

Chemistry in context: A Guide to Site Visits in Secondary Education Chemistry

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ABSTRACT

The Chemistry SEC 06 syllabus 2025, saw the introduction of new coursework modes, one of which is Site Visits. Being a novel approach to assessment in secondary education Chemistry, educators may be unaware of local sites that could meet the exigencies of the curriculum. Also, guides to organise such visits, in Chemistry, are lacking. This project set out to identify some of these sites and to develop a resource pack to help teachers transition to Site Visits as coursework.

Education design research methods were used in this study. During the first phase, exploratory visits to six sites were conducted. Data were collected through semi-structured interviews and guided tours around each of the sites. Five sites were then chosen to be part of the resource pack. A students' resource pack supported by a teachers' guide was developed for each site. The students' resource pack includes Introductory, Preparatory and Site activities inspired by social constructivist ideologies, particularly intersubjective and narrative approaches. The pack was then presented for evaluation to teachers from the state, church and independent schools. Feedback was collected using an online, semi-structured questionnaire.

The research findings show that teachers valued site visits as opportunities to enhance learning since they impart objective and social relevance to the theory taught in class and these views were also sufficiently complemented by the activities in the pack. The pack was described as a useful tool to help teachers plan site visits in non-formal, highly contextualised environments. Some proposed revising some activities to be accessible to a wider student cohort. However, most educators agreed that the pack adequately provides for mixed-ability cohorts through a student-centred approach, thereby facilitating the achievement of the learning outcomes by the students. In general, the teachers seemed to entertain attitudes that favour the effective use of contexts in chemistry and were rather unperturbed by most reasons commonly quoted as deterrents to non-formal learning activities. This, and the fact that local sites have been identified to meet the syllabus requirements, makes this coursework mode very much feasible.

KEYWORDS:

Site Visits	Secondary Education Chemistry	Non-formal learning
Resource pack	Context-Based Approach	Out-of-classroom activities

Dedication

To my wife Mildred
and
my daughter Kryssa,

for their patience and unwavering support,

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"Alone we can do so little; together we can do so much."

Helen Keller

I would like to express my deepest gratitude to my supervisor, Dr Doreen Mizzi, for seeing me through this journey from start to finish. Her dedication and patience fuelled my motivation to deliver to the best of my abilities.

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Table of Contents

DECLARATIONS BY POSTGRADUATE STUDENTS	i
ABSTRACT	ii
Dedication	iii
Acknowledgements	iv
Table of Contents	v
List of Figures	viii
List of Tables	x
List of Abbreviations	xi
1. Introduction	1
1.1 Rationale of the study	1
1.2 Background to the study	1
1.3 Aim of the project	2
1.4 The project	3
1.4.1 The research questions	3
1.5 Structure of the dissertation	4
1.6 Conclusion	4
2. Literature Review	5
2.1 Formal learning	5
2.2 Out-of-school learning	5
2.3 About learning	7
2.3.1 Constructivism: a brief history.	7
2.3.2 Constructivist views for science education	9
2.4 The Context-Based Approach	12
2.4.1 Effective use of contexts in Chemistry	14
2.5 Beyond the classroom	15
2.5.1 Site Visits as context-based, non-formal learning environments	16
2.5.2 Benefits and challenges of site visits	18
2.5.3 Planning for Site Visits	19
2.6 Conclusion	22
3. Methodology	23
3.1 Research Design	23
3.1.1 Research questions	24
3.2 Project outline	25

3.3 Designing the resource pack	25
3.3.1 Linking the resource pack to the Chemistry SEC Syllabus	27
3.3.2 Choosing the sites.....	29
3.3.3 Exploratory visits	31
3.3.3.1 Choosing the five sites.....	33
3.3.4 The Resource Pack.....	35
3.3.4.1 The Student Resource Pack.....	36
3.3.4.2 The Teachers' Guide	47
3.4 Evaluating the resource pack	49
3.4.1 Sampling	49
3.5 Data collection methods	49
3.5.1 Semi-structured interviews	50
3.5.2 Questionnaires	51
3.5.3 Timeframes	53
3.6 Data Analysis.....	53
3.7 Ethical considerations.....	53
3.8 Conclusion.....	55
4. Results	56
4.1 Introduction	56
4.2 Participant profile	56
4.3 Teachers' views on site visits.....	57
4.4 Teachers' feedback on the resource packs	58
4.4.1 General views	58
4.4.2 Presentation and layout	60
4.4.3 Quality of activities	61
4.4.4 Challenges	65
4.4.4.1 Level of difficulty	65
4.4.4.2 Students' prior knowledge	66
4.4.4.3 Students' behaviour	66
4.4.4.4 Other concerns	67
4.4.5 Recommendations	67
4.5 Conclusion.....	69
5. Discussion and Conclusion	70
5.1 Introduction	70
5.2 Potential Site Visits related to the chemistry syllabus	70

5.3 Site Visits as opportunities to enhance learning	71
5.3.1 Knowledge contextualisation and relevance	72
5.3.2 Student-centred learning	74
5.4 Project limitations.....	74
5.5 Opportunities for future research	75
5.6 Reflection.....	76
5.7 Conclusion.....	78
5.7.1 Final words (in prima persona).....	79
References.....	81
APPENDICES	92
APPENDIX A: Stage 1 Research Instrument: Semi-structured interview	93
APPENDIX B: Research Instrument Stage 2: Semi-structured questionnaire	95
APPENDIX C: Stage 1: Information Letter sent to sites considered for the exploratory visits.	100
APPENDIX D: Stage 1: Permission Letter	102
APPENDIX E: Stage 1: Participant's Consent Form.....	103
APPENDIX F: Stage 2: Information Letter inviting teachers to review the pack.	105
APPENDIX G: Authorisation to carry out this research in state schools	107
APPENDIX H: Authorisation to carry out this research in church schools.	108
APPENDIX I: Rubric for Site Visits as coursework	109
 THE RESOURCE PACK.....	111

List of Figures

Figure 3.1:	<i>Cover pages of the Farsons Student Resource Pack and the ERA Teachers' Guide</i>	35
Figure 3.2:	<i>Learning outcomes and assessment criteria for the ERA (left) and Farsons (right) packs.</i>	37
Figure 3.3:	<i>Examples of extension activities. Top: An activity encouraging critical debate concerning the future of water supply in Malta in the WSC Luqa Laboratory pack. Bottom: Idea for project-based coursework in the ERA resource pack.</i>	38
Figure 3.4:	<i>Examples of Introductory activities in the WSC Luqa pack (IA1) and WSC Pembroke pack (IA2 and IA3).</i>	39
Figure 3.5:	<i>Examples of Introductory activities in the ERA (right) and Farsons packs (left).</i>	40
Figure 3.6	<i>An introductory activity in the Solid Base pack spurring discussion on the use of limestone and concrete in the local construction industry.</i>	40
Figure 3.7:	<i>Preparatory activities in the ERA (left) and Solid Base (right) packs encourage intersubjective approaches through discussion with the site experts.</i>	41
Figure 3.8:	<i>Preparatory activities based on newspaper articles in the Solid Base pack (left) and suggesting ideas for practicals in the Farsons pack (right).</i>	42
Figure 3.9:	<i>Preparatory activities in the Farsons (left) and Solid Base (right) packs with prompts to help students prepare quality questions for the visit.</i>	43
Figure 3.10:	<i>Cover page for the Site Activities (SA) section from the ERA pack.</i>	44
Figure 3.11:	<i>Activities promoting discussion of the reverse osmosis process at the Pembroke RO plant (left) and air monitoring sites at ERA (right) with scientists active in the field.</i>	44
Figure 3.12:	<i>Site activities encouraging the use of state-of-the-art equipment at Farsons (left) and Solid Base (right) for practical activities.</i>	45

Figure 3.13:	<i>Linking chemistry concepts to real life and contemporary issues: WSC Pembroke RO (left) and Solid Base Lab (right).</i>	45
Figure 3.14:	<i>Post-visit exercises at the end of each pack, ERA (left) and WSC Luqa (right), are designed to facilitate report writing according to the requirements of the rubric.</i>	46
Figure 3.15:	<i>Excerpt of the Teachers' Guide for the ERA site visit providing site-specific information.</i>	47
Figure 3.16:	<i>Model answers are provided in the Teachers' Guides for the Farsons (left) and Solid Base (right) packs.</i>	48
Figure 3.17:	<i>Examples of prompts provided in the Teachers' Guide for the WSC Luqa site visit to spur discussion.</i>	48
Figure 4.1:	<i>Responses to the close-ended question about teachers' views on site visits.</i>	57
Figure 4.2:	<i>Level of teachers' agreement with the statements shown.</i>	59
Figure 4.3:	<i>Participants' rating of the overall presentation of the packs.</i>	60
Figure 4.4:	<i>Respondent ratings of relevancy of learning outcomes to the activities proposed for each site visit.</i>	61
Figure 4.5:	<i>Respondents' level of agreement with how well the Introductory activities introduce the students to the processes occurring at the site and to any relevant general knowledge.</i>	62
Figure 4.6:	<i>Respondents' level of agreement with how well the Preparatory activities impart to students more in-depth knowledge of processes on the site.</i>	62
Figure 4.7:	<i>Respondents' level of agreement with how well Site activities allow students to sufficiently engage with the environment on site, which could result in significant learning gains.</i>	63
Figure 4.8:	<i>Respondents' level of agreement with how adequately the prompts, presented in each pack, guide students into preparing quality questions to ask during the visit.</i>	63
Figure 4.9:	<i>The perceived difficulty of proposed activities, for each site.</i>	65

List of Tables

Table 3.1:	<i>List of subject foci and their prescribed learning outcomes</i>	28
Table 3.2:	<i>List of six sites considered for the resource pack and the assigned LOs.</i>	30
Table 3.3:	<i>The six sites compared following the exploratory visits. (For the final five sites more detailed information is given in the Teachers' Guides).</i>	34
Table 3.4:	The guiding questions for the interview were organised into sections as shown.	50
Table 3.5:	<i>The online questionnaire was structured into the sections shown below.</i>	52
Table 4.1:	<i>Profile of school sectors and years of teaching experience for the participants.</i>	56

List of Abbreviations

Context-Based Approach	CBA
Coronavirus disease	COVID
Directorate for Quality and Standards in Education	DQSE
Education Design Research	EDR
Education for sustainable development	ESD
Environmental Resources Authority	ERA
Faculty Research Ethics Committee	FREC
Introductory Activities	IA
Learning outcome	LO
Malta Qualifications Framework	MQF
Matriculation and Secondary Education Certificate	MATSEC
National Curriculum Framework	NCF
Organisation for Economic Co-operation and Development	OECD
Preparatory Activities	PA
Programme for International Student Assessment	PISA
Reverse Osmosis	RO
School based assessment	SBA
Site Activities	SA
University Research Ethics Committee	UREC
Water Services Corporation	WSC

1. Introduction

1.1 Rationale of the study

“It is the supreme art of the teacher to awaken joy in creative expression and knowledge.”

Albert Einstein

Learning always happens in a context, whether it be in a classroom, a playground, a laboratory, a workplace. Contexts can be intangible: historic, thematic, built around social and political issues, virtual or imaginative. An important mediator of context is the environment, physical or otherwise. Education in its formal sense, the kind usually prevalent in controlled classroom environments, can only provide limited contexts, and mostly by conjecture. Such an environment might be inconsistent with students’ interests or preferred learning modes, making a subject, like Chemistry, seemingly abstract, irrelevant, and abstruse.

This formal educational environment often raises too many barriers for effective learning to occur. An educational environment should be one where all actors are allowed to freely interact without fear or regret; it is a safe, democratic space that advocates for inclusion because diversity is cherished. In this space creative expression is encouraged, because creativity is original, colourful, inspiring and, at times, even unorthodox. Learning is of itself an act of creativity. This kind of environment makes learning a gratifying experience, where all actors are masters of their teaching and learning.

Currently, there is too great a gap between schools and the external scientific community, which is withholding students from a plenitude of practical and vocational knowledge, especially in chemistry. These views on learning, informed by experience in the field, combined with a passion for chemistry and its real-life applications, motivated the researcher to embark on this project.

1.2 Background to the study

Linking “science to daily living and the local environment” whilst developing “an interest in ethical issues and a respect for safety and sustainability” is among the

philosophical undertakings of the National Curriculum Framework (NCF), 2012, for science education (Ministry of Education and Employment, 2012, p. 35). Being founded on the NCF, the MATSEC Chemistry SEC 06 Syllabus 2025 document also pursues this intention: “Every opportunity should be taken to expose the students to the applications of Chemistry to everyday situations and to help students develop higher-order thinking skills” (MATSEC Examinations Board University of Malta, 2022, p. 2). Therefore, according to local curriculum designers, making science relevant by linking it to local and real-life contexts, is desirable for effective science education.

One approach towards realising this goal was the introduction of site visits as a coursework assessment mode in secondary education Chemistry. Site visits present opportunities for coursework in Chemistry to happen outside of formal classroom environments, and apart from making chemistry relevant to real life, they also introduce “students to the world of work” (MATSEC Examinations Board University of Malta, 2022, p. 62). However, being an unprecedented mode of assessment, that consequently needs to be linked to the requirements of the curriculum, could dissuade teachers from considering site visits as part of their pedagogical practices. The possibility that most teachers have limited experience of chemistry applied outside of academic spheres, could further discourage this transition. Another compounding issue is that while guides for organising such out-of-classroom activities are readily available for other subjects, like Biology (e.g. DQSE, 2013), in Chemistry they are not particularly forthcoming.

The compromising uncertainty of novel approaches and lack of guiding and support resources concerning site visits presented a lacuna the researcher felt could help address, based on experience acquired from a career in industrial chemistry.

1.3 Aim of the project

The Chemistry SEC 06 syllabus 2025, introduced new coursework modes in addition to the, now prosaic, laboratory practical and investigation assessments. These include fieldwork, site visits and project-based methods of assessments.¹ This

¹ At the time of writing, further amendments were introduced about the school based assessment (SBA) which is being defined as “any type of assessment of a student made by the school relevant to the respective SEC syllabus that contributes to the final MATSEC level awarded in the subject” (Ministry for Education, Sport, Youth, Research and Innovation, 2022, p. 1). Site visits could be one of the SBA.

syllabus prescribes fifteen main learning outcomes (LOs), nine of which are earmarked for coursework. The document also proposes several activities (MATSEC Examinations Board University of Malta, 2022, Appendix H) that could be taken up for these new assessment modes. The scope of this project is to give some perspective on how the obligations foregrounded in the new syllabus, can be put into practice by focusing on the use of Site Visits as coursework assessment modes.

