PUPIL RESEARCHER INITIATIVE

Out of site out of mind?

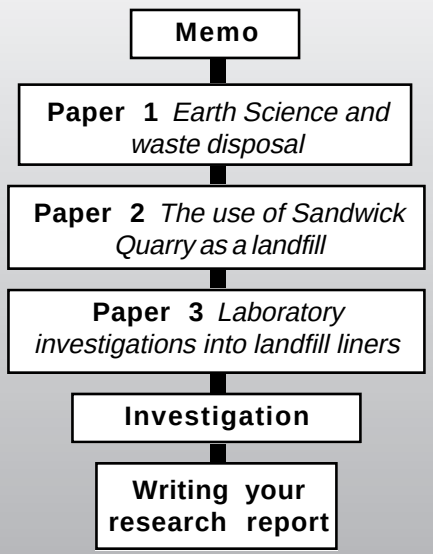
Pupil Research Brief

Teachers' Notes

Syllabus Coverage *Subject Knowledge and Understanding*

- ❑ humans reduce the amount of land available for other animals and plants by dumping waste
- ❑ human activities may pollute land with toxic chemicals which may be washed from land into water
- ❑ human activities may pollute water with toxic chemicals
- ❑ unless waste is properly handled more pollution will be caused

Route through the Brief



Introduction

In this Brief the pupils take on the role of new research students in a university environmental chemistry unit. The unit has been asked by a waste disposal company to make a recommendation concerning the most suitable natural material, or combination of materials, to act as a liner for a landfill site. Pupils are asked to read background papers, report back to their team and then plan and carry out the investigations. A report must be written to the waste disposal company, who will then use it in an application to the county council for a licence.

Experimental and investigative skills

- planning experimental procedures
- obtaining evidence
- analysing evidence and drawing conclusions
- evaluating evidence

Prior knowledge

Before attempting this Brief pupils should be aware of acid and alkali reactions, neutralisation and some common examples of waste materials from domestic and industrial sources, including sources of water pollution. Although not essential, it would be advantageous to the pupils if they were familiar with rock types, particularly sedimentary rocks, their properties and uses.

Pupil Research Brief

Teachers' Notes continued

Running the Brief

Pupil grouping

Pupils could work in a number of groupings during this Brief. Suggestions are:

Initial briefing	-	whole class; teacher briefly introduces and sets the context for the Brief
Planning meeting	-	groups of 6 suggested. One pupil could be nominated as the research team leader (Dr. J. Brown)
Analysis of three background papers	-	suggested that pairs of pupils could each be given one of the papers to analyse and report back to the meeting with summaries
Carrying out investigation	-	pairs or groups of three or four (depends on equipment availability)
Analysis of results	-	in pairs, threes or individually if the work is to be assessed
Communication	-	compilation of written reports (individual or group) and whole class discussion of results (optional)

Timing

The Brief should take 2-3 hours of classroom time. The time spent on the investigation can vary but the setting up of the test liners (cells) and the collection of leachate could be done in a double lesson. To save time, the papers could be set for homework. It would be beneficial if pupils could be given the opportunity later to report back to the rest of their group. Extra time may be needed to write up individual investigation reports, if these are to be used for examination assessment purposes

Activities

The teacher should issue the pupils with the **Study Guide** which provides pupils with a summary of what they should produce as they work through the Brief. It can also act as a checklist for pupils to monitor their own progress. The Head of the Chemistry Division (teacher) should issue each group with a copy or copies of the **fax** and the **memo.** Each group will require one copy of each of the three **background papers.**

The memo acts as an agenda for group discussion and directs the pupils towards the required reading. The Brief is written so as to encourage the pupils to divide the reading tasks to save time (and paper) as well as giving them practice in communicating their findings. The papers are not 'real' but they are realistic. They draw on government documents, planning applications, and research carried out in the School of Earth Sciences, University of Birmingham.

Paper 1 is written in a journalistic style and gives some background information about landfills, especially the vital role played by the geology of the area. The pairs looking at this paper are encouraged to reflect on the content by having to address comments written on the paper by the Head of the Chemistry Division. This paper describes some of the issues associated with landfill sites.

Paper 2 is a report of a site investigation. This is an important prerequisite to obtaining a licence for waste disposal in landfill sites. The paper describes the location and gives site details. In addition, it mentions some of the practical ways that landfill sites can be managed to reduce pollution and nuisance.

Paper 3 provides information about methods of researching liner materials, including examples of setting up test columns or cells. It also provides technical background into the composition of some materials suitable for liners. Again, comments written on the paper direct pupils in their reading.

The **final report** could be written in sections, with each pair producing a specific section, or it could be given to each pupil as a complete task. The sub-sections of the final report are listed on the fax sheet This should guide the pupils towards a realistic report structure.

