A2 Biology coursework
Skill P: Planning

Title: *An investigation into the effects of different concentrations of lead chloride on the growth of plants, (cress).*

Aim: *To find out how changing different concentrations of a heavy metal chloride, namely lead chloride, affects the growth of cress seeds.*

Background information:

Lead is a grey metal, derived from ore-bearing minerals. Heavy metals compounds, such as lead chloride are able to dissolve in rain and enter the soil surrounding the plants. Lead is largely emitted into the atmosphere in a gaseous state through emissions of vehicles using fuel that contains lead. Other sources include additives in gasoline and paints, fertilisers and mining.

For plants, lead is a toxin and when present in large amounts it can cause severe decreases in their growth. Symptoms include stunted growth and the yellowing of plants (called chlorosis). Heavy metals collect in different organs of a plant and produce variable effects. Lead disrupts the plant's plasma membrane structure as well as permeability (proteins in the membrane), osmotic balance (the intake of water and ions) and indirectly, plant metabolism (the availability of nutrients for chemical reactions.) I will go into detail about these factors further on.

The first set of proteins to come in contact with the minerals and ions in the surrounding soil and are involved in the transport of micronutrients such as iron are called chelates. This is a protein carried by the root cell. Lead has a high affinity for sulphur, and as sulphur is present in the chelate molecule, lead binds with the sulphur and causes the inhibition of iron transport.

This means that there is a deficiency of iron therefore slowing down all reactions, which mean there is a lack in chrophyll formation, which can lead to chlorosis, which is the decolourisation of the leaves. This therefore leads to a decrease in light absorption, less glucose made, and decreasing in photosynthesis meaning the plant may eventually die.

For lead to be transported from the soil to the root cells, it must cross the cell membranes of the root cells. Lead is able to cross the cell membranes via voltage-gated calcium channels. These channels are for the transport of calcium. Lead blocks these channels and causes the inhibition of their activity, preventing calcium being transported.

For photosynthesis to occur plants require water. When lead is present in high concentrations in soil, it decreases the water potential of the soil. It therefore, has a lower water potential than the root cells, causing water to move from a region of higher water potential (root cells) to a region of lower water potential (soil), via osmosis (Biology 1, OCR, pg 56).

This disrupts the osmotic balance of the plants and prevents sufficient amounts of water entering the cells.

Both photosynthesis and respiration require all types of enzymes, and some of these may be affected by lead chloride, therefore inhibiting both processes.

The process of photosynthesis is affected by heavy metals in a negative way. Lead inhibits photosynthetic enzymes (involved in the Calvin cycle such as ribulose bisphosphate carboxylase) and is highly effective at inhibiting ATPase – an enzyme required in the production of ATP in photosynthesis (and respiration). It also disrupts the chloroplasts and, reduces the production of chlorophyll and carotenoids, interrupts the electron transport chain and causes the closure of stomata which results in a lack of carbon dioxide. Many features of photosynthesis are therefore affected.

Many chemical reactions occur in living organisms. In plants, the uptake of lead affects the functioning of enzymes.

Enzymes are protein molecules which contain amino acids which may contain cysteine. A component of cysteine includes sulphur and as lead has a high affinity for this element, it is immediately attracted to the bonding between molecules of cysteine called disulphide bridges. This causes them to break, therefore altering the tertiary structure of the protein which thus changes the shape of the enzyme, and its active sites. This means no enzyme-substrate can form therefore the enzymes no longer play a role in that particular reaction

It can be seen that lead has many adverse effects on the growth of plants. This investigation will examine exactly how different concentrations of lead chloride will affect the growth of cress seedlings.

