	○	○	×	○	×	○	○	○	○	○	○	○
Concrete & plaster - wet	Contact with	×	×	×	○	×	○	⊙	○	○	●	○	○	○
	Runoff onto	×	●	×	○	×	○	⊙	○	○	×	○	○	○
Concrete & plaster - dry	Contact with	●	○	○	○	○	○	○	○	○	○	○	○	○
	Runoff onto	●	○	○	○	○	○	○	○	○	○	○	○	○
CCA treated timber	Contact with	×	×	×	×	×	×	○	○	×	○	○	○	○
	Runoff onto	×	×	×	×	×	×	○	○	×	○	○	○	○

Learnops

Materials and corrosion

Materials used in the trade must also be capable of resisting the effects of chemical action and/or corrosion.

Material degradation

Chemical action may cause a material to degrade, break down, form deposits or to add foreign matter to water. If a material degrades, it may become structurally unsound or it may permit leakages to occur. Deposits may obstruct or block waterways.

Foreign matter may cause discoloration, add a bad taste or even be poisonous, and so affect the quality of the water.

Light (UV) can also cause materials such as plastics and rubber to degrade over time. The UV light interacts with chemical bonds in non-metals, and then further reactions with oxygen causes issues such as cracks or disintegration.

Corrosion

Corrosion only occurs in metals. It can be caused by any or all of the following:

- the chemical properties of the materials
- the presence of certain gases
- the presence of organic matter or certain salts
- the presence of water
- the electrolytic action between different materials in contact.

Chemical properties

As a rule, pure metals resist chemical action better than metals which contain other substances. Aluminium, copper, lead, tin and zinc are usually in a relatively pure state, but commercial iron always contains other substances.

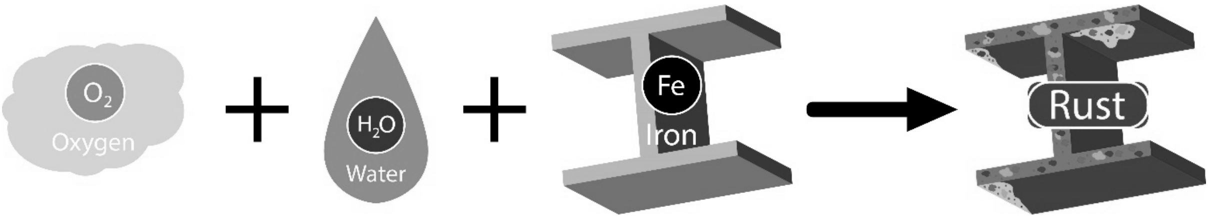
Gases and their effects

Atmospheric air contains oxygen, nitrogen and a small amount of carbon dioxide. In towns the atmosphere may contain additional carbon dioxide, sulphur dioxide and other gases.

Of these oxygen, carbon dioxide and sulphur dioxide are the principal causes of corrosion.

In absolutely dry air, these gases have no effect on metals. However, air usually contains water vapour, which reacts when these gases are present.

Oxygen dissolves in droplets of water and becomes more concentrated than it was in the air.



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Carbon dioxide and sulphur dioxide combine with water to form carbonic acid and sulphuric acid respectively.

The difference in the chemical effect of moist air compared with that of dry air may be seen on the corrugated iron below. The rust is worse in the grooves where beads of water have remained on the surface for some time.

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Effects of organic matter or of salts

The decay of organic matter produces carbonic and other organic acids which cause chemical decomposition of metals. Roofing materials may be affected by chemical action resulting from the decay of mosses, leaves and bird droppings. Water supplies may contain organic matter from leaves and animal droppings.

Certain mineral salts tend to cause chemical action. These salts may be carried into the atmosphere from the sea, or they may be absorbed by water flowing over or under the ground.

Effects of water

Because water is one of the best solvents, it readily takes into solution substances in gaseous, liquid and solid form. Consequently, natural waters are never absolutely pure. The combination of water with oxygen, carbon dioxide and sulphur dioxide has already been referred to. Natural waters, particularly those which have been in contact with the ground, also contain salts of various kinds. All of these dissolved substances tend to cause corrosion.

