Learn Chemistry

Pollutant Detection and Remediation

Student Guide

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National HE STEM Programme

RSC | Advancing the Chemical Sciences

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Introduction - About this learning resource

This case study focuses on the development of remediation strategies for a polluted water pond at a fish farm in the fictional county of Fercullen. The context is based on real media reports of the use of malachite green as a fungicide in aquaculture, which despite being illegal because of toxicity, is still used because of low cost and effectiveness. In this case study, a spillage of malachite green at a fish farm has created an environmental alert because it may result in subsequent pollution of neighbouring water bodies.

In this role, you will act as scientific consultants reporting to the Fercullen County Scientific Officer. Your brief is outlined in a letter from the council to Whitewater Environmental Services. You are required to validate a method for quantifying the amount of malachite green in a sample and develop methods for removal of malachite green from water in an environmentally sustainable manner. To do this, you need to devise and run several laboratory experiments to obtain results required to make a recommendation to the Council.

The experiments are informed by the Royal Society of Chemistry's *Sustainable Water* policy document. They include:

- Absorption spectroscopy to quantify the amount of malachite green present in the sample.
- Development and trialling of adsorption experiments for removal of malachite green from water.
- Development and trialling of photocatalytic degradation of malachite green.

Much of the work will involve sharing your data with others in your class, so a range of results can be efficiently obtained. Your work is logged in a laboratory notebook, and a report is compiled on an on-going basis on a wiki – an online document writing space. The final presentation will address the experiments you conducted and how they informed your recommendations made to the County Scientific Officer.

Assessment

The resource contains three main elements: planning laboratory experiments, conducting experiments and analysis and reporting of data obtained. Therefore, assessment focuses on the planning of the group project, most conveniently monitored using a wiki, your laboratory books on experiments conducted and the reporting, analysis and recommendations arising out of the data obtained. An overview of assessment components are provided in Table 1.

Table 1: Assessment components

Activity		% mark allocation (guideline)
Participation in laboratory and workshop sessions and contribution to group wiki	Individual	15
Laboratory notebook	Individual	25
Reflective piece	Individual	10
Final wiki report (Criteria - content, accuracy, structure, clarity, references to the literature)	Group	30
Presentation (assessment by tutor, feedback from tutor and peers, peer assessment is optional)	Group	20

Learning Outcomes

On completion of the resource you should be able to do the following within the context provided:

1. Use a provided literature source to write laboratory procedures to complete absorption spectroscopy, adsorption studies and photocatalytic degradation studies, including a list of materials and equipment required.
2. Prepare a short chemical risk assessment for the experimental work to be undertaken.
3. Plan time in the laboratory effectively in order to complete the work assigned.
4. Keep an accurate and current record of experimental details and data in a laboratory notebook.
5. Draw conclusions from experimental data so as to choose the next step in a research process.
6. Produce a professional report, including an executive summary and an assessment of the scope for each step to be improved, that is supported by the relevant experimental data and a laboratory notebook.
7. Prepare an oral presentation on the findings from the study to present to Fercullen Council.
8. Prepare a short individual reflective statement on the group process, transferable skills developed and the extent to which the stated learning outcomes were met.

Transferable Skills

This resource allows you to further develop the following transferable skills:

- Team work: you work in groups to complete the task assigned, use a wiki to facilitate collaboration and meet between sessions to review progress.
- Organisation and planning: you prepare procedures on a suitable scale and plan your time in the laboratory effectively.
- Communication skills: you present (oral presentation) and report (wiki and final report) on the scientific work performed in keeping with the context.
- Drawing conclusions and recommendations from data: you justify decisions, assumptions and conclusions made with reference to results from other group and supporting literature in order to produce a logical and clearly reasoned scientific report.
- Numeracy: analysis of data obtained from experimental results.
- Professional role and responsibilities: you adopt the role of a professional chemist and are required to make a recommendation based on professional opinion.
- Problem solving: you work in groups to address the brief presented in the context scenario.
- Information technology skills: you use a wiki to collaborate and develop your ability to use word-processing, spreadsheet, presentation, chemical drawing and library database software.
- Metacognition: you reflect on the process involved in working on the brief given, the extent to which the stated learning outcomes were met and to which your transferable skills were developed.

How is it delivered?

The activity is completed over several weeks and includes workshops, self-study group work and laboratory sessions. These aim to provide you with the necessary background information to the project and to develop suitable pollutant remediation strategies, assist you in the development of laboratory protocols, and to complete laboratory work to try out different remediation strategies. The sequence of completion of the activity is given in Table 2. As well as maintaining a laboratory notebook, your team will also be required to maintain a wiki – an online website which you update with information on your project and results as you obtain them. Some guidelines for keeping a wiki are given in the Appendix.

Table 2: Schedule of Workshops and Laboratory Classes

Session (3 hrs)	Activities	Learning Outcomes		
		Concepts	**Laboratory Skills**	**Transferable Skills**
1	Introduction and Project Planning	Water Pollution Beer-Lambert Law	N/A	Team work Organisation and planning Problem solving Use a literature source to write laboratory procedures Drawing conclusions and recommendations from data Numeracy Information technology skills
2	Laboratory 1: Beer Lambert Law	Beer-Lambert Law Quality Control Information	Prepare chemical risk assessment Plan laboratory time Solution preparation UV/visible spectroscopy	
3	Laboratory 2: Adsorption I	Surface adsorption Langmuir isotherms	Prepare chemical risk assessment Plan laboratory time Solution preparation UV/visible spectroscopy Adsorption studies	
4	Laboratory 3: Adsorption II			
5	Laboratory 4: Photocatalysis Planning	Advanced oxidation processes (photocatalysis) Kinetics	Prepare chemical risk assessment Solution preparation Reactor design Absorbance spectroscopy Centrifugation	
6	Laboratory 5: Photocatalysis			
7	Feedback Clinic	Produce a professional report	N/A	Team work Organisation and Planning Problem Solving Drawing conclusions and recommendations from data
8	Presentations	Produce a professional report Prepare an oral presentation Prepare a short individual reflective statement	N/A	Team work Communication skills Professional role and responsibilities Metacognition

Session 1: Introduction to Project and Planning First Laboratory Session

The purpose of this induction session is to:

1. Introduce you to the case study context and outline the schedule of work, the learning outcomes, and assessment components and criteria.
2. Provide information on the background to the experiments to the project and further reading required.
3. Provide information on the references to be consulted to plan the first stage of laboratory work.
4. Demonstrate how to use a sample wiki (adding and editing pages, uploading files and adding comments).

Group Work

Read the attached letter from *Fercullen District Council* which provides your brief for this project. Along with the members of your group, your aim to address the requests made in this letter. To do this, you should work in your assigned group to compile a list of actions, assigning responsibilities and due dates for group work. Arrange a time when the group will have short meeting to review progress before the next workshop. In each meeting, one member should act as chair (who will prepare a short agenda) and another as recorder (who will prepare a short summary of decisions made and progress reported the meeting and post it on the wiki). These positions rotate each week. Ensure to complete all the tasks listed in Table 3.

Table 3: Tasks each group should complete before Session 2

Task	**Individual/ Group**	**Activity**
Read the guidelines for "*How to use a Wiki*" in the Appendix and post a piece of information and a comment to the sample Wiki.	Individual	Log onto your wiki and post your name and contact details to the contact page of your group's wiki.
Read the guidelines for "*Preparing a Laboratory Procedure*" and "*Preparing Chemical Safety Data*" and "*Writing up your laboratory notebook*" in the Appendix 2, 3 & 4.	Individual	Contribute to the preparation of a laboratory procedure, below.
Prepare a laboratory procedure for session 2 Laboratory session, using the reading material below	Group	Meet as a group in advance of session2 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session2 until this procedure has been satisfactorily completed.