1.4 The project

This project addresses a foreseeable need for Chemistry educators to organise site visits as a means for students to achieve their learning outcomes. For this to be possible, sites with processes relevant to the syllabus learning outcomes had to be identified first. Once some of these sites were identified, teachers needed to be provided with an outset of ideas on how to prepare students for the eventuality of these visits as part of their coursework. Such provision was catered for through the development of a resource pack for students consisting of a collection of introductory, preparatory and site activities tailored for each site, and a corresponding teachers' guide intended to help Chemistry educators implement this newly available coursework mode, thereby extending Chemistry education outside the formal boundaries of the classroom. This was followed by a teachers' evaluation of the pack to get insight into how well the project achieved its intended goals.

1.4.1 The research questions

The focus and context of this project were directed by the following two research questions:

1. Which sites are available, locally, for educators to visit with their students to meet part of the coursework requirements of the SEC 2025 Syllabus?
2. How can these site visits contribute to helping students achieve the learning outcomes stipulated by this syllabus?

This study was conducted in two stages, with each stage intended to answer each of these questions by first identifying some sites that could be included in a resource pack. The resource pack was then designed to guide Chemistry educators into

planning site visits. Teachers' feedback was gathered to find out how these site visits could help students achieve the learning outcomes stipulated in the syllabus.

1.5 Structure of the dissertation

This dissertation is project based in its approach and consists of two parts: the project and a written report. The project component consists of a pack containing students' resources and teachers' support guides for five sites. The written report gives a detailed description of how this research transpired from its inception to its conclusion and consists of five chapters.

The 'Introduction' describes the circumstances motivating this research, its aims, a brief of what the project entails and introduces the research questions. A 'Literature review' follows that presents arguments and evidence from various areas in educational research, including philosophies and theories of learning, that provided creative inspiration and justification for ideas actualised in the project. The 'Methodology' details the methods followed for research design and data collection. A detailed account of the processes employed in each stage of the project along with the research instruments used and ethics adhered to is also given here. The results obtained from the evaluation stage of the research are reported in the 'Results' chapter, while the 'Discussion and Conclusion' provides a discursive analysis of the results, conclusions, limitations of the project and opportunities for future research.

1.6 Conclusion

The MATSEC Chemistry SEC 06 Syllabus 2025 stipulates that students should be made aware of applications of chemistry in everyday contexts. One way it endeavours to pursue this requirement is through the introduction of site visits as a coursework mode since such visits will extend to students the opportunity to learn chemistry from real-life contexts outside of the classroom. This project aims to identify local sites that could be relevant for LOs earmarked for coursework in the syllabus and to provide teachers with resources to facilitate their transition to this novel coursework mode. The literature review that follows gives an overview of the research that provided creative inspiration and justification for ideas actualised in the project.

2. Literature Review

“The principle that development of experience comes about through interaction means that education is essentially a social process.”

(Dewey, 1938, p. 59)

2.1 Formal learning

A good part of schooling still happens in environments built around the factory model paradigm that evolved during the late 19th century to cater for the demands of the society of the time (Chen, 2020; Leland & Kasten, 2002). In this kind of schooling environment, practically the same resources: rooms, books, curricula, timetables and pedagogies, are often used to teach all students (Chen, 2020). This style of education system made the three types of learning environments prevalent in schools, as described by Ratinen et al. (2021): the physical, the psychological and social, and the pedagogical, very much systematised. Unsurprisingly, this paradigm has favoured and propagated educational programs that have become associated with the notion of formal schooling; this persists as the predominant form of schooling to date.

Several studies and reports, dating back at least three decades, for example, London's Department of Education (1994), Osborne & Dillon (2008), the Rocard Report (Rocard et al., 2007), the ROSE project (Sjøberg & Schreiner, 2010), Smithers (1997) and other references therein, have highlighted a continued decline in interest in the science subjects. One conclusion, common to most of these reports, seems to be that traditional formal science education can negatively impact enthusiasm in learning science, in particular, because it fails to give context to the, often abstract, concepts being taught, especially about socio-cultural issues (Eilks & Hofstein., 2015a; Hugerat et al., 2015; Hugerat et al., 2018; Halonen et al., 2018).

2.2 Out-of-school learning

This situation prompted, among other measures (for example those proposed in Rocard et al., 2007), the emergence of *non-formal* education programs, similar to

the “Millennium Youth Camp” in Finland and the “Chemistry, Environment, Sustainability: Non-formal Learning Environments for all Students” in Germany (Affeldt et al., 2017), as a means to curb this decline (Schmidt et al., 2014, Affeldt et al., 2017). *Non-formal* learning has been used in certain research areas to refer to learning that occurs in out-of-school settings where even though the environment may not be as structured or as controlled as in school classrooms, learning may still follow a structure prescribed by a curriculum (Affeldt et al., 2015). Another key term used in related research is *informal* learning. In comparison to *non-formal learning*, and in contrast to the institutionalised approach of *formal learning*, *informal learning* has been described by Nygren et al. (2019) as being that unstructured learning that is not intentional on part of the learner and has no set objectives. It is ubiquitous as it involves learning also from daily experiences (Nygren et al., 2019). The OECD (Organisation for Economic Co-operation and Development) has described non-formal learning as being mid-way between formal and informal learning (OECD, 2012).

Despite these descriptions, years of research on the subject have failed to provide categorical distinctions between the three kinds of learning (Werquin, 2008). This lack of consensus makes it difficult to classify site visits, or its closely related counterpart: fieldwork, as informal or non-formal learning as both terms are interchangeably used to refer to any out-of-school, or even out-of-class, learning activities (Garner et al. 2014). This predicament becomes immediately evident when looking at research focusing on fieldwork and site visits, for example, Affeldt et al. (2015 and 2017), Gerrard (2020), Bustamante & Vanegas (2018), Halonen et al. (2018), Muscat & Pace, (2013) and Ratinen et al. (2021), where both activities are being indiscriminately characterised as either informal or non-formal learning. Although a definite categorisation of site visits could not be realised from literature, the saliency here is that a substantial body of research perspicuously indicates that out-of-school learning contexts, including site visits, offer very favourable milieus to mitigate some of the worrying trends encountered in formal science education.

2.3 About learning

The need to move away from the factory model of schools, based on knowledge transmission has long been recognised and became more urgent at the turn of the 21st Century (Affeldt, 2017; de Kock et al., 2004; Leland, 2002). Researchers from numerous disciplines: psychology, education, neuroscience, philosophy, sociology and others, whose findings have converged into the interdisciplinary fields of the cognitive and learning sciences, have dispelled much of the traditional views on learning and increasingly embraced, amongst others, *constructivist* views (Woolfolk, 2016).

Tennyson and Volk (2015) provide a concise review of some of the most influential paradigms that guided the two foundational areas of education: learning philosophy and learning theory, and how these have developed over the years. They posit that even if the distinction between these two areas can be confusing, it is important for educators to be aware of which philosophical position on learning they identify themselves with the most as this will inherently influence their choice of learning theories and associated pedagogical methods. This review also makes the reader aware that even the more recent theories of constructivism and cognitive psychology are by no means the final definitive theories of learning. They are only the contemporary most popular paradigms, possibly a reflection of the trending *zeitgeist* where globalised societies are struggling with an abundant influx of information that is continuously changing, brought about by rapid advances in Information and Communications Technology: ICT (Symeonidis & Schwarz, 2016).

Following is a brief account of some literature that informed the philosophical views of the researcher at the time of compiling this project and that, subsequently, provided creative inspiration for the activities presented in the resource packs.

2.3.1 Constructivism: a brief history.

The concept of constructivism is far from straightforward as the term has been used, at times rather loosely, to refer to numerous concepts and meanings across various disciplines (Sjøberg, 2010). Some critics even contend that the word has lost

any concrete meaning it was intended for and devolved to purely an ideology, one that is used to distinguish 'good' progressive pedagogies from the 'bad' traditional ones (Matthews, 1994). Nevertheless, in discourse related to science education, constructivism is arguably one of the best perspectives to engage with to attest in favour of out-of-school learning (Eshach, 2007).

According to some scholars, it was Swiss psychologist Jean Piaget who first gave an epistemological meaning to the term in his early writings dating back to the 1920s (Sjøberg, 2010). Much later, the underpinnings of what became recognised as Piagetian Constructivism, provided the onset of the constructivist tradition in science education research, for example through the seminal work of prominent researchers Rosalind Driver and Jack Easley in 1978 (Sjøberg, 2010). To date, it remains accepted as one of the most effective means of learning in the science classroom (Larison, 2021).

Piaget's perspective dealt mostly with the role of constructivism in children's cognitive development - cognitive constructivism. This contrasted with previous innate and empiricist views of learning, for example, the concept of John Locke's (1632-1704) 'tabula rasa', where learning is perceived as the filling of children's minds with knowledge transferred from more experienced others. Proponents of cognitive constructivism presume knowledge is being constructed by the learners themselves; it is not simply a transaction of knowledge transfer from teachers to students. When learners are exposed to new knowledge it is not just memorised and apprehended. Learners internalise this new knowledge using contexts they are already familiar with from previous experiences: *prior knowledge*. Making meaning, therefore, requires each learner to construct new knowledge upon which they define their understanding, or conceptions, of reality. This Piagetian view was often debated as it did not acknowledge much the influence of the environment on learning and development. It was more concerned with cognitive development from a biological point of view. A child's learning is determined by the level of their biological maturity: "Piagetian concepts like self-regulation also indicate his basic belief that the development of intelligence and thinking should also be understood as the individual's biological adaptation to the external world." (Sjøberg, 2010, p. 3).

This view was eventually widened to include social and cultural influences on learning – social constructivism, with the main contribution to this ‘second-wave constructivism’ being the work of Russian psychologist Lev Vygotsky (Woolfolk, 2016). Vygotsky’s emphasis was on the social aspect, how learning and subsequent development necessitates a dialogue between more knowledgeable others and the learners. Cognitive development is driven by social interactions that are inherently embedded in the learners’ cultural settings. Indeed, his theory is often recognized as a sociocultural or sociohistoric theory. So while Piaget didn’t associate too much importance to cultural influences, arguing that cognitive development is the same universally and is driven by the self, Vygotsky argued that it varies across cultures and time, influenced by the various forms of social interaction (Lourenço, 2012).

Vygotsky’s and Piaget’s theories of cognitive development have been at the centre of several critical debates and comparisons (see for example Lourenço, 2012, Vianna & Stetensko, 2006). Notwithstanding the contentions, both Piaget and Vygotsky would probably have agreed that teaching and learning are best done in that special place, which is just right to “scaffold” (Wood, Bruner & Ross, 1976, p. 90) students to a new level of cognition without being bored nor discouraged, a place that affords learners the intellectual excitement of constructing their own knowledge and mastering new skills through social interactions with their teachers and peers, one that brings joy to instruction and study, the so-called magic middle (Berger, 2014). This view of constructivism, which encompasses complementing aspects of both cognitive and social traditions, has guided educational reforms since the 1990s (Windschitl, 2002).

2.3.2 Constructivist views for science education

Constructivist epistemology has practically become synonymous with science education and over the past few decades has gained momentum in conditioning educational policy reform documents (Larison, 2021). The claims of constructivism are purportedly quite confluent with the, presumed, expectations of students wanting to pursue careers in science: the ability to study and explore the physical world using one’s perceptive systems to create and systematise knowledge at an individual level. So even if prominent constructivist theorists, for example, von Glasersfeld, and

others cited in Larison (2021), and even Piaget himself, acknowledge the influence of social interactions, they do not attribute much importance to their effect on learning. Miller et al. (2018) went so far as to posit that constructivism can produce self-directed independent learners capable of doing science by constructing their knowledge; they define these learners as *epistemic agents*.

In her review, Larison (2021) scathingly criticises these views and rejects them outright. She asserts that constructivism, at least in the science classroom, is not only overvalued but is also elitist, as it favours only that contingent of students interested in becoming scientists and consequently, predisposes privileged, western and white classes of learners. It also introduces a dichotomous 'either - or' construal of educational forms: notions of 'transmission' vs 'constructivism'; similar to the ideological 'bad' vs 'good' arguments, referred to earlier, by Matthews (1994). Additionally, in disparaging the social and affective dimensions and emphasising content-driven science education, constructivist methods are bound to do more harm than good (Larison, 2021). Teachers are also expected to teach students how science is done, when very few of them would have participated much in real-life scientific endeavours, especially outside of educational institutions. What makes Larison's critiques especially serious are her claims that the individualistic constructivist educational approach is inconsistent with ostensibly irrefutable evidence from very recent neuroscience and neuroimaging research.

Larison (2021) draws on arguments from philosophers of education and psychologists active in the fields of the cognitive sciences and foregrounds them with factual neuroimaging findings to imply that *intersubjective approaches*, especially those mediated through *narrative practices*, contribute to effective brain development as a result of increased interconnection between neural networks and enhanced myelination. *Intersubjectivity* requires a 'triangulation' between the students (as a class and also as individuals), the teacher and the scientific knowledge being taught (in the context of science education). In this case, teachers assume a second-person relationship with their students thereby creating spaces that allow for human-human interactions and active participation that are conducive to learning. Also, revealing the true face of the scientific endeavour through a narrative approach, by recounting the true stories of how discoveries were made, exposes the students to the social

and cultural influences on the progress in science, which makes the subject more humane and therefore relatable. According to Larison, this approach is inherently the most effective means to make science salient not only to scientifically inclined students but also to the general population of learners. Only so could more students be inspired and motivated into learning science or pursuing it further as a career opportunity: “Personally, I think science education fails because we’ve wrung all humanity out of the subject, reducing it to a pile of facts and concepts.” (Larison, 2021, p. 219-220).

These findings are akin to Kuhn’s (1970) sentiments in his philosophical unpacking of how progress in science occurs through revolutions that bring about paradigmatic shifts that *incommensurably* change the way humans view the world. Also, according to Kuhn, the social and cultural context within which these ‘revolutions’ take place cannot be ignored. Science is ultimately a product of the society in which it is practised. These views ushered post-positivist epistemologies to the scientific method, which eventually evolved into the sociology of science (Silva, 2007). Larison (2021) delves deeper into her philosophical arguments to implicate a more fundamental or ontological goal for science education. Humans infer meaning to the very nature of their reality by appropriating and internalising the perspectives of others and this can only happen through social interactions. Perceived this way, knowledge can never be objective as there is no unmediated access to reality (Matthews, 2004). Most of what we learn, and even our subjectiveness, is construed through the address of the other (Biesta, 2016).

