Acids and acid rock drainage

Acid rock drainage (ARD) is a process that is common on many mines and is a cause of environmental damage in many places.
This booklet explains what acids are, what acid rock drainage is, and how it is managed on Lihir.
Read on to find out more. > >

Acids and acid rock drainage

To understand the effects of acid rock drainage on Lihir we will look at:

Read the smaller text in the orange bar at the bottom of each page if you want to understand the detailed scientific explanation. > >

1 What is an acid?

Acids are substances that release a hydrogen atom when they are **dissolved** in water. The word 'acid' comes from the Latin 'acere' (pronounced 'ah-seh-reh') which means 'sour'. Strong acids, such as battery acid, are usually **corrosive**, which means they can burn your skin. Our stomach contains acids which are almost as strong as battery acid, but the inner lining of our stomach is constructed from special cells that protect us from the corrosive effects of our own stomach acid. The stomach acids of dogs are even stronger, strong enough to dissolve bones that they eat!

The opposite of an acid is an **alkali** or **base**. Soap and bleach are examples of **alkaline** or **basic substances**. Bases usually feel slippery to touch. Like strong acids, strong alkalis, such as bleach, are also corrosive and can damage or burn your skin.

Pomelos at Palie are acidic but not corrosive.

Many acids however are not dangerous at all. For example, many common foods such as lemons, pomelos, tomatoes, Sprite, Fanta, beer and Coca Cola are acids! Even pure rainwater is slightly acid because carbon dioxide (CO_2) from the atmosphere dissolves in rain drops to form weak carbonic acid (H_2CO_3).

The strength of acids and alkaline substances is measured by the **pH scale**. Look at the diagram on pages 5–6 to see the pH of many common substances.

Corrosive acids experiment

All acids are ***corrosive*** to metals. To see this for yourself put a 1 toea coin in a glass of Coca Cola (which is strongly acidic), and leave it for a few hours. It will come out looking very shiny. This is because the acid in the Coca Cola has stripped off, or ***corroded***, the outer layer of metal on the coin.

You can do an experiment to see the way that acids are corrosive.

2 Ways of testing acidity

The roots of the Noni tree can be used as an indicator of acidity or pH, because they turn yellow when exposed to acids and red when exposed to bases.

There are ways of testing or checking to see whether something is **acidic**. You can use paper that is soaked in a special chemical (**litmus paper**) or you can use some plants, for example the roots of the Wol or Noni (*Morinda citrifolia*) plant. If the substance you are testing is acidic, the colour of the litmus paper or Noni roots will change.

- Acids turn litmus paper red
  and the roots of the Noni tree yellow
- Bases turn litmus paper blue
  and the roots of the Noni tree red.

Some acids are stronger than others.
The strength of the acid can be measured on the **pH scale**. > >

The chemistry of acids and bases

Acids and bases are only acidic and basic when they are dissolved in water.
The chemical equations opposite show how this happens.

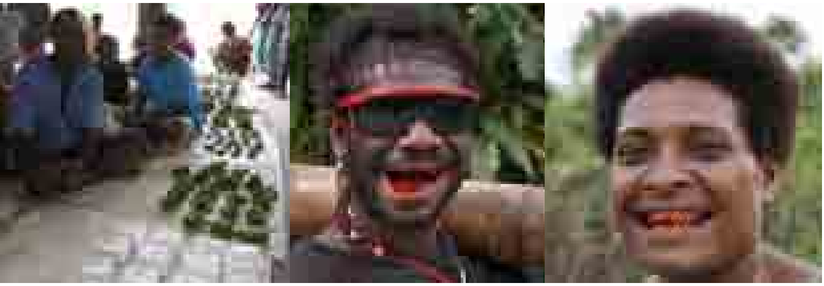
Hydrochloric acid (HCl) dissolves in water as follows:

$$HCl + H_2O \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

A typical base, sodium hydroxide (NaOH) dissolves in water as follows:

$$NaOH + H_2O \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

3 The pH scale and pH values



Kambang (lime) from Londolovit market is strongly basic. It makes the red colour when chewing betel nut.

