Learn Chemistry

Pollutant Detection and Remediation

Resource Overview

Developed by Dr. Michael Seery, Dublin Institute of Technology

This resource was produced as part of the National HE STEM Programme

National HE STEM Programme

RSC | Advancing the Chemical Sciences

www.rsc.org/learn-chemistry

Registered Charity Number 207890

Acknowledgements
The author would like to thank the following people who contributed to this work: Mr Damien Coman for carrying out experimental work, Dr Brigid Lanigan, Dr Claire Mc Donnell, Dr Christine O'Connor and Dr Sarah Rawe of the DIT Chemistry Education Research Team for their input and for many useful discussions, and the reviewer and trial teams who provided useful feedback for the development of the final resource.

Introduction to Context and Problem Based Learning

The resource differs from a traditional laboratory course in several ways. Firstly, it is a **context-based case study**, so that students can relate the experiments being conducted to a real-world application. The context is the development of remediation strategies for a polluted water pond at a fish farm in the fictional county of Fercullen. It 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. Students act as scientific consultants working for Whitewater Environmental Services, who are requested to validate a method for quantifying the amount of malachite green in a sample, develop methods for removal of malachite green from water in an environmentally sustainable manner, and use their experimental evidence to recommend a remediation strategy to the Council.

The second difference between this resource and a traditional laboratory approach is the use of a **problem-based approach**. This means that the laboratory sessions do not provide students with direct instructions requiring them to develop their own experimental protocols. Guidance on how to do this is provided and the sessions are arranged so that the experimental protocols become progressively more complex, allowing students to develop this skill over the course of completing the resource. Literature references (compiled list in Appendix) are provided to help students source relevant information to develop experimental protocols and outline protocols are provided in this guide. Requiring students to develop protocols means that more laboratory time is needed to allow students to pilot experimental techniques. This is built into the schedule of implementation. While this approach takes more time to complete than traditional laboratory activities, the intention is that as well as becoming proficient in the relevant laboratory techniques, students gain more experience in information retrieval and application, laboratory planning, and trouble-shooting than they might with a traditional laboratory teaching method.

Thirdly, the resource exposes the student to meaningful **group work**, both within their assigned group and as a class. Students work in small teams with guidance provided on how to complete each session's activities, before, during, and after the weekly contact session. In addition, several of the laboratory sessions offer the opportunity to share results across the class, so that students can formally compare and contrast their experimental data to others and draw conclusions from this. This approach aims to provide a greater sense of motivation in that the students are completing activities to contribute to the greater body of knowledge required to complete the project, rather than just "get the right answer", which is a common student conception of traditional laboratory classes.

Finally, the resource uses an online document building environment called a **wiki** to collaboratively build a report over the course of the case study. This allows all students to contribute to the final report, and allows the tutor monitor progress and contributions of both groups and individuals as the resource is being developed. Extensive guidelines for wikis are provided in the Appendix to this *Tutor Guide*. A brief synopsis follows.

A word about wikis

There are many advantages to using a wiki when collaboration on a group project is required and these are dealt with in more detail in the Appendix. To summarise, it provides an effective and flexible means for learners to work as a team on a report or presentation while generating an archive of all information used and of all previous versions of the final pages. The main benefit to a tutor is that the quality and quantity of contributions made by each student can be tracked relatively easily and that the process as well as the product can be assessed.

Although it is recommended that a wiki be used as a component of this C/PBL activity, an alternative can be adopted if preferred. Some type of online interaction among a group such as a discussion board or online group is very useful and, if this has been set up by the tutor, there is the advantage that they will be able to monitor progress being made. If this option is not used, the weekly group meeting summaries that are required from each group can be used to monitor progress and to check that all members are making a contribution. To provide a facility similar to the wiki for organisation of the work being undertaken, it would be useful for groups to use a Lever Arch file with sections that correspond to the main parts of the report to which useful documents and draft work can be added. Under these circumstances, it is recommended that this draft work and supporting information is submitted as an appendix to the final report.

Resource at a Glance

The resource is a laboratory-based case study involving five core laboratory sessions, and ancillary preparatory and feedback sessions. Opportunities to extend the resource if more time is available or to curtail it to a smaller number of sessions are highlighted in the *Navigating the Case study* section below. In completing the resource, students will:

- Use UV/visible spectroscopy to quantify the amount of malachite green present.
- Study the effect of physical adsorption as a remediation strategy.
- Study the effect of photocatalysis as a remediation strategy.

Navigating the Resource

This case study resource consists of 8 three hour sessions designed to fit into a laboratory schedule at an intermediate level chemistry degree. As such it represents approximately 2.5 European Credit Transfer System (ECTS) or 5 UK credits of work or 1.5 US credits (based on 24 contact hours, 26 self study). The resource includes an induction session, five laboratory sessions, a feedback session and a presentation session. Information on planning and running each of these sessions is provided in this *Tutor Guide*, with parallel information for students provided in the *Student Guide*. Each session outlines what to do before, during and, for the student, after each session. For the tutor, a schedule of what feedback/prompts/actions may be required is shown in Table 2, aligned with the requirements of the students.