Larison’s dissensions seem to be directed at a very specific and radical view of constructivism. However, as described earlier, the social aspect of constructivism has long been recognised and has influenced education reforms. Site visits, in science education, along with other non-formal learning programs, could be an offshoot of these reforms. For example, the MATSEC Chemistry 2025 syllabus explicitly states that: “Site visits offer opportunities to observe the actual world and relate the theory learned in class to a contextualised setting giving an authentic picture of science, its relevance to everyday life and its social purposes.” (MATSEC Examinations Board University of Malta, 2022, p. 62). The implications of the neuroimaging evidence that Larison presents in her review go beyond making a

critique against the constructivist classroom. Most importantly they infer an urgency to introduce intersubjective and narrative approaches to engage students, especially, on an affective level, as they have been intrinsically linked with stimulating brain development and learning.

Site visits may provide opportune environments for intersubjective and narrative approaches; during these visits, learners can interact not only with their teachers and peers but also with more knowledgeable others outside of the formal school environments, such as scientific experts from various areas of specialisation. Furthermore, they get to meet these experts in authentic locations where the action or *narrative* is happening: in real-time and in real-world scenarios, in contrast to what can only be conjectured in class. Site visits can be envisioned as an out-of-classroom context-based approach to science education as they give both objective and social contexts to the theory learnt in school.

2.4 The Context-Based Approach

The Context-Based Approach (CBA) in Chemistry is founded on social constructivist theory (Overman et al., 2019) and has been developed to address the several problems associated with traditional, content-focused, Chemistry curricula that are coaxing a reduction in students following this subject. Research overwhelmingly concurs that apart from being disconnected from socio-cultural issues and students' interests, thereby making the subject seemingly irrelevant, the traditional curriculum content is often: over-loaded, fragmented, difficult to transfer concepts to new situations and does not allow enough time for sufficient emphasis (see, for example, Avargil & Piorko, 2022; Hugerat et al., 2018; Overman et al., 2019; Wilson et al., 2015; Vogelzang et al. 2021; Wei & Long, 2021 and other references therein). Interestingly the ROSE report (Sjøberg & Schreiner, 2010) indicates that even if secondary school students are not particularly interested in science subjects, they do acknowledge the importance of science and technology for society. So the problem pertinently is with how science is taught in schools; similar findings also emerged from the ASPIRES study (Overman et al., 2019).

CBA attempts to mitigate problems of 'concept-led' courses by removing boundaries between science in school and science in everyday life. This approach has been known to: improve student understanding and reception during lessons as it made learning easier and the subject more meaningful (Bonello, 2016; Muscat & Pace, 2013), make the subject more accessible to minority groups (Wilson et al., 2015), enhance student motivation and satisfaction (Hugerat et al., 2018), reduce the gender gap in science education and foster positive attitudes towards science education (Bennett, 2016). Dori et al. (2018) mention Finland as an example of a country that scored higher in its PISA scores since they started implementing context-based approaches in their science curriculum. They also emphasise the need for literacy in chemistry to be able to discuss related social issues and explain daily phenomena.

A shortcoming of CBA relates to its interpretation, as the term *context* has many connotations. Giamellaro (2014) proposes that giving context in education, or *contextualisation*, refers to the process of reifying curriculum content knowledge by linking it to authentic environments where it is being applied. The environment comprises not only the physical space or the scenario, for example, a pharmaceutical or food quality laboratory but also the social and cultural backdrop within which any actors: scientists, field specialists, technicians and others, are active.

Student-centred pedagogies are usually preferred in context-led courses. For instance, CBA features prominently in teaching and learning praxis considered to be at the forefront of science education: Problem-based learning (Overton, 2007), Inquiry-based learning (Herranen et al., 2019) and even Finland's quite recent and innovative Phenomenon-Based learning (Symeonidis & Schwarz, 2016). In these types of approaches, concepts may be presented from different perspectives across multiple contexts thereby subscribing to the notion of the 'spiral curriculum' (Wilson et al., 2015). However, even traditional instruction approaches have been found to relatively improve student performances when elements of context-based learning are introduced (Eshetu & Assefa, 2019; Peşman & Özdemir, 2012).

2.4.1 Effective use of contexts in Chemistry

Wilson et al. (2015), adapting from Gilbert (2006), outline four attributes that are relevant to Chemistry education for making successful use of context:

1) Setting

The where, when and how of the context being adopted must be one the students are familiar with or can easily relate to and should be relevant to chemistry. They should be of contemporary importance to society: for instance, the role of surfactants in helping prevent the spread of viruses during the COVID pandemic.

2) Behavioural Environment

The kind of behaviour adopted by people operating in the said context, such as how quality is ensured in analytical chemistry laboratories, protocols that are followed to safeguard the health of personnel or for proper waste disposal, the kind of work ethic expected in a commercial laboratory carrying out sensitive analyses for their clients.

3) Language

Chemistry has a language of its own with symbols and systematic rules of how to communicate and write concepts, processes and chemical transformations. Students should learn to appreciate how important accurate use of this language is to communicate with others in the field and how often it can become even more specialised, depending on the context.

4) Background Knowledge

Students should have relevant general and theoretical knowledge to be able to relate this to the context being given.

In general, educators should as much as possible use contexts that are relevant to everyday life, including social issues but should refrain from using

contexts that are overly complicated or that are very interesting but not relevant, as these might disengage or confuse the learners. Furthermore, they must consider the diverse backgrounds of their students when using contexts that are culturally sensitive as some students may not identify with them or, contrarily, may become so emotionally involved to be distracted (Wilson et al., 2015).

2.5 Beyond the classroom

“I got to learn a bunch of stuff, and hands-on activities make it easier to remember”

“It is a wonderful way to learn because you get fresh air and you’re not cooped up in a classroom”

“We didn’t just get data from some worksheet; we saw *how* the data was collected, and that makes it much more meaningful”

(Middle school student responses,
quoted from James & Williams, 2017 p. 64)

Of the natural sciences, Chemistry is probably the one most touted as being too abstract and therefore irrelevant for matters relating to everyday life and society (Halonen & Aksela, 2018). Newton’s (1988) philosophical analysis shows how the notion of *relevance* in science education is surrounded by ambiguity as what is relevant depends on the context of what is intended to be achieved. He distinguishes between two broad categories of relevance: *internal* and *external* relevance. While *internal* relevance is primarily concerned with making different parts of the subject seemingly interdependent and unified, *external* relevance is “outward looking” (Newton, 1988, p. 9), as it implicates a social utility to the subject. Newton’s article also goes to show how, already at the time, the need to modify pedagogies to impart external relevance was recognised as important to motivate students to take up science subjects.

Subsequent and ongoing research has increasingly portrayed the education potential of non-formal, out-of-school environments. Guided by this research, several

international organisations and government entities responsible for education in several countries, have issued reports, recommendations, policy statements and reforms (Bevan et al. 2010; Department for Education and Skills, 2006; Finnish National Board of Education, 2014; OECD, 2012; Ministry of Education, Employment and the Family, 2011; National Research Council, 2015) to emphasise the necessity of learning in contexts outside of the classroom.

2.5.1 Site Visits as context-based, non-formal learning environments

Learning is a complex dynamic process, influenced by factors ranging from the microscopic to the macroscopic (National Academies of Sciences, Engineering, and Medicine, 2018). It is an ongoing process that takes place across multiple contexts, environments and timescales, mediated through myriad activities and experiences (Staus et al., 2021). Learning shapes the brain, while the brain influences learning as it develops over a lifespan; learning happens both deliberately and subconsciously and is inextricably linked to social and physical environments (National Academies of Sciences, Engineering, and Medicine, 2018). What is certain is that learning does not happen only in the classroom. Most of the learning happens outside of school because according to Bransford (2006), as cited in King & Galakin (2010), only about 18.5% of the time is spent in formal education contexts, while Falk & Dierking (2010) posit that pupils, referring in this case to average Americans, spend less than 5% of their life in classrooms. It is therefore only understandable to think of formal education, which happens inside schools, as being supplemental to informal learning that happens throughout a lifetime (King & Galakin, 2010).

Site visits are a means of learning outside the classroom which, according to the definitions proffered earlier, when linked to subject learning outcomes, as detailed, for instance, in the Chemistry Syllabus document 2025 (MATSEC Examinations Board University of Malta, 2022), can be categorised under the umbrella of *non-formal learning*. Furthermore, they are unquestionably embedded in real and concrete contexts, thereby affording learners also the benefits associated with the Context-Based Approach. Indeed, there is substantial research in the areas of context-based learning (Bonello, 2016; King & Galakin, 2010; Muscat & Pace, 2013) and also experiential learning (Kolb, 2015; Mills, Ashford & McLaughlin, 2006)

that advocates for implementation of site-visits as an integral part of a curriculum. Site visits have also been found to be effective in increasing student interest in topics related to chemistry and Education for Sustainable Development: ESD (Affeldt et al. 2015; Affeldt et al. 2017; Fowler & Cox, 2004; Bustamante & Vanegas, 2018). They also provide avenues for engaging with cross-disciplinary issues especially in environmental and geological sciences (King & Galakin, 2010) while providing opportunities to discuss cutting-edge topics that are not yet in curricula (Affeldt et al., 2017).

Since site visits provide a space where concepts learnt in class can be grounded by students engaging with the phenomena in their real-life contexts (Smith, 2002), they offer opportunities for a Phenomenon-Based approach to learning. Such phenomenological views of learning have guided the recent reform of the curriculum in Finland that introduced Phenomenon-Based pedagogies as a means to keep up with the impact of globalisation and address challenges imposed by sustainability issues (Symeonidis & Schwarz, 2016). Some criteria pertinent to what Phenomenon-Based learning should include, are:

- “An authentic object of observation.
- A systemic framework for the things to be learned (systemic model).
- A metaphorical framework for the things to be learned (analogous model).
- A motivating “base” for attaching the things to be learned,” (Silander, 2015, p. 18).

Most of these can be met during properly organised site visits. Such direct and immediate application of theory provides learners with the basis for honing their critical analysis skills, encouraging reflective thinking and action (Fowler & Cox, 2004). Social constructivist theories advocate for meaningful experiences that are shared not just within classrooms but also with external communities of practice.

Site visits create opportunities for learning to happen through social interactions with people actively involved in local scientific communities, thereby engaging students also on an affective level (Moore et al., 2011).

2.5.2 Benefits and challenges of site visits

Visits to industrial sites can help move away from fragmented and often inert knowledge and towards holistic learning as pupils can experience and draw relationships “between people, machines, materials, processes, products, the environment, and more” (Townsend & Urbanic, 2013, p. 1). During industrial visits, especially in higher education programs, students get to experience in person specialised workplaces thereby increasing their awareness of possible career opportunities (González-Peña et al., 2021; Morgan et al., 2021). They may also inculcate an appreciation of how valuable curricular knowledge can be in the workplace (Carbone et al., 2020). There is also evidence that site visits affect students’ long-term memory as their unique settings provide learning anchors that make it easier for them to consolidate and connect future knowledge, therefore, developing their cognitive performance (King & Galakin, 2010; Townsend & Urbanic, 2013). Even so, some research has shown that while non-formal learning environments have been found to have long-lasting effects on enthusiasm, motivation and eagerness, the effects were rather short lasting in terms of supporting science learning and interest (Affledt et al., 2017). Insufficient follow-up with post-visit activities and insufficient linking of on-site experiences to what was learned in school, have been suggested as possible reasons for such limiting effects (Affledt et al., 2017).

Despite that the benefits of site visits, and other similar out-of-classroom learning activities, have been reported over decades of research, much reticence to their use persists and their provision seems to be disproportionately reserved to the subjects of Biology, Environmental Science and Geography (Coll et al. 2018b; King & Galakin, 2010). Several reasons have been put forward from research for this disjuncture between pedagogical potential and actual implementation (Coll et al., 2018b; González-Peña et al., 2021; King & Galakin, 2010; MacQuarrie, 2016; Prince, 2018; Rickinson et al., 2004). These can be broadly categorised as follows:

- Time

Curricular and school demands and complex timetables may preclude these visits due to time shortages and the unavailability of convenient time slots.

- Teacher expertise and confidence

Teachers may not feel confident enough to plan and lead these visits as they lack the necessary training or are not knowledgeable enough about the science behind the processes transpiring on-site. Others may not agree with the pretext of site visits as an eclectic instrument to provide quality learning opportunities to the learners or may not perceive them as adequate support for curriculum delivery. Some research (Tilling & Dillon, 2007) has shown that professional development courses can foster more positive attitudes among teachers towards out-of-school learning activities.

- Lack of resources and support

Some schools lack the contacts, money, staff, logistics and other resources necessary to organise the activities safely and effectively.

- Health and safety concerns

Out-of-school activities could present hazards and dangers not otherwise present in normally controlled school environments. Educators may not be willing to take responsibility for extra risks incurred especially if they are personally liable.

Understandably, Coll (2018b) posits that teachers need to be encouraged to progress towards non-formal learning teaching methods.

In conclusion, site visits offer unique learning opportunities to impact student learning from multiple perspectives at the: cognitive, affective and physical and behavioural domains, as identified by Bloom et al. (1956) because, as aptly stated in the Chemistry Syllabus document 2025, during site visits: “students are exposed to multiple stimuli, thus attracting students of different learning styles, learning abilities and backgrounds” (MATSEC Examinations Board University of Malta, 2022, p. 62).

2.5.3 Planning for Site Visits

Out-of-school activities serve to relieve the boredom of traditional classroom lessons and are often more about excitement and fun (Coll et al. 2018b). Hence, despite their potential, site visits may fail to achieve their desired level of

effectiveness and may even devolve into being an extension of traditional, teacher-centred pedagogies. Research has shown that crucial reasons why out-of-school learning activities may fall short of their potential are a lack of preparedness combined with poor pedagogies (Coll et al., 2018b; King & Galakin, 2010; Rennie, 2007). Evidence from the literature reviewed by Coll et al. (2018b) reveals a strong connection between learning outside of school and pedagogies that allow students some agency over their learning: inquiry learning, group work, open-ended activities, discussions, opportunities for dialogue and debate, critical analysis and self-reflection. These findings are consistent with social constructivist theories of learning described earlier, but contrast with the traditional practices of just filling in worksheets and taking notes during guided visits, where students are allowed little or no involvement. Such traditional approaches to site visits have been criticised by some researchers and educators (Muscat & Pace, 2013; Vella, 2000) as they quell student enthusiasm. It is worthwhile pointing out, however, that other literature shows that worksheets can be beneficial if students are allowed to participate in their compilation (Coll et al., 2018a).