Galvanic cell corrosion

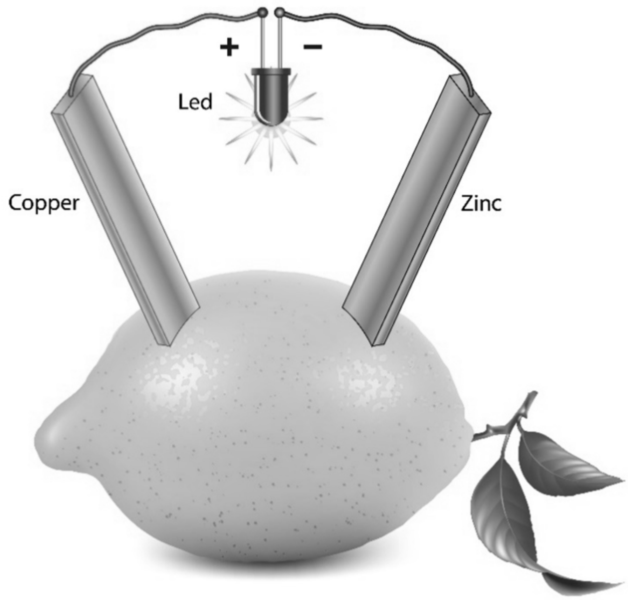
Electrolytic corrosion is of two kinds – electrolysis and galvanic cell action.

1. Electrolysis

Electrolysis results from stray currents of electricity coming from any source of direct current supply. A common source of this type of corrosion is fault current from electrical systems which use metal pipework as part of the earth system. The corrosion occurs where the current leaves the pipe to continue its path back to the source of supply.

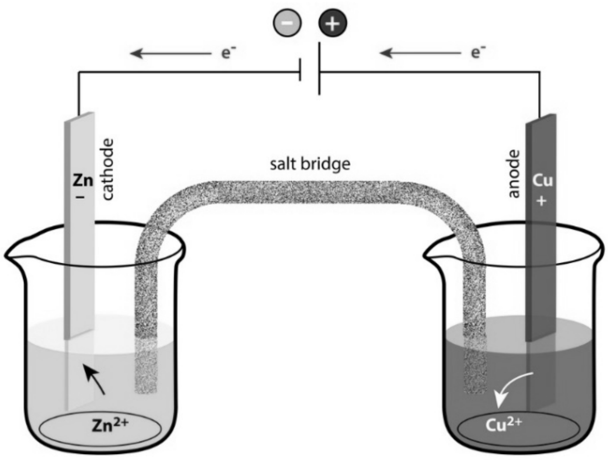
2. Galvanic cell action

Galvanic cell action, generally referred to as galvanic action, is also an electrochemical reaction but is due to a current generated within the cell itself. This type of corrosion can effect plumbing materials.



If copper and zinc plates are put in an electrolyte solution a simple electric cell is formed. Current will flow through a wire if connected to both the metal plates. This is due to the electromotive force (emf) between the metals (copper is more likely to be reduced than zinc). Natural water, being relatively impure, can act as an electrolyte.

A related effect occurs in electroplating, when current from a battery or from direct current mains passes through a solution contained in an 'electrolytic cell'. The electrolyte in this example is a solution containing a salt of the plating metal. The anode, the point where the current leaves the electrolyte, is the metal to be plated.



When current is passed through the cell, some of the plating metal from the electrolyte is deposited as a coating on the cathode, this being replaced from the anode.

The same principle applies to 'cathodic protection' of pipes in corrosive soils. The anode consists of plates of magnesium or zinc buried in the soil and connected to the metal to be protected. On passing an electric current from the anode through the corrosive medium (the soil) to the metal requiring protection, the anode corrodes in preference to the pipe or tank.

Experiments show that the emf of a galvanic cell depends upon the oxidising and reducing nature of the substances forming. From the table below, the emf between any two metals (immersed in a suitable electrolyte) may be found. The actual emf and the direction in which the current will flow will depend upon the position of each metal in the table and, to some extent, on the electrolyte. Such a table is known as an 'electrochemical series'.

The following table, which is an extract from an electrochemical series of elements, lists the metals of particular interest in plumbing.