Currently, a great deal of research is taking place into liner technology. This involves investigating the relative merits of different liner materials (both synthetic and natural) and in devising tests on liners. Some of the latter involve compressed air testing of seams (welds) and electronic mapping. Leak detection has evolved its own very advanced technology. Modern landfill sites use complete containment as the most effective means of controlling pollution. Landfill gas and leachate is collected and then pumped away from the site for

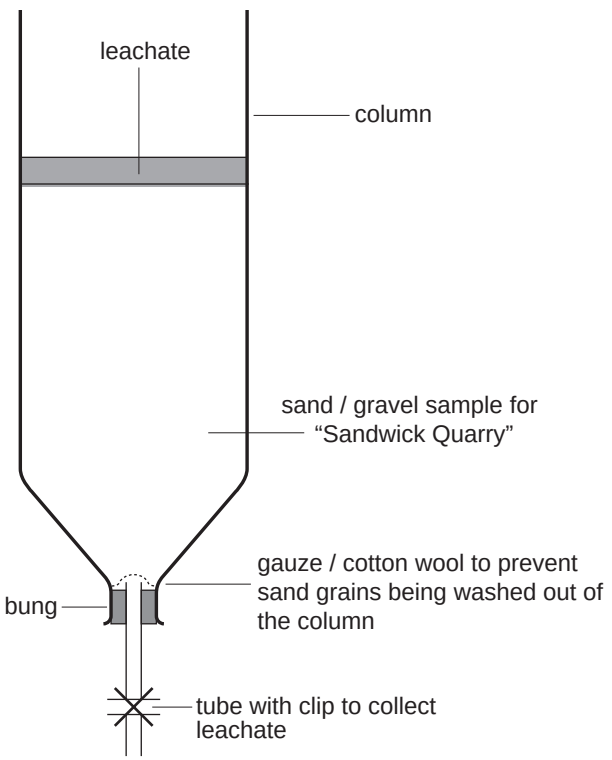
treatment or to be used. The work that the pupils are being asked to carry out mimics the work in some research establishments, in that the pupils are designing and testing 'controlled cells'.

Investigation and technical details

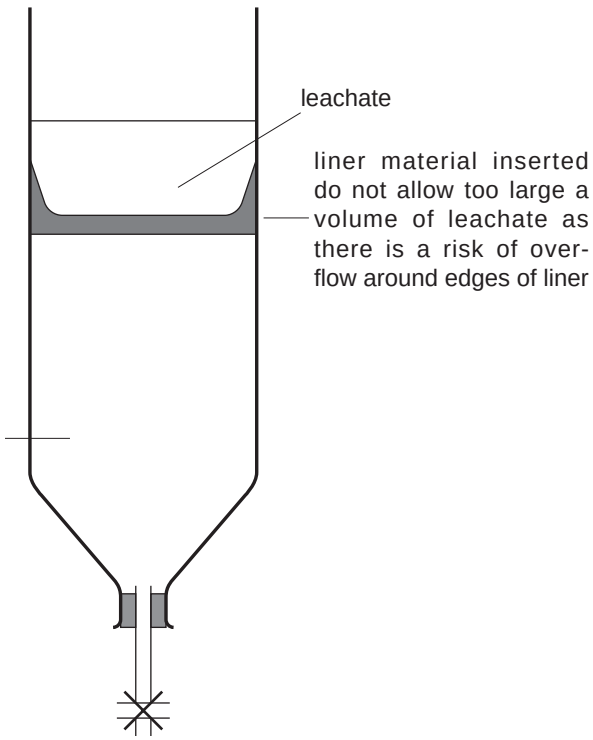
The pupils take on the role of consultants, providing an answer to the question "What will be the best liner for the site?" Possible solutions/models can range from column experiments such as outlined in Figure 1 to scale models such as that in Figure 2. These models can be as sophisticated as the group wish. Paper 3 - Laboratory investigations into landfill liners - is based on the research carried out at the School of Earth Sciences, University of Birmingham, as mentioned in the Introduction.

"Toxic" chemicals leaching from the site (leachate) could include cooking oil, acids (using normal pH range considered safe), food colourings or inks to give visible trace etc. The "leachate" will need to be prepared beforehand and could include a mixture of the above. If food colourings or inks are used, pupils could follow the movement of leachate through the column. Following collection at the end of the column the leachate could be analysed in simple terms e.g. pH, looking for traces of oil, and clarity.

Fig. 1 : Column Experiments
a) model using sand and gravel



b) model using liner materials above sand and gravel



Notes on Figure 2 (on next page)

1. Use damp sand and gravel to facilitate model making.
2. A hole will need to be drilled into the base of the tank to take a bung or tap.
3. The tank should be supported at the clay end to encourage drainage of the "leachate" towards the tap.
4. An alternative to the tap is to use plastic tubes as model "boreholes" down through the sand and collect samples from the bottom of these using a tube and syringe.