To be effective pedagogical tools, a rethinking of site visits as opportunities for student-centred activities, as opposed to guided tours, is necessary (Clark, 1996) and this requires adequate and rigorous planning. The authors of all the literature reviewed on the subject seem to concur that planning out-of-school learning experiences would be best approached from three perspectives (King & Galakin, 2010). Various researchers: Behrendt & Franklin (2014), Coll et al. (2018b), González-Peña et al. (2021), King & Galakin (2010), MacQuarrie (2016), Rickinson et al. (2004), and Spagnol (2009), propose as follows:

Before the visits

While the thrill of the unknown when visiting a new site may enhance student enthusiasm and foster motivation, excessive novelty can be overwhelming. Also, learners need to be able to make explicit connections between what is being learnt on site to what is being learnt in class. Most authors recommend class preparatory activities to orient the students on the layout of the venues, their purposes and what is expected of them in terms of learning outcomes. These activities could include

browsing through the site websites, viewing pictures and photos of the venue and getting access to brochures and/or maps prepared by the personnel involved in the site. This way students may attain an orienting conceptual foundation of the purpose of the site: what goes on there and what they would need to focus on to satisfy curriculum requirements. Preferably, during these pre-activities students are supported in preparing any worksheets, questions and planning of activities that will be carried out on site. Having pre-established objectives has been found to foster student interest. At this stage, student groups need to be assigned and any ground rules to be observed on site made clear.

The teachers themselves should be well acquainted with ongoing processes at the site, for instance, chemical reactions or tests being carried out, and which relevant learning outcomes learners can aspire to achieve whilst there. Some authors even prescribe prior teacher visits so they can familiarise themselves with the venue and assess whether it is suitable for all students.

During the visits

The teachers' role is critical for the success of the visit and should not limit themselves to being passive observers or acting only in a support capacity. They should actively participate with the guides or experts on site and intervene as necessary to clarify concerns or misunderstandings for confused students and to make explicit connections between the contexts being observed and theory.

Students respond to new environments in different ways and may require emotional support in case of over-excitement, apprehension or uneasiness. Teachers need to keep students focused and on task apropos any worksheets that need to be filled, planned questions to be asked and activities to complete while making sure any decided-upon ground rules are observed. If necessary teachers could liaise with the venue's staff to schedule a timetable or program before the visit. It is crucial to keep the visit streamlined with minimal time lost to get students oriented when arriving on site. The teachers' key role is therefore one of facilitation, to stimulate interest in the topic and engender both cognitive and affective development.

After the visits

To ensure maximum gains in terms of learning outcomes, visits should be adequately followed-up. It is important to consolidate and reinforce what was learnt with the curriculum soon after the visit while the student's recollections are still fresh. The use of photos or videos, possibly taken by the learners themselves, is encouraged as these may serve as *anchors* for certain concepts that can be expanded upon in class. At this stage, any data collected should be analysed and results interpreted. Students should be given time to reflect on their experiences on an individual level and as a group. They could be asked to share with their peers, ideas on how the visit could have been better or which ground rules were effective in allowing them to work cohesively as a group. Such practices will enhance learning also in the physical and behavioural domains.

2.6 Conclusion

Site visits are an instance of non-formal learning methodologies in out-of-school environments. So they are epistemologically founded on social constructivist theories of learning. Neuroimaging studies show that this style of learning can influence brain development. Site visits embed concepts learnt in class into objective and social contexts, so they benefit from the advantages of the Context-Based Approach. Notwithstanding their benefits, site visits in Chemistry are still underutilised in secondary education. Commonly quoted reasons are time, teacher expertise and confidence, lack of resources and health and safety issues. Unless they are well-planned, site visits may fail to attain their full potential. So meticulous preparation is required for all three stages of the visits: before, during and after. Student agency is adamant at every phase of the visit to ensure maximum impact on learning in the cognitive, affective, physical and behavioural domains.

These arguments and suggestions, propounded from literature, directed the research design and methods employed in this project to answer the research questions and are reported in detail in the next chapter.

3. Methodology

The introduction of site visits as part of the coursework assessment for secondary education Chemistry in Malta is a novel approach, and guides for this type of out-of-classroom activities in Chemistry, are not forthcoming. This project intends to address this need by identifying some sites available locally that can be linked to some of the subject foci listed in the Chemistry syllabus (MATSEC Examinations Board University of Malta, 2022)², particularly those that include learning outcomes earmarked for coursework. This chapter describes how the resource pack was compiled and evaluated.

Following a site information gathering phase, a resource pack was designed to facilitate the educators' transition to this new type of coursework assessment mode. The pack includes a repertoire of introductory, preparatory and on-site activities, for five sites. Secondary Chemistry educators from the state, church and independent sectors, were invited to review and give feedback on the pack.

3.1 Research Design

This project follows education design research (EDR) methods insofar as it sets out to address a foreseeable need for Chemistry educators where guidelines for addressing this need are unavailable (Kelly, 2009). Education design research has been used to develop interventions in Chemistry education and themes relevant to this project, such as context-based teaching (Ikävalko & Aksela, 2015), design of hands-on activities (Anderson et al., 2021), cooperation with industry to develop meaningful learning environments (Ikävalko, 2016) and Inquiry-based site visit teaching (Loukomies, 2013).

Design research is recommended when practical solutions to complex educational problems are needed, and to advance knowledge on the design and development processes leading to these solutions (Plomp, 2013). Interventions are informed by reviews of literature and prior research and are planned and developed

² Will be henceforth referred to as 'syllabus'.

through collaboration between the researchers and practitioners (Plomp, 2013). Nieveen (2007) refers to this as the preliminary research phase, part of which includes proposing a tentative intervention design (Nieveen 2007, p. 154). This phase is usually followed by a prototyping or development phase (Nieveen 2007, p. 154) which includes iterative cycles of analysis, design and formative evaluation until an optimal solution is found. The design research usually ends with a summative evaluation phase where more confident assertions are proposed, the outcomes of which can be used for the preliminary research phase of a new design research study (Nieveen 2007).

This research was conducted in two stages, the first corresponds to the preliminary research phase of EDR, which involved the gathering of information from site visits as described in section 3.3.2, while the second stage could be described as the prototyping or development phase, that involved the design and compilation of the students' and teachers' pack. The iterative process, commonly requested of the latter phase, consists of one formative evaluation process which was the teachers' feedback. It has been restricted to one process due to the timeframe allocated for this project.

3.1.1 Research questions

This project intends to answer the following research questions:

1. Which sites are available in Malta for educators to visit with their students to meet part of the coursework requirements of the Secondary Education Certificate in Chemistry 2025?
2. How can these site visits contribute to helping students achieve the subject learning outcomes?

Research questions dictate the focus and context of the research itself, such that improper formulation may cause any eventual conclusions to be implausible or even invalid (Mantzoukas, 2008).

3.2 Project outline

To answer the research questions, the project was developed in two phases:

Stage 1: Gathering site information before designing the resource pack.

Guided by the learning outcomes prescribed in the syllabus, six potential sites were chosen and the respective responsible persons were approached to organise an exploratory visit with the researcher. This visit included an interview and a guided tour of the site. Following these visits, five sites were shortlisted for the resource pack, based on criteria that will be expounded upon in section 3.3.3.1.

Stage 2: Producing the resource pack and evaluation.

For the second stage of the project, a resource pack was produced which includes several activities and resources. These were designed using information collected during the exploratory visits and based on recommendations from literature on how to make such visits more effective. The pack also includes teachers' guides to support educators in using the resources presented for each site visit. Once finalised the pack was submitted for review to, a maximum of ten, secondary Chemistry educators coming from different sectors. Feedback was collected using a questionnaire.

3.3 Designing the resource pack

The resource pack was primarily designed around the requirements of the syllabus, as discussed in section 3.3.2, and by implementing some of the suggestions put forward from a review of literature on the subject. The researcher's views on learning, motivated by philosophical outlooks described in the literature review (section 2.3), served as creative inspiration behind the activities in the packs.

The inceptive precept behind the activities proposed in the pack originated from literature. More specifically from Clark's (1996) concluding remarks, when he posits that to exploit the full educational potential of out-of-school activities, the emphasis must shift from "teaching in the field to learning in the field" (Clark, 1996, p.390). This translates into rethinking site visits as opportunities for student-centred

activities, in contrast to predominantly guided excursions. Similarly, the syllabus contends that site visits should not be about just learning facts, but: "Learning outcomes set must be achieved during the site visit" (MATSEC, 2022, p.62).

Another salient aspect derived from literature is knowledge contextualisation (Giamellaro, 2014), more specifically, the value of imparting external relevance (Newton, 1988) to the subject matter, as can be achieved by a context-based approach as discussed in section 2.4. Context-led courses tend to predispose student-centred pedagogies and have been found to improve student performances (Eshetu & Assefa, 2019; Peşman & Özdemir, 2012). The Chemistry syllabus around which this project is designed, is context-based in its approach and the sites were chosen in line with the subject foci prescribed within.

Most authors, of the literature reviewed (section 2.5.3), concur that the planning of site visits is best approached from three perspectives: before, during and after the visit (Behrendt & Franklin, 2014; Coll et al., 2018a; King & Galakin, 2010; González-Peña et al., 2021; MacQuarrie, 2016; Rickinson et al., 2004; and Spagnol, 2009). Indeed, the students' packs include activities that will be carried out in preparation for the site visit, during the site visit and after the visit (section 3.3.4.1).

On a more personal note, social constructivist perspectives of learning resonate strongly with the researcher's preferred approach to teaching. Larison's (2021) arguments in favour of intersubjective and narrative approaches, backed by neuroscience, have especially piqued the researcher's interest in finding ways to move away from the austerity of formal practices towards methods of making science education enjoyable, relevant, social and humane.

Intersubjective approaches necessarily favour self-directed autonomous learning, where students take the perspectives of a more knowledgeable other, through social interaction, and compare it to their own. For this to happen effectively, the educator must not simply transmit knowledge, but must actively participate with the pupils in a "collaborative learning situation" (Larison, 2021, p. 217). Activities in the pack, such as 'Passive Diffusion Tubes: The Challenge' in the ERA pack or 'Laboratory testing competence' in the WSC Luqa pack, strive towards an intersubjective approach by encouraging group work where even the teacher can participate actively with the students.

In the case of narratives, inasmuch as stories of the past are often enthralling, these need not necessarily be constrained to centuries-old history of scientific endeavour. Narratives that are still unfolding in the here and now, and where scientific knowledge has a crucial role in directing their outcome, can be very much alluring, especially if these concern current social issues such as climate change or sustainable practices. For example, the use of newspaper articles was found to be effective in conveying real and contemporaneous narrative contexts when teaching science, which transpired in considerable improvement in motivation and learning (Kuhn & Müller, 2014). The introduction of newspaper stories to provide contexts in teaching Chemistry seemed promising to the researcher since they are more accessible and appealing than scientific textbooks and are more likely to act as *anchors* for active construction of knowledge by the students (Kuhn & Müller, 2014). The activities: 'Quality matters' in the Solid Base Laboratory visit and 'Mixing waters to improve quality' in the WSC Pembroke RO visit are two examples of how narrative approaches were introduced in the pack.

As a final point, the fact that the current generation of students are digital natives (Prensky, 2001), that are so "immersed in digital technologies that they learn differently from previous generations" (Ng W, 2012, p. 1), cannot be ignored. A consequence of this reality is that students are no longer comfortable with predominantly text-based communication as they are "more heavily engaged with visual and multimedia communication, based on their experiences with the Internet" (Affeldt et al., 2018, p. 93). Contemporary and graphic visual representations are often more easily apprehended than conventional textbooks, even in science. Affeldt et al. (2018) show this to be true through the use of comics to give instructions in non-formal Chemistry learning contexts. The ERA pack was designed around this concept. Also, links to online resources, especially videos, feature prominently throughout the pack.

3.3.1 Linking the resource pack to the Chemistry SEC Syllabus

The syllabus features fifteen main Learning Outcomes (LO) that are associated with five Subject Foci as detailed in Table 3.1. Each of these Learning Outcomes prescribes assessment criteria that are categorised into three Malta Qualifications Framework (MQF) levels: MQF 1, MQF 2 and MQF 3. The

assessment criteria for Learning Outcomes: 1, 2, 3, 4, 5, 7, 8, 11 and 15 are earmarked for coursework by the syllabus and one of the allowed coursework modes is: Site Visits.

Table 3.1: List of subject foci and their prescribed learning outcomes

Subject Foci	Main Learning Outcomes At the end of the programme, I can:
Substances from the Earth: The Atmosphere.	LO 2. Describe and explain the properties of gases that may be found in air and how to prepare them in the lab.
Substances from the Earth: Aquatic environments.	LO 3. Describe the solvent action of water including the impact of water hardness. LO 4. Describe the chemical properties of acids, bases and salts. LO 5. Describe the conduction of electricity through solutions and molten salts. LO 6. Describe the major groups of the periodic table including their physical and chemical properties. LO 7. Describe how substances dissolved in water can be identified and how their concentration can be measured.
Substances from the Earth: The Land.	LO 8. Describe how different rocks contain important substances, their extraction, chemical nature, responsible use and environmental impact.
Making New Materials: How fast? How far? How much?	LO 9. Describe how and why physical and chemical changes happen. LO 10. Perform quantitative calculations. LO 11. Investigate why and how chemical reactions proceed at different rates. LO 12. Describe dynamic equilibria and the conditions needed to shift a reaction in equilibrium
Carbon compounds. Meeting our energy needs.	LO 13. Describe the chemical nature of crude oil and the substances obtained from it. LO 14. Distinguish different homologous series and their physical and chemical properties. LO 15. Describe the energy changes accompanying chemical changes.

LO 1, which states that students can *demonstrate an understanding of how chemistry works and is communicated*, is not contingent to any one particular subject focus, as its assessment criteria are foundational and therefore relevant throughout all of secondary Chemistry education.

