Teacher’s Guide
Booklets 1–4
Environmental Impacts of Mining on Lihir

Resource book for Upper Primary and Lower Secondary

This booklet guides teachers to effectively use the four EEPL resource booklets to help students understand the environmental impacts of mining using the Lihir example as a case study.
Scientific concepts
EEPL Booklets 1–4
Resource book for
Upper Primary and
Lower Secondary

Direct Environmental
Impacts of Mining at Lihir

Teacher’s Guide
EEPL Booklets 1–4

Developed by Solwara Research
Sponsored by Lihir Gold Limited
Developed by
Dr Martha Macintyre and Dr Simon Foale
of Solwara Research with
Mouli MacKenzie of M Squared Design in
consultation with
The Curriculum Development Division of the
National Department of Education
Papua New Guinea

Illustrations and animations for DVD
developed in conjunction with Paul Huskinson,
Shane McKenzie and the 2006 Multi Media
students, Design Department, Canberra
Institute of Technology

Cartoons by Bob Browne
Grass Roots Comic Company, NCD, PNG

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Introduction

This guide is designed to help Upper Primary and Lower Secondary teachers to make the most effective classroom use of the four EEPL student resource booklets, to teach Papua New Guinean school children about the environmental impacts of extractive industries in their country. EEPL stands for Environmental Education Plan for Lihir. These four booklets were designed by a team of science and social science researchers together with an education materials developer and staff of the Curriculum Development Division, in response to a number of important concerns raised by the people of Lihir about the environmental impacts of the gold mine on their environment. Some of these concerns, as the booklets reveal, were well founded, and others were not. In the majority of cases, the people of Lihir were more concerned than they needed to be. The project was funded by Lihir Gold Limited.

The EEPL booklets were developed originally for the people of Lihir, but have broader national value for teachers and students all over PNG. Mining is an increasingly common industry in the country, and most Papua New Guinean students are aware of the large mining operations, past and present, and the fact that some of them have had significant environmental impacts. Some of the environmental problems that are indirect effects of mining — such as accelerated population growth and migration which result in increased land pressure and soil degradation — are also happening in many places where there is no mining, and are increasingly relevant all over the country. Teachers outside New Ireland Province, are recommended to use Lihir as a case study, and then discuss any similar impacts in their specific region.

Mining also frequently generates significant social impacts, such as increased inequality, disruption of family life, increases in alcohol consumption and violence, and collapse of traditional authority, but these issues are beyond the scope of this material.
Some explanation of the Lihir context is necessary. There are two main reasons for the production of these booklets. Firstly, there has been a widespread belief on Lihir that ‘acid rain’ from the mine has been responsible for a decline in fertility of gardens (Booklets 1 and 2 show that this is not true). One commonly-asked question on Lihir was, ‘Is the smoke from the mine causing acid rain that is damaging Lihirian gardens?’ These and other questions are relevant to other mining communities in PNG. The four booklets express the concerns of the Lihirian community as questions like this, and then answer the questions by clearly communicating the scientific principles behind environmental impacts such as acid rain, acid rock drainage, and land degradation due to population pressure.

Secondly, when the mine closes, there will be a sudden and severe reduction in the amount of money on the island, and most people, including those who are currently buying the bulk of their food with money, are going to have to return to producing much of their food from gardening. Since the mine was constructed, there has been a steady loss of gardening knowledge, as people have become increasingly dependent on money, and spent less and less time growing food. It is important that the rich knowledge of gardening on Lihir (and elsewhere in PNG), most of which is unwritten, is not lost as a result of this process. Booklet 4 is both a contribution to the preservation of that knowledge, and an exploration of the intersection between traditional gardening knowledge and modern agricultural science.

The booklets can be used for Grade 6 (if talked through by the teacher) and independently from Grade 7 through to Grade 10 and above. The material contained in the booklets includes both relatively simple explanations as well as more complex ones for each scientific principle that relates to the environmental issue in question. In general the top panel of the booklets, with the larger type and white background, contains the simpler explanations, and the bottom coloured panels contain the more detailed
explanations that are more suitable for older students and extension studies. The information is extremely student-friendly, with pictures and diagrams which reinforce the adjacent texts maintaining student interest. Each booklet has a glossary for unfamiliar and scientific terms (these terms are all bolded in the text). Teachers may like to use the booklets in an English class first, to familiarise students with new vocabulary, before using them in science and social science curriculum. Each booklet ends with a list of self-check questions to ensure students have understood the concepts in the booklets.

Because some of the environmental impacts are quite complex, and can also be the subject of debates and disputes between land-owners, mining companies, governments and non-government organizations, it is important that the future leaders of PNG are as well informed as possible about scientific understandings of the environmental impacts of mining.

This Teacher’s Guide provides an effective reference to using the EEPL booklets by 1) indicating the sections of the Upper Primary and Lower Secondary Syllabus that each booklet relates to, and 2) providing suggestions for learning activities relevant to each component of the booklets.

The learning activities are organised by booklet. Each activity is preceded by a list of equipment and materials needed, so that teachers can quickly find which activities they will be able to teach, based on what they have available. In most cases the equipment needed for the learning investigations and experiments is readily available, even in remote locations.