The **pH scale** is a means of measuring how **acidic** and **basic** different substances are.
The pH scale goes from 0 to 14.
The middle of this scale is 7, which is **neutral**, so anything with a pH value of 7 is neither acidic nor basic.
Distilled water which has a pH of 7 is neutral.

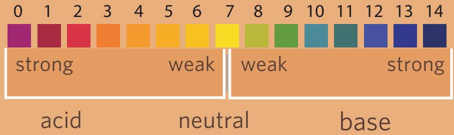
Substances that have a pH *less* than 7 are acidic.
Stronger acids have a small pH value, for example, stomach acid has a pH of 1, and lemons, a common source of citric acid, have a pH of just above 2.

All bases (also called **alkalis**) have a pH of *more* than 7.
Stronger bases have a larger pH, for example kambang has pH of 12. Bleach has a pH of over 12, is highly basic, and just as corrosive as strong acids.

Thus the strongest acids are closest to 0 on the scale, and the strongest bases are closest to 14.

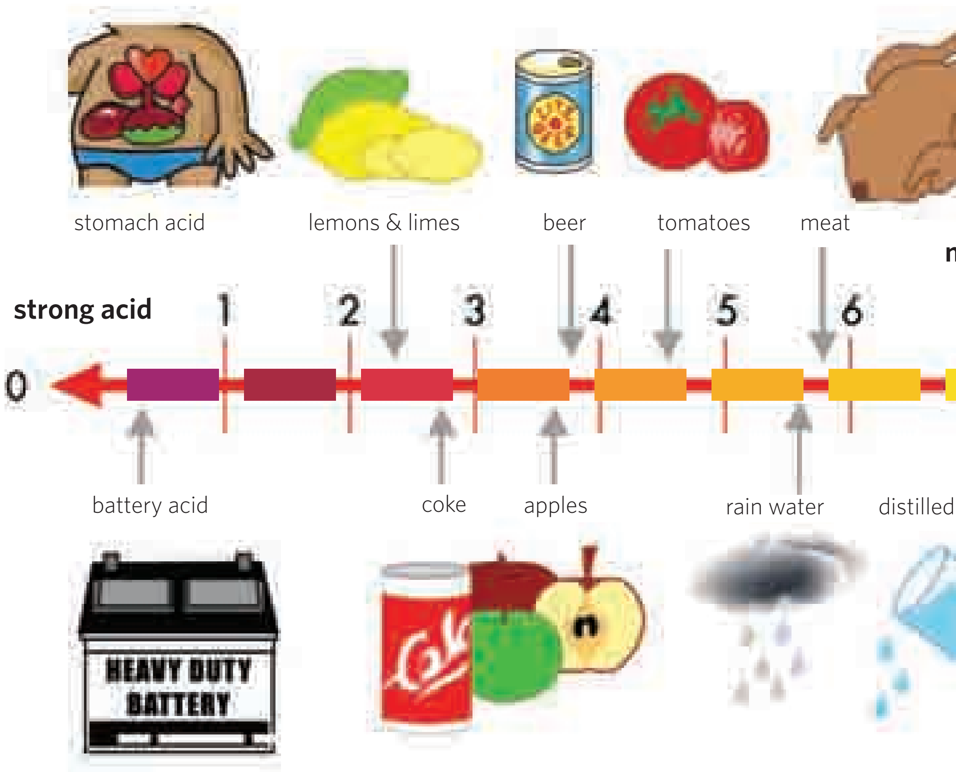
Values of the pH scale

Each number on the pH scale, from 1 to 14, represents a change of ***ten times*** from the previous number. A highly acidic substance with a pH of 1, such as stomach acid, is ten times more acidic than lemon juice which has a pH of 2, and ***100 times*** more acidic than something with a pH of 3, like vinegar.



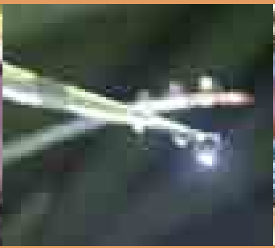
Similarly, a strong basic such as bleach, with a pH of 12, is ten times more basic than laundry detergent, which has a pH of 11.