The syllabus document makes two main assertions about why site visits should be implemented as part of the curriculum, namely that site visits:

1. Give real-life context to theory as students can engage with the phenomena in real life,
2. Show how science also has a social purpose (MATSEC Examinations Board University of Malta, 2022, p. 62).

Similar statements are also founded in literature (Bonello, 2016; Mills, Ashford & McLaughlin, 2006; Muscat & Pace, 2013). The syllabus goes on to state that site visits have the potential to engage students with different learning abilities as they provide multiple stimuli with less compartmentalisation among subjects (MATSEC Examinations Board University of Malta, 2022, p. 62). The importance of site visits to increase awareness of socio-scientific issues as well as introducing the students to real-life work environments is also emphasized. When planning these visits, the syllabus document recommends:

- planning ahead, to complement work carried out in class,
- carrying out a risk assessment of the site,
- use of pictures to familiarise the students with the premises,
- to liaise with the site responsible, before the students' visit, to determine the learning objectives.

Following the visit, students must present a report that will be assessed; the marks will contribute to the final grade of the matriculation certificate. A rubric is provided in the syllabus to facilitate report writing (MATSEC Examinations Board University of Malta, 2002, p.62); a copy of this is presented in Appendix I. As part of the preparatory activities, the rubric demands that students prepare questions to ask the practitioners on site.

3.3.2 Choosing the sites

A list of sites was drawn up by considering suggestions given in the syllabus document (MATSEC Examinations Board University of Malta, 2002, p. 44 – 46) and an initial assessment of which of the learning outcomes could be relevant, based on

information available on the sites' respective websites. Following an intensive internet search, the tentative list consisted of sites spanning the following sectors:

- higher education institutions, such as the University of Malta,
- government entities, not related to education,
- the private industry sector.

Six potential sites were then chosen to cover each subject focus as shown in Table 3.2. Here the learning outcomes assigned for each of these sites and a short description outlining why each site was chosen, are also shown.

Table 3.2: *List of six sites considered for the resource pack and the assigned LOs.*

Site Name	Assigned LOs	Comments
Environmental Resources Authority (ERA) 2 sites visited: Marsa workshop and Zejtun air monitoring station.	LO 2.	The syllabus suggests to: "Visit sites that are concerned with air quality and monitoring" (MATSEC, 2022, p.44) for LO 2. ERA publish their real-time data online. This provided easier opportunities for pre-visit activities.
Water Services Corporation (WSC): Pembroke RO Plant	LO 3.	The syllabus suggests to: "Visit a reverse osmosis plant" (MATSEC, 2022, p.44) for LO 3. Locally, and at the time of writing, only WSC operates large scale RO plants.
Water Services Corporation (WSC): Water Quality Laboratory	LO 3. LO 7.	The syllabus suggests: "Visit labs that ensure water quality" for LO 3 and "Visit sites where qualitative analysis is used" for LO 7 (MATSEC, 2022, p.44 - 45). Information from the WSC website seemed to indicate that these two LOs could be effectively covered in this visit.
Farsons: Main Laboratory	LO 4. LO 7.	Pre-assessment of this visit was mostly based on the researcher's prior knowledge of the site from past interactions not related to this project.
Solid Base Laboratory	LO 8.	The management expressed keen interest to participate in this project. Also one of the few sites available locally relevant to LO 8.
Consolidated Biscuits	LO 15.	This site was thought to be relevant to LO 15 for which the syllabus recommends visits to laboratories that determine the energy content of food (MATSEC, 2022, p.46).

The responsible persons for six sites were approached through purposive sampling. Purposive sampling is often used in qualitative studies where the researcher is not interested in generalisations but seeks samples that are best discerned to conform to distinct criteria or for a specific purpose (Cohen et al., 2017).

In the first stage of the project, the emphasis is, predominantly, criterion-based (Palinkas et al., 2015), as the prescribed learning outcomes assigned to the subject foci were used as reference criteria when shortlisting potential sites. There was also an element of convenience sampling, which is another emphasis of purposive sampling (Palinkas et al., 2015), as those sites which showed more disposition, were given preference.

Purposive sampling has some limitations, notably that it is rather subjective as it relies on the judgement of the researcher, so different experts can come up with different samples from the same population, based on what criteria they think are most relevant (Lavarkas, 2008). Also, purposive sampling can be challenging as the researcher may not be aware of the whole range of variation within the population to be studied from the onset (Palinkas et al., 2015). For instance, particular to this research, choosing the best sites might presume that the researcher is familiar with all the sites within the population, which might not necessarily be the case. So purposive sampling is often considered pertinent to small samples from a restricted geographical area (Lavarkas, 2008), as was the case for this project.

3.3.3 Exploratory visits

First contact with each site was made using phone contact details that were publicly available on their respective websites. The rationale behind this research was briefly explained to the responding party who was then courteously asked to share the phone/mobile and email contacts of the person who could be responsible for overseeing these visits on their site; this person will henceforth be referred to as the *site responsible person*. Following a second introductory call to the site responsible person, an information letter, a permission letter and a consent form were forwarded.

The information and permission letters included detailed explanations of what the research entails and that the participants would need to consent to an exploratory visit consisting of a guided tour of the site, supported by a semi-structured interview which would be audio recorded. Verbal consent for any photos

was asked for during the visit. In some instances, permission for the exploratory visit had to be obtained from the manager or human resources office of the site responsible person. In such cases, the information and permission letters and consent forms were forwarded accordingly, as directed by the site responsible person. The full contents of these letters and forms, including details of research ethics adhered to are presented in Appendices C – E, while the prompt questions for the semi-structured interview, are shown in Appendix A.

Two of the sites, whose names cannot be divulged, additionally requested the signature of a non-disclosure agreement on behalf of the researcher. These sites requested for the resource packs to be reviewed before they could be included in this project to ensure that no sensitive information is inadvertently revealed.

Details, including phone numbers and email addresses, of how this initial contact was made were included in the Teachers' Guides with a cautionary note that these details could change. For this reason, and to protect the anonymity of the site responsible persons, as demanded by the research ethics, any contact references quoted in the resource pack were kept generalized by pointing to a department, rather than to an individual. For example, human resources or operations management.

The researcher met the responsible person on an agreed date and time that was convenient for both parties. Following a brief exchange of cordialities and face-to-face introductions, any pending consent forms were signed and an outline of the research project was given again verbally. The formal interview, which was audio recorded, was then started using the introductory prompt questions detailed in section 3.5.1 as a guide, which were mostly concerned with the researcher getting a brief overview of the purpose of the site. This was followed by a tour of the site during which other questions were asked, always guided by the prompts in section 3.5.1. During the tour, in addition to the audio recording, photos and notes were taken as necessary. At the end of the tour, a few minutes were spent summarising the salient points followed by a brief discussion of the site responsible person's personal views on site visits and their introduction into the Chemistry curriculum.

After each visit, a short reflection on the merits and weaknesses of the site as well as ideas for possible on-site activities were recorded to support the researcher in Stage 2 of the project: preparing the resource packs.

3.3.3.1 Choosing the five sites

Once all six exploratory visits were completed, the audio-recorded interviews were reviewed attentively whilst taking additional notes to include any important details that were missed. The strengths and weaknesses of the initial six sites were summarised and compared as shown in Table 3.3. The Consolidated Biscuits site was not included in the pack since the operations of the laboratory of this site were not found to be relevant to LO 15 or any other of the learning outcomes in the syllabus.

Table 3.3: The six sites compared following the exploratory visits. (For the final five sites more detailed information is given in the Teachers' Guides).

Site	ERA	WSC Pembroke RO Plant	WSC Quality Lab	Farsons Main Lab	Solid Base Laboratory	Consolidated Biscuits
Target LOs:	2	3	3, 7	4, 7	8	15
Relevant to LOs?	Yes	Yes	Yes	Yes	Yes	No
Possibility of onsite Activities:	Yes	Yes	Yes	Yes	Yes	Limited
Logistical factors:						
Max number of students	16 (groups of 4)	15	30 (groups of 10)	15	15	20 (groups of 6)
Health Risks	Medium to Low	Medium to Low	Low	Low	Medium to Low	Medium to Low
Availability during the scholastic year	All year	All year	All year	All year	All year	All year
Access to students with disabilities	Limited	Limited	Good	Good	Limited	Limited
Facilities:						
Restrooms	Depends on site	Yes	Yes	Yes	Yes	Yes
Lunch/ recreational areas	Available in most sites	Available	Available	Available	Available	No
Other:						
	Easy to organise onsite activities to keep waiting groups occupied.	Persistent loud noise may deter certain students.	Different groups can visit different areas.			Rather challenging to organise onsite activities for waiting groups.

3.3.4 The Resource Pack

The pack's underlying intention is to provide an outset for the introduction of site visits as coursework. The resource pack consists of a 'Students' Resource Pack' and a 'Teachers' Guide' for five site visits (Figure 3.1). The activities include a variety of resources encompassed within diverse teaching modes spanning traditional, practical and critical approaches.



Figure 3.1: Cover pages of the Farsons Student Resource Pack and the ERA Teachers' Guide.

The resources for each site were modelled around the concept of a restaurant menu, whereby patrons choose their meals depending on their mood and preferred tastes. Similarly, teachers using the pack are invited to choose any of the pack's resources they prefer. The pack's quintessential goal is to spur teachers into eventually creating their personalised site-related resources by either choosing which activities to use or reorganizing them in a different sequence while adding their content. This might be necessary so the resources are more confluent with the context they are working in, for instance: class competence, scheme of work schedules, available resources and other factors typical of the teaching profession. The pack includes various activities that are also suggestive of ideas for lesson

planning and other coursework modes: fieldwork, investigations, project-based and laboratory practical sessions.

Even though reference is being made to a resource pack, the completed work is not presented as a single comprehensive handbook. It comprises five distinct sections, one for each site visit, that can be printed out and used separately. The reason was to avoid unnecessary waste of resources: paper, ink and money, since it was presumed unlikely for teachers to manage all the visits throughout the secondary school years, especially during the first years of introduction of the new syllabus. Therefore, some sections of the introduction and the concluding remarks were repeated for each visit.

3.3.4.1 The Student Resource Pack

The following section gives an outline of the students' resource pack. Each pack consists of the following sections: a list of assessment criteria, Introductory activities, Preparatory activities (that includes a Prepare your questions activity), Site activities and post-visit guidelines for report writing.

These activities incorporate ideas, instructions, articles and links to online resources such as videos and widgets, for activities pertinent to a particular site visit, that can be attempted by the students. The student pack is meant to facilitate preparation for the visit and achievement of the assessment criteria throughout all the phases of the site visit: before, during and after. Traditional worksheets have been kept to a minimum. For example, fill-in-the-blanks have been replaced with short answer questions and other exercises to teach students how to organise data and information into tables. Activities spurring discussion and debates transpose long answer and essay-type questions. Others guide students into taking concise but relevant notes in the space provided. Most activities are flavoured with photos, links to online resources and colourful graphic illustrations, most of which are taken from local contexts, to cater for students who are deterred by excessively long texts. Even debates and discussions focus on issues that are relevant to contemporary Maltese contexts, as creating an intimate link between the chemistry learnt in class and the local socio-political scenario was constitutive to this project.

Each pack commences with a list of proposed learning outcomes and associated assessment criteria that could be attempted by each site visit, as shown in Figure 3.2.

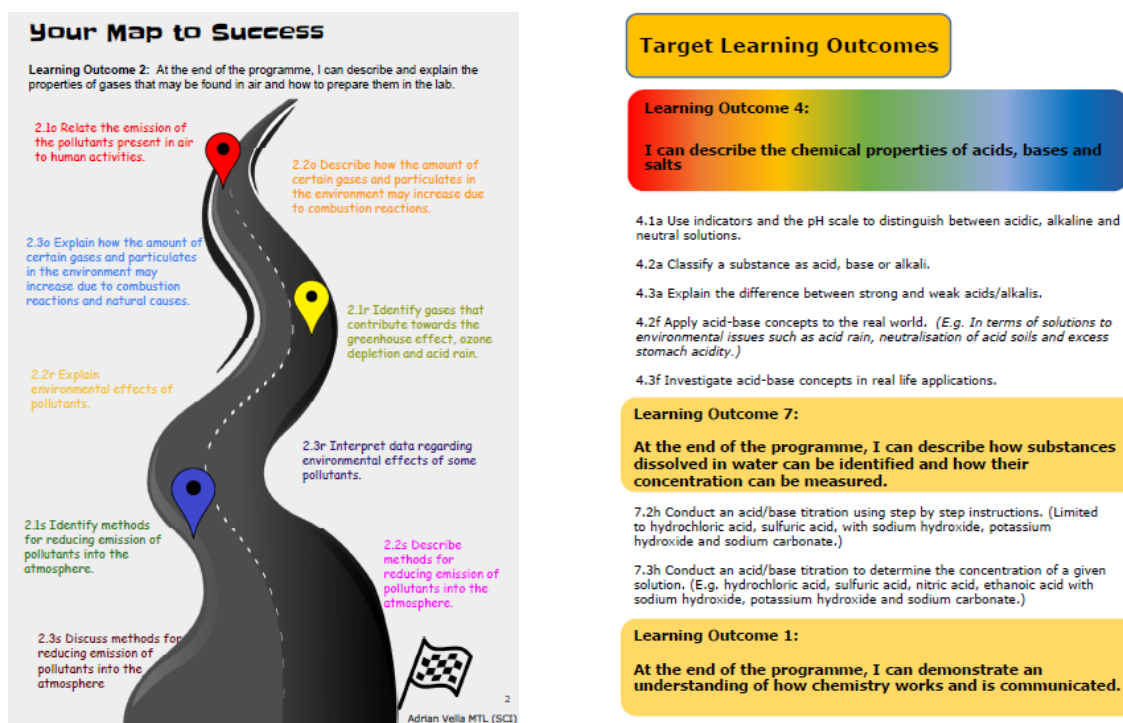


Figure 3.2: Learning outcomes and assessment criteria for the ERA (left) and Farsons (right) packs.

This is followed by a collection of activities categorised as Introductory Activities (IA), Preparatory Activities (PA) and Site Activities (SA). Some of the activities are labelled as ‘Extension’ or ‘Optional’; these can be either more challenging activities, to cater for those students who are keen on progressing their learning beyond what is expected or to give ideas for other available coursework modes such as projects or fieldwork. Examples of these activities are given in Figure 3.3. Here, the ‘comics’ style presentation of the ERA pack is also shown.