The activities follow the Predict-Observe-Explain strategy outlined in the Lower Secondary Teacher Guide. Where applicable, teachers should also encourage students to follow the four step procedure on page 11 of the Lower Secondary Teacher Guide:

1) Plan the investigation, 2) Conduct the investigation, 3) Process the data / results, 4) Evaluate the investigation.
**Introductory activities**

1. **The location of Lihir**

   The location of Lihir is shown on Map 1 below.
   As an initial activity, get the students to find Lihir in their atlases.

![Map 1](image)

*The Lihir gold mine at Ladolam*

*Map 1*
*The location of Lihir in PNG, and the islands in the Lihir Group. The mine is located at Ladolam and the processing plant at Putput.*
2. The location of mining operations throughout PNG

Ask the students to find the locations of other mining operations in PNG in their atlases, plus any new mining operations that they may know about.

What other extractive industries in other regions of PNG may have similar environmental impacts?

Map 2
The location of operating, finished and possible mines in PNG. There are several gas and oil mines around Lake Kutubu. There are many other mining exploration operations, which are not shown.
3. Comparative material

Ask the students to find photographs of other mining operations in PNG, at Misima, Porgera, Ok Tedi, Bougainville, Tolukuma, and Kutubu.

What other extractive industries may have similar environmental impacts?
Background information

**Other mining operations in PNG**

Production figures (in tonnes) for the existing mineral mines in PNG for the period 2003 to 2005 are as follows:

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<thead>
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</thead>
<tbody>
<tr>
<td>Ok Tedi</td>
<td>17.85</td>
<td>16.3</td>
<td>16.0</td>
<td>40.984</td>
<td>36.1</td>
<td>34.5</td>
<td>192,978</td>
<td>173,370</td>
<td>201,300</td>
</tr>
<tr>
<td>Porgera</td>
<td>26.996</td>
<td>31.7</td>
<td>26.5</td>
<td>4.906</td>
<td>7.5</td>
<td>5.1</td>
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<tr>
<td>Misima</td>
<td>1.6</td>
<td>3.7</td>
<td>6.8</td>
<td>16.8</td>
<td></td>
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<tr>
<td>Lihir</td>
<td>18.538</td>
<td>18.6</td>
<td>17.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tolukuma</td>
<td>2.374</td>
<td>2.67</td>
<td>2.5</td>
<td>5.235</td>
<td>5.2</td>
<td>5.5</td>
<td></td>
<td></td>
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<tr>
<td>small scale</td>
<td>2.7</td>
<td>2.8</td>
<td>2.2</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>68.483</td>
<td>73.67</td>
<td>68.0</td>
<td>51.125</td>
<td>55.6</td>
<td>61.9</td>
<td>192,978</td>
<td>173,370</td>
<td>201,300</td>
</tr>
</tbody>
</table>

The data in this table was provided by the PNG Chamber of Mines and Petroleum

> In 2005 the four gold mines in PNG plus the alluvial miners produced just over 68 tonnes of gold.

> Minerals make up 49.4% of PNG’s export revenue.

> Production in 2006 is estimated to be over 70 tonnes.

> PNG has three out of the six top gold producing mines in Australasia.

> The mine at Kainantu owned by Highlands Pacific, which started production in 2006, forecast to be producing 115,000 ounces of gold per year by the end of 2006.

\[
3.243 \text{ tonnes;} \quad 1 \text{ ounce} = 28.2 \text{ grams}
\]

> Production data for the year 2005 for the various oil and gas projects around Lake Kutubu are as follows:

- Kutubu oil: 5.1 million barrels
- Gobe oil: 0.85 million barrels
- Moran oil: 3.64 million barrels
- Mananda oil: no data at time of writing
- Hides gas: 5.426 billion cubic feet

\[
1 \text{ barrel} = 158.99 \text{ litres, or} \quad 0.15899 \text{ cubic metres} \\
35.55 \text{ cubic ft} = 1 \text{ cubic meter;} \quad 1 \text{ cubic ft} = 28.32 \text{ litres}
\]
Background information  30 mw geothermal power station at Lihir mine site

Stages in producing electricity from volcanic steam

Steam — vented all over the mine site
is now used to produce electricity

Well head — brings
steam and water from
hundreds of metres
underground to supply
the power plant

Separator — removes water,
supplies good clean steam to
drive the steam turbine

Silencers — reduces
noise level of escaping
water and steam

Steam turbine and generator
— Steam turns steam
turbine, turbine turns the
generator to produce power
— power plant
Condenser — cools steam from the turbine, condenses it to water, and pumps the hot water to the cooling tower, increasing the turbine efficiency cycle and doubling the power supply.

Cooling tower — cools hot water and supplies cooling water to condenser and to rest of the plant.

Gas removal system — removes non-condensable gas from condenser and discharges it at top of cooling tower.

Electricity — for Lihir plant operations.
Booklet 1  The cloud cycle and acid rain

Introduction
The key concepts in Booklet 1: Cloud cycle and acid rain that lend themselves to experimentation are evaporation and condensation. Some of the themes in Booklet 1 are revisited in Booklet 2: Smoke and Steam, most importantly the relationships between steam, water vapour and condensation (see pages 22–25).