***Prediction**: I predict that as the concentration of lead chloride increases, the growth of the cress seeds will decrease. The lead chloride will inhibit the growth of the cress seeds.*

***Preliminary Experiment:** Preliminary work was carried out, so when the final experiment is carried out, the best results are able to be obtained.*

<u>The aim of the preliminary work was to find out:</u>

1. *Which medium cress seeds grow best in.*
2. *The method in which to distribute the cress seed, on the most effective medium, to obtain maximum growth.*
3. *The range of concentrations of lead chloride to use in the experiment, which will allow enough growth of the cress seeds in order to produce measurable results.*

The test was also carried out to see if the heavy metal chloride really has an adverse effect on the growth of plants.

Test 1-
To find a medium in which cress seeds will grow most well in.

This test was carried out to see which medium the cress seeds grew most effectively in. A stable environment was needed and a number of different mediums were considered in which the cress seeds could be grown in. These included cotton wool, cotton face pads, filter paper, and soil.
Soil was not used as a test medium because of its inconsistent composition, and not being homogenous.
The mineral and nutrient content in the soil may not be uniform which would prevent a fair test from being carried out, as some seeds would be in surroundings with higher nutrient content than others in lower nutrient content environments. Since lead chloride is being investigated in this experiment, it is also best to have no other heavy metal ions involved which may be present in the soil. Therefore the three mediums chosen were filter paper, cotton wool, and cotton face pads, as all three were homogenous.

Here is a basic method illustrating how this test was carried out.

1. *Position a layer of each medium into separate petri dishes. Use two layers of filter paper or else it will not soak up enough water. Label each petri dish with its equivalent medium.*
2. *Measure 15ml of distilled water using a measuring cylinder and carefully pour into each petri dish, covering as much of the medium.*
3. *Using tweezers, place 25 cress seeds carefully on each medium, spacing them apart equally.*
4. *Place each petri dish into a separate polythene bag and fill with some air. Tie the bag and allow the cress seeds to grow for 5 days in an area with lots of sunlight .(To get the air in the bag prior to placing the dish in, sway the bag in the air back and fourth)*
5. *After 5 days, measure the length of the shoot (starting from the seed and not including the root) of each cress seed in all three petri dishes. Use a ruler to do this, measuring in millimetres.*

On the next page is a table illustrating the results of this experiment.

The shoot lengths of all 25 cress seeds in each medium were measured. The length of the roots was not measured because the roots were found to be entwined around each other in at least one petri dish. An average length of shoot of cress seeds was calculated for each medium by adding up all 25 lengths and dividing the result by 25 (which is the number of seeds planted (see appendix for calculations)

A table to show the average length of the shoot of the cress seed grown in three different mediums

Medium in which cress	***Average length***

seeds were grown	*of the shoot of the cress seeds (mm)*
Cotton pad	*17.7*
Filter paper	*9.44*
Cotton wool	*15.9*

Note: All figures in the table are correct to 3 significant figures.

From the results I can see that cress seeds grew most effectively in the medium of the cotton face pads. This may be due to the cotton face pads being a suitable and uniform thickness that could support the growth of the cress seeds well. They also may have a moderate capacity of soaking up water so that the cress seeds are not drowned underwater but are still in contact with the damp surroundings. Although the length of the roots were not measured, observing the growth of the roots showed that the roots of the cress seeds in the cotton pad were not trapped in the pad and could be easily picked out.
However, this was not the case for cotton wool in which the roots were very entangled and sometimes caused the shoots to break when trying to remove them from the medium. The growth of the shoots in the cotton wool may also have been inhibited if the shoots could not grow out and beyond the cotton wool. The results for filter paper showed the lowest average length of shoot of cress seeds and this may be because of the filter paper could not soak up enough water and so the seeds were submerged under the water. The filter paper may have been too thin to provide enough anchorage for the growth of the cress seeds as well.

So for the final experiment, I will therefore be using cotton face pads as this was the most effective medium for growth.

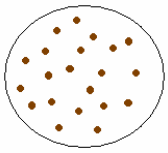
Test 2-
The method in which to distribute the cress seed, on the most effective medium, to obtain maximum growth.