PA5: Extension: New Water from wastewater!

With the help of EU endorsed funds*, Malta, through WSC, has invested in technologies to produce:

"New Water" [which] is highly polished reclaimed water, which can be used for agriculture, industry, landscaping and other applications.

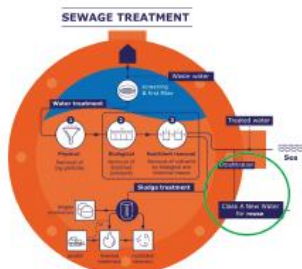
<https://www.wsc.com.mt/information/new-water/>

Simply put 'New Water' is water reclaimed from wastewater (sewage) after it undergoes a number of treatment processes. So it is necessary to understand what happens to wastewater in Malta first.

Up until a few years ago wastewater used to be dumped as raw (untreated) sewage directly into the sea. This sewage caused ample pollution along parts of the coastline (try searching online for photos and videos showing this). Now sewage is being treated by a number of waste treatment plants, also operated by WSC, before being discharged into the sea and this:

"has eliminated the coastline pollution in Kalkara, Xghajra, Marsascala and Marsaxlokk thereby upgrading the bathing water quality."

You can read more about this here: <https://www.wsc.com.mt/about-us/wastewater/>.



* <https://eufundsmalta.gov.mt/content/supply-highly-polished-tertiary-treated-water-agricultural-use>

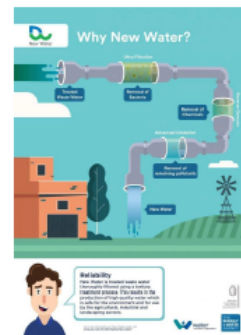
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13

WSC has taken this process a step further. Part of the treated wastewater is diverted to tertiary water polishing plants, as shown in the green circle on page 13 (Sewage treatment), to produce this 'New Water'.

You can read more about this here:

<https://www.wsc.com.mt/information/new-water/>



Now, read through the following links:

<https://timesofmalta.com/articles/view/freshwater-securing-our-future.876182>

<https://www.wsc.com.mt/two-major-milestones-for-malta-in-the-water-sector>

and take note of figures referring to:

- volumes of water produced by RO plants,
- volumes of 'New Water' produced from sewage treatment plants,
- costs of building RO and New Water plants and
- water used up in agriculture.

Debate these two statements:

'New Water' projects should be prioritised as they are a sustainable means of reducing the demand on Malta's potable water sources for agricultural use.

Investment in RO plants makes more sense as they can produce good quality potable water that can also be used for agriculture.

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14

PA3: Extension
Passive Diffusion Tubes: The Challenge

We don't want you to get bored!

I read somewhere that ERA are supplying these tubes even to schools!

Wow! Wouldn't it be great to know what the air quality is like in our school?

Sure! I say we talk to the guys at ERA during our visit and let's do this.

Passive Diffusion Tubes look something like this. They are very easy to use.

Once ERA supply these you need to set them up in suitable shelters such as the ones shown here. These would need to be prepared by you.

The tubes will have to be returned after a number of days to ERA for analysis.

Think about what you would need to ask scientists at ERA should you decide to take up this project.

Where to locate the tubes.
The correct procedure to set them up.
How to collect and return the tubes.
Dimensions of the shelter, etc.....

10
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Figure 3.3: Examples of extension activities.

Top: An activity encouraging critical debate concerning the future of water supply in Malta in the WSC Luqa Laboratory pack.

Bottom: Idea for project-based coursework in the ERA resource pack.

Introductory Activities (IA)

These activities are designed to introduce the students to the processes occurring at the site and to any relevant general knowledge, without which important aspects of the site visit might be lost. Figure 3.4 portrays examples of these activities and how online tools are used to access data and guide critical discussion concerning social issues with the site experts during the visit. In these activities, tables and short notes are given preference over traditional fill-in-the-blank exercises.

Introductory Activities (IA)

IA1: Water testing

Read through the information given in this link (download also the accreditation scope document) and other parts of the WSC website:
<https://www.wsc.com.mt/facilities/laboratory>

Find out what tests are being carried out by WSC and list some of them in the table below.

WSC analyse two main categories of water samples. Which are they?

--	--

Do you recognise any of the laboratory techniques WSC use to analyse for some of the water quality parameters? List these down below and keep them in mind for later. (Feel free to include one technique you never heard of and may want to learn more about).

Question ideas:

There are a number of terms and laboratory techniques you may not be familiar with and may want to learn more about during your site visit. Take a note of them and decide whether to include them in the questions you need to formulate before the visit.

(For example: Accreditation, ISO 17025, bacteriological testing, Atomic Absorption Spectrophotometric analysis, ICPMS)

IA2: Water Quality

Visit: <https://www.wsc.com.mt/>

Click on: VIEW LIVE MAP
 In the Menu bar on left:

Click on 'Control room'

Choose 'Water Quality'

You can access water quality information for each locality shown on the map of the Maltese islands, as described in the website prompt below:



Click on a locality and the following table will be displayed:

The ⓘ button will call up some information on each parameter. Read through some of these and compare the conductivity values at different localities, including the ones where you live.

Choose five localities and take note of the parameters circled in RED, namely: Conductivity, Total Hardness and Nitrates, by filling them out in Table 1 below.

Collection Date	Locality	Conductivity µS/cm	Total Hardness mg/L CaCO ₃	Nitrates mg/L NO ₃ ⁻

IA3: Discussion

Analyse again the conductivity values for various localities.

- Is the water quality, on average, the same all over Malta and Gozo, or does it vary between localities?
- From the values deduce which localities are likely to be receiving mostly reverse osmosis water and which are receiving groundwater.
- Could there be any link to how close they are to the RO plants?
- WSC ensures that all the quality parameters of tap water over Malta and Gozo are within the acceptable, safe ranges. Notwithstanding, how does the fact that you could be receiving better or inferior water quality than other localities make you feel? Is this an issue of social justice?

Follow this up with experts at the RO plant.

Figure 3.4:

Examples of Introductory activities in the WSC Luqa pack (IA1) and WSC Pembroke pack (IA2 and IA3).

Figure 3.5 shows the extensive use of graphics and visuals in some activities to make the packs more attractive to 'digital natives', while Figure 3.6 shows the use of newspaper articles to give local, real-life, narrative contexts in the Solid Base pack.

IA2: Living with Acids and Bases.

Watch: www.youtube.com/watch?v=r3hizlWJLM

Which of the acids and bases in the table are present in the items shown below. (Some items may contain more than one acid/base). Research if necessary....

Sodium hypochlorite	Lactic acid	Ammonia	Acetic acid
Citric Acid	Calcium Carbonate	Hydrochloric Acid	Calcium hypochlorite
Phosphoric Acid	Sodium Hydroxide	Carbonated Water	Sodium hydrogen carbonate

Which of the items in bold are:

Acids:

Bases:

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Figure 3.5: Examples of Introductory activities in the ERA (right) and Farsons packs (left).

Figure 3.6

An introductory activity in the Solid Base pack spurring discussion on the use of limestone and concrete in the local construction industry.

IA2: A primer on Limestone

We have seen how cement is a key ingredient in concrete as without it the mixture cannot harden. Cement is a fine mineral powder usually grey in colour. One of the most important raw materials for producing cement is **limestone**. Up until a few years ago, limestone was still used extensively for construction in Malta. Nowadays, not so much. Limestone is a type of naturally occurring sedimentary rock and needs to be quarried from the land for use.

a. Discuss:

The economic and environmental impact of limestone quarrying in Malta. What can be done to mitigate this impact?

The following can guide your discussion:

- Use Google Earth to look for satellite images of quarries in Malta and Gozo. Assess their impact on the environment.
- <https://www.bbc.co.uk/bitesize/guides/z6qqmsg/revision/4>
- <https://tvmnews.mt/en/news/use-of-maltese-limestone-has-decreased-as-it-is-backbreaking-work-says-stonemason/>

b. Debate

Locally the building industry has switched to the use of concrete and bricks (also made from concrete). Was this a wise choice?

Here are some points to think about for your discussion:



- Strength of limestone slabs (eg xorok) vs concrete.
- Stone craftsmanship.
- Height of buildings.
- Quarrying and environmental implications.
- Buildings close to the sea.
- Workability of concrete.

Anything you want to ask the site experts you will be meeting?

<https://timesofmalta.com/articles/view/watch-arte-documentary-tackles-maltes-paradise-of-concrete.876665>

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Preparatory Activities (PA)

Preparatory Activities are meant to get students more in-depth knowledge of processes on the site by encouraging them to do some prior research and to adopt a more critical approach, especially in matters related to socio-scientific issues. Figure 3.7 demonstrates how some activities attempt this through intersubjective approaches while others, Figure 3.8, include newspaper articles and ideas for school-based practical activities.

Preparatory Activities (PA) Adrian Vella MTL (SCI)

PA1: Which Site?

ERA have multiple stations that are continuously monitoring the air quality in their surrounding environment.

Using Google Maps, scout a bit the area of where each station is located. Think about pollution sources and *sinks* in the vicinity, as well as other factors such as seasonal variations in traffic.

- Which sites experience the most/least air pollution? (Predict giving reasons).
- Choose a site to visit (Keep in mind logistic issues: time of day, distance from school, and traffic conditions to get there). Give reasons for your choice.

Attard: <https://goo.gl/maps/v3bwCaduLDMkoYEZ8>
Gharb: <https://goo.gl/maps/pF33Kram3qdWjGz7>
Msida: <https://goo.gl/maps/ZadrECCrH4wdtdTH7>
St Paul's Bay: <https://goo.gl/maps/vRqCq84EY79qJfB6>
Zejtun: <https://goo.gl/maps/Ep25LDQ6Mpm8GqH8>

How did ERA choose these sites? Their decisions were not just random. They had to adhere to criteria specified by the EU. The document shown here (pg 24), states that the measurements must specifically be made in:

- areas with the highest concentrations of pollutants and where it is likely for the population to be directly exposed for significant time periods;
- areas which are representative for the exposure of the general population.

Discuss what these could mean and why the site you chose above could meet these criteria.

Propose a new site to ERA that could qualify for an air monitoring station.

In Site activity SA2 you have the opportunity to discuss your ideas with ERA. I encourage you to do so!

PA3: Quality matters

TVM NEWS May 21, 2015

€30 million required to repair inferior quality concrete at Mater Dei

"...although the concrete in Malta should have been made of hard rock (*tal-gawwi*), it turns out that the concrete used to build the hospital was made of concrete mixed with soft globigerina limestone (*tal-franka*). The tests carried out on the columns show that while their strength should have been Grade **C30**, many of the tests yielded different results, with the strength of the columns in the Emergency ward registering at a mere **C18**."

"...all the blocks at Mater Dei were built with concrete which is less than Grade **C30**. The structures in Block D are at Grade **C23**, which is much lower than the stipulated requirement of **C30**."

tvmnews.mt/en/news/e30-million-required-to-repair-inferior-concrete-at-mater-dei/

Task 1:
Sort the items shown according to how hard you predict each is to break.

Task 2:
Are any items difficult to sort? Propose a set-up that could be used to measure the force necessary to break each item.

Solid Base have special instruments that can measure the compressive force (N) needed to break a sample cube of concrete. This instrument actually measures the **pressure** (force per unit area: N/mm^2) at which the cubes break (*the same size of cube is used for all samples. Why?*). This number defines the grade ('C' rating) of concrete. The higher the number, the stronger and the better the quality of the concrete. Example: C30 concrete will break at $30N/mm^2$.

Task 3: Research and list some applications for the different grades of concrete.

Why does 'tal-franka' aggregate produce lower quality concrete than 'tal-gawwi'?
What else affects the quality of concrete?

Anything else you want to ask the experts please do!

Checkout how strong my friends are in site activity: **SA1!**

Did you know....

Roman concrete was the best concrete EVER!
But we kept our mix secret, even from you guys!!

www.youtube.com/watch?v=Gxj8PnQTY

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Figure 3.7: Preparatory activities in the ERA (left) and Solid Base (right) packs encourage intersubjective approaches through discussion with the site experts.

PA4: Carbonation (the chemistry of falling balconies!)

'It was like a bomb exploding' - the danger of balcony collapses



<https://timesofmalta.com/articles/view/it-was-like-a-bomb-exploding-the-danger-of-balcony-collapses.899888>

What is rusting? (Explain using a chemical equation.)

Imagine a piece of iron rod that is undergoing a rusting reaction. The volume of this rod increases as a result of this reaction. Why?

Previously we mentioned how rebar is used to reinforce concrete structures. Rebar is made of steel (which is an alloy of iron and carbon). When this rusts, its volume will increase. Since concrete is very brittle, this increase in volume will cause it to crack, severely damaging the structure (spalling).

Discuss:

Is there any evidence of rust in the picture above?
Could this be what caused the balcony to collapse and very nearly kill someone?

What could be the fate of this bridge if no maintenance is carried out?

<https://www.independent.com.mt/articles/2018-08-17/local-news/Marsa-Qormi-intersection-flyover-structurally-safe-Infrastructure-Malta-6736194980>



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11

Preparatory Activities (PA)

PA1: Strong acids/weak acids, a practical approach.

Aim: To compare the strength of two acids: Hydrochloric Acid vs Ethanoic Acid

Apparatus:

Test tube rack, test tubes x2, beakers 100cm³ x2, glass rod, measuring cylinder 10ml, Dropping pipettes.

Chemicals:

Ethanoic acid solution 0.05 moldm⁻³ (15 cm³), Hydrochloric acid solution 0.05 moldm⁻³ (15 cm³), Sodium carbonate solution 0.4 moldm⁻³ (50cm³), Universal indicator solution and Chart (pH1-14).

Procedure: Adapted from: edu.rsc.org/experiments/the-acidic-reactions-of-ethanoic-acid/462/article

(Observe usual health and safety precautions)

1. Set up a test tube rack containing two test tubes.
2. Into one of the test tubes place 5cm³ of ethanoic acid solution (0.05 moldm⁻³).
3. Into the other tube place 5cm³ of hydrochloric acid (0.05 moldm⁻³).
4. Add two drops of full-range universal indicator solution to one of the ethanoic acid tubes and note the pH.
5. Add two drops of full-range universal indicator solution to one of the hydrochloric acid tubes and note the pH.
6. Place about 0.5 cm depth of sodium carbonate (0.4 moldm⁻³) solution in a small beaker.
7. Use a dropping pipette to add one drop of sodium carbonate solution to the ethanoic acid tube which contains the indicator. Stir the tube with a glass rod and note any observations. Continue to add drops until the pH is neutral. Count the number of drops you have used.
8. Repeat '7' for the tube containing hydrochloric acid.