Booklet 1 helps students to understand the relationship between steam, water vapour, humidity and rain. Booklet 1 also covers the formation of acid rain, but the key concepts relating to acidity and pH, including the measurement of the pH of rain, are covered in detail in the activities relating to Booklet 3 (see pages 26–32).

Relevant learning outcomes for Booklet 1

Upper Primary

7.1.1, 8.1.1 — Working scientifically
7.3.1, 8.3.1 — Learning about substances
7.3.2 — Explaining physical and chemical changes in matter using simple experiments

Lower Secondary

9.1.5 — Indigenous (local) knowledge and practices
9.3.1, 9.3.2 — Ecology
9.5.1, 9.5.2, 9.5.3 — Atoms and the periodic table
9.7.1, 9.7.2, 9.7.3 — Earth and atmosphere
10.1.1, 10.1.2 — Working scientifically through projects and investigations
10.3.1, 10.3.2, 10.3.3 — Chemical reactions
Suggested learning activities

Evaporation and condensation can be investigated in many ways.

1. **Measuring evaporation**  
   **Grades 7–8; Outcomes: 7.1.1, 7.3.1, 7.3.2, 8.1.1, 8.3.1**

   **Tools and materials required**
   
   > a measuring flask. If this is not available, the experiment can still be done with a glass or plastic container.
   
   > another glass, metal or plastic container with a large opening, such a large jar or a bucket — the volume of this container must be larger than the one used for measuring.

   **Procedure to demonstrate evaporation**

   1. **Precisely** measure (to the nearest milliliter if possible) an amount of water using a measuring flask from the laboratory. At the same time, place exactly the same amount of water in another similar or same kind of container, but with a lid or some kind of close-fitting covering.  
      
      *If you do not have a measuring flask, fill some other container such as a plastic water bottle right to the very top and use this as your measure.*

   2. Leave the water in both the open and closed containers in the classroom for one or two days.

   3. Get the students to measure and compare the amount of water left in both containers at the end of this period.

   **Assessment**

   The volume of water in the closed container should not have changed significantly, while the amount of water in the open container should have reduced measurably.

   Get the students to explain what happened to the water in the open container.
2. **Demonstrating condensation, part 1**

   Grades 7–8; Outcomes: 7.1.1, 7.3.1, 8.1.1, 8.3.1

**Tools and materials required**

- a clear plastic or glass soft-drink bottle, with screw-on lid

**Procedure**

Half fill a clear plastic soft-drink bottle with water, put the lid back on, and leave the bottle in the sun for a few hours. At the end of this period, you will observe many drops of water that have condensed on the inside of the top half of the container.

**Assessment**

Get the students to observe the container carefully at the beginning and at the end of the experiment, and get them to explain the changes they observe.
3. Demonstrating condensation, part 2
Grade 8; Outcomes: 8.1.1, 8.3.1

Tools and materials required

- a refrigerator
- any glass container such as a beer or soft-drink bottle. The experiment will work better if the bottle is full
  
  *Refill empty bottles with water if you do not have any unopened bottles.*

- a clean dry cloth or paper towel or tissue

Procedure

1. Leave the full bottle in the refrigerator for a few hours until it is cold, and then take it out. Immediately wipe the outside of the bottle with a cloth or paper towel to make sure it is completely dry.

2. Leave the bottle at room temperature for a few minutes and observe water droplets that form on the outside of the bottle.

Assessment

Ask the students where the water has come from.

*Explain that it is the drop in temperature that causes the water vapour in the warm air to condense on the outside of the cold bottle to form the water droplets.*
4. Demonstrating condensation by building a still  
Grades 8-10; Outcomes: 8.1.1, 8.3.1, 9.5.1, 10.1.1, 10.3.1

Tools and materials required

> a large cooking pot with a tight-fitting lid that has a knob in the centre that can be removed
> about two meters of flexible plastic tubing — the tubing must be the right diameter to fit tightly inside the hole in the centre of the pot lid
> two other containers — wide-mouth jars or any plastic equivalent

Procedure

1. Half-fill the cooking pot with water.
2. Remove the knob from the centre of the lid of the pot and insert the plastic tubing into this. Make sure it is a tight fit.
3. Place the other end of the tubing in another empty container to collect the condensate.
4. Make a few coils in the tubing, between the pot and the container, and immerse them in a jar or another pot of cold water. Keep this higher than the point at which the condensate is to be collected.
   
   *This step will make the condensing more effective, but if you are unable to secure the coils of the tube in a pot of cold water the experiment will still work.*

5. Some condensate will form eventually at room temperature, but you will get results much more quickly if you heat the pot to increase the rate of evaporation and accumulation of condensate through the still.
   
   *Use thcomparison with the increase in condensate through heating to remind the students that evaporation is higher in warm places.*
Assessment

Get the students to observe and explain the process.

They should understand that the greater the heat applied to the water in the pot, the higher the energy state of the molecules, and the larger the number of molecules that will move from liquid to gas phase (evaporation). When these evaporated molecules then come into contact with the cooler tubing, they condense back to the liquid phase.