While the resource has been designed as an entire unit, it may be desirable to just use one or a few components, or to extend the implementation of the resource beyond the scope described here. Some brief comments on each session follow so that tutors may decide whether there is scope to limit/extend the resource to suit academic requirements. Of course in limiting the implementation, some of the learning outcomes may not be achieved.

Session 1: This is an induction session in a classroom setting. The purpose of the session is to introduce students to the resource and begin the experimental planning with the support of the tutor (in future sessions this planning will be done in the students' own time).

Session 2: This session is a laboratory session where the students have to implement their first experimental protocol. The subject of the laboratory work (Beer-Lambert Law) is purposefully easy, as feedback has demonstrated that there is an initial steep learning curve for students given freedom to implement their own laboratory procedures (i.e. without a 'recipe' provided). Tutors whose students are at a more advance stage or with experience in less expository-based practical classes may wish to incorporate some information here on water sampling to link in with the context, or provide students with an unknown sample to test the calibration data.

Sessions 3 and 4: These sessions, both laboratory sessions, are about designing and implementing an adsorption study for the model pollutant onto surfaces. In the first session, students become familiar with the Langmuir analysis through a laboratory using filter paper. Guidance notes from the literature are provided. This is followed in the second session with a similar protocol for another adsorbent – titanium dioxide is the example illustrated here. It may be that students already have experience in a surface-chemistry laboratory of this nature, and may not need two sessions. Those wishing to extend the resource are pointed to a review of low-cost adsorbents for the purpose described in this case study, which would allow for substantial data gathering to be implemented by several students. These sessions are the most challenging in terms of data analysis.

Sessions 5 and 6: These sessions, both laboratory sessions, are about designing and implementing a photocatalysis study for the degradation of the model pollutant. Photocatalysis is not a common laboratory in physical chemistry curricula, but is one of a growing number of advanced oxidation processes (AOPs) being considered for environmental remediation. Again, those wishing to limit the number of sessions could provide more guidance or limit the number of parameters to be investigated, so as to reduce it to one session. Those looking to extend it are provided with several parameters for investigation. Advance planning is required here in terms of sourcing suitable photocatalytic materials.

Session 7: This is a feedback clinic, which aims to give the students some interim feedback on their final report. If time is limited, this could be completed electronically via the virtual learning environment.

Session 8: This is a presentation session where students present their work. Again, if time is limited, the assessment could be modified and the presentation omitted.

Assessment

The resource contains three main elements: planning laboratory experiments, conducting experiments and analysis and reporting of data obtained. Therefore, assessment focuses on:

1. The planning of the group project: most conveniently monitored using a wiki.
2. The conducting of experiments: Student laboratory books that should record experiments conducted.
3. The reporting: analysis and recommendations arising from the data obtained.

More details on assessment are provided at appropriate points in this guide and the assessment components and a guideline weighting are provided in Table 1 (also used in the Student Guide (Table 1) and introductory presentation).

Table 1: Assessment components

Activity		% mark allocation (guideline)
Participation in laboratory and workshop sessions and contribution to group wiki *You may choose a component of this mark (e.g 5%) to be peer assessment by other group members (frequency and quality of contributions, both online and face-to-face)*	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

Implementation: Class organisation

The resource is designed so that students work in small groups (typically three students) to complete the brief provided. The assessment components (Table 1) require that each student submits a laboratory book as well as a short reflective summary for individual assessment. The assessed group work covers the presentation and report and the group wiki, which provides a record of how the group collaborated and their rate of progress. The report can be generated directly from the wiki either by converting wiki pages to PDF files or by printing the pages (depending on the software used). Advice on monitoring and correcting wikis is provided in this guide, but, in short, the tutor should log into each group's wiki approximately once per week if possible (assuming 3 hours contact per week), and provide brief feedback on progress reported. Feedback is also provided on any components of the group report that are submitted in a given session (e.g. experimental graphs from data), and the draft group reports are reviewed before Workshop 7. The remaining correction time is spent on the presentation and the completed reports. In this manner, students receive feedback at various stages throughout the process. A suggested schedule of work to be submitted by students and the suggested feedback provided is shown in Table 2, but it will be at a tutor's discretion to decide the extent of the feedback that it is reasonable for them to provide. The assignment of tasks as individual or group activities can also be adjusted as the tutor feels is appropriate. The work is designed so that students are preparing elements of their final report as they go along. The tutor workload aims to be similar to that required in running a traditional laboratory programme (e.g. correction of laboratory reports).