Results: Collect your data including any observations in the table below.

Test			
Ethanoic acid			
Hydrochloric acid			

Discuss: Which acid was stronger? Explain how you arrived at this conclusion. Mention two precautions necessary to ensure fair testing. Include also any relevant chemical equations.



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6

Figure 3.8: Preparatory activities based on newspaper articles in the Solid Base pack (left) and suggesting ideas for practicals in the Farsons pack (right).

Preparing quality questions

One requirement for site visits in the SEC 06 Chemistry syllabus 2025 is for students to prepare questions to ask the site experts. Therefore, all activities are designed to cater for this prerequisite. One preparatory activity in each pack is also dedicated to helping students prepare their questions (Figure 3.9). Ideally, students should use the prompts, included throughout, to guide their research to formulate quality, focused questions to ask during their site visit. For example, during the Farsons visit, instead of asking: 'What is conductivity?' a better question could be: 'Why is conductivity testing important in your lab?'. This would indicate to the scientists that the students have prepared themselves well because they are keen on learning. This, in turn, could transcribe into a more positive disposition of the site experts towards the students, thereby making the experience more fruitful and rewarding to all actors. It is advisable to share the questions with the site guides before the visit so they can plan the tour accordingly, thereby further bolstering the learning efficacy of the site visit.

PA5: Prepare your questions.

Based on what you have learned so far, propose 3 questions you would like to ask the scientists at Farsons laboratory during your site visit.

Some ideas you may use to formulate your questions:

- ✓ Quality checks: ensuring accurate and reliable results.
- ✓ Checking that all analytical instruments are working properly.
- ✓ Handling and disposing of chemical waste from the laboratory.
- ✓ Qualifications required to work in this laboratory.
- ✓ Keeping records of the test results. Their implications for production and other processes in the factory.
- ✓ Examples of important tests carried out on a particular product and how they influence their production.
- ✓ Applications related to acid/base concepts in their factory.
- ✓ The company's attitude towards caring and sustaining the environment.

Here is one way you can organise your questions and answers:

Question:	
Answer:	
(Notes)	

PA5: Prepare your questions

Based on what you have learned so far, as a group, propose 3 questions you would like to ask the experts at Solid Base during your site visit.

Some ideas you may use to formulate your questions:

- ✓ The use of aggregates and concrete mix design.
- ✓ Measuring the strength of concrete: good vs inferior concrete mixes.
- ✓ Steel reinforcement.
- ✓ Quarrying land for limestone and other minerals in Malta.
- ✓ Limestone vs concrete in Malta.
- ✓ Construction, the environment and sustainability.
- ✓ Cement and global warming.
- ✓ Alternatives to cement.

Here is one way you can organise your questions and answers:

Question:	
Answer:	
(Notes)	

Adrian Vella (MTL3C)

14

Figure 3.9: Preparatory activities in the Farsons (left) and Solid Base (right) packs with prompts to help students prepare quality questions for the visit.

Site Activities (SA)

These are activities that can be carried out on site, designed around the researcher's experiences during the exploratory visits. These activities aim to encourage students to actively participate in the visit by interacting, through discussion, with scientists working in the field (Figure 3.11) and, when possible, by using state-of-the-art laboratory equipment on site (Figure 3.12). During the exploratory visits, most of the site responsible persons agreed to allowing students conduct simple experiments on site, provided that health and safety standards are observed. Teachers who would like to organise such activities are expected to liaise with the site responsible persons, well in advance, on what activities are possible at the time. Apart from health and safety issues, they must discuss in detail the planned activities focussing on any procedures the students will be carrying out and the availability of resources on site: equipment, consumables, supervising personnel and venue.

Figure 3.10:

Cover page for the Site Activities (SA) section from the ERA pack.

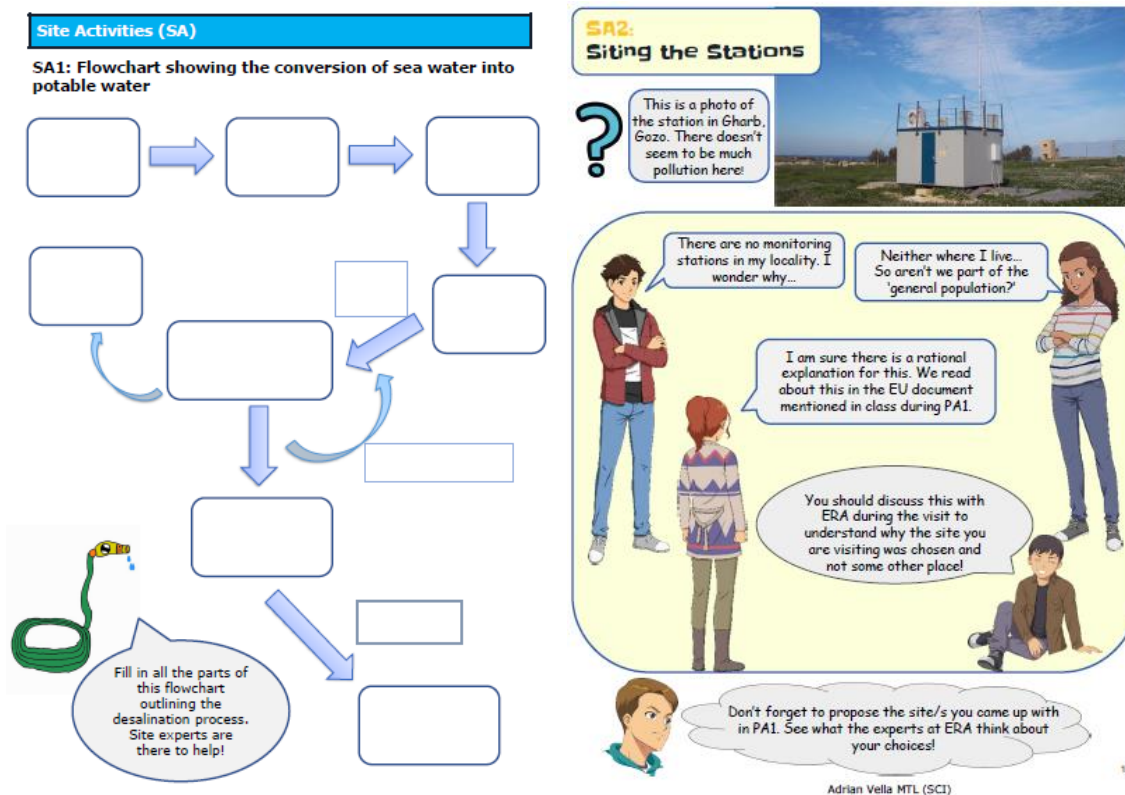
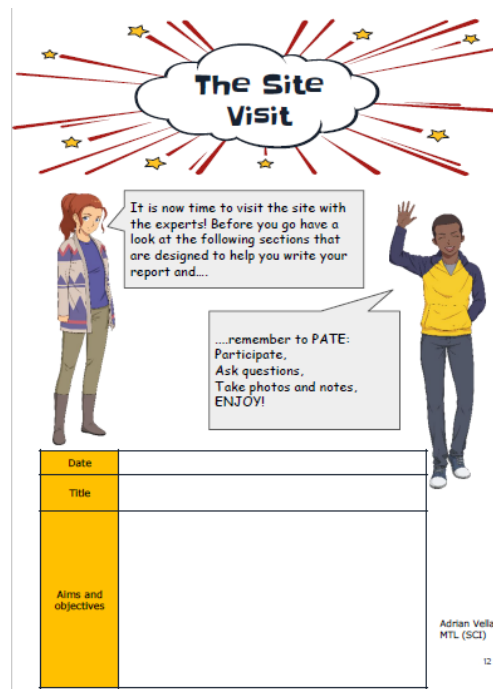


Figure 3.11: *Activities promoting discussion of the reverse osmosis process at the Pembroke RO plant (left) and air monitoring sites at ERA (right) with scientists active in the field.*

Other activities allow students to engage with real-life issues and to complete tasks started at school, based on scientific data obtained on site (Figure 3.13).

Site Activities (SA)

SA1: pH and conductivity meters: calibration and use.

Ask the laboratory personnel to show you how pH and conductivity meters are first calibrated and then used to take readings of samples. Observe closely how each meter is used.



- Write two precautions that are necessary for accurate readings.
- Measure the pH and conductivity of the solutions prepared in PA4 and complete the table.
- Explain any conclusions based on the data you collect. Compare them with your predictions.
- Ask the lab scientists why pH and conductivity are important for their operations.

SA2: Meet the rest of the crew.

Below are some of the instruments used by Parsons laboratory for chemical analysis. Learn more about them and ask your guide for a demo if possible. You will notice most of them have calibration labels. Questions anyone?.....



We do shake and spin, but we NEVER do laundry! How bitter is that?!



Our tests are colourful and very useful!



Alcohol is my game, but getting drunk is lame, so I don't!



As sweet as sugar, that's me!

Adrian Vella (MTL SCI) 52

Site Activities (SA)

SA1: How strong is concrete?

Concrete is classified in grades (C10/C20/C25/C30 etc) according to how strong it is after 28 days from being poured.

The equipment shown here, is used by Solid Base Laboratory to measure the strength of sample concrete blocks. Site technicians can demonstrate the use of this equipment.



You can also decide to try an experiment:

Aim: To investigate the relationship between concrete strength and density.

Results: (the square brackets are for the units)

Mass of block []	Volume of block []	Density of block []	Compressive strength []

Observe how the strength varies with how dark the grey of the blocks is. Try to explain this.

Use this activity to learn about and understand:

- The units used to measure concrete strength.
- Why is the test usually performed after 28 days.
- Which of the reactions in the limestone cycle is important in the concrete hardening process.
- What affects the density and strength of concrete.
- How are these measurements used to classify concrete.
- Why is it important to classify concrete according to its strength.

Conclusion:

Is there a relationship between concrete strength and density? Explain.

Adrian Vella (MTL SCI) 56

Figure 3.12: Site activities encouraging the use of state-of-the-art equipment at Parsons (left) and Solid Base (right) for practical activities.

SA5: Mixing waters to improve quality

News: The Ta' Qali to Pembroke Tunnel

L-ahhar fazi tax-xoghlijiet tal-mina taht l-art bejn Pembroke u Ta' Qali ghal ilma ahjar

[The final stages of works on the Pembroke to Ta Qali underground tunnel for improved water quality]

<https://www.wsc.com.mt/l-ahhar-fazi-tax-xoghlijiet-tal-mina-taht-l-art-bejn-pembroke-u-ta-qali-ghal-ilma-ahjar/>
Posted on October 1, 2021 at 1:29 pm.

Malta will see an overhaul of the distribution and blending system. A large underground tunnel was drilled from Pembroke RO to Ta' Qali Group of reservoirs. Through this 9.4 km tunnel a 1,200mm diameter main pipe was installed to convey desalinated water to the reservoirs at Ta' Qali to increase Ta' Qali's blending potential. Another 800mm pipe will convey blended water back to the central part of the island, where a centralized hub feeding via gravity and booster pumps will supply quality water to consumers effectively and efficiently.

While on-site, consider an activity where you blend tap water (with a high conductivity) with RO water in different ratios and check how conductivities change in each case. Discover what kind of ratios WSC are aiming for and any reasons behind their choice (more info on: <https://www.wsc.com.mt/fireworks-chemicals-tap-water-no-cause-for-alarm/>).

Tabulate your results in a table such as the one below (the two blends shown are sufficient).

Conductivity: RO Water		Conductivity: Tap Water	
Locality: Attard (example)			
µS/cm		µS/cm	
Volume Tap Water [ml]	Volume RO Water [ml]	Ratio Tap / RO %	Final conductivity
		30 / 70	
		40 / 60	

Take with you a bottle of tap water from a locality with high conductivity. Use the online water quality tables from the WSC website to decide who will bring a tap water sample.

Below are some points to help you focus the discussion in your report:

- ✓ How effective is blending in improving water quality?
- ✓ Which blend is WSC currently using? Why?
- ✓ Which blend is WSC aiming for? Why?

Adrian Vella (MTL SCI)

58

SA2: A spoonful of CO₂, makes the balcony go down.....solving the case

In PA4 (pg 11), the chemistry behind carbonation was discussed. Below are some of the key words used during the activity:

Phenolphthalein, passivation layer, rebar corrosion, pH values and spalling.

Learn about how all these are linked and how carbonation is tested for at Solid Base Laboratory. The picture below is a clue.



<https://www.sciencedirect.com/science/article/pii/S2214509516300434>

Task:

1. Ask the lab technicians for a demo.
2. Observe and take note of the apparatus used.
3. Write a procedure, in point form, describing the process.

In your report:

Write a short discussion explaining how carbonation may severely damage concrete structures; include any relevant chemical equations (PA1, pg 7).

Acid rain can have a similar effect on concrete. Explain, including at least one chemical equation that is relevant.

Suggest ways by which concrete structures can be protected.

Conclusion:

Explain what could have caused the balcony/parts of the bridge to collapse.

Adrian Vella (MTL SCI)

57

Figure 3.13: Linking chemistry concepts to real life and contemporary issues: WSC Pembroke RO (left) and Solid Base Lab (right).

Post visit

The general layout of the packs is structured around the rubric presented in the syllabus document, to facilitate the students' report writing. The rubric stipulates that a set of preparatory and site activities need to be described in the report, so the teachers should discuss with the students, either as a class or in groups, which of the activities to include. Towards the end, the rubric also encourages students to reflect on their experiences of the visit and write about them. They are also asked to provide an evaluation by describing any difficulties encountered and recommend any suggestions for improvement. All this is laid out in the final page of each pack, that also includes some instructions and guiding questions for writing the report as shown in Figure 3.14.

The figure displays two side-by-side worksheets for post-visit exercises. The left worksheet is for the ERA pack, and the right is for the WSC Luqa pack. Both worksheets are divided into sections for 'Communication of outcomes', 'Discussion, Evaluation, Reflection and References', and 'References'.