Get the students also to taste the water that drains out of the still. What if seawater is put in the pot? (You could try this as another experiment). Is the water that comes out of the other end of the still also salty? Get the students to explain their findings.

Stills are also used to concentrate alcohol from fermented vegetable matter — a common practice around the world, including in many Papua New Guinean villages. Get the students to explain why alcohol and water both evaporate relatively easily, but salts do not. What is the boiling point of ethanol? Methanol?
5. **Temperature and evaporation**  
**Grades 7-9; Outcomes: 7.1.1, 7.3.1, 7.3.2, 8.1.1, 9.7.2**

*Tools and materials required*  
- two clear plastic or glass bottles, with lids  
- a thermometer (not vital, but useful)

*Procedure*  
1. A simple way to demonstrate the influence of temperature on evaporation would be to repeat the experiment on page 12, but this time take two soft-drink bottles and half-fill each of them with water (don’t worry about measuring the water this time). Put the lids on both bottles.  
2. Place one of the bottles outside in the sun, and leave the other one inside the classroom, in the shade.  

   *This experiment may only need one hour to show results, but might take longer.*

*Assessment*  
At the end of the period, compare the amount of condensation on the inside of each bottle — there should be more water droplets on the inside of the bottle that was left in the sun than the one in the classroom.  

If a thermometer is available, measure the temperature of the water in each container at the end of the experiment.  

Get the students to explain why higher temperature causes greater rates of evaporation.

*Exercise 1 for Booklet 2 also works with the issues of steam, water vapour, humidity, condensation and the energy states of the various forms of water. See pages 23-24.*
6. The effect of surface area on rate of evaporation
Grades 8–9; Outcomes: 8.1.1, 8.3.1, 9.7.2, 9.7.3

Tools and materials required
>
> two plastic or glass bottles of identical size
> a large bucket or cooking pot
> a funnel

Procedure
This experiment demonstrates the effect of surface area on the rate of evaporation.

In general, the greater the surface area of a body of water that is exposed to the air, the greater the rate of evaporation, all other things being equal.

1. Fill the first of the two identical bottles with water and tip the contents into a big cooking pot.
2. Fill the second identical bottle to the top and place it and the cooking pot in the sun for a day. Leave the lid off the bottle.
3. At the end of the day tip the water in the cooking pot back into its water bottle. Compare the level of water in the two bottles.

Assessment
The first water bottle should have more water remaining because it has a smaller evaporative surface than the pot. Get the students to think about how much water evaporates from the surface of the ocean every day. Where does this water go?
7. Cloud formation
Grades 6–7

If possible, take the students to a location where they can view high islands or mountains to observe whether they have clouds forming above them.

*Cloud formation is often observed as a result of humid air over the ocean colliding with islands and being forced upwards into layers of the atmosphere where the temperature is lower, causing condensation of the water vapour into droplets that form clouds and rain.*

Many Pacific Islanders used to use clouds as a sign of land when voyaging at sea, because the clouds are usually visible from greater distances than islands. Most islands are usually relatively cloud free in the early morning, and clouds usually build up during the course of the day — ask the students to explain this.
8. Is there acid rain in your area?
Grades 9-10; Outcomes: 9.1.5, 9.3.1, 9.3.2, 9.7.1, 9.7.2, 9.7.3, 10.1.1, 10.1.2, 10.3.1, 10.3.2, 10.3.3

**Tools and materials required**
- litmus paper or a pH meter
- access to a creek or river

**Procedure**
Go to a river or creek near your school, one that you know is not affected by land-based sources of pollution such as the mine site, or the dumping of waste. Collect some water in a clean jar and measure the pH with litmus paper or a pH meter. Repeat the test for at least three different samples of water and note the results for each sample.

**Assessment**
If the average pH of the samples is lower than 5.0 then it is possible that it has been affected by some sort of pollution, including the pollution that causes acid rain.

*Remember that pure, unpolluted rainwater has a pH of around 5.6.*

Ask the students why some people might think there is acid rain on Lihir.
Booklet 2  Smoke and steam

Introduction

Booklet 2: *Smoke and steam* has links to Booklet 1: *Cloud cycle and acid rain*, particularly the material on steam and condensation. Smoke is treated together with steam because some people appear not to distinguish between them, referring to both as ‘smoke’. The concepts in Booklet 2 also explain much about the unique geology of Lihir Island, particularly the volcanically active material in Luise Caldera, which generates large amounts of steam — steam which used to be released through large pipes installed by the mining operation. The steam is generated by thermal energy emanating from the earth’s molten mantle, which is unusually close to the earth’s surface at Lihir. This energy is now being harnessed on Lihir to generate electricity through a geothermal power plant (see pp 10–11).