The second test was conducted to find out which distribution of cress seeds in the petri dishes gave the maximum growth of the seeds. A variety of distributions were considered in which the cress seeds could be grown. These included a grid, a scatter and a cluster. The idea of distributing the seeds in a cluster was at first not going to be used because of the fact that a cluster would result in the seeds being too close together and this could result in intraspecific competition for space, however in the end it was used.

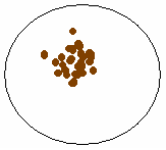
Here is how this experiment was carried out. For this experiment, cotton face pads were used in all distributions as in experiment 1, this was the medium that produced the best results.

1. *Firstly place a cotton face pad into three separate petri dishes, and on each petri dish label the following headings with a china graph pencil, "cluster", "scatter", and "grid"*

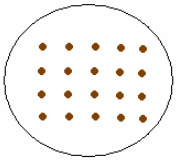
2. *Measure 15ml of distilled water using a measuring cylinder and carefully pour into each petri dish, covering as much of the medium.*
3. *Take 25 seeds, and by hand scatter them across the cotton face pad in the first petri dish, labelled with the corresponding heading.*



4. *Then collect another 25 seeds, and place in a thin measuring cylinder, and pour over the second petri dish. This produces a cluster distribution.*



5. *In the third petri dish, place 25 seeds in rows of "5", to produce a grid affect.*



6. *Place each petri dish into a separate polythene bag and fill with some air. Tie the bag and allow the cress seeds to grow for 5 days in an area with lots of sunlight.*
7. *After 5 days, measure the length of the shoot (starting from the seed and not including the root) of each cress seed in all three petri dishes. This is done using a ruler.*

Below is a table of the results of this experiment. Once again the average length of shoot of cress seeds was calculated using the previous method. (see appendix for calculations)

A table to show the average length of shoot of cress seeds grown in different distributions.

Arrangement of cress seeds	***Average length of shoot of cress seeds (mm)***
Scatter	*11.8*
Cluster	*9.24*
Grid	*16.5*

Note: All figures in the table are correct to 3 significant figures

The results illustrate that the most effective distribution in planting the cress seeds is by using a grid method where rows of "5 seeds are arranged, to produce a grid affect.
This method had the greatest average length of 16.5 mm. This may be because the seeds in this distribution were arranged at equal distance apart so that each seed gets an equal share of the surrounding resources. They are not too close to result in intraspecific competition between them.
Good use was also made of the space in the petri dish when the seeds were arranged in this manner.

The distribution of seeds using the scatter method, showed the second highest average length of shoot of cress seeds with 11.8mm. There may have been some competition for space between the cress seeds in this petri dish because some may have been closer than others.

The clustered distribution showed the lowest average growth of cress seeds and this may be because the clustered method meant that not all the seeds were the same distance apart. Some seeds may have ended up very close together when emptied out. This may have resulted intraspecific competition between the seeds for resources.

So for the final experiment, I will therefore be using the grid method to arrange the cress seed as this was the most effective distribution for growth.

Test 3-
The range of concentrations of lead chloride to use in the experiment, which will allow enough growth of the cress seeds in order to produce measurable results.

This test was carried out to see whether if lead chloride actually did have a negative effect on the growth of cress seeds. The range of lead chloride concentrations that could be used in the final experiment, which would give sufficient growths of the cress seeds, also needed to be established.
This was so ensure that measurable results are produced which can be compared to see the effects of the different lead chloride concentrations on the growth of the seeds.
Five different concentrations of lead chloride were tested in the preliminary run.
Each concentration was prepared from a concentrated solution of lead chloride with a molarity of 0.02moldm^{-3} which was already made. To produce the desired concentrations of lead chloride with distilled water, different calculations were calculated using a dilution factor formula, (see appendix for calculations).Since the second test identified that the most effective method of arranging the seeds on the petri dish was in a form of a grid, this arrangement was used in this experiment.