Table 2: Work to be completed after each session & associated suggested feedback

(Suggested comments for different levels of feedback in the wiki are provided in the appendix)

Session	Work Required	Suggested feedback
Week 1 Date:	**Group** • Experimental procedure for Session 2 (Beer-Lambert Law) with chemical safety assessment. • Summary of group meeting posted on group wiki. **Individual** • Contribute some information on background to Session 2 to *Project Introduction* section of wiki in preparation for final presentation. • Maintain independent laboratory book and group wiki.	Any required changes. Acknowledgement. Brief comment to group on wiki. Brief comment on wiki. Check to see everyone has logged in and contributed. Sign and date laboratory book at next session.
Week 2 Date:	**Group** • Summary of data obtained from Session 2 with associated graphs. • Compilation and sharing of group results from Session 2 experiments with other groups. • Experimental procedure for Session 3 (Adsorption Experiments I) with chemical safety assessment. • Summary of group meeting posted on group wiki. **Individual** • Contribute some information on background to Session 3 to *Project Introduction* section of wiki in preparation for final presentation • Maintain independent laboratory book and group wiki.	Brief comment on wiki. Acknowledgement Any required changes. Acknowledgement. Brief comment to group on wiki. Brief comment on wiki, sign and date laboratory book at next session.
Week 3 Date:	**Group** • Summary of data obtained from Session 3 with associated graphs. • Experimental procedure for Session 4 (Adsorption Experiments II) with chemical safety assessment. • Complete background to adsorption experiments to *Project Introduction* section of wiki in preparation for final presentation. • Summary of group meeting posted on group wiki. **Individual** • Maintain independent laboratory book and group wiki.	Brief comment on wiki. Any required changes. Acknowledgement. Brief comment on wiki. Brief comment on wiki, sign and date laboratory book at next session.
Week 4 Date:	**Group** • Summary of data obtained from Session 4 with associated graphs. • Compilation and sharing of data on group results for adsorption experiments with other groups. • Experimental procedure for Session 5 (Photocatalysis I) with chemical safety assessment. • Summary of group meeting posted on group wiki.	Brief comment on wiki. Acknowledgement. Any required changes. Acknowledgement.

	Individual • Contribute some information on background to Session 5 to *Project Introduction* section of wiki in preparation for final presentation • Maintain independent laboratory book and group wiki.	Brief comment to group on wiki. Brief comment on wiki, sign and date laboratory book at next session.
Week 5 Date:	**Group** • Summary of data obtained from Session 5 with associated graphs. • Experimental procedure for Session 6 (Photocatalysis II) with chemical safety assessment. • Complete background to photocatalysis experiments to *Project Introduction* section of wiki in preparation for final presentation. • Summary of group meeting posted on group wiki. **Individual** • Maintain independent laboratory book and group wiki.	Brief comment on wiki. Any required changes. Acknowledgement. Brief comment on wiki Brief comment on wiki, sign and date laboratory book at next session.
Week 6 Date:	**Group** • Compilation and sharing of data on group results for photocatalysis experiments with other groups. • Analysis of results for both remediation strategies across various parameters studied by all groups. • Summary of group meeting posted on group wiki. • Work in progress draft report ("interim report") posted on group wiki. **Individual** • Maintain independent laboratory book and group wiki.	Acknowledgement. Acknowledgement. Acknowledgement. Review before next session and prepare a short summary of the aspects dealt with well and those that need more work. Check to see if anyone has not been contributing at all. Brief comment on wiki.
Week 7 Date:	**Group** • Incorporation of feedback from clinic workshop into the group's wiki report. • Discussion of the data obtained from group and class experiments for each method (adsorption and photocatalysis). • Practise group presentation to ensure it is coherent, structured, accurate and meets the time requirements (the wiki itself can be used as a visual aid or, alternatively, you may prefer that PowerPoint slides be prepared). • Summary of group meeting posted on group wiki. • Maintain group wiki.	Any required changes. Provide oral and brief written feedback after presentation at next session. Acknowledgement. Brief comment on wiki.
Week 8 Date:	**Group** • Incorporation of feedback from presentation into the group's wiki report. • Final editing and completion of group's wiki report.	Grade and give optional general feedback or group specific feedback added to wikis.

	• Submission of wiki report – you should instruct students as to whether you require that the final report be printed and a copy submitted (most wikis allow pages to be saved as pdfs). You may also require that it is submitted in a format to be checked by plagiarism detection software. • An “executive summary” should be included as part of the report.	Grade using guidance notes (see appendix).
	Individual • Reflective piece to be submitted. • Laboratory book to be submitted. • Peer assessment of other students in a group (optional).	Grade and add some comments.

Learning Outcomes

On completion of the resource, the learner 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 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 learners to further develop the following transferable skills:

- Team work: they work in groups to complete the task assigned, use a wiki to facilitate collaboration and meet between sessions to review progress.
- Organisation and planning: they prepare procedures on a suitable scale and plan their time in the laboratory effectively.
- Communication skills: they 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: they 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: they adopt the role of a professional chemist and are required to make a recommendation based on professional opinion.
- Problem solving: they work in groups to address the brief presented in the context scenario.
- Information technology skills: they use a wiki to collaborate and develop their ability to use word-processing, spreadsheet, presentation, chemical drawing and library database software.
- Metacognition: they reflect on the process involved in working on the brief given, the extent to which the stated learning outcomes were met and to which their transferable skills were developed.

Table 3: Schedule of Workshops and Laboratory Classes

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