4 The pH of common substances



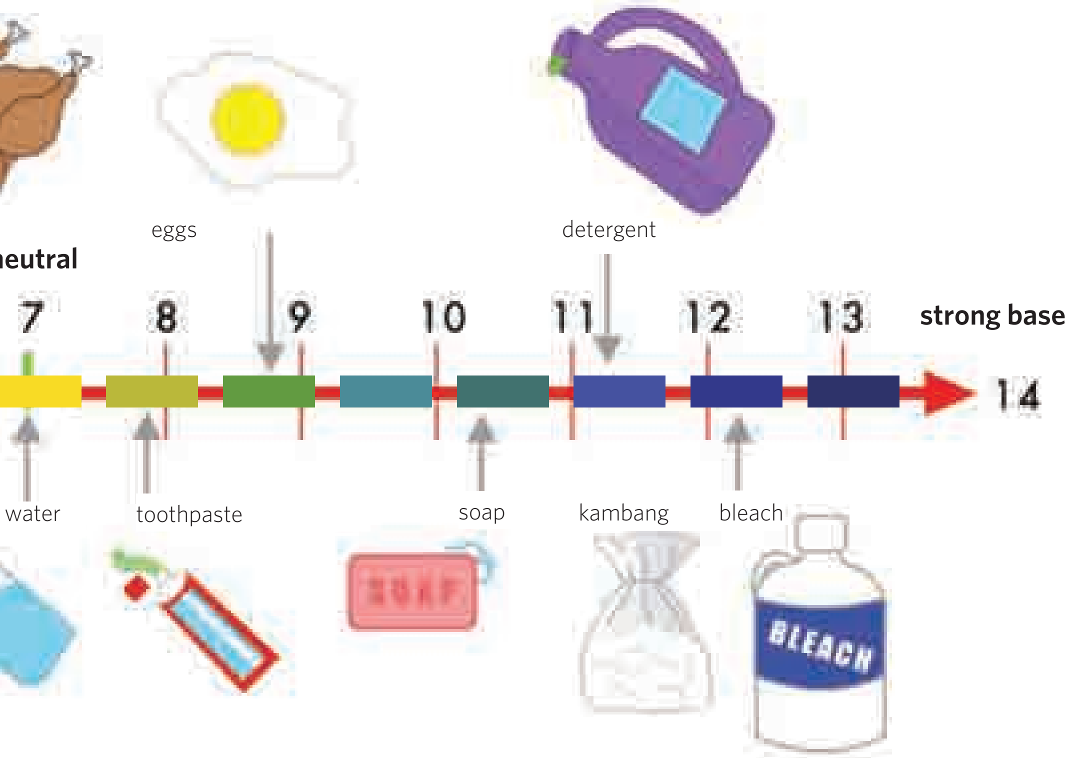

lemons, limes pH 2.3


noni fruit, pomelo pH 2.7


normal rain water pH 5.6


fresh pork pH 5.6 to 6.2

A good website with a pH meter that shows the pH of common substances is: www.miamisci.org/ph/phbaking.html



coconuts pH 7.4 seawater pH 8.3 kambang lime pH 12 detergent pH 11 bleach 12+

Glossary for acids and acid rock drainage

acid/acidic any chemical compound that releases a hydrogen ion (H+) when dissolved in water. All acids have a pH lower than 7.

alkali/base a substance with a pH greater than 7 when dissolved in water — also called a **base**. The adjectives are **alkaline** and **basic**.

buffering the word buffer means to soften or lessen a shock or protect from impact. In chemistry a buffer is an ionic solution, usually a salt solution or a weak acid or base, which functions to resist changes to the pH of another solution that it is mixed with and to stabilise its pH.

corrosive causes damage to other substances or to people. Very strong acids as well as very strong bases are corrosive to clothes and to skin.

dilute to make something less concentrated

dissolve when a solid becomes integrated into a liquid after being added to it.

distilled water pure water that has been made by the condensation of steam from boiling another container of water, which may not be completely pure. People usually use a glass or plastic structure called a ***still*** which makes the steam cool and condense, so they can then catch it as pure distilled water. When water is boiled, most of the impurities in it are left behind as it turns into steam. This does not apply to all impurities.