Reading and information to help you prepare for Session 2

Session 2 Laboratory involves (i) completing a Beer-Lambert plot for malachite green, (ii) finding the limit of detection of UV/visible absorption spectroscopy for malachite green, and (iii) completing quality control chart.

The following reading is recommended in preparing your protocol:

- A standard protocol for completing UV/visible spectroscopy experiments will be provided to you (e.g. *European Pharmacopoeia*) or use the 🕮*Briefing Document* on UV/visible spectroscopy, attached.
- Some aspects of quality control are presented in 🕮*Briefing Document*.

Fercullen District Council

Office of Environmental Control and Remediation

Foton House, County Offices, Fercullen.

To: Whitewater Environmental Services

Re: Analysis and remediation of polluted water at Fercullen Fish Farm

As you may have seen in local media reports, a recent accident at a local fish farm resulted in a spillage of a large quantity of malachite green into the main holding tank at the farm. Malachite green is not permitted for use in aquaculture and was being used illegally. As a result, the owner was reluctant to alert the authorities of the spillage, and did not do so until our monitoring stations detected some small amounts of the substance downstream in another licensed fishing area.

We wish to request your services in dealing with this problem. Having had a consultation with our Scientific Officer, we would like the following work to be carried out:

- Analysis of the concentration of malachite green.

- Determination of the effectiveness of removal of this pollution source from the spill site by developing and trialling protocols for remediation of water. Our Scientific Officer has determined two techniques from the Royal Society of Chemistry *Sustainable Water document* that may be suitable:
    - Adsorption onto low-cost adsorbents.
    - Metal oxide photocatalysis.

- Compile a report for our Scientific Officer recommending an appropriate strategy for dealing with this spillage in order to prevent the consequent pollution of nearby fishing areas. Justification of this recommendation is required, along with costing of the adsorbent. An interim report should be submitted to our Scientific Officer by an agreed date.

- Prepare an executive summary that can be used as a basis for a press-release for local media outlining the extent of the problem and how the spillage will be dealt with effectively.

- In order to fulfil subsequent Freedom of Information requests easily, all work completed for project, including data collected, analysis and conclusions drawn should be logged on a website – a wiki is most appropriate.

You will report directly to our Scientific Officer. The house guidelines for structuring a report for Fercullen District Council are given overleaf. We look forward to working with you in dealing with this issue in as rapid and effective a manner possible.

Yours sincerely,

Emer Power

E. Power

Fercullen District Council

Office of Environmental Control and Remediation

FDC

Foton House, County Offices, Fercullen.

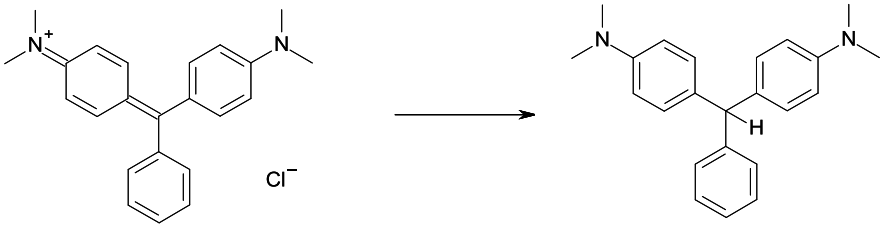
Guidelines for Structure of Scientific Reports for Fercullen District Council

Reports should be a maximum of 2,000 words (not including figures, tables etc.) and should contain the following elements:

1. Report title, date submitted and author name(s).
2. An executive summary (aimed at a non-technical audience, maximum 200 words)
3. The main body of the report to include:
    - Aims and objectives
    - Background information and related previous work
    - Experimental details
    - Results and discussion
    - Conclusion including recommendations
    - Glossary of definitions for all terminology used to ensure clarity.
4. References should be formatted according to the Royal Society of Chemistry Publishing author guidelines format. (See page eleven of the document at this link: http://www.rsc.org/images/Guidelines_tcm18-186308.pdf)

🕮Briefing Document: UV/Visible Spectroscopy

Malachite green is a triphenylmethane salt (Figure 1) which has as intense green colour. It had been a popular anti-fungal agent in fish farming, but after concerns about the toxicity of the material it was banned in many countries for this purpose. However, it is still used illegally because it is effective and cheap. Fish in water exposed to malachite green have been found to contain high amounts of leucomalachite, the reduced form of malachite green. The intense colour of malachite green is easily detected by UV-visible absorption spectroscopy.



Malachite green

Leuco malachite green

Figure 1: Malachite green and leucomalachite green

UV/VIS Spectroscopy is used to measure the **absorbance** of a solution. Absorbance (A) is defined as the logarithm of the ratio of the intensity of light (radiation) striking the sample (I_0) at any wavelength divided by the intensity of light transmitted through the sample. Assuming no other physico-chemical factors are involved (e.g. aggregation), the measured absorbance is proportional to the concentration of a substance in solution (C) for a given path-length (*l*). The constant of proportionality is known as the extinction coefficient (ε). This relationship is expressed in the Beer-Lambert Law:

$$A = \varepsilon.C.l$$

If concentration has units mol.dm^{-3} and the cell path-length is 1 cm, then the units of ε are dm^3 mol^{-1} cm^{-1}. In a typical experiment to analyse the Beer-Lambert law, a range of solution concentrations are prepared and the absorbance at the wavelength of maximum absorbance is measured (λ_{max}) for different concentrations, using solvent as a reference. A plot of the graph A against C will therefore produce a linear calibration curve, with slope ε. Because of the definition of A (ratio of incident light over ratio of transmitted light), absorbance values of less than 2 are considered suitable.

The following details are usually recorded for a UV/visible spectroscopy experiment. Use this information to help you plan the experiment you carry out.

- Identity of the substance (name, date of analysis, nature of substance (solid or liquid), structural formula
- Test conditions (spectrometer (name, type, operational parameters (e.g. slit width)), cell type (e.g. silica quartz, glass, PMMA), wavelength range (e.g. 350 – 700 nm), path length (e.g. 0.1 –10 cm), solvent (e.g. water, methanol, acetonitrile), concentration of test substance, test temperature (e.g. 20-25 ºC), pH environments used: neutral (pH = 7), acid (pH < 2) and alkaline (pH > 10)

Quality Control

You may wish to extend the determination of your extinction coefficient to placing it in the context of how it compares to other groups who have done the same determination. In this case, each group can complete a quality control chart by calculating the average and standard-deviation of the extinction coefficients.

A QC chart can be constructed by plotting the extinction coefficient each group obtains as shown in Figure 2. It is usual to add in lines to represent the average, warning (2σ) and signal (3σ) lines. The QC chart can then be used to test the accuracy of a subsequent extinction coefficient measurement, which should fall in between the average ± 2σ or average ± 2σ range.