The fax transmission refers to rock samples from the Quarry that must be used to find out if they react with the leachate. Three sample materials from the quarry could be:

- clay
- sand
- chalk (calcium carbonate powder)

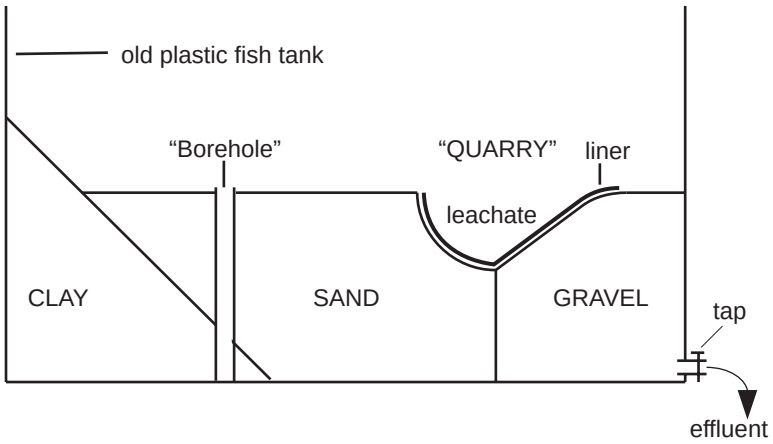
Possible other lining materials that could be incorporated to extend the investigation could include:

- waste paper
- plastic sheeting
- cement powder
- coal dust
- soil

plus any other sensible suggestions from the pupils.

Teachers' Notes continued

Figure 2. A model of Sandwick quarry



Pupils should be able to make predictions based on the background information and their knowledge of materials. Variables include the types of pollutants; type and depth of liner; sand or gravel as the rock and volume/rate of flow of the pollutants.

Different groups could be given different aspects of the problem with perhaps some using the column type experiment, whilst others used the modelling approach.

Using IT. Light sensors could be used to measure leachate clarity.

Safety issues

PLEASE NOTE: It is also important that you prepare your own risk assessments for the practical work in this Brief in the usual way.

Dilute acids: irritant
If swallowed: wash mouth and give water to drink. Seek medical attention.
If in eyes: flood eye with flowing tap water for at least 10 minutes. Seek medical attention
If on skin: flood area with water. Remove contaminated clothing. Seek medical attention if skin damaged.

Wear eye protection

Calcium hydroxide (cement powder): irritant
If swallowed: wash mouth and give water to drink. Seek medical attention.
if inhaled: remove to fresh air. Seek medical attention if breathing is even slightly affected.
If in eyes: flood eye with flowing tap water and keep it flooded until no further effects. Seek medical attention and inform that material is alkali.
If on skin: brush off solid and flood area with water. Remove contaminated clothing. Seek medical attention if large area affected or blistering occurs.

Wear eye protection. Wash hands after use. Cover cuts - gloves may be advisable.

Dusts (coal / cement)
Breathing affected; more serious for asthmatics.

If affected: remove calmly to fresh air. Allow asthmatics to take medication; seek immediate medical attention if attack persists.

Do not allow dust to rise into air.

Assessment issues for *Experimental and Investigative Science* (National Curriculum for England and Wales, Northern Ireland Curriculum)

P	Planning	O	Obtaining evidence
A	Analysing evidence	E	Evaluating evidence

There are two investigations ,i.e. investigating the reaction between leachates and different rock samples and using columns or models to look at the effect of using various landfill liners.

The level of scientific knowledge needed to carry out these investigations will possibly restrict the level of marks which can be achieved by pupils in **Skill Area P** to the middle range or below. This is also likely to limit the marks available for **Skill Areas O, A and E.**

Pupil Researcher Brief

Teachers' Notes continued

Scottish syllabus coverage

Standard Grade Biology - *Biosphere*

Further pupil research opportunities

Pupils could seek out further information on dealing with waste materials such as incineration and reed bed technology. They could carry out a survey into how the local authority treats waste and to what extent recycling of waste takes place. Pupils could also monitor their own household waste on a weekly/monthly basis and identify what and how much could be recycled.

PUPIL
RESEARCHER
INITIATIVE

Out of site, out of mind?

Pupil Research Brief

Setting the scene

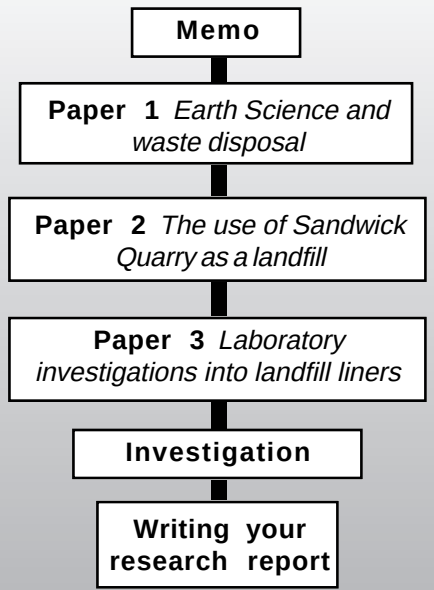
You will be working as a member of a team of new research students in a university chemistry department. The department has been asked to provide advice to a waste disposal company about the most suitable material to use to line a landfill site to stop toxic chemicals getting into the environment. You will carry out investigations to help you write your report to the company.

Study Guide

Syllabus Targets *Science you will learn about in this Brief*

- ❑ humans reduce the amount of land available for animals and plants by dumping waste
- ❑ human activities may pollute land with toxic chemicals which may be washed from land into water
- ❑ human activities may pollute water with toxic chemicals
- ❑ unless waste is properly handled more pollution will be caused

Route through the Brief



Outcome Checklist

You will produce a report to the waste disposal company outlining your recommendations about the landfill liner. A fax and a memo guide you through the Brief. You should make sure you produce the following items as you work through the Brief.