litmus paper a type of paper that changes to a particular colour when it is dipped into a liquid depending on whether the liquid is acidic or a basic. The colour can be compared to an indicator chart that tells us the pH of the solution. A more accurate way of measuring pH is with a pH meter.

neutralise to cancel out; to equalise; to stop something from having an effect by applying an opposite force.

pH scale a system of measuring the strength of acids and bases. The pH scale goes from 0 to 14. Substances that are neutral, neither acidic nor basic, have a pH of 7. Acids have a pH of less than 7 and bases have a pH of more than 7. The system is based on a set of mathematical calculations relating to the chemistry of acids and bases. pH can be measured using colour-based indicators such as litmus paper, or a pH meter.

precipitate out similar to the process of precipitation that produces rain, but in this case solids are precipitated out from solution.

5 What is acid rock drainage?

1 Acid rock drainage (ARD) or **acid mine drainage** (AMD) is caused when sulfuric acid develops from sulphur compounds in the ore which are exposed to oxygen and water. On Lihir this happens to surface layers of ore in the second-grade ore stockpiles at Kapit when it rains. (Picture 1).

2 Sulfuric acid makes some of the metals that are present in the ore dissolve, and they are washed out of the ore in solution and eventually reach the sea (Picture 2). On Lihir ARD flows into the **siltation pond** (pages 9 & 10) before it reaches the sea.

3 When the acid drainage mixes with seawater it becomes **buffered** by the seawater, because the seawater has an alkaline pH of 8.3 (Picture 3). This buffering action **neutralises** the acids.

4 When the acids are **neutralised**, the heavy metals, like iron (Fe) are no longer able to stay in solution, and they **precipitate out** as solid particles, which eventually fall to the sea bed (Picture 4).

Dilution and neutralisation

When an acid becomes ***diluted*** it becomes ***weaker or less concentrated***. So, if a bucket of acidic liquid with pH 3 is added to a fresh-water stream which is pH 6, the acidic liquid will be diluted and become weaker as it mixes with the water in the stream. If acid is added to water that has an alkaline pH (for example seawater, which has a pH of 8.3), then another process is also taking place—***neutralisation***.

When acidic runoff from the mine site enters the sea, it is being ***diluted and neutralised*** at the same time. Both of these processes have the effect of making the pH of the runoff ***equal*** to that of the seawater by the time it is 30 metres from the shore.

6 What happens to the acids from the mine when they reach the sea?

Plastic covers on the second grade ore stockpiles reduce the amount of acid rock drainage by protecting the ore from oxygen and rain water.

When **acids** from the mine site flow into the sea in Luise Harbour, the acid is both **diluted** by, and **neutralised** or cancelled out by the **alkaline** (pH 8.3) seawater. So, by the time the runoff from the mine site is 30 metres away from the shore, its pH is already the same as that of the ocean.

To understand more about concentration and dilution, read Booklet 2

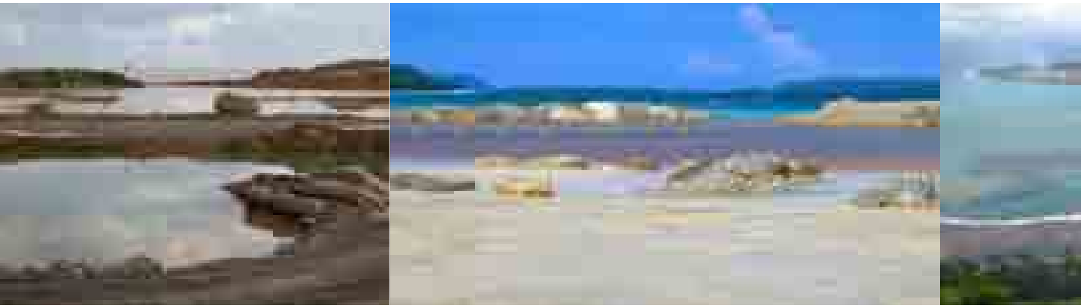
Neutralising the acid in stock pile drainage

The acidity of the water that drains from second grade ore stockpiles at Lihir, called ***acid mine drainage*** or ***acid rock drainage,*** is mostly around pH 4, but occasionally goes lower, sometimes reaching pH 3 or even just above pH 2.