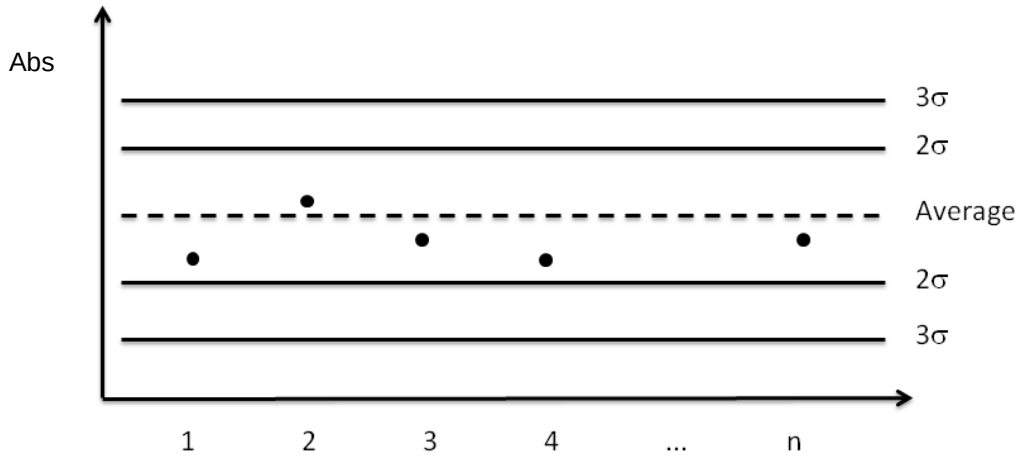


Figure 2: A sample quality-control chart showing average of data, 2σ, and 3σ lines

Limit of Detection and Limit of Quantitation

It is also possible to determine the limit of detection (LoD) – the lowest concentration that an analyte in a sample that can be detected (not quantified) – and the limit of quantitation (LoQ) – the lowest concentration that an analyte in a sample can be quantified. These are conveniently determined by successive dilutions until a signal to noise ratio of 10 is reached for LoQ and 3 is reached for LoD. These values will illustrate the suitability of UV/visible spectroscopy for analysing the presence of small amounts of malachite green in the sample.

The values obtained from the QC analysis should be included in the UV/visible results for the first laboratory session.

Session 2: The Beer-Lambert Law (Laboratory)

Aim of this laboratory session:

The primary goal of this session is for you to carry out the experimental procedure to produce a Beer-Lambert calibration chart for the quantification of malachite green.

You should write up your laboratory book as you go along according to the guidelines provided (see appendix).

At the end of this laboratory you should have the following information to log onto the wiki before Session 3:

- The experimental procedure for the Beer-Lambert Law, updated for any changes noted when carrying out the experiment.
- The absorbance-concentration results obtained (tabulated) and a Beer-Lambert Law plotted.
- The extinction coefficient for malachite green determined from your data.
- The limit of detection of malachite green using UV/visible spectroscopy.
- Exchange your extinction coefficient with the rest of the class, and use their information to build up a quality-control chart with the mean, warning (2σ), and control lines (3σ) included.

This information should be ready for checking and feedback by your laboratory tutor at an agreed date after the laboratory session. Ensure that you complete all the tasks listed in Table 4 before the next session.

Table 4: Tasks each group should complete before Session 3

Task	Individual/ Group	Activity
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.
Prepare a laboratory procedure for session 3 Laboratory session, using the reading material below	Group	Meet as a group in advance of session 3 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session 3 until this procedure has been satisfactorily completed.

Reading and information to help you prepare for Session 3

In order to help you prepare for session 3 laboratory session, some reading material is provided to you. Session 3 Laboratory session involves completing adsorption studies of malachite green on filter paper so as to help you develop a protocol for *Session 4: Adsorption Studies*.

The following reading is recommended in preparing your protocol:

- *A Simple Adsorption Experiment*, G. Guirado and J. A. Ayllón, *Journal of Chemical Education*, 2011, **88**, 624–628 (*see also supplementary information*)

In using this reference to plan your laboratory procedure, you will need to plan two experimental protocols in tandem:

1. The first protocol is that required to produce a Langmuir isotherm (and a Freundlich isotherm if desired). To do this, each group in the laboratory class should take 3 – 4 concentrations within the overall desired concentration range and pool the data, so that there are 20-30 concentrations represented in the final data set. The equilibrium concentrations can be determined after allowing one session of equilibration—these can be measured at the beginning of Session 4 Laboratory.
2. The second protocol aims to quantify the adsorption of the malachite green as a function of time. To do this, we wish to monitor the absorption of a solution containing a known amount of filter paper over the duration of the laboratory, and one session later. This is used to determine whether the equilibrium concentration (C_{eq}) used in the isotherm plots is valid.

Session 3: Adsorption Experiments I (Laboratory)

Aim of this laboratory session:

The primary goal of this session is for you to carry out the experimental procedure to quantify the adsorption of malachite green onto filter paper. We will use the skills developed in this session and apply them to other adsorbent materials in the next laboratory session.

You should write up your laboratory book as you go along according to the guidelines provided (see appendix).

At the end of this laboratory you should have the following information to log onto the wiki before Session 4:

- The experimental procedure for the adsorption experiments carried out, updated for any changes noted when carrying out the experiment.
- The absorbance-concentration results obtained for any solutions prepared.
- Other experimental data recorded (e.g. mass of filter paper used, temperature, *etc*).
- Absorbance data for kinetic experiment (to address protocol 2, above).

This information should be ready for checking and feedback by your laboratory tutor at an agreed date after the laboratory session. Ensure to complete all the tasks listed in *Table 5* before the next session.

Table 5: Tasks each group should complete before Session 4

Task	Individual/ Group	Activity
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.
Prepare a laboratory procedure for session 4 Laboratory session, using the reading material below. You will be assigned an adsorbent to use for analysis.	Group	Meet as a group in advance of session 4 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. This procedure will be very similar to the procedure developed for Session 3, except that a known mass of adsorbent used will replace the known mass of filter paper. You cannot start the laboratory in session 4 until this procedure has been satisfactorily completed.

Reading and information to help you prepare for Session 4

In order to help you prepare for session 4 laboratory session, some reading material is provided for you. Having tested the protocol for adsorption on filter paper, Session 4 laboratory involves completing adsorption studies of malachite green on another substance decided upon with your laboratory tutor in advance.

The following reading is recommended in preparing your protocol with reference to the material you will use:

- *Adsorption of methylene blue on low-cost adsorbents: A review*, M. Rafatullaha, O. Sulaimana, R. Hashima, A. Ahmadb, *Journal of Hazardous Materials*, 2010, **177,** 70–80.

Some common low-cost adsorbents include activated carbon, zeolites, clays, as well as by-products such as baker's yeast and grass waste. Full details are provided in the reference above.

Session 4: Adsorption Experiments II (Laboratory)

Aim of this laboratory session:

The primary goal of this session is for you to carry out the agreed experimental procedure to quantify the adsorption of malachite green onto a commercial adsorbent (your tutor will inform you in advance which adsorbent to use). You should again have two protocols to work from: one to quantify the adsorption of malachite green onto your adsorbent of choice using Langmuir isotherm (and Freundlich if desired) and one to quantify the kinetics of adsorption. As in session 3, you will need to determine the equilibrium concentrations of your solutions at the beginning of the following session's laboratory class.

You will also need to complete the measurements from the previous session's laboratory to quantify the equilibrium concentration of the solution in the filter paper experiment.

You should write up your laboratory book as you go along according to the guidelines provided.

At the end of this laboratory you should have the following information to log onto the wiki before Session 5:

- Your equilibrium concentration data from the previous session's experiment which is pooled with the class data and used to draw the isotherms.
- The experimental procedure for the adsorption experiments carried out, updated for any changes noted when carrying out the experiment.
- Other experimental data recorded (e.g. mass of adsorbent used, temperature, *etc*).
- Absorbance data for adsorption kinetics experiment.

This information should be ready for checking and feedback by your laboratory tutor at an agreed date after the laboratory session.