Paper 1, 2 or 3

- ❑ answers to questions and points raised by the notes written on the papers
- ❑ summary of your paper to report back to the group

Group discussion

- ❑ plan for investigation(s) into landfill liner material

Report to HWD plc

- ❑ report on investigation
- ❑ summary of advantages and disadvantages of types of liners
- ❑ recommendations as to the most suitable liner
- ❑ list of other factors the company could investigate to minimise pollution and noise

Regents University

Fax Transmission

To: Dr. J. Brown, Research Team Leader
Department: Environmental Chemistry Unit, Broomhill Campus

Number of pages (including cover sheet): 2

From: Prof. A. Thompson, Head of Chemistry Division
Department: Chemistry Division, City Campus
Fax: 0192 532299
Telephone: 0192 532209 ext. 2205

Message

Re: Hamside Waste Disposal plc (HWD): Sandwick Quarry landfill site liner contract

HWD has now finished a report on the use of the old Sandwick Quarry as a landfill site. They want to obtain a licence to allow them to put household waste into the site. Before they can obtain this licence from the County Council they must provide information about how the site will be lined to stop polluted water from running out of the site. This polluted water is called leachate. We have been awarded a contract from HWD to investigate three possible liners and make recommendations on which will be the most suitable. We have samples of the lining materials which we can mix into various combinations.

The time scale for the project is very tight. I suggest you involve your new research students but as they have no experience of the technical problems linked to landfill sites we will have to get their knowledge up to a suitable level quickly.

I've enclosed 3 papers which may be helpful. These are listed below. The research team members should work through these before starting the research investigation. I've also written a few comments on the papers which should stimulate some thought and help their understanding. It would be a good idea if the research students made notes based on their answers to my hand written questions and comments.

1. Thompson, A. (1994) "Earth Science and waste disposal" in *Environmental Matters* Vol 3, pp224-5

2. Roberts, R. and Wilks, F. (1996) *The Use of Sandwick Quarry as a landfill site*. HWD Site Investigation Report

3. Thornton, S.F., Bright M.I., Lerner D.N. and Tellam J.H. (1995) "Laboratory investigations into landfill liners" *Journal of Waste Science and Technology* Vol 81, pp74-5

..continued on next page

I've copied the relevant section from the HWD research contract below.

The contractor is required to carry out the necessary research to determine the most appropriate liner for the Sandwick Quarry landfill site. The following factors must be taken into account in making recommendations:

- *rock samples from the quarry must be used in order to find out if they react with the leachate;*
- *the liner must be produced from one or more of the natural materials provided and be able to protect local water supplies, especially the River Aron;*
- *the recommended solution must be based on evidence from investigations and supported by information from the research literature;*
- *a written report of the work with conclusions and recommendations is required. The contractor may also be requested to present a summary of the report to the HWD Management Committee. The report must include:*

    a) a summary of the advantages and disadvantages of natural and synthetic liners;
    b) a description of any reaction between the leachate samples with rock from the quarry;
    c) a description of the liner investigations, including all data collected;
    d) a clear recommendation as to the most suitable liner;
    e) a list of other aspects of landfill which our company could investigate to minimise pollution and nuisance.

I suggest you arrange a meeting of your research team as soon as possible. Please let me know if there are any problems and keep me informed of progress.

A. Thompson

Memo

To: Research students newly appointed to the Environmental Chemistry Unit Research Team

From: J. Brown

Subject: HWD Sandwick Quarry landfill site liner contract: planning meeting

Planning meeting agenda (Chair: J. Brown)

1 Background information: presentation and discussion of Prof. Thompson's fax and papers
(Copy of fax and papers enclosed) *(10 mins.)*

Issues for discussion

a) What do we need to investigate? (J. Brown to outline) *(5 mins.)*

b) Getting to grips with the technical problems associated with landfill sites. (J. Brown to allocate background reading tasks identified below) *(20 mins.)*

Paper 1: Earth Science and waste disposal article (Thompson, 1994)

Paper 2: HWD Site investigation report (Roberts and Wilkes, 1996)

Paper 3: Laboratory investigations into landfill liners (Thornton et al, 1995)

2 Brief report back from team members on their reading tasks, followed by discussion *(20 mins.)*

3 Planning the research investigation and allocating group tasks (refer again to papers and fax, and the action plan below) *(30 mins.)*

An action plan

What are the tasks?

What order must they be done in?

Who will do each task?

How long will they take and what do we need?

How will we check on progress?

How do we report back?