When this water reaches the sea, which is alkaline (pH 8.3), its pH rapidly increases to around pH 8 because seawater acts as a pH ***buffer*** and ***neutralises*** the acidic runoff water that is flowing into it.

This means that acid from the mine cannot, under normal operating conditions, damage the ocean, because the acidity of the runoff is neutralised or cancelled out by the alkalinity of the seawater.

7 What does the siltation pond do?



The siltation pond, where the sea mixes with the acidic runoff from the stockpiles and mine site, and buffers the pH back toward 8.

The siltation pond is a semi-contained area at the sea-shore where the sea is let in to mix with the acidic runoff from the stockpiles and mine site. It is here that the **neutralisation process** starts to take place. We call this **buffering**.

Buffering does two things:

1. The acidic runoff (pH 3.0) is made alkaline by the seawater. Once it has been diluted and buffered by enough seawater, the pH is the same as seawater (pH 8.3).
2. Most of the heavy metals (mainly iron, Fe) which were dissolved in the runoff are transformed back to becoming solids again, and sink to the bottom of the pond.
   This process is called **precipitation**.

The heavy metals precipitate out and in this way are contained inside the pond rather than dispersing into the ocean.

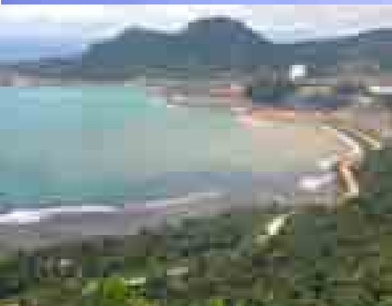
The siltation pond thus reduces the polluting effect of the acid drainage water on Luise Harbour.

Buffering experiment

Collect some of the drainage water from the stock piles. This should have a strongly acidic pH and a certain quantity of dissolved heavy metals including iron. Test the pH with litmus paper. Collect a bucket of clean seawater and measure its pH with litmus paper. Now mix the drainage water with a larger quantity of sea water. Now test the pH again.

What effect does the seawater have? Check to see whether any iron particles have precipitated out.

You can do an experiment to learn about buffering.



Luise Harbour and the mine site. The plume of red in the water shows the discolouration from the acidic runoff from the stock piles.

Trucking second grade ore to the stock piles at Kapit.

Neutralisation reaction

When acids and bases of equal strengths are mixed together they neutralise each other, or cancel each other's effect.

The neutralisation reaction of an acid with a base will always produce water and a salt, as shown below:

Acid		**Base**		**Water**		**Salt**
HCl	+	$NaOH$	→	H_2O	+	$NaCl$
HBr	+	KOH	→	H_2O	+	KBr

8 The difference between acid and corrosive

Powdered lime (kambang) made from crushed coral is strongly basic, pH 12, but it can have a corrosive effect in the mouth.

The word acid is sometimes used to refer to anything that is **corrosive** or even poisonous.

But both acids and bases can be corrosive!

If you put a spoonful of lime powder (kambang) from the market into your mouth it would have a corrosive burning effect on the inside of your mouth Do not try this!

Remember, not all acids are corrosive!

Some acids, like Coca Cola are harmless to drink.
The stomach contains extremely strong acid, but the special lining of the stomach protects the rest of the body from its corrosive effects.

Demonstrating the meaning of corrosive

Dissolve a generous amount of kambang (two or three spoons full) in a glass of water.

Measure the pH.
It should be quite strongly basic or alkaline, ie higher than pH 10.

What would happen if we put this in our mouth?

You can do an experiment to check the corrosiveness of both bases and acids.

9 Time to check how much you've learnt

Answer the questions below to see how well you understand about acids, bases, pH values and the effects of acid rock drainage on Lihir.

1 What is an acid?

2 Name two different ways of measuring pH.

3 What is the middle of the pH scale?

4 Which common substances are acids and which are bases? What is the pH of stomach acid? and of seawater?

5 How is ARD (acid rock drainage) formed ?

6 Explain what happens when acid rock drainage mixes with seawater?

7 What does the siltation pond do?

8 Name a common substance that is corrosive, but not an acid?

Now, answer the question asked on the front of this booklet:

Could acid from the mine damage our oceans?