Ensure to complete all the tasks listed in Table 6 before the next session.

Table 6: Tasks each group should complete before Session 5

Task	Individual/ Group	Activity
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.
Prepare a laboratory procedure for session 5 laboratory session, using the reading material below. You will be assigned an adsorbent to use for analysis.	Group	Meet as a group in advance of session 5 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session 5 until this procedure has been satisfactorily completed.

Reading and information to help you prepare for Session 5 and Session 6

In order to help you prepare for session 5 laboratory, some reading material is provided to you. This laboratory session involves considering another technique for the degradation of malachite green: photocatalysis. In session 5 you will have the opportunity to develop your apparatus in the laboratory and perfect your technique. In Session 6, you can complete your photocatalysis experiments.

The following reading is recommended in preparing your protocol with reference to the material you will use:

- *Photodegradation of methylene blue: Using solar light and semiconductor (TiO_2),* R. F. P. Nogueira and W. F. Jardim, *Journal of Chemical Education*, 1993, **70 (10)**, p 861-862.
- *Photodegradation of malachite green under natural sunlight irradiation: Kinetic and toxicity of the transformation products*, L. A. Pérez-Estrada, A. Agüera, M. D. Hernando, S. Malato, A. R. Fernández-Alba, *Chemosphere*, 2008, **70(11)**, 2068-2075.

Session 5: Photocatalysis Experiments I (Laboratory)

Aim of this laboratory session:

The primary goal of this session is for you to develop an experimental procedure to allow you to study the photodegradation of malachite green in the presence of the photocatalyst, titanium dioxide. You will also need to complete the measurements from the previous session's laboratory to quantify the equilibrium concentration of the solution in the filter paper experiment.

You should write up your laboratory book as you go along according to the guidelines provided.

At the end of this laboratory you should have the following information to log onto the wiki before Session 6:

- The conditions optimised in developing the experimental protocol – e.g. amount of catalyst, light source, distance of sample from lamp, solution pH, bubbling of solution with air, *etc.*
- A detailed protocol for use in the following session's laboratory session.

This information should be ready for checking and feedback by your laboratory tutor at an agreed date after the laboratory session.

Ensure to complete all the tasks listed in Table 7 before the next session.

Table 7: Tasks each group should complete before Session 5

Task	Individual/ Group	Activity
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.
Prepare a laboratory procedure for session 6 laboratory session, based on experimental optimisation in Session 5.	Group	Meet as a group in advance of session 5 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session 5 until this procedure has been satisfactorily completed.

Reading and information to help you prepare for Session 6

Session 6 continues on from Session 5, but the following information may be useful in helping you analyse the data obtained from the experiment:

- The Use of Titanium Dioxide-Mediated Photocatalysis in the Treatment of Wastewater: An Undergraduate Laboratory Experiment, MK Seery, L Clarke, SC Pillai, Chem. Educator, 2006, 11, 1-3.

Session 6: Photocatalysis Experiments II (Laboratory)

Aim of this laboratory session:

The primary goal of this session is quantify the kinetics of photodegradation of malachite green in the presence of the photocatalyst, titanium dioxide.

You should write up your laboratory book as you go along according to the guidelines provided.

At the end of this laboratory you should have the following information to log onto the wiki before Session 7:

- Data from a time-dependent study of the photodegradation of malachite green using your chosen conditions.
- A kinetics plot that will allow you to determine a rate constant for degradation to allow for class comparison.
- Rate constants and conditions used to be shared with class so as to identify optimum conditions for degradation.

This information should be ready for checking and feedback by your laboratory tutor at an agreed date after the laboratory session.

Ensure to complete all the tasks listed in Table 8 before the next session.

Table 8: Tasks each group should complete before Session 7

Task	Individual/ Group	Activity
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.
Submit a draft report with a work in progress summary of which areas of the final report the group feel they have addressed and which ones they have yet to complete with details on who is responsible and due dates. Any clarifications required or queries should also be noted.	Group	Notify tutor when draft report is available for viewing.

Session 7: Feedback Clinic

Aim of this Session:

The purpose of this workshop session is to:

- Discuss your work to date with your tutor and obtain formative feedback (as an entire class and as an individual group) from your tutor on which areas of the report you need to work on and which ones have been addressed satisfactorily.
- Discuss any queries your group have on the assignment any problems that have been encountered.
- Identify the tasks remaining and plan when they will be completed.

In this workshop you will have the opportunity to receive formal feedback from your tutor who will highlight any areas that require work, any misunderstandings and identify the strengths of the work produced to date. It also gives you the opportunity to review your work as a group and to complete any tasks that you have not been able to do before this session while your tutor is speaking to other groups.

Your tutor will provide specific guidelines for the final presentation of your work that will take place in Session 8. You should have time to plan the work required to produce and give your presentation. General guidelines for preparing presentations are provided in the appendices. Remember to refer back to the original brief from Fercullen Council to ensure that your presentation is addressing each aspect.

At the end of this session you should have completed the following:

- Note and act on feedback provided from your tutor.
- Review your work as a group and identify tasks that need to be completed.
- Complete any outstanding work from previous workshops.
- Plan and begin preparations for your presentation.

Ensure to complete all the tasks listed in Table 9 before the next session.

Table 9: Tasks each group should complete before Session 8

Task	Individual/ Group	Activity
Meet as a group to finalise your presentation. Practise it several times as a “dry run” and ensure it meets the time requirement.	Group	Read oral presentation guidelines and ensure everybody in group is confident before presentation, and is making an equal contribution.
Continue to update and edit the wiki by uploading files and summaries, drafting sections of the proposal and responding to contributions from other group members. The structure, coherence and consistency of style and formatting of the final report are important considerations at this stage.	Individual	Complete tasks assigned during group meeting.
Post information on who attended meetings as well as the tasks completed at them on your wiki.	Group	Log notes from meeting and reporting required on wiki.

Session 8: Oral presentations

Aim / Goal of this Session:

The purpose of this workshop session is to:

1. Present your group's work to your peers and tutor summarising the work undertaken, your recommendations and answer any questions they may have.
2. Obtain oral feedback from your tutor (with optional written feedback on each presentation to each group from your tutor and peers).
3. Learn about alternative approaches to the project from the other presentations and provide a supportive audience with constructive feedback to your peers.

In this workshop your group will present your work and recommendations to Fercullen Council and you will listen to and assess the presentations of the other groups in your class. Your tutor may opt to invite some guest tutors who have a background in environmental chemistry to provide additional feedback.

You should be prepared to provide others with constructive feedback as well as receive constructive feedback from your peers and tutor. It is important that you realise you play an important role as an audience member for your peers. You should contribute to a supportive environment by listening attentively, making some eye contact with the presenter, asking any questions you have in a respectful and non-confrontational way and (if requested to) making some constructive comments on the peer feedback forms for the group assigned. Listening to the other group's presentations also provides a very useful opportunity to see how others approached the same project and to assess what you might incorporate from their methods in the future.

You will be reminded about the deadline for the submission of your final report (generated from your wiki). At this stage, your executive summary should be the main task remaining as it cannot be prepared until the main body of the proposal has been written. In addition, it is expected that you will incorporate any relevant feedback (oral or written) from your tutor into the report after your presentation. You should note down the oral feedback and ask for clarification from your tutor at the end of the session if needed.

Your final task is the production of a reflective piece and this should be done once all other tasks are complete. The deadline for submission of your reflective piece will usually be several days after that for the group report to give you some time to complete it. Along with any notes you made during the process, you should also find that reviewing some of the group wiki will be helpful. Guidelines are given in the appendices.