Environmental Matters Vol 3
November 1994

Paper 1

Earth Science and waste disposal

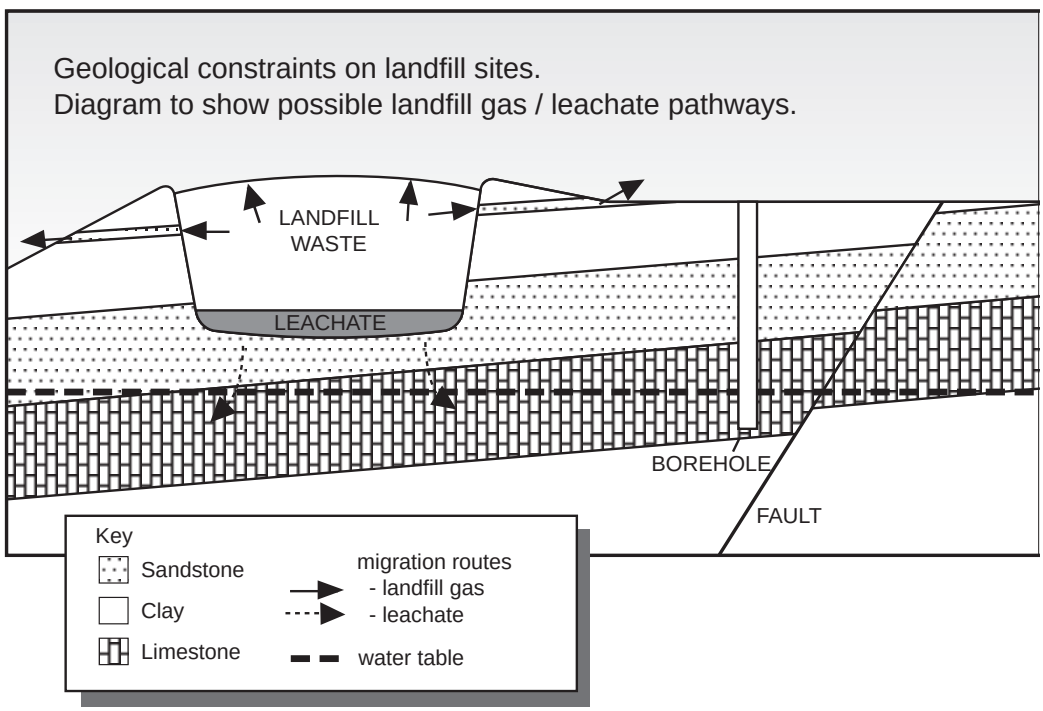
Anne Thompson discusses some of the issues linked to handling the mountain of waste produced today.

Every year the amount of waste material that we produce increases. Up to 90% of this waste will end up in landfill sites. Usually these sites are old quarries or mines. It seems to make sense to put materials we do not want back in! Unfortunately, it is not that simple. Just burying the waste does not bury the problem. The waste can be broken down by microorganisms once it is underground, just like material in a compost heap, and this can produce harmful gases and liquids. If these gases and liquids escape they can cause problems.

Landfill gas is mostly methane and carbon dioxide. Methane is flammable when mixed with air. Rainwater, and liquid products from the waste, will produce a toxic liquid called leachate. The leachate can pollute both rivers and ground water close to the landfill. If this happens it can have serious effects on the surrounding area. Effective management of landfill sites is essential to stop this from happening.

make sure we know what this is

Figure 1
Geological constraints on landfill sites.



Where should landfill sites be placed?

The types of rocks at a landfill site determine whether gas or leachate will escape. If a rock will let liquids and gases pass through it easily, the rock is called permeable. Permeable rocks are not suitable for a landfill site base. The leachate and gas can either move through tiny holes in the rock or may move through cracks or faults.

Why are permeable rocks unsuitable and what problems would arise?

The most permeable materials are sands and gravels. Many older landfills were established in pits where sand and gravel have been extracted for use in the building industry. Other highly permeable rocks include limestone and some types of volcanic rocks with well developed cracks. Landfill gas has been recorded hundreds of metres away from such landfill sites.

what does this mean?

how will this happen?

In the past, landfill sites relied on the leachate being 'treated' by the rocks it passed through. For example, alkaline rocks would help to neutralise acids in leachate. Low permeability rocks such as clay are best suited to this approach. High permeability rocks are not considered suitable as the movement of the leachate is too fast. Unmodified sites of this type were used in the past for industrial chemical waste and for biodegradable waste but this often had serious effects on surrounding water resources. Now the main methods of controlling pollution from landfill involves lining them so materials cannot escape. It is now standard practice at sites on permeable rocks to include some kind of impermeable barrier, known as a liner, to prevent the movement of both leachate and gas.

Lining materials can be divided into natural and synthetic. The most commonly used natural liners are clay, bentonite (a special type of clay), colliery shale and pulverised fuel ash (PFA).

Synthetic liners include butyl rubber, polyethylene, neoprene and polyvinyl chloride (PVC). Although synthetic liners are made from totally impermeable materials they can be less than perfect. There may be damage during laying, poor joins between sheets and damage caused by plants and chemicals.