This is how it was carried out:

- *Place a cotton face pad into 5 petri dishes.*
- *Prepare the following lead chloride concentrations using the volumes of the concentrated lead chloride solution and distilled water shown in the*

table below. Use a measuring cylinder to do this, and place each solution in its separate test tube, to avoid contamination

Concentration of lead chloride solution desired (mol dm^{-3})	***Volume of 0.02moldm^{-3} lead chloride solution required (ml)***	***Volume of distilled water required (ml)***
0.000	*0.00*	*15.00*
0.005	*3.75*	*11.25*
0.010	*7.50*	*7.50*
0.015	*11.25*	*3.75*
0.020	*15.00*	*0.00*

- *Once all the 5 concentrations are made up, place them over each cotton face pad in each petri dish, and label the dish with its corresponding label*
- *Using tweezers, arrange 25 seeds in each petri dish using the method of distribution shown by the grid in the second test above.*
- *Place each petri dish into a separate polythene bag and fill with some air. Tie the bag and allow the cress seeds to grow for 5 days in an area with lots of sunlight.*
- *After 5 days, measure the length of the shoot (starting from the seed and not including the root) of each cress seed in all five petri dishes. This is done using a ruler.*

N:B whilst carrying out this experiment, make sure eye protection is worn at all times, with plastic gloves carrying the hands. Protective clothing should also be worn as well

The table below shows the results of this experiment. The average length of shoot of cress seeds was calculated once more, using the previous method – (see appendix for calculations).

A table to show the average length of shoot of cress seeds grown in different concentrations of lead chloride.

Concentration of lead chloride (moldm^{-3})	*Average length of shoot of cress seeds (mm)*
0.000	*47.8*
0.005	*23.3*
0.010	*12.6*
0.015	*5.68*
0.020	*4.28*

Note: All figures in the table are correct to 3 significant figures.

The results show that as the concentration of the lead chloride increases, the growth of the cress seeds decreases. This means that lead chloride, does have a negative effect on the growth of cress seeds.

The results also show that the growth of the cress seeds is measurable, with the lowest average length of shoot being no less than 4.28mm for 0.02moldm^{-3} lead chloride.

There are also significant differences between the average lengths of the shoots of the seeds when grown in varying strengths of lead chloride. For example, the average length of the shoots decreases from 47.8mm to 23.3mm when the concentration of lead chloride increases from 0.000moldm-^{3} to 0.005moldm^{-3}. This is a considerable difference of almost 25mm. Therefore, the good variation in the results of how lead chloride inhibits the growth of cress seeds can be clearly compared and explained well, using scientific details.

So for the final experiment, I will therefore be using these concentrations, to illustrate the effects of different concentrations of lead chloride on plant growth.

Conclusion of preliminary tests

By carrying out all the different tests for the preliminary work, I can now decide what would be appropriate to be carried out in the final experiment.

I have decided that the cotton face pads will be used as the growth medium for the cress seeds as this medium produced the best results in the first experiment. Cotton pads are of uniform thickness with moderate water holding capacities and are very suitable for the cress seeds. They also fit well in the petri dish.

The distribution of the seeds would be in a form of a grid, of rows of "5". This will provide enough distance between each cress seed so that they have adequate space to grow and will not compete intraspecifically for room

The lead chloride concentrations used in the preliminary experiment will also be used in the final experiment because measurable results were obtained when using these concentrations and there were significant differences in the growth of the cress seeds when immersed in the different concentrations. This means that the five concentrations will be appropriate in allowing the results to be compared and contrasted well and will be used to explain exactly why lead chloride inhibits the growth of plants.

Once the preliminary work had been carried out, certain aspects of the procedure stood out, that would probably need modifying in the final experiment.

For example we used length of the shoots of the cress seeds was as an indication for the amount of growth. So this implied that tall plants had the largest growth. However, the length of shoots does not take in to consideration the width of shoots and the growth of roots.