 Relevant learning outcomes for Booklet 2

**Upper Primary**

6.1.1, 7.1.1, 8.1.1 — Working scientifically
6.3.1, 7.3.1, 8.3.1 — Learning about substances
6.3.2, 7.3.2 — Explaining physical and chemical changes in matter using simple experiments
6.3.3, 7.3.3, 8.3.3 — Understanding energy in its different forms
6.4.1, 8.4.1 — Earth’s structure, and the formation of igneous and metamorphic rocks

**Lower Secondary**

9.1.5 — Indigenous (local) knowledge and practices
9.5.1, 9.5.2, 9.5.3 — Atoms and the periodic table
9.7.1, 9.7.2, 9.7.3 — Earth and atmosphere
10.1.1, 10.1.2 — Working scientifically through projects and investigations
Suggested learning activities

1. Observing steam
   Grades 7–8; Outcomes: 7.3.1, 7.3.3, 8.3.1, 8.3.3

   Tools and materials required
   - a kettle with water in it
   - a source of heat sufficient to boil the water
   - a piece of black cardboard or paper
   - a cold smooth hard object like a pen, metal plate or bottle

   Procedure
   1. Boil water in a kettle using a hot fire, and after the water has started to boil actively, place a piece of black cardboard or plastic next to the side of the spout to make it easier for the students to see the steam coming from the spout. Observe the point at which the steam becomes visible.
      This is where the process of condensation is transforming the gaseous steam to tiny droplets which make it visible. Individual water molecules, separated from each other by the very high energy they acquire when heated to 100°C are cooling, losing their energy, and as a result starting to stick together as tiny droplets which become visible as white ‘steam’.
   2. Hold an object with a smooth, hard surface (e.g. a bottle, a plastic container, a pencil) in the steam plume for a few seconds. Examine the surface of the object — it should have many small droplets of water on it. Ask the students to explain how the water got there.

   Assessment
   Get the students to give accurate definitions of a) steam, b) water vapour, c) humidity and d) condensation. Get them to explain the energy states of the various forms of water (liquid, gas, solid), as well as the changes in energy involved in transformation between liquid to gas and back again.
2. Understanding dilution
Grades 7-8; Outcomes: 7.3.1, 8.3.1)

Tools and materials required

- an accurate means of measuring the volume of liquids in milliliters, such as a graduated cylinder
- a glass dropper or container that can measure small volumes to the nearest milliliter
- food or clothing dye, or any other water-soluble coloured substance or natural plant dyes, in liquid form
  
  If dye is available initially as a powder, dissolve a good amount in a spoonful of water first

- five clean jars, beakers or cups made of clear glass or plastic

Procedure

1. Drop two milliliters of liquid dye or colouring into a jar or beaker with 98 milliliters of water and stir it so it is well mixed. Get students to calculate the concentration of the dye in solution, as a percent (2%) or proportion (0.02) of the original concentration of the dye.

2. Now drop two milliliters of this solution into a second jar containing 98 milliliters of pure water. Calculate the concentration of the dye now.

   \[
   2\% \times 2\% = 0.04\%; \text{ proportion: } 0.02 \times 0.02 = 0.0004
   \]

3. Repeat the exercise another three times. Each time ask the students to recalculate the concentration of the dye.

   - 3 0.0008%;
   - 4 0.000016%;
   - 5 0.00000032%

This is the basis of dilution.

Assessment

Discuss the similarities between this process and what happens to smoke as it disperses away from its source. Discuss the relative harm to human health posed by smoke from a distant power generator with smoke inhaled from a cigarette, a kitchen fire, or a vehicle exhaust.
Discussion points

3. Steam generation at Lihir
   Grades 7-8; Outcomes: 6.3.1, 6.3.3, 7.3.1, 7.3.3, 8.3.1, 8.3.3
   Discuss the processes involved in the generation of the steam at Lihir. Where does the heat come from to produce the steam? Where does the water come from? Is the steam pure water or are there other substances / chemicals in it?
   *This should include a discussion of the nature of volcanoes and the geology of the Lihir group of islands.*

4. Smoke is made of particles
   Grades 7-8; Outcomes: 6.3.1, 6.3.3, 7.3.1, 7.3.3, 8.3.1
   Get the students to discuss why the rafters and the underside of the roof of most village kitchens are black.
   *The black substance is soot particles which comes from the smoke from kitchen fires.*
   Discuss: What is this substance? What might the inside of the lungs of a smoker look like?

5. Smoke and sorcery
   Grades 9-10; Outcomes: 9.1.5, 10.1.1, 10.1.2
   Why do people sometimes use smoke as a means of transmitting magic in gardens? Discuss. Why is smoke often used in sorcery?

6. Smoke and dust
   Grades 7-9; Outcomes: 6.3.1, 7.3.1, 8.3.1, 9.1.5, 9.7.1, 9.7.2, 9.7.3
   What is the difference between smoke and dust? Why do people worry about dust?
Booklet 3  Acids and acid rock drainage

Introduction

The word ‘acid’ is often used to signify anything corrosive or even poisonous. In Booklet 3: Acids and acid rock drainage, the difference between acid and corrosive is made clear, and the nature of acids, and their opposites, bases, is explained. Understanding this material requires some knowledge of chemistry, and is likely to be easier to explain to older students. The key concepts of this booklet will be best demonstrated with equipment that can measure changes in pH.