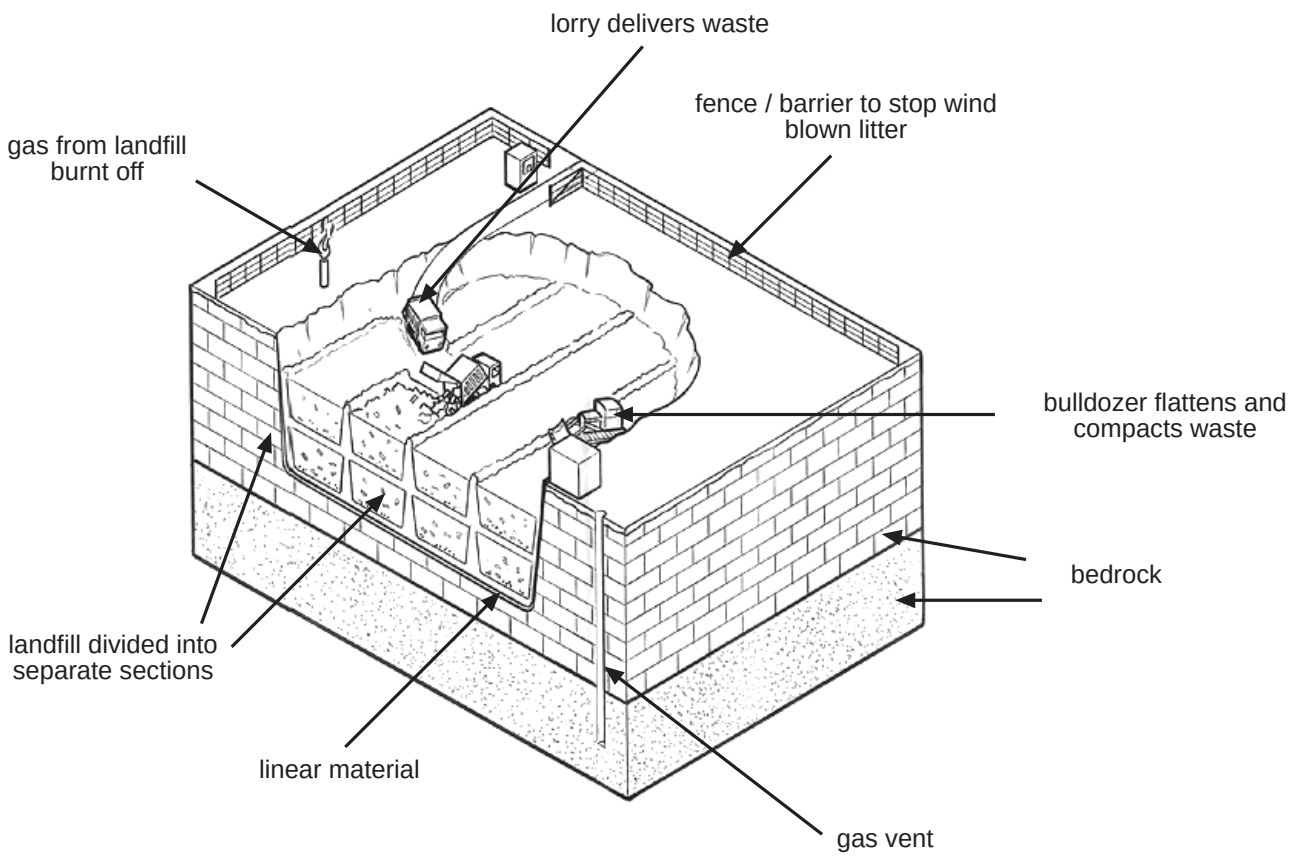
The design of a typical landfill site is shown in *Figure 2* below. Note that the site is covered whenever possible because stopping rain from washing down through the waste reduces leachate. Also note that fences surround the site to stop wind-blown litter scattering beyond the site.

Other inconveniences to the public which must be considered are increases in traffic, noise pollution, extra road building, vibrations, smells and removal of footpaths and rights of way. However, a well managed site should minimise pollution, environmental impact and problems for the public.

Why doesn't the gas and leachate just build up?

How can smell and noise be minimised?

Figure 2
The design of a typical landfill site



HWD plc

site investigation report

The use of Sandwick Quarry as a landfill site

Roberts, R. and Wilks, F.

March 1996

Background

Sandwick Quarry has reached the end of its life for the extraction of sand and gravel deposits for use in the building industry. HWD is applying for a licence to allow them to use the quarry as a landfill site for the disposal of general household refuse. The quarry is situated close to a village (see fig.1) and within a short distance of the river. The villagers and the River Inspection Authority are concerned that liquids leaking from the site (leachate) could affect the ground water and river. Villagers are also concerned about potential problems from landfill gas.

What might these problems be? - and what other problems might the landfill cause the villagers?