Metal	Electrode potential in volts
Magnesium (Mg)	– 2.37 corroded (anodic)
Aluminium (Al)	– 1.66
Manganese (Mn)	– 1.18
Zinc (Zn)	– 0.76
Chromium (Cr)	– 0.74
Iron (Fe)	– 0.41
Cadmium (Cd)	– 0.40
Nickel (Ni)	– 0.23
Tin (Sn)	– 0.14
Lead (Pb)	– 0.13
Copper (Cu)	+0.34 protected (cathodic)

Electrochemical series of metals

Magnesium, aluminium and chromium should also protect steel, but in most normal applications magnesium is highly reactive and is too rapidly consumed, while aluminium forms a resistant oxide coating and its effectiveness is limited. Manganese and chromium are more expensive and not as effective as zinc, so zinc is the preferred material.

An example of the application of the electrochemical series is in the explanation of the relative rates of corrosion of tinplate (steel coated with tin) and galvanised iron (steel coated with zinc).

It is well known that a ‘tin’ made of tinplate will rust very quickly once the tin coating has been damaged by a scratch or cut, while a galvanised iron dustbin will resist many years of abuse without undue rusting.

Because rainwater is slightly acidic, having absorbed gases from the atmosphere, when damaged tinplate is wetted by rain, a galvanic cell (tin-dilute acid-steel) is set up. The steel is higher in the table than tin and therefore passes into solution, and rusting takes place rapidly, even more rapidly than it would with steel exposed to chemical action alone. Incidentally, the tin coating will often flake off the parent metal on account of the rusting extending beneath the coating.

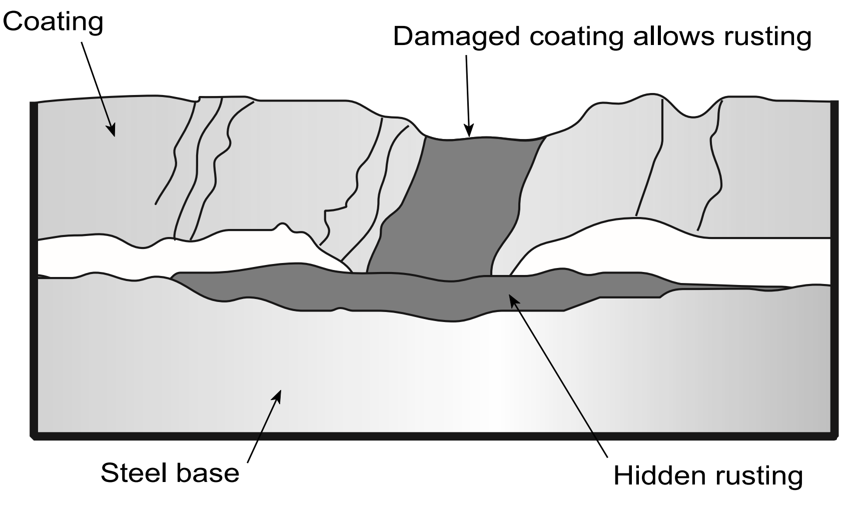
Similarly, an article made of galvanised iron, which has had the zinc scratched off in one place and has been exposed to air and rain, sets up a galvanic cell (zinc-dilute acid-steel). The zinc is higher in the table than the steel and therefore it is the zinc and not the steel which passes into solution. Thus, the steel is protected as long as there is zinc present.

In general, it may be said that a metal high in the table will decompose when placed in electrolyte with a metal low in the table. This is used to protect metals – for example:

- steel will decompose in the presence of copper but if aluminium is substituted for the copper, then the aluminium will decompose and not the steel. The greater the distance in the table between two metals, (i.e. the greater the difference between the electrode potentials of those metals), the greater the rate of decomposition.
- zinc will decompose a great deal in the presence of copper, but the rate of decomposition of zinc when zinc and steel are together is much less.

Coatings and paint

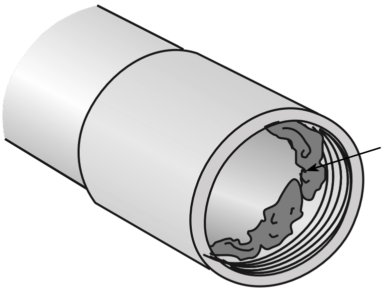
Most organic coatings and paint films depend entirely on their sealing ability to protect steel from corrosion. They offer no protection to bare steel exposed by failure, damage or discontinuity in the coating film. Corrosion starts and spreads rapidly beneath the coating.