Tasks to complete by the end of the module:

- Incorporation of feedback from the presentation into the group report.
- Final editing and completion of group's wiki report.
- Printing out and submitting the final report (most wikis allow pages to be saved as pdfs). You may also be required to submit your report for checking by plagiarism detection software.
- Laboratory book to be submitted by the deadline provided.
- Preparing and submitting your individual reflective piece.
- Peer assessment of the other students in your group based on frequency and quality of contributions to the group (optional).

Appendices: Student guidelines

The following guidelines are given to help you in preparing your laboratory work and reporting requirements:

1. Using a wiki.
2. Preparing laboratory procedures.
3. Preparing chemical safety data.
4. Keeping a laboratory notebook.
5. Oral presentation guidelines.
6. Plagiarism.
7. Guidelines for an executive summary.
8. Guidelines for your reflective piece.
9. Weekly task checklist.

Appendix 1: Using a wiki

"Wiki: A collaborative website consisting of one or more pages that allow authorized users to contribute to or edit page content." (Source: http://usermanual.pbworks.com/Glossary)

Why use a wiki?

Wiki software is very easy to use and allows people to work and to write collaboratively to produce a report / presentation / webpage. The wiki is a means of generating a very useful archive of all of the information that is relevant to a project as it proceeds. It provides the added flexibility of being able to work anywhere where a PC or laptop and internet connection are available at any time. Wikis are regularly used in organisations to allow groups to collaborate on projects and documents and to share knowledge and the ability to use one is a valuable transferable skill (see the references at end of this section).

All previous versions of each page can be accessed using the Page History function which means that no work can be permanently overwritten or deleted. Contributions made by each member can be easily tracked to assess their quality, quantity and whether they were made across the entire timeframe of the assignment. Peer feedback and review is facilitated by the comments and page editing option. The assignments and the feedback provided can be accessed easily and stored indefinitely for future reference and are available in a flexible format (pages can usually be saved as pdfs).

An existing wiki on environmental chemistry is available here:
https://sites.google.com/site/environmentalchemistryoptione/home

What do you need to be able to do?

Instructions on the technical details of using the selected wiki are given on its website, but it is important to remember basic etiquette when preparing and updating your wiki.

The common tasks you will perform using the wiki are:

- adding and editing wiki pages,
- adding comments and links to pages, and
- inserting tables and chemical schemes / structures.

Most chemical drawing software allows for structures to be saved as images (required format is usually specified in the help menu).

If you have a specific technical problem, it is recommended that you check any guidelines that have been provided to you by your tutor and also ask the other members of your group for help. If you are still having a problem, you should then contact your tutor.

Always remember:

- Use folders, link related pages and name files and pages in a logical and structured way so that you can find information on the wiki easily. To help with this, your group are provided with names that should be used for the pages that will make up the main body of your report / presentation (see end of this section).
- References should be cited when necessary and all information should be put into your own words
- This information is intended for publication online so **ensure that the information is accurate, will not offend anyone and is not plagiarised.**
- The page should be informative and engaging and make a visual impact.
- Try to keep the page to a reasonable length. Long pages can cause the reader to lose interest. Try to arrange data in sensible subcategories with pages for each to make it more engaging for the reader. If your page is quite long, you may reach a stage where you can't save any additional information. If this happens, you can return to the previous version of that page in page history to retrieve it and you should begin a new second page to continue.
- Note that there is a space limit on each wiki page. If you find that a page is no longer accepting edits, you have probably reached the limit. You will need to add a new page, and link to this page from the end of the existing one to continue that section.

Netiquette and online communication

The concept of "netiquette" is very important because when you are communicating online, there are no visual cues (you can't see the face of the person or people you are in contact with). This means that it is more difficult to communicate clearly and it is more likely that a comment may be misunderstood or misinterpreted. Also, you should remember that all comments made on a wiki remain in the page history even after they are deleted.

It is recommended that you read over a comment carefully before you add it to the wiki to make sure that it is clear and there aren't any spelling mistakes that will make it confusing. You should be respectful and polite to each other, and be conscious of not offending or insulting anyone. Use of capital letters only is the online equivalent of shouting at someone and should be avoided. The same approach applies in any professional environment.

Ground rules for your group

You may want to consider establishing some ground rules about working in your groups such as remaining respectful towards a group member who you feel is not contributing, providing constructive feedback to peers (e.g. posting a comment first before making changes to someone else's work), responding to a query or message within a reasonable timeframe, communicating with the group to let them know if you will be late or absent and consulting with the group in relation to important decisions.

Remember that working in a group can be very productive, but it requires communication, planning and compromise.

Peer feedback and review

In the initial weeks, your group could consider waiting until a group member asks for feedback or editing of their contribution before making changes to their work. It is helpful if contributors are specific about feedback required (e.g. proof-reading for grammar, spelling and formatting or aspects such as relevance, structure, clarity and validity of the conclusions drawn). It is recommended that feedback and changes are constructive. A comment should address what was done well, and also the areas where it was felt changes were required and why.

Structure of your wiki report

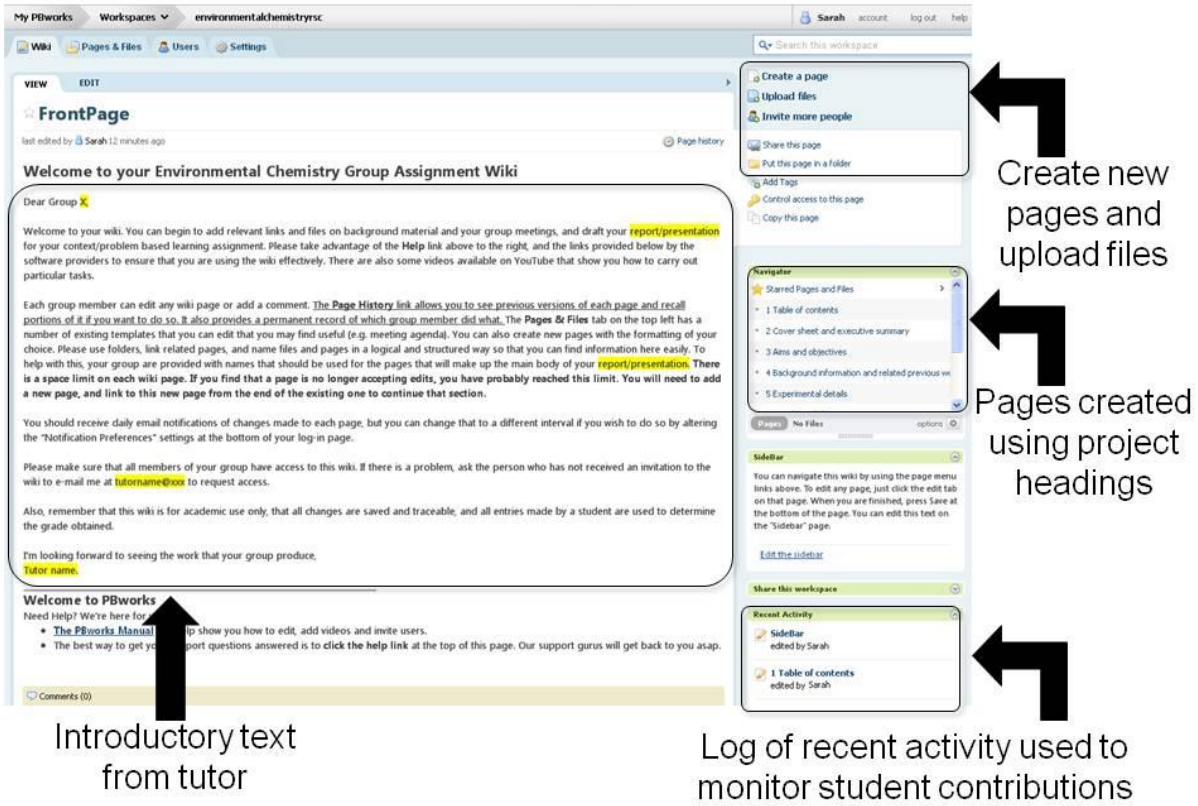
The following are the names of the pages that should be used to make up the main body of your report / presentation:

- Table of contents (with links to the other report pages)
- Cover sheet and executive summary
- Aims and objectives
- Background information and related previous work
- Experimental details
- Results and discussion (this can be subdivided into separate results and discussion pages)
- Conclusion and recommendations for future work
- Appendices (if relevant files have a lot of content, they can be uploaded to the wiki and linked to the Appendix page)

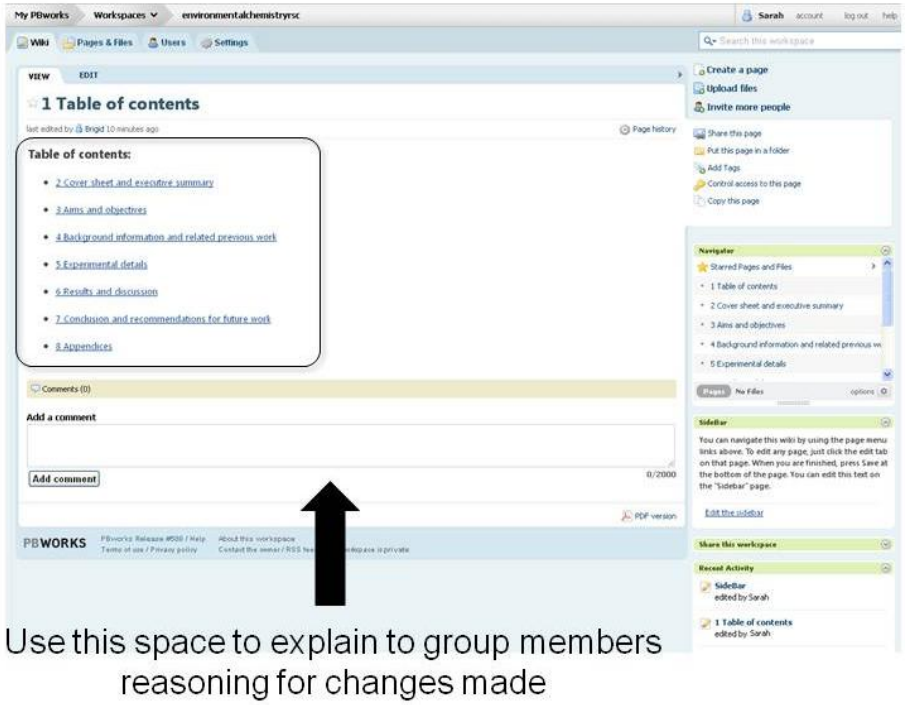
The following page shows screenshots of the PBworks wiki, with a suggested layout. There are also a number of pages that your group should consider adding to the wiki that will help with planning and communication. These are:

- Weekly work assigned - Use this page to submit any assignments you are asked to submit via the wiki.
- Project planning and meetings - Use this page for summaries of your group's weekly meetings and any other project planning. Some wikis include templates for reporting on meetings that could be incorporated here.
- Ideas and suggestions - Use this page as a sounding board and suggestion box for general issues.

- Annotated bibliography - Use this page to post links or citations to useful websites, videos, articles or textbooks. Each one must include a short summary of why this information source is useful and refer to a specific page/section in it if necessary.



Pages can be edited and linked to other pages throughout the wiki.



References on the use of wikis in organisations:

- "Corporate Wiki Users: Results of a Survey", A. Majchrzak, C. Wagner & D. Yates, *WikiSym'06, Proceedings of the 2006 international symposium on Wikis*, D. Riehle, J. Noble, Eds. (ACM Press, 2006), vol. Odense, De, pp. 99-104, accessed 18 October 2011 at https://blog.itu.dk/MVOL-F2010/files/2010/02/corporate-wiki-users-results-of-a-survey.pdf
- A Drug Discovery Today article from 2011 on an in-house wiki used by Hoffman La Roche to share medicinal chemistry knowledge; Mayweg, A.; Hofer, U.; Schnider, P.; Agnetti, F.; Galley, G.; Mattei, P.; Lucas, M.; Boehm, H. J., ROCK: the Roche medicinal chemistry knowledge application - design, use and impact. *Drug Discovery Today* **2011,** *16* (15-16), 691-696.

Appendix 2: Preparing laboratory procedures

The following format is suggested:

- Give the title of the experimental procedure, with the author names and the date.
- Include information on the reagents to be used (amount in g or mL, concentration in moles or mmoles, equivalents, density (if required) in g cm^{-3} and quality or purity).

Suggested layout for information on reagents used

Chemical	Molar mass (g/mol)	Solution concentration (M)	No. of moles	Quantity (mass or volume)	Density (g/cm^3)
Malachite green	364.91	1×10^{-3}	N/A	0.365 g/L	N/A

- List the apparatus needed (remember to specify the size and quantity) and any instruments to be used (including experimental parameters).
- You should write the procedure to be followed in the present tense in the same way that those in your laboratory manuals are presented e.g. "Add the malachite green solution (5×10^{-4} M) to the plastic cuvette…, "Obtain an absorption spectrum in the region 350 – 800 nm", etc.
- Structure the procedure so that it is clear and easy to follow.
- Include details of any analysis to be performed at the end of the procedure.
- You must also consider the equipment and glassware available in your laboratory so that the procedure can be completed.

Appendix 3: Preparing chemical safety data

A table should be prepared for each experiment of all chemical substances to be used. Table 10 shows the format and headings which should be used. Any significant hazard and handling issues identified should be discussed with your tutor in advance of the laboratory session, and the measures to deal with it should be included in your procedure and laboratory report.

Material safety data sheets (MSDS) can be obtained from the chemical vendor's website (for example Sigma Aldrich). These will provide the GHS hazard pictogram, CAS number, hazard classification and hazard statements and risk phrases. Occupational Exposure Limit values (OELs) are set by national

authorities as limits for concentrations of hazardous compounds in workplace air. These values are an important tool for risk assessment and management. Sources of this information for specific countries are listed on: http://osha.europa.eu/en/topics/ds/oel/index.stm (last assessed 11.01.12).

Table 10: Example Safety Data Sheet

Substance name	CAS no	Hazard Classification	Hazard statement/Risk phrase	Route of exposure	OELV
Malachite green oxalate salt 	2437-29-8	Possible risk of harm to the unborn child. Harmful if swallowed. Risk of serious damage to eyes. Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. **DANGER**	H302 Harmful if swallowed. H318 Causes serious eye damage. H361d Suspected of damaging the unborn child. H410 Very toxic to aquatic life with long lasting effects.	Skin Contact, Inhalation	

Further Information:

- Sigma Aldrich website (free to use): http://www.sigmaaldrich.com/
- Chemspider database (free to use): http://www.chemspider.com/

Appendix 4: Writing up your laboratory notebook

Why Keep a Laboratory Notebook?