The site

Fig.1 Location map - Sandwick Quarry

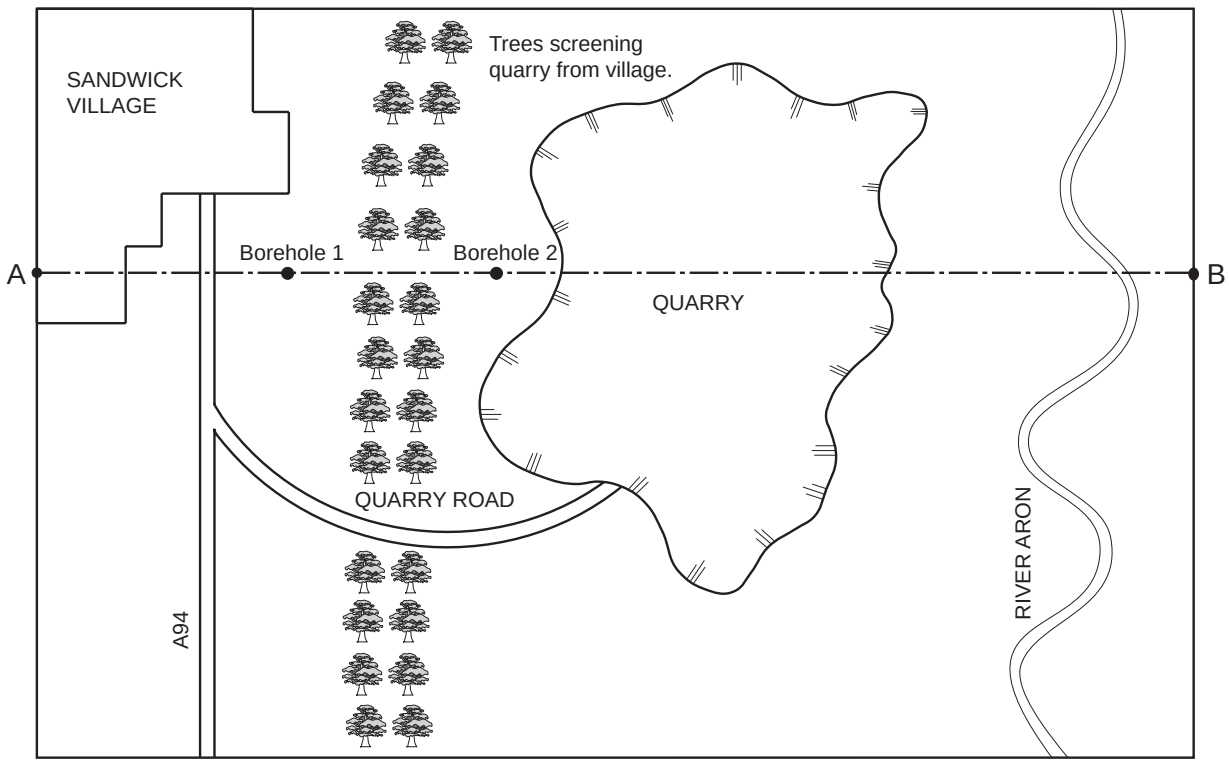
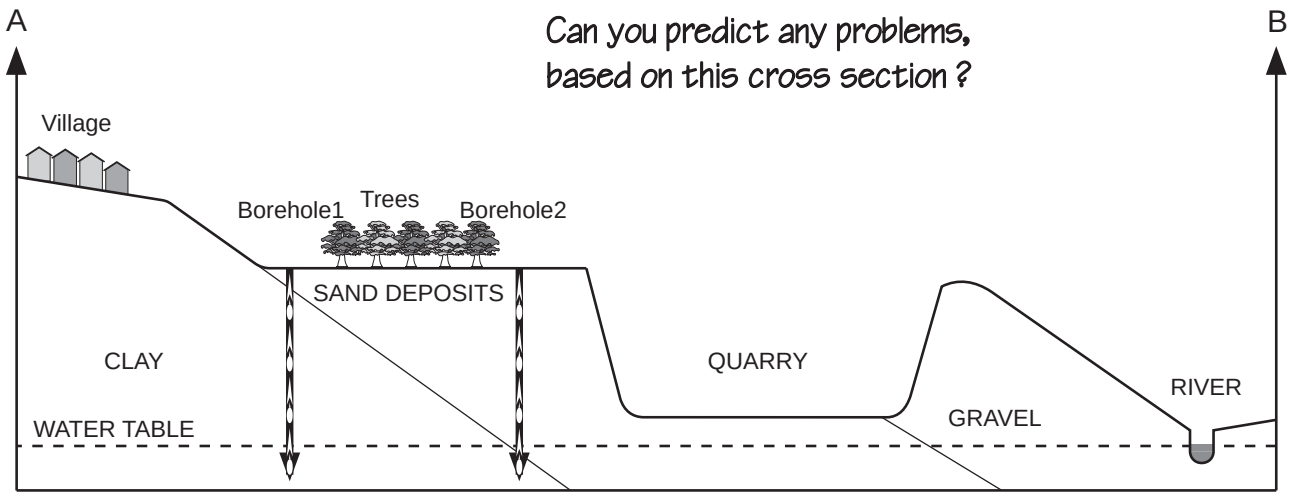


Fig. 2 Cross section of site



Risk of leachate pollution

The sands and gravels of the quarry may pose a risk of leachate pollution. These rocks are permeable and the base of the quarry is within a few metres of the ground water.

Could leachate reach the ground water and river? Explain how and what problems would result.

Recommendations:

Suitable materials should be found to line the sides and base of the quarry. The liner must prevent the movement of leachate out of the quarry. If possible the liner should also react with any leachate to reduce any pollution risk.

How?

Risk to Sandwick village from landfill gas and other nuisance

The clay deposits beneath the village form an impermeable barrier to the movement of gas. There is no risk to the village. However, no further building should be allowed on this side of the village to prevent development beyond the clay/sand boundary.

Recommendations:

The hole should be covered whenever and wherever possible with the impermeable material to deal with wind-blown litter, to prevent rainwater washing down through the waste and to reduce gas and smells escaping. The gas should be removed and if possible used. The site should not be used for construction following its use as a landfill site. A litter fence should be built around the site and working hours should be Monday to Friday, 09:00 to 18:00 only. No additional access roads should be constructed.