Rusting due to paint or plastic coating failure

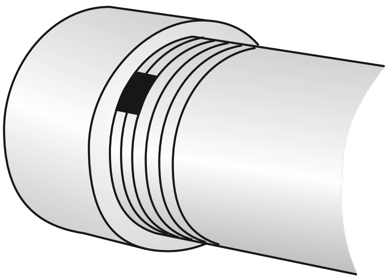
The metals need not be connected by a wire as in an electric cell. If they are dissimilar and are together in an electrolyte, then galvanic action will occur.

For example, small particles of copper falling to the bottom of a galvanised iron tank will cause the zinc to decompose. The copper source might be filings or traces of copper in acid water from a copper water service. A cut edge or a damaged surface of galvanised iron in a tank containing such water, will expose the steel and cause both the zinc and the steel to corrode.



Deposit when brass thread attacks an iron socket

As a result of galvanic action, a deposit has accumulated at the point where a brass fitting has been screwed into an iron socket.



Chemical decomposition of an iron pipe in a brass fitting

This shows the thread of a steel pipe which has been decomposed at the point where water has been leaking between the threads of the pipe and those of a brass cylinder connection.

Galvanic action may occur when different parts of one metal are exposed to contrasting conditions. For example, consider a bar of iron projecting out from water. The metal out of the water is fully aerated and will act as the anode. The rest of the metal under the water will act as the cathode. Electrolytic action will occur where the anode and the cathode are in contact, that is, just below the surface.

As the electrochemical series lists only pure metals, care must be taken in interpreting the table when any metal may be impure or contain other substances. For example, where a foreign substance exists with a pure metal in the presence of an electrolyte, and that substance happens to lie below the metal in the table, then the pure metal will decompose.

For example, mill scale, a compound of iron produced during the manufacture of steel, would be lower than copper in an electrochemical series such as that shown in the table. If galvanic action takes place when mill scale and copper are present, the copper will decompose. Where such impurity exists, the action is usually more localised than general, and the chemical action extends deeper into the metal. A pit may then be formed instead of general decomposition. Cases of pitting decomposition of copper have occurred where small pieces of mill scale have been carried from steel water mains to copper supply tanks.

Galvanic corrosion of copper tubes is caused by the influence of carbonaceous films resulting from the residual drawing lubricant on copper tubes during annealing. These carbonaceous films promote the corrosion of the copper because carbon is lower than copper in an electrochemical series such as that shown in the table.

Decomposition of some brasses by a process known as ‘dezincification’ is also due to galvanic action. Saltwater or water which contains carbonic or other organic acids acts as an electrolyte. Where brass contains a high proportion of zinc, and particularly where there is an excess of zinc (under such conditions as were explained in connection with the making of an alloy), the zinc decomposes and goes into solution, leaving the copper as a porous mass. In this case the colour of the original brass changes to become more the colour of copper.

Sacrificial protection

Sacrificial protection is where a more reactive metal is oxidised in place of another metal, thus protecting it from corrosion. A common example of this is the placing of pieces of zinc (zinc fish) in cast-iron boilers so that the zinc decomposes in preference to the iron, thus protecting the iron. An example of a sacrificial anode is shown below on the side of the pipe.

Although aluminium pipework has been used in plumbing systems (because of its resistance to corrosion), it is also recognised that aluminium will decompose wherever it is joined to another metal. In anticipation of this decomposition, a short length of aluminium pipe is inserted where the aluminium joins another metal, in a position where it may be readily replaced when required.

Steel hot water cylinders can have a glass lining to prevent galvanic action, however, if a fault develops in the glass lining, galvanic action will take place and the steel will decompose without the addition of some sort of protection. This is done by installing a sacrificial rod or anode with a lower electrode potential than steel. It is the anode that slowly decomposes, thereby protecting the steel which becomes the cathode.

Got questions?

If you have any questions, please contact your assessor directly.

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