Relevant learning outcomes for Booklet 3

Upper Primary

6.1.1, 7.1.1, 8.1.1 — Working scientifically
7.3.1, 8.3.1 — Learning about substances
7.3.2, 8.3.2 — Investigate physical and chemical changes, and identify and collect basic and acidic substances found in nature

Lower Secondary

9.2.1 — Working scientifically
9.4.1, 9.4.2 — Our body
9.5.3 — Atoms and the periodic table
Suggested learning activities

Activity 1 is useful to teachers in remote areas with no access to litmus paper. Activities 2 to 4 teach students the difference between the meaning of ‘acid’ and the meaning of ‘corrosive’.

1. **Noni roots as a pH indicator**
   Grades 6–8; Outcomes: 6.1.1, 7.1.1, 7.3.1, 7.3.2, 8.1.1, 8.3.1, 8.3.2

   **Tools and materials required**
   - some roots from a Noni tree (*Morinda citrifolia*)
   - cola
   - lime juice
   - battery acid *Take care obtaining this!*
   - bleach
   - powdered lime (kambang)
   - detergent
   - containers in which to place all of the above substances

   **Procedure**
   Use the roots of the Noni tree (*Morinda citrifolia*) as a pH indicator. Try testing various common acids and bases. Try cola, lime (muli) juice, battery acid, bleach, dissolved lime (kambang) powder, detergent.

   **Assessment**
   Noni roots turn yellow when exposed to acids, and red when exposed to bases.
2. The meaning of 'corrosive', part 1
Grades 7-9; Outcomes: 7.1.1, 7.3.1, 8.1.1, 9.2.1, 9.5.3

Tools and materials required
- glass or cup of Coca-cola or Pepsi-cola
- a glass or cup of lemon or lime juice
- a glass or cup of vinegar
- a glass or cup of water and detergent (any kind)
- a pH meter or litmus paper or noni roots
- toea coins
- soft cloth or paper towel

Procedure
1. In each of four glasses or cups place the following:
   1) Coca-Cola or Pepsi-cola, 2) lemon or lime juice, 3) vinegar,
   4) water with a generous amount of detergent.
2. If a pH meter or litmus paper is available, measure the pH of
   the liquid in each glass. Make sure the glasses are labelled.
3. Place a 1 or 2 toea coin in each glass and leave it overnight
   (best done between consecutive science classes).
4. Remove the coin from each glass at the end of the
   experiment, with a spoon.
5. Now rub each coin with a soft cloth or paper towel.

Assessment
The coins from the cola, the lime juice and the vinegar should be
‘clean’, i.e. shiny, while the coin from the detergent is unchanged.

The acids from each of the first three liquids remove the
metal oxides (‘rust’) from the surface of the coin. Cola
contains phosphoric acid, lemon or lime juice contains
citric acid, and vinegar contains acetic acid. Detergent is a
base, so the corrosive reaction does not occur. The reaction
between the acids and the copper oxide is a reduction
reaction in which the hydrogen ions in the acid split the metal
oxide bond, binding with the oxygen to form water ($H_2O$),
and releasing metal ions (e.g. $Cu^+$).
3. Demonstrating the meaning of corrosive, part 2  
Grades 7–9; Outcomes: 7.1.1, 7.3.1, 8.1.1, 9.2.1, 9.5.3

**Tools and materials required**

- a glass eye-dropper or pipette
- a small volume of battery acid
- an old piece of cloth or clothing that is no longer needed
- pH meter or litmus paper, or noni roots

**Procedure**

1. Obtain a small volume of battery acid by extracting it with a dropper or pipette from a car or truck battery.

   *Battery acid is extremely acidic and very corrosive.*
   
   *Exercise great care in handling this acid!*

2. Measure the pH of the battery acid with litmus paper or a pH meter. It should be around pH 1 or lower.

3. Pour the battery acid onto the piece of cloth that is no longer needed, and leave it for a few days.

**Assessment**

The acid will burn a hole in the cloth. The damage will become more evident after washing the cloth in water.
4. Demonstrating the meaning of corrosive, Part 3.
Grades 7-9; Outcomes: 7.1.1, 7.3.1, 8.1.1, 9.2.1, 9.4.1, 9.4.2, 9.5.3

Tools and materials required
> lime (kambang) powder
> a glass of water
> pH meter or litmus paper

Procedure
1. Dissolve a generous amount (two or three spoons) of lime powder (i.e. kambang from the market) in a glass of water.
2. Measure the pH. It should be quite strongly basic.
   *Strongly basic has a pH higher than pH 10.*

Assessment
Ask the students what happens if we put a spoonful of lime powder in our mouth (don’t ask them to actually do this!). It burns, i.e. it has a corrosive effect on the tissues of our mouth. But this is not an acid — quite the opposite. It’s an alkali, or a base.

*The lesson from this and the previous experiment is that the chemistry of corrosive reactions is actually quite a complicated matter and depends a great deal on the particular substances involved. Both acids and bases can be corrosive. We know that battery acid can burn our skin and mouths, and destroy clothing, but some acids, such as in cola and other soft drinks, are harmless to drink, yet still capable of corroding copper coins. Students should be reminded that our stomachs contain extremely strong acid, but the special lining of the stomach protects the rest of our body from its corrosive effects.*
5. Investigating Acid Rock Drainage (ARD). 
Grades 7-9; Outcomes: 7.3.2, 8.3.2, 9.2.1, 9.5.3

Tools and materials required

- this experiment requires access to the Lihir gold mine, or another mine which has sulphurous ore in stockpiles. Access should be arranged ahead of time.
- at least 10 glass or plastic containers with sealable lids
- stick-on paper labels or marker pen for labeling the containers
  
  *If labels cannot be obtained then you can try writing directly on the containers with a marker pen*

- pH meter or litmus paper or Noni roots

Procedure

This experiment is best done as a school excursion to the mine site, and should be done in consultation with the mining company.