A laboratory notebook is your record of the work you completed in the laboratory. You are required to keep a laboratory notebook for the duration of the work, and submit this at the end. In industry and in research laboratories, the notebook is the property of the company or supervisor. They are extremely important legal documents that must be able to withstand the scrutiny of a court if required. Without a notebook, patents could not be filed, and academics would not be able to publish papers. Most importantly, the notebook should be a "live" document, written as you work.

Tips on how to keep a notebook and what should be included:

- The notebook should have an overall organised structure that can be clearly followed.
- Use the laboratory notebook to reflect on your work periodically, question your approach, write in comments about what you are thinking, different approaches you might take, and how subsequent results might be interpreted.
- A laboratory notebook is also important to provide information to somebody who may want to repeat your work. As such, it should be clear and legible.
- **The notebook should be hardback A4, with lines on the front and back pages.** Ideally the pages should be pre-numbered, and if they are not, number the pages in the top right hand corner. You should write in permanent ink (never pencil), and date each page.

- On the cover, write your name, laboratory and module name. Leave the first few pages blank, so that you can add a Table of Contents as you progress through the book, which will list the experiments (both successful and unsuccessful) you completed.
- Write on both left and right pages, with a clear consistent formatting throughout the book. It may be useful to use the right hand page for your 'neat' record and the left hand page for 'rough' notes. (**Note that even rough notes should be clear and labelled with appropriate units if required**).
- Do not remove pages from the notebook and do not use correcting fluid. If you make a mistake, draw a thin line through the work.
- Do not use the notebook for indecipherable notes to yourself– everything should be clear for somebody else to follow, including rough calculations and ideas.
- You should take your laboratory book with you as you go around the laboratory. It should be next to you at the balance so that you can enter your measurements directly as you go along. It should be next to you as you set up a reaction so that you can record any observations directly into it.

What to put in the notebook

Your notebook should include (but is not limited to) the following:

- Start a new double page for each experiment; the top of the page should be dated, labelled with an experiment code (usually your initials followed by a number, *e.g.* JJ1) and a title.
- The aim of the experiment should then be stated. If the work is based on information from a journal article, this source should be referenced under the scheme.
- The information outlined in Appendix 2 (*Planning Laboratory Procedures*)
- You should write the method used in the **passive voice** and in the past tense (e.g. The malachite green solution (5×10^{-4} M) was added to the plastic cuvette…., "An absorption spectrum was recorded in the region 350 – 800 nm", etc.
- Include reaction times, colours and appearance of reagents, water type used (deionised, distilled, tap…), solution strength, experimental observations (e.g. striking colour change), instrument details, and anything else *you* would like to know if you were repeating this work.
- Include the outcome of the experiment in a short conclusion, even if it is negative.
- If repeating an experiment, make sure to note any deviations from the previous procedure – at least one full procedure should be provided however.
- For spectroscopic studies, include concentrations of analyte, solvent used for analysis, visualisation methods (e.g. UV). Include instrument make and model information, and any operating parameters (wavelength range, etc).
- If an experimental set-up is unusual or new to you, a sketch of the apparatus is useful.
- Any calculations or numbers used in calculations should be annotated correctly so that it is clear where the numbers you are using come from. Remember to check the number of significant figures you should have in your final answer. It is sufficient to show a detailed calculation for one set of data and then summarise the calculation and refer to where it has been provided in detail if it is repeated for similar sets of data.

Chemical safety information

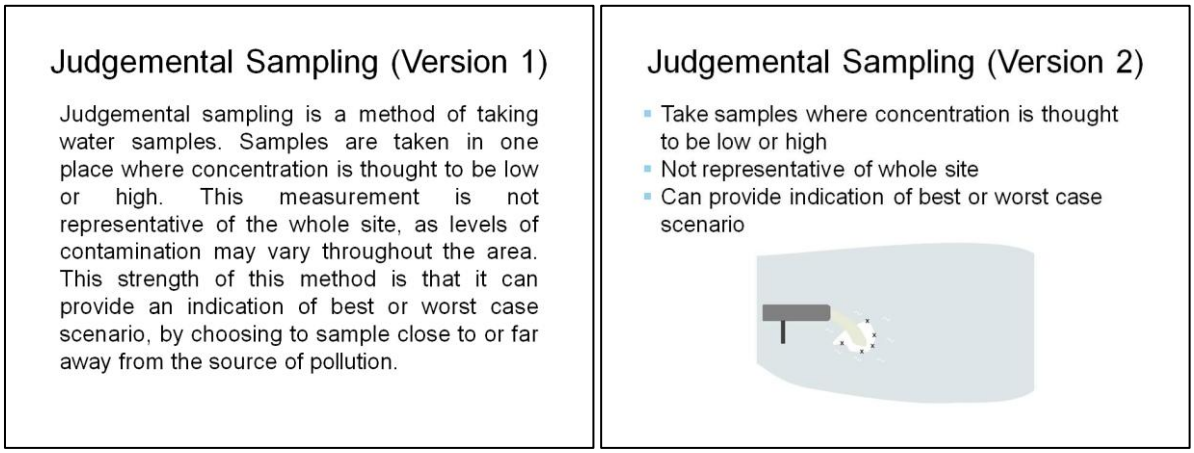
Ensure that you include a table of the chemical safety information already compiled for the experiment in your laboratory notebook. If it was typed, it can be pasted into the laboratory notebook.

Appendix 5: Oral Presentation Guidelines

When preparing a presentation, take care to:

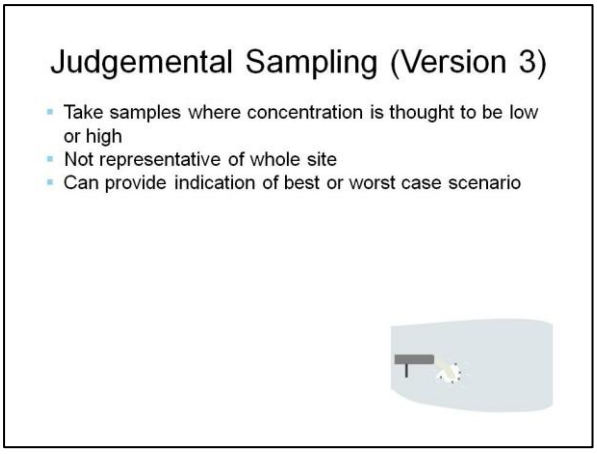
- Tailor the tone and content to the audience.
- Be informative and interesting.
- Keep to appropriate timing.
- Make slides simple and visually engaging.

Slides 1 to 3 show sample presentation slides. Slide 1 shows the common mistake of overloading slides with information. Remember you will be talking about the slides when they are shown so can provide the additional detail then. Slide 2 expresses the same information, but the use of pictures and bullets makes it easier for the audience to take the information on board.



Dos and don’ts in slide preparation

Slide 3 shows that when you have chosen the best content for the slide, it is important to present it well. Ensure pictures are big enough and clear so that the audience can read the detail. Make use of the space available to you, and use a reasonable font size (preferably minimum size 20 in Arial).



Poor use of slide space.

If presenting directly from your wiki, it may be useful to lay your pages out with subheadings in larger font than the general text. In this way, you can use the subheadings as your bullet points in the presentation and briefly discuss the paragraph content without reading it directly.

Remember:

- Keep slides simple – large font, simple colours
- Bulletise text - aim for maximum 6 bullet points containing 6 words
- Pictures speak a thousand words, but make sure they are clear and big enough
- Don't over use animations
- Credit sources and provide references

It is important to carefully structure your presentation to ensure it flows well. Content can be split into three categories:

- Beginning - introduce topic on level suitable to audience
- Core - longest section covering key messages
- End - summarise results and emphasise main point

Plan your content carefully. It may not be necessary or possible to include all of the data you collected so be critical when choosing what to include. Too much information may cause you to overrun the time slot, and result in loss of marks or having to stop before you reach the final slide.