Why might rainwater be such a problem?

Explain why each of the recommendations in the above paragraph should be implemented.

Paper 3

Laboratory investigations into landfill liners

Thornton, S.F., Bright, M.I., Lerner, D.N. and Tellam, J.H.

Abstract

The design of liners from natural materials that could prevent the leakage of polluted waters from landfill sites is discussed. Laboratory experiments are currently under way to test the performance of natural liners made by combining a range of widely available materials.

Introduction

what does this mean?

In recent years waste liquids or leachates have been prevented from polluting the environment by using impermeable liners such as heavy plastic sheeting materials. However, the liner and leachate collection systems cannot be guaranteed not to leak and so it is vital to consider back-up measures, such as using a liner composed of a mixture of natural materials known to reduce the harmful effects of leachate.

There are a number of processes capable of making leachate less harmful during its movement through natural materials. These are a combination of physical, chemical and biological processes e.g. dilution, precipitation of metals, and the action of bacteria in breaking down organic compounds. These processes are maximised by a high clay content, organic carbon content and carbonate content. The carbonate will help to neutralise acids and help the growth of bacteria. Few natural materials contain all of these substances so the liner has to be constructed from locally available materials modified by adding clay, carbonate or organic-rich materials. To test this approach, laboratory experiments are currently being carried out as detailed below.

Experimental design

A set of columns was packed with example liner recipes. Leachate was fed through the columns and the effluent analysed. Three natural materials were selected to form the basis for the recipes. At one end of the spectrum was sandstone which would make a very unsuitable liner without modification. In contrast, Oxford Clay appears to possess the best properties as a liner. Coal Measures clay represents a material of intermediate properties.
See Table 1 below.

why is Oxford Clay likely to be a good liner material?

	sandstone	*Coal Measures clay*	*Oxford Clay*
organic carbon %	0.0023	2.6	3.9
carbonates %	<1	<1	14.8
pH	4.8	2.5	7.7

do you know what this means?

Table 1 Typical properties of materials used in the investigation

Based on the properties shown in Table 1, recipes were designed and designated "poor", "improved" or "good" according to the extent to which each is predicted to reduce the harmful effects of the leachate.

Column experiments

Twenty plastic columns were packed with the various test recipes and fitted with collection systems. The columns are fed at a rate of 140ml/day from supply tanks of leachate. Column effluents are sampled twice a week via sampling valves located at the top of the columns and then analysed.

What do you think of the predictions? Do you agree with them?

explain

Material	*Materials added*	*Prediction*
Inert sand	-	Control
Sandstone	-	Poor
Oxford Clay	Inert sand*	Good
Sandstone	Oxford Clay (20%)	Improved
Coal Measures clay	Inert sand* + CaCO3	Improved

* Added simply to increase flow rates for laboratory experimentation

Table 2 Predicted properties of test materials

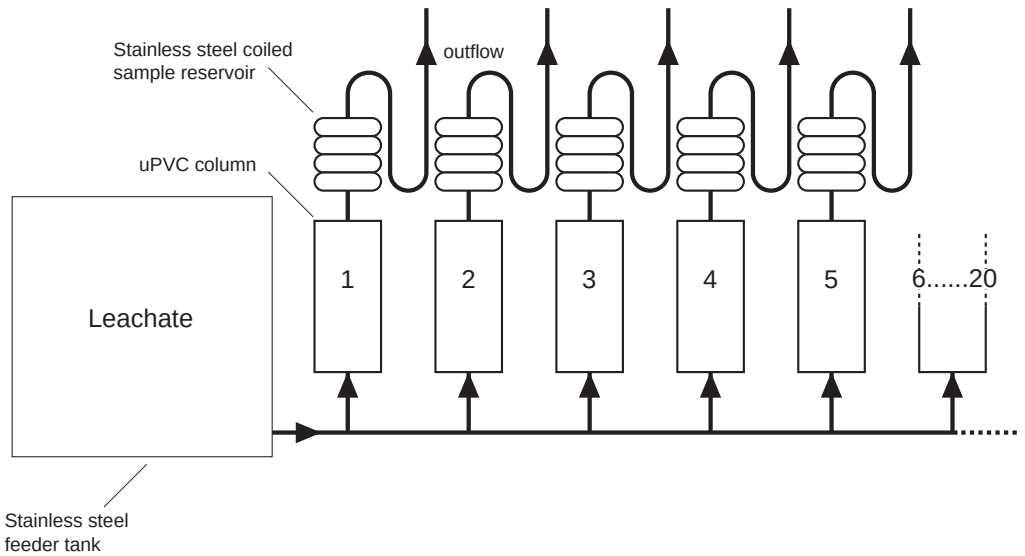


Figure 1 Column Apparatus

Preliminary results and conclusion

how can we learn from the methods used in this paper?

Initial evidence suggests that the test recipes are behaving as predicted in Table 2. The extent to which the results are permanent will be studied at the end of the experiment. The approach, if successful, should permit the engineering of low cost back-up liners for landfill sites from widely available materials.