An alternative would be to measure the dry mass of the cress seeds, as this would be comparative to the overall growth of the seeds.

Also maintaining a constant environment around the cress seeds whilst left to grow is extremely difficult and this is an important factor in determining the growth of plants.

- *For example, light, humidity and temperature are all variables which may affect the growth of a plant and therefore, need to be kept constant so that any differences in growth are due to the lead chloride concentration.*

In the preliminary experiment, polythene bags filled with air were used to provide a closed environment around the cress seeds.

- *However, the amount of air in each bag may have varied, which may have varied the humidity. In addition, some of the solution in the petri dishes may also have evaporated and this may have affected the concentration of the lead chloride solutions in Test 3.*

If this was to happen in the final experiment, inaccurate results would be produced. An alternative would be to use a Dewpoint propagator which controls light, temperature and humidity. It also prevents evaporation of solutions which would be ideal for the experiment in order to obtain accurate and reliable results.

The following pages explain how the final experiment would be carried out

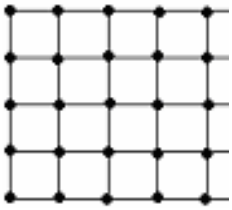
Apparatus:

- *0.02moldm^{-3} lead chloride solution*
- *Distilled water*
- *Beakers(2)*
- *Petri dish (5)*
- *Cotton face pads (5)*
- *20ml (2), 10ml (2) and 5ml (2) syringes*
- *Cress seeds(25 X 5)*
- *Test tubes (5)*
- *Test tube rack (1)*
- *Tweezers (1)*
- *China graph pencil (1)*
- *Electronic balance (1)*
- *Baking oven (1)*
- *Baking tray (1)*
- *Acetate circle – grid (1)*
- *Dewpoint propagator (1)*
- *Protective gloves (1)*
- *Safety goggles (1)*
- *Lab Coat (1)*

Diagram:

Method:

1. *Pour some 0.02mo ldm^{-3} lead chloride solution and some distilled water into two separate clean beakers and label them using the China graph pencil. This is to be used throughout the experiment, when preparing the different concentrations.*
2. *Label a petri dish 0.00 mol dm^{-3}, and place a cotton face pad into the petri dish.*
3. *Measure 15ml of distilled water from the beaker using a 20ml syringe and pour it into a test tube, held in a test tube rack.*
4. *Add the solution of the test tube to the petri dish, evenly pouring it onto the cotton face pad so that all areas are damp and covered in the solution.*
5. *Count 25 cress seeds and use the acetate grid to distribute them evenly onto the petri dish. Using tweezers, place one seed at each corner of the squares making up the grid. An example of this is shown in the diagram on the next page.*



6. *Repeat steps 2-5 for the remaining concentrations of lead chloride. The table below shows how to make up the different concentrations.*

- *For volumes of 5ml and under, use the 5ml syringe.*
- *For volumes between 5ml and 10ml, use the 10ml syringe and,*
- *For volumes above 10ml, use the 20ml syringe.*

To avoid mix up of the syringes, label on each syringe the substance its being used for, i.e. Lead chloride or distilled water.

Concentration of lead chloride solution desired (mol dm-3)	***Volume of 0.02moldm-3 lead chloride solution required (ml)***	***Volume of distilled water required (ml)***
0.000	*0.00*	*15.00*
0.005	*3.75*	*11.25*
0.010	*7.50*	*7.50*
0.015	*11.25*	*3.75*
0.020	*15.00*	*0.00*