When delivering the presentation be sure to:

- Practice several times, preferably with an audience
- Check you can use the technology
- Be confident – make eye contact and try to smile
- Speak slowly and clearly
- Face your audience when you speak
- Avoid blocking the screen
- Stay calm - if you make a mistake or something goes wrong you may be the only one who notices, so take your time, correct the mistake, and move on.
- Take your time answering questions, and if you don't know an answer, just say so.

Useful resources:

- Key Skills for Scientists – Getting the Message Across, ed. Natalie Mansfield, Royal Society of Chemistry, 2007
- Effective Communication for Science and Technology, Joan van Emden, 2001, Palgrave, Hampshire (Chapters 6 & 7)

Appendix 6: Plagiarism

Plagiarism is not acknowledging the work of others. Therefore, all work which is not of your own creation must be accompanied by a reference which gives a detailed description of the item from which you have obtained information (e.g. article, website, book).

Important things to remember:

- Make sure that you acknowledge any information that you obtain from a particular source by including a reference.
- You should not reproduce information word for word from a reference even when you have acknowledged the source. The only exception is for a quotation, however direct quotations should be used sparingly. You are expected to communicate the information in your own words.
- Failure to meet these requirements means you have plagiarised work. This is the same as stealing someone else's work.
- If you are found to have plagiarised material, marks will be deducted.
- References should be formatted according to the Royal Society of Chemistry Publishing author guidelines format. (See page eleven of the document at this link: http://www.rsc.org/images/Guidelines_tcm18-186308.pdf)

Appendix 7: Guidelines for an executive summary

An executive summary provides an overview in non-specialist language to an executive/management audience. It is generally about one tenth the length of the whole report, and is directed at managerial readers who may not read the whole report, and who may not have the relevant technical knowledge.

The purpose of an executive summary is:

- To provide the reader with a shortened version of a report to allow them to identify the key information quickly.
- To act as a navigational tool for the report. An overview should help the reader to understand and assess the more detailed information in the main body of the report.
- To help the reader to decide whether they need to read the whole report.

Common difficulties when preparing an executive summary are:

- Deciding on core information.
- Linking the information into a coherent piece of writing that stands alone and is clearly written and structured.

The summary should be organised under descriptive headings highlighted in bold. It should be formatted with consideration for fast accessibility of information and the convenience of the reader. The structure should follow that of the body of the report and non-technical terms should be used as far as possible. No tables or figures should be used.

Use the brief provided from the council asking you to carry out this work to help you to decide on the important information to be included.

Do not forget to mention whether any further/recommended work is required.

You should make sure that you have included:

- A statement that places the work in context
- The method used (summary of synthetic steps in 1-2 sentences)
- The main results
- The main conclusions
- Your main recommendations

The information above on writing executive summaries has been sourced from;

Chapter 3 of *Writing For Science and Engineering* by Heather Silyn-Roberts, Butterworth-Heinmann, Oxford, 2000.

Appendix 8: Guidelines for your reflective piece

In this short report (500 to 800 words approx), you should:

1. Briefly derecorder your role in the project and the contribution you made.
2. Discuss how you experienced working in a team (consider both the positive and negative aspects).
3. Discuss any changes that you would make to how you and your group went about the project if you were repeating it.
4. Summarise what you found to be most the interesting aspect of the project as well as the most challenging aspect.
5. Consider whether you think the project was useful to your learning and whether all of the learning outcomes (see page 5) were met.
6. Assess whether you have further developed the transferable skills listed at the beginning of this guide as a result of this project. Highlight any that you think are particularly important or that you have now gained confidence in.
7. Consider whether you have found that writing a reflective piece like this helps you to review what you learned over the course of the project.

This reflective piece is assessed based on:

- **content** (60% - there are no right or wrong opinions but you must make sure that you discuss **all** of the topics listed above)
- **presentation** (10%) and
- **coherence, accuracy and structure** (30%).

Appendix 9: Weekly Task Checklist

Task	Individual / Group	Activity	✓
Before Session 2			
Read the guidelines for "*How to use a Wiki*" in the Appendix and post a piece of information and a comment to the sample Wiki.	Individual	Log onto your wiki and post your name and contact details to the contact page of your group's wiki.	
Read the guidelines for "*Preparing a Laboratory Procedure*" and "*Preparing Chemical Safety Data*" and "*Writing up your laboratory notebook*" in the Appendix 2, 3 & 4.	Individual	Contribute to the preparation of a laboratory procedure, below.	
Prepare a laboratory procedure for session 2 Laboratory session, using the reading material below	Group	Meet as a group in advance of session2 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session2 until this procedure has been satisfactorily completed.	
Before Session 3			
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.	
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.	
Prepare a laboratory procedure for session 3 Laboratory session, using the reading material below	Group	Meet as a group in advance of session 3 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session 3 until this procedure has been satisfactorily completed.	
Before Session 4			
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.	
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.	
Prepare a laboratory procedure for session 4 Laboratory session, using the reading material below. You will be assigned an adsorbent to use for	Group	Meet as a group in advance of session 4 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in	

analysis.		advance of the laboratory. This procedure will be very similar to the procedure developed for Session 3, except that a known mass of adsorbent used will replace the known mass of filter paper. You cannot start the laboratory in session 4 until this procedure has been satisfactorily completed.	
Before Session 5			
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.	
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.	
Prepare a laboratory procedure for session 5 laboratory session, using the reading material below. You will be assigned an adsorbent to use for analysis.	Group	Meet as a group in advance of session 5 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session 5 until this procedure has been satisfactorily completed.	
Before Session 6			
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.	
Meet as a group to review progress on the list of actions for the group. Again, the chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.	Group	Log notes from meeting and reporting required on wiki.	
Prepare a laboratory procedure for session 6 laboratory session, based on experimental optimisation in Session 5.	Group	Meet as a group in advance of session 5 laboratory and prepare your procedure with associated chemical safety guidelines. This should be logged onto your wiki in advance of the laboratory. You cannot start the laboratory in session 5 until this procedure has been satisfactorily completed.	
Before Session 7			
Add the experimental details and results obtained to your laboratory notebook, along with information on the experiment available in advance (materials, equipment, literature reference etc.).	Individual	Complete some notes on the background to the project to bring to the group meeting. The final presentation will need a summary of the relevant information to the project.	
Meet as a group to review progress on the list of actions for the group. Again, the	Group	Log notes from meeting and reporting required on wiki.	

chair should have prepared a short agenda and the recorder will post a short summary of decisions made and report progress on the wiki.			
Submit a draft report with a work in progress summary of which areas of the final report the group feel they have addressed and which ones they have yet to complete with details on who is responsible and due dates. Any clarifications required or queries should also be noted.	Group	Notify tutor when draft report is available for viewing.	
Before Session 8			
Meet as a group to finalise your presentation. Practise it several times as a “dry run” and ensure it meets the time requirement.	Group	Read oral presentation guidelines and ensure everybody in group is confident before presentation, and is making an equal contribution.	
Continue to update and edit the wiki by uploading files and summaries, drafting sections of the proposal and responding to contributions from other group members. The structure, coherence and consistency of style and formatting of the final report are important considerations at this stage.	Individual	Complete tasks assigned during group meeting.	
Post information on who attended meetings as well as the tasks completed at them on your wiki.	Group	Log notes from meeting and reporting required on wiki.	