1. Obtain four or five samples of water from various points along the drains that run off from the stockpiles, using the containers.
2. Make a note on the containers of the place where the samples were taken.
   
   *If possible, obtain samples from inside the siltation pond, from outside the siltation pond (near the place where the water exits to the sea) and from the beach 50 metres or so from the siltation pond (this obviously requires boat access, which the company may be willing to provide, especially if their Environment Section is doing sampling at the same time). Obtain another sample from the Small Boat Harbour, and another from the sea near the town site or other location at similar distance from Luise Harbour.*
3. Take the samples back to the laboratory and measure the pH of each with a pH meter or litmus paper.
Assessment

What does this tell us about the effect of the sea on the pH of the runoff from the mine? What is happening to the acids when they mix with the seawater?

The results should show that the water from the stockpile drains is quite acid (around pH 3) and that seawater more than 50m distant from the siltation pond should be around normal pH (about 8.3).
Booklet 4  Gardening and soil fertility

Introduction

Booklet 4: Gardening and soil fertility is designed to engage students about 1) the importance of a detailed understanding of the soil for the efficient production of food: 2) the way in which the traditional fallow cycle replenishes the fertility and productivity of the soil; and 3) the effect of allowing shorter fallow cycles as a result of increased population. The material deals with the contributions of both traditional and scientific knowledge to this understanding. There are some aspects of traditional understandings and beliefs about gardening that do not agree with science, but there are also many that do. It is important for students to appreciate the richness and sophistication of traditional gardening knowledge, and also to think about the areas where there is disagreement with science, and why.

Since this booklet is about the growth of plants under different conditions, some of the more useful learning activities will be those involving the experimental manipulation of food crop plants, and will require several months to complete.

Relevant learning outcomes for Booklet 4

Upper Primary
6.1.1, 7.1.1, 8.1.1 — Working scientifically
6.2.1, 7.2.1, 8.2.1 — Living things in their environment
6.2.2, 7.2.2, 8.2.2 — Environmental energy flows and food webs

Lower Secondary
9.1.1, 9.1.2, 9.1.3, 9.1.4, 9.1.5 — Indigenous knowledge and practices
9.2.1, 9.2.2 — Working scientifically
9.3.1, 9.3.2 — Ecology
Suggested learning activities

1. **Basic needs of plants, part 1 (light, water, air)**  
   Grades 6-8; Outcomes: 6.1.1, 7.1.1, 8.1.1, 6.2.1, 7.2.1, 8.2.1

   **Tools and materials required**
   - fresh sweet potato vines fit for planting
   - 20 plastic pots or large poly-bags, all of the same size
   - access to a good supply of good soil
   - clear plastic bags
   - clear plastic sheeting
   - a large box or a room or cupboard in the school that can be made completely dark even in the daytime

   **Procedure**
   1. Plant sweet potatoes in good soil in the pots or poly-bags. Then place five plants in each of four different conditions:
      - **Total darkness** — construct a treatment to ensure the vines are deprived of all light.
        
        *Either place a weatherproof box over the top of them, or grow them inside a dark cupboard or room at school. Make sure however that the students water these plants regularly.*

      - **Drought conditions** — construct a plastic ‘roof’ to ensure one set of plants get enough light, but no water.

      - **Airless conditions** — place five of the vines in the open, but tie a plastic bag around the plants once they have grown a bit, and seal the bag around the stem with tape, to ensure no air can get in or out.
        
        *Be careful not to damage the stem however.*

      - **Normal conditions** — light, air and water — place the last five plants in an open spot with lots of sun and regular water.
        
        *This is the ‘control’ treatment.*

   2. Let the plants grow for 2–3 months.
Assessment

At the end of the growing period, get the students to assess how the plants fared in each of the four different growing conditions. Get the students to explain what happened to each treatment.

All of them except for the ‘normal’ conditions should have either died or grown very little.
2. Basic needs of plants, part 2 (nutrients)
Grades 6–8; Outcomes: 6.1.1, 7.1.1, 8.1.1, 6.2.1, 7.2.1, 8.2.1

**Tools and materials required**

- cassava stems cut the right size for planting — try to select a fast-growing variety
- 25 large plastic pots or large poly-bags, all of uniform size
- access to a good supply of good soil
- a dozen or so mature bamboo stems
- plant material to use for mulch
- chicken manure
- a small quantity of fertilizer (preferably slow-release type)
- a means of labeling each treatment
  
  *Plastic labels that can be written on with marker pen are best, and they can be poked into the soil at the base of the plant and not be damaged by water or sun.*