7. *Using a Dewpoint Propagator place all the petri dishes inside of it. This piece of apparatus controls the light, temperature and humidity of the surroundings of the cress seeds. Leave here to grow for 7 days*
8. *After 7 days, take the petri dishes out of the Dewpoint propagator.*
9. *Carefully remove each seedling from the cotton face pad of one petri dish, using tweezers, and place together on a clean baking tray.*
10. *Repeat step 9 for the other petri dishes. Do not mix up the seedlings (arrange them in small groups on the baking tray, separate from each other). Record the concentration of the lead chloride that each group of seedlings was grown in.*
11. *Put the baking tray into an oven set at 78℃ and leave it to bake overnight.*
12. *Remove the baking tray from the oven.*
13. *Take the seedlings grown in 0.000moldm-3 from the baking tray with tweezers and place them onto an electronic balance.*
14. *Then weigh the seeds together and record the mass for that particular concentration.*
15. *Place the seeds back onto the baking tray in the same position.*
16. *Repeat steps 12 to 15 for the other seedlings grown in the various lead chloride concentrations.*
17. *Heat the seeds in the oven for a further 6 hours.*
18. *After 6 hours, repeat steps 13, 14 and 16 again. If the seeds grown in a particular lead chloride concentration are found to have the same mass again, then this is the actual dry mass (biomass) of the seeds grown in that particular lead chloride solution and is recorded.*
19. *If the mass reading is less when measured the second time, heat the seeds again for a further 6 hours. Continue doing this until two equal consecutive masses have been obtained. This will then be the mass of the cress seeds.*

Justification of apparatus and method:

- ***Petri dishes*** *will be used to place the cotton face pads in as they are of reasonable size and shape and the cotton pads fit well in them. Also the petri dishes will be labelled to ensure that there is no confusion in remembering which concentration of lead chloride is present in each petri dish.*
  Each petri dish will contain 15ml of the lead chloride concentration. This is because during the preliminary work, 15ml was found to match well with the size of the petri dish and the cotton pads. The capacity of the cotton pads to soak up water was moderate – the seeds were neither flooded nor deprived of the solution. The same amount will be used in each petri dish to make it a fair test. Otherwise, inaccurate outcomes of the experiment will result.
- ***Distilled water*** *will be used to dilute the lead chloride because it has fewer impurities than tap water. It will not be contaminated with any minerals or ions, which may be the case if using tap water. It is also best to have no other minerals or ions present, other than the lead chloride being investigated. This is so that any differences in the results are due to the lead chloride only.*
- ***Cress Seeds*** *will be used as they grow quickly, and results are produced rapidly. They are easy to grow only needing light, water and warmth. They are also small and therefore do not take up too much room .Twenty - five cress seeds will be used in each petri dish. The preliminary work carried out showed that this is a sufficient amount of seeds to plant in the petri dish, as measurable results were produced. It would not be practical to plant only one seed in each petri dish, as the test would then have to be repeated to give reliable results. By planting 25 seeds, this is in consequence repeating the experiment and will give significant amounts of biomass to record and analyse. This in turn, increases the reliability of the results.*
  The cress seeds will be left to grow for 7 days because the tests done for the preliminary work, which were left for 5 days resulted in some seeds not germinating completely, therefore needing a few more days of growth. This means that 7 days is plenty of time for the cress seeds to grow. All the petri dishes will be left to grow for the same length of time to make it a fair test. If this did not happen, then the cress seeds in some of the petri dishes may grow more than those in others, leading to inaccurate and unreliable results.
- ***Beakers*** *will be used to contain the lead chloride and distilled water because it will be easier to measure the required amounts of each solution from beakers instead of measuring them directly from the bottles. This will also minimises the possibility of an accident occurring, as small amounts of the liquids will be dealt with at any one time. Clean beakers will be required to ensure there is no contamination by other substances which may affect the accuracy of the experiment.*
- ***Tweezers*** *will be used to grip the cress seeds, as this is the most convenient way of handling and moving the small seeds around.*