**Procedure**

1. Fill the pots or poly-bags with soil, ensuring there is no significant variation in the type of soil. Make sure each treatment is properly labeled so that students don’t forget which is which. Use one plant per pot and five plants per treatment. Try to ensure that all treatments are kept free of insect pests and weeds. Use the following nutrient regimes:
   - **Normal** — no extra treatment.
   - **Ash** — this treatment is complex because what happens when people burn the vegetation on newly cleared gardens is that the burning scorches the surface layers of the soil and this is thought to release a lot of nutrients from the rapid breakdown of bacteria, insects and other organisms living in the surface layer of the soil. So for this treatment to perfectly mimic what is done in PNG traditionally, the burning needs to happen before the soil is put into the poly-bags or pots. Try and find a clear patch of the soil used for the other pots.
and burn some of the dried bamboo on it. Then put this soil (along with some of the ash) in five of the bags and plant the cassava.

- **Mulching** — place mulch on the surface of the bag or pot once only, at the time of planting, making sure to keep it clear of the plant stem once it starts to grow.

- **Chicken manure** — as for the mulching, keep the chicken manure away from the plant stem.
  
  *The mulch and chicken manure might damage the plant if it contacts the stem directly.*

- **Artificial fertilizer** — a slow-release type of fertilizer is probably the best one to try, but if not, compare a treatment in which fertilizer is applied once, at the start, with another treatment in which fertilizer is applied several times during the growing period.
  
  *Make sure the students measure and record the amount of fertilizer applied. Obtain advice from the DPI about the right amount of fertilizer to apply (or if this is not possible, try the information on the side of the fertilizer bag).*

2. Let the experiment run for at least three months, ideally five months.

- Make sure the watering regime is exactly the same for each pot, and that all pots are exposed to the same amount of light.

- Try to protect the plants from strong winds.

**Assessment**

Compare the harvest for each treatment at the end of the growing period (weigh and measure the dimensions of both the stems and the tubers) and get the students to discuss the results. Were there any other factors (e.g. drought, insect pests, weeds) that affected the outcome? Get the students to discuss whether the extra work involved in each of the treatments was worth the extra yield in each case.
3. Land degradation
Grades 7-9; Outcomes: 7.2.1, 7.2.2, 8.2.1, 8.2.2, 9.1.1, 9.1.2, 9.1.3, 9.1.4, 9.1.5, 9.3.1, 9.3.2

Tools and materials required
- spade(s)
- access to land covered in malo ferns

Procedure and assessment
Take the students to some grassland or land dominated by ferns (*Dicranopteris* species — this is called Malo on Lihir).
Get the students to try to dig the ground to observe the rhizomes. Why is it so hard to dig? Discuss the factors involved in the establishment of these species.
How does fire affect a) the ecology of these ecosystems and b) the nutrient status of these soils? What does this imply for being able to make food gardens in these systems?
Ask the students what their grandparents would say about how malo degrades the land.

> Remind the students that these ecosystems experience fire regularly and that both the grasses and ferns regenerate very well after fire.
4. Land pressure and change in length of fallow period  
Grades 7–9; Outcomes: 7.2.1, 7.2.2, 8.2.1, 8.2.2, 9.1.1, 9.1.2, 9.1.3, 9.1.4, 9.1.5, 9.3.1, 9.3.2

Discussion

Get the students to discuss any changes in the length of the fallow period around their home village. If they don’t know get them to ask their family about it. Has anyone observed a change in yield with shortening fallow period? In the Lihir group of islands, many people from the small, heavily populated islands of Malie and Masahet make gardens on Niolam (the big, less densely-populated island) — ask the students to discuss the reasons for this.

*Hold this discussion over at least two days, to give the students a chance to discuss the issues with their parents and other elder relatives.*
5. **Traditional gardening methods**  
*Grades 8-9; Outcomes: 8.2.1, 8.2.2, 9.1.1, 9.1.2, 9.1.3, 9.1.4, 9.1.5, 9.3.1, 9.3.2*

**Discussion**

Many traditional gardening methods are based on long experience and usually ensure maximum productivity on any given piece of land. Some on the other hand are based on ideas that have no correspondence with scientific understandings. An example of the latter is the use of the smoke of certain magical substances to increase the fertility of a garden. An example of the former is the use in many New Ireland gardens of *Hibiscus tiliaceus* (Ol in Lihirian) as a fallow species (see the section on this in Booklet 4) to extract nutrients from deep in the soil and deposit them back on the surface via leaf fall (the ‘Nutrient Pump’). Ask the students to discuss each of the following in terms of its correspondence (or not) with scientific understandings

*The students need to study Booklet 4, and discuss the issues with their parents, before the discussion*

a. Use of certain types of smoke as a means of enhancing garden fertility;

b. Keeping the ground in yam gardens bare of all vegetable matter;

c. Planting yams in the first year, and sweet potatoes, cassava and bananas in the second;

d. Using yam stakes;

e. Using *Hibiscus tiliaceus* as yam stakes;

f. Burning the bush before planting;

g. Many traditional gardeners refuse to use chicken manure for certain crops, including yams — why?
Direct environmental effects of mining on Lihir. Teachers Guide, EEPL Booklets 1–4, Upper Primary and Lower Secondary


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