- *The **test tubes** will be used to hold the different concentrations. The test tubes allow the solutions of water and lead chloride to be mixed or else, pouring them separately onto the cotton pads would not give accurate results. This is because all parts of the cotton pads will not be surrounded by an equal concentration of the lead chloride. Separate test tubes will be used for each concentration so that they are not contaminated as this may lead to inaccurate results.*
- *The **acetate grid** will be used to distribute the seeds and to make sure that the seeds are equally spaced apart. As the seeds are spread apart this will reduce intraspecific competition giving accurate and reliable results.*
- *A **Dewpoint propagator** will be used to provide a constant environment for the cress seeds whilst they are growing. The propagator is able to control light, temperature and humidity of the surroundings as well as prevent evaporation of the solutions in the petri dishes. It is therefore, an effective piece of apparatus to use and is better than using polythene bags which were used in the preliminary experiment (the reasons for this have been discussed).*
- *When measuring the amounts of solutions, **syringes** will be used because these are more accurate than using measuring cylinders which were used in the preliminary experiment. The reasons for this are that syringes have a narrower lumen and consequently smaller increments. They are therefore, more accurate than using a measuring cylinder. Measuring cylinders are wider and so there is more chance of an error occurring when using these. The syringes used will be of varying sizes so that for different amounts of solution, different syringes can be used. For example, to measure below 5ml of a solution, it is more accurate to use a 5ml syringe than using a 10ml syringe, as once again, the increments will be smaller. This means there will be a smaller percentage error in measuring the volume. It would be impractical for instance, to use a 5ml syringe to measure 10ml because this means that the syringe would have to be filled twice, increasing the chance of error.*
- *The biomass of the cress seeds will be used as an indication of the amount of growth in the different concentrations of lead chloride, instead of the stem length. The reason being that measuring the length of the shoots does not take into account the width and root growth. Therefore, measuring the biomass gives a more accurate indication of the total amount of growth of the seeds that has taken place.*

The biomass will be found when the seeds are heated and weighed several times until two consecutive masses are obtained. This increases the reliability of the results because if the mass of the cress seeds found the first time was taken as the actual biomass, this may have given inaccurate results. This is due to the fact that all the water may not have evaporated in the oven and so the mass obtained would not be the actual dry mass.

Safety:

Lead chloride is a harmful substance for humans as well as plants. Safety goggles, protective gloves and lab coats should be worn at all times during the experiment, with hair tied back.

Lead chloride is an irritant and can cause painful skin irritations and serious damage when in contact with the eyes. Lead chloride, being toxic and a poison, can be very dangerous if it is inhaled or swallowed – it can damage internal systems such as the respiratory tract, the central nervous system, reproductive system and the blood. Lead poisoning can also develop causing muscle cramps and vomiting. It is therefore essential to keep the room well ventilated in order to avoid inhaling dust and fumes from the lead chloride. The lead chloride should be removed from the bottle and poured into a beaker, as it will be easier to handle smaller amounts of the lead chloride than using it straight from the bottle. However, at other times, it is necessary

to keep the lead chloride in a tightly sealed bottle. The cotton pads soaked with lead chloride should be placed in a bag to give to the teacher who can safely dispose it.

Bibliography:

Books:

- **Advanced Sciences, Biology 1, ~** *by Mary Jones, Richard Fosbery, Dennis Taylor- pages 48-49, 56*
- **Advanced Sciences, Biology 2,** *~ by Mary Jones, Jennifer Gregory- page 120*
- **AS Level Biology** ~ Phil Bradfield, John Dodds, Judy Dodds, Norma Taylor

Websites:

- ***www.s-cool.co.uk***
- ***http://plantphys.info/seedg/seed1.html***
- ***http://www.eskom.co.za/content/GFS%200025%20Environment%20understanding%20Pollution%20Rev%2003%20#1.doc***
- ***www.jtbaker.com/msds/englishhtml/1782.htm***

Appendix:

The following tables show the full set of results collated from the preliminary work.

Preliminary experiment 1

The table shows the length of shoots of the cress seeds in different mediums.

	Length of shoot (mm) of cress grown on different mediums		
Trial	***Cotton Wool***	***Cotton face pads***	***Filter Paper***
1	*19*	*16*	*14*
2	*0*	*15*	*14*
3	*0*	*6*	*14*
4	*9*	*27*	*19*
5	*9*	*22*	*18*
6	*15*	*25*	*21*
7	*23*	*20*	*15*
8	*25*	*21*	*10*
9	*26*	*18*	*11*
10	*16*	*10*	*3*
11	*24*	*14*	*6*
12	*15*	*22*	*20*
13	*25*	*16*	*3*
14	*5*	*14*	*9*
15	*5*	*22*	*19*
16	*19*	*20*	*9*
17	*1*	*11*	*12*
18	*17*	*17*	*18*
19	*15*	*19*	*1*
20	*12*	*10*	*0*
21	*22*	*12*	*0*
22	*21*	*24*	*0*
23	*14*	*23*	*0*
24	*27*	*20*	*0*
25	*21*	*19*	*0*
Mean	*15.92*	*17.72*	*9.44*

0 = did not germinate

Preliminary experiment 2

The table shows the length of s hoots of the cress seeds in different arrangements.

	Length of shoot (mm) of cress grown in three different distribution patterns		
Trial	***Grid***	***Scatter***	***Cluster***
1	*0*	*0*	*0*
2	*0*	*0*	*0*
3	*0*	*0*	*0*
4	*1*	*0*	*0*
5	*23*	*0*	*0*
6	*1*	*0*	*0*
7	*15*	*0*	*20*
8	*24*	*0*	*20*
9	*20*	*19*	*6*
10	*25*	*17*	*21*
11	*19*	*14*	*10*
12	*15*	*23*	*21*
13	*11*	*27*	*13*
14	*16*	*17*	*19*
15	*25*	*5*	*12*
16	*23*	*7*	*11*
17	*28*	*10*	*12*
18	*23*	*21*	*21*
19	*19*	*20*	*5*
20	*24*	*18*	*5*
21	*28*	*23*	*3*
22	*11*	*19*	*2*
23	*22*	*23*	*10*
24	*14*	*15*	*11*
25	*26*	*17*	*9*
Mean	*16.52*	*11.8*	*9.24*

Preliminary experiment 3

The table shows the length of shoots of the cress seeds in different concentrations of lead chloride.

	Length of cress shoot (mm) grown in different concentrations of lead chloride				
	Concentration (mol dm^{-3})				
Trial	***0.000***	***0.005***	***0.010***	***0.015***	***0.020***
1	*33*	*10*	*15*	*1*	*0*
2	*39*	*15*	*10*	*0*	*0*
3	*41*	*24*	*14*	*2*	*0*
4	*49*	*21*	*18*	*1*	*1*
5	*56*	*27*	*23*	*1*	*2*
6	*46*	*25*	*0*	*3*	*4*
7	*59*	*18*	*16*	*3*	*0*
8	*44*	*14*	*24*	*5*	*5*
9	*51*	*23*	*19*	*0*	*0*
10	*63*	*24*	*15*	*8*	*3*
11	*56*	*25*	*13*	*7*	*1*
12	*44*	*35*	*13*	*10*	*5*
13	*59*	*29*	*14*	*10*	*4*
14	*51*	*27*	*10*	*8*	*11*
15	*40*	*32*	*9*	*7*	*10*
16	*57*	*30*	*0*	*6*	*11*
17	*42*	*24*	*6*	*7*	*8*
18	*54*	*26*	*5*	*9*	*10*
19	*43*	*14*	*4*	*9*	*0*
20	*51*	*23*	*18*	*7*	*5*
21	*46*	*26*	*17*	*9*	*6*
22	*55*	*31*	*13*	*13*	*5*
23	*47*	*16*	*13*	*16*	*8*
24	*33*	*29*	*14*	*0*	*6*
25	*36*	*15*	*11*	*0*	*7*
Mean	*47.8*	*23.3*	*12.6*	*5.68*	*4.28*

Dilution factors