ERA Pack (Left):

- Communication of outcomes:** Includes a section for 'Back in school....' with instructions on how to use notes from the visit to help with the report. It also includes a section for 'In your report it is important to describe your findings...' with a list of points to include.
- Discussion, Evaluation, Reflection and References:** This section is divided into four sub-sections: Discussion, Evaluation, Reflection, and References. Each sub-section contains guiding questions for students to complete.
- References:** A section for listing sources cited or referred to.

WSC Luqa Pack (Right):

- Communication of outcomes:** Includes a section for 'In your report it is important to describe your findings...' with a list of points to include. It also includes a table for organizing notes/information.
- Discussion, Evaluation, Reflection and References:** This section is divided into four sub-sections: Discussion, Evaluation, Reflection, and References. Each sub-section contains guiding questions for students to complete.
- References:** A section for listing sources cited or referred to.

Figure 3.14: Post-visit exercises at the end of each pack, ERA (left) and WSC Luqa (right), are designed to facilitate report writing according to the requirements of the rubric.

3.3.4.2 The Teachers' Guide

For each Student Resource Pack, there is an accompanying Teachers' Guide. These guides contain information to help the teachers organise the visits and manage any of the activities proposed in the pack. The first page of these guides includes the list of learning outcomes followed by pages providing site-specific information on how to go about contacting the site and other logistical details such as approximate duration of the visit, safety, access, a list of the activities in the pack and other considerations (Figure 3.15).

General Site information		Access to students with disabilities	Depends on site. Check with ERA whether the planned site has adequate access.
Environment and Resources Authority Hexagon House Spencer Hill Marsa, MRS 1441 Tel: 2292 3500 Emails: Human resources: hr.era@era.org.mt General: info@era.org.mt		Facilities:	
Locations: 1. Workshop: https://goo.gl/maps/erKh8tSRFvWFPYb17 2. One of the Air monitoring stations: (as at time of writing) Gharb (Gozo), Msida, St Paul's Bay, Attard, Zejtun and Senglea (mobile). era.org.mt/wp-content/uploads/2022/01/AQStationsLocation.pdf		Restrooms	Depends on site
How to contact: Call or send an email to human resources, as per contacts given above (double check the website in case of changes). Alternatively fill in the Customer Care enquiry form on the website. Always include your position as science educator, contact details and explain clearly your intentions. Start communications early, at least three months before the visit.		Lunch/ recreational Areas	Available at most sites, but check before.
Logistical Considerations: ERA: Air monitoring stations and workshop. (This site visit might require transport to two different locations)		Lecture/board room	Available at the headquarters; subject to availability at time of visit.
Student pack resources:		Introductory Activities (IA) IA1: About ERA IA2: Air Quality	
Tour Duration (approx., not including travel time)		Preparatory Activities (PA) PA1: Which Site? PA2: Passive Diffusion Tubes PA3: Extension: Passive Diffusion Tubes: The Challenge PA4: Prepare your questions	
Recommended number of students:		Site Activities (SA) SA1: Site Walk SA2: Siting the Stations SA3: Which pollutants? <i>Optional</i> SA4: The weight of pollution	
Safety considerations			
Availability during scholastic year			

Adrian Velle (MTL SCI)

3

Adrian Velle (MTL SCI)

4

Figure 3.15: Excerpt of the Teachers' Guide for the ERA site visit providing site-specific information.

The next pages explain the scope of the packs, including the restaurant menu concept around which they were designed, and the general layout. The rest of the Teachers' Guide explains each activity, in each case giving: a list of assessment criteria that could be met, a short explanation of the rationale guiding the activity and a more in-depth insight into what is expected of the students. In some cases, a more detailed explanation is given for some of the processes or instrumentation used on

the site to save teachers some time when conducting their research. Answers to all the direct questions are also included (Figure 3.16), whilst ideas in the form of prompts or questions are given for discussion or debate activities (Figure 3.17).

Introductory Activities (IA)

IA1: About Farsons.

A short introduction to the site and its purposes.

Task 1 asks students to list some brands that are manufactured at Farsons. Learners are familiar to a number of these already example: Kinnie, Cisk, San Michel, Elan, Aquadot etc. The common ingredient is water.

Task 2 gets students to think about the enormous environmental impact of industry, even if for seemingly benign objectives such as food and beverage production. Some of the resources that could be included in the table here are:

Resource	Air	Water	Land
Production machinery	Indirect emissions of CO ₂ , particulate matter and other pollutants due to high consumption of electricity.	Washing and rinsing for decontamination. Waste water generation.	Extraction of rare metals and others for manufacturing the machinery. Use of raw materials such as plastic, carton etc needed for production. Waste generation.
Transport vehicles	Emissions of CO ₂ , particulate matter and other pollutants (also for vehicle manufacture)	Indirect: acid rain. Run off oil and fuel road spills.	Extraction of metals and other ores for vehicle manufacture. Road infrastructure.
Office related equipment	Indirect emissions of CO ₂ , particulate matter and other pollutants (electricity)	Manufacture of paper, electronics, wood needed for furniture.	Extraction of rare metals and others for electronics manufacture. Deforestation (furniture manufacture). Toxic waste generation: Ink cartridges, toners etc.

Task 3 focuses on humans as underlying resources in all industrial and business ventures. Sometimes employees are taken for granted at the workplace and treated as machines. This activity attempts to make students aware that humans have rights, notwithstanding that they are being paid a salary. Eventually, when they themselves will be employers or employees, they have to realise that for civil business practices (and society in general) to thrive these rights must be safeguarded and respected. This task uses Farsons as a case study to introduce learners to concepts related to workplace rights and ethical business conduct.

Preparatory Activities (PA)

(Assessment criteria:

8.1a State uses of limestone.

8.2a Describe the use of limestone in industry. (Including the manufacture of quicklime and slaked lime. As an aggregate in construction.

8.2c Describe the economic and environmental impact of open quarrying of stone.

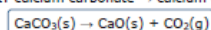
8.3c Debate the economic and environmental impact of open quarrying of stone.)

PA1: The chemistry of limestone: The Limestone Cycle

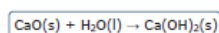
Students can learn about the chemical reactions that are important in the production of cement, hardening of concrete and deterioration of concrete structures. These will be expounded upon in the upcoming activities. The names of common lime compounds are clearly laid out as they are often used interchangeably. The activity is also a revision exercise on past topics.

Answers:

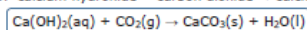
1. calcium carbonate → calcium oxide + carbon dioxide



2. calcium oxide + water → calcium hydroxide



3. calcium hydroxide + carbon dioxide → calcium carbonate + water



Which of reactions 1, 2 and 3:

i. Is a thermal decomposition reaction? 1

ii. Is a metal oxide with water reaction? 2

If the product of this reaction is dissolved in water, how would it affect litmus paper? Why?

It would change red litmus to blue since calcium hydroxide releases hydroxide ions (OH⁻) in solution, which makes the solution alkali.

iii. Is a neutralisation reaction? 3

Why can it be classified as a neutralisation reaction?

An acidic gas (CO₂) is reacting with a base (Ca(OH)₂), in solution, to give salt and water only.

Adrian Vella (MTL SCI)

9

Figure 3.16:

Model answers are provided in the Teachers' Guides for the Farsons (left) and Solid Base (right) packs.

Preparatory Activities (PA)

PA1: Understanding conductivity in practice 1

PA2: Understanding conductivity in practice 2

(Assessment criteria:

3.2b State criteria of purity for water. (Limited to melting point, boiling point and conductivity.)

3.3f Explain the properties of ionic compounds.)

Two activities that allow students to deepen their understanding of the theory explored in previous activities through practical work. They also suggest possibilities for fieldwork or laboratory practicals.

PA3: Acceptable levels of water quality: who decides?

An activity designed to expose students to socio-scientific issues related to water quality. Access to good quality water is a basic human right that is highly regarded and legally enforced in Europe. Learners are further encouraged to be critical in their analysis of water quality data.

PA4: Prepare your questions

Here students are given time to consolidate what they have learnt into questions which they will be asking during the visit as a group.

PA5: Extension: New Water from wastewater!

This activity attempts to stimulate debate regarding local investments into projects related to sustainability. Students are asked to adopt a critical stance in defending their own proposal against another. This activity would be very suited also for the RO plant visit. The arguments may be rather complex and teacher intervention is encouraged. Below are a few prompt ideas:

- Wastewater can be safely dumped into the sea once treated and RO plants can produce potable water from seawater. Given that RO plants cost roughly the same (if not a bit less) as New Water plants, why invest in the latter?
- Desalination of water through RO is safer and less demanding than producing lower class 'New Water' that has limited applications, such as agriculture. Also any dangerous substances that may escape New Water filtration technology can end up in local agricultural produce.
- Dumping wastewater into the sea, even if treated, is still a source of pollution of the aquatic environment. With New Water projects, up to a third of the wastewater can be reclaimed, thereby reducing coastal pollution.
- It would be a waste to use potable quality water for agricultural when plants can thrive with lower quality reclaimed water.

Adrian Vella (MTL SCI)

10

Figure 3.17:

Examples of prompts provided in the Teachers' Guide for the WSC Luqa site visit to spur discussion.

3.4 Evaluating the resource pack

Chemistry teachers from the state, church and independent school sectors, were invited to review the resource pack and fill in an online questionnaire, designed to get feedback on the pack. To do this, the Education Officer for Chemistry, the Head of Department for Chemistry within the Secretariat of Catholic Education and the respective Heads of the independent schools, were asked to act as intermediaries to share a link to an online drive containing the pack and the questionnaire only with those teachers who expressed their interest to participate in the study. This procedure was adopted to adhere to the research ethics directing this project and as an added level of protection for the anonymity of the teachers, to ensure that the feedback obtained is as reliable and unbiased as possible.

This evaluation exercise attempted to recruit ten Year 9 to Year 11 Chemistry educators on a first come first serve basis as follows:

- the first five (5) respondents from state schools,
- the first four (4) respondents from church schools
- the first (1) respondent from independent schools.

3.4.1 Sampling

Since only secondary Chemistry educators were invited to evaluate the pack, sampling for this second stage was also purposive as feedback is only being sought from a particular group of expert individuals to confirm or disconfirm (Palinkas et. al, 2015) the assertions in the resource pack.

3.5 Data collection methods

The research tools for this dissertation include semi-structured interviews and questionnaires. These have been used in similar projects, for example, Mills, Ashford & McLaughlin (2006) and Muscat & Pace (2013).

3.5.1 Semi-structured interviews

Semi-structured interviews were conducted during the exploratory visits as explained in section 3.3.3. The following table shows the content of these interviews.

Table 3.4: The guiding questions for the interview were organised into sections as shown.

Section	Purpose
Introduction	To obtain information about the main operation of the site. It included questions about any chemical processes that are used, quality control procedures and research projects, especially those related to chemistry. At this stage, possible learning outcomes that could be addressed during this visit were proposed by the researcher and discussed with the site responsible person.
Logistics	To obtain logistical information to organise the visits such as contact procedures, number of students, available facilities, safety considerations and other factors as shown in Table 3.2
During the Site Tour	To obtain site-specific information; for instance, to learn more about the most important aspects of the operation educators should focus on, because they are relevant to the learning outcomes.
Conclusion	To get information about the interviewees' personal views on the subject, as informed by their personal experiences working in the field. Most importantly, about whether the introduction of site visits as an integral aspect of the curriculum could: be conducive to a deeper understanding of chemistry and motivate students to pursue careers in science.

A copy of the semi-structured interview is found in Appendix A.

The semi-structured interview was seen as the most fit for purpose when collecting information on the sites. This method of data collection occupies a particular place on the quantitative/qualitative continuum where objective information

can be collected for easier decision taking as subjective bias is kept to a minimum, whilst allowing for some heuristic flexibility to, for example, tailor guiding questions according to site specific qualities (Cohen et al., 2017, p. 508-511).

Since the interview was intended as a semi-structured one, the purpose of these questions was only to serve as a guide, since a dialogic approach was preferred in contrast to a rigorous question and answer routine. The researcher often redirected certain lines of enquiry or added new ones to obtain as much information on the site and about how students could benefit from this visit.

After each exploratory visit, notes from these interviews together with the researchers' reflections, observations, casual conversations and ideas for activities were logged. These were referred to again when designing the resource pack.

3.5.2 Questionnaires

A questionnaire was the instrument of choice to obtain feedback on the resource pack from Chemistry teachers. Since the sample size was small, an online semi-structured questionnaire was used. Semi-structured questionnaires have been described as powerful tools as they direct the focus of the themes for which data is sought without "presupposing the nature of the response" (Cohen et al., 2017, p.475). So even here, respondents are allowed to contribute their own insights, which are considered more valuable to this dissertation in contrast to purely quantitative methods. Questionnaires also allow for quick and easy collection of data while protecting the anonymity of the respondents; these were both necessary requirements for this project.

The questionnaire contained mainly close-ended questions, in the form of Likert scales, and a few open-ended questions where participants could add their own views, comments and suggestions. It was divided into four main sections as shown in Table 3.5 below.

Table 3.5: *The online questionnaire was structured into the sections shown below.*

Section	Description
Teachers' views on site visits	This section contained five questions, one of them open-ended, intended to explore teachers' perception of site visits.
Teachers' general outlook on the packs	Here two close-ended questions were presented to gauge how well the pack conforms to the general requirements of the syllabus and to obtain a rating of the general presentation/layout of the pack.
Teachers' feedback on the packs specific to each site visit	This section is divided into six sub-sections. The first one contains two close-ended questions comparing the level of difficulty for each visit and their relevance to the learning outcomes proposed in the pack. This is followed by another five sections, one for each site, each containing four close-ended questions and two open-ended. The close-ended questions ask respondents for feedback specific to the site visit's introductory, preparatory and site activities and their ability to guide students into preparing quality questions. The open-ended questions ask teachers for their views on the strengths and challenges of each visit and also to propose any recommendations.
Conclusion	One open-ended question is presented here allowing participants to proffer any general comments and suggestions.

3.5.3 Timeframes

The invitation to participate in this project was extended to the intermediaries: the Education Officer for Chemistry, the Head of Department for Chemistry within the Secretariat of Catholic Education and the respective Heads of the independent schools, at the end of the scholastic year. Two reminders were sent, through the intermediaries, during summer. A final reminder was sent just before the new scholastic year. Nine responses were received by the end of the evaluation process.

3.6 Data Analysis

The data collected in this project was intended to guide the researcher in proposing valid and plausible solutions to the research questions. Attempts to find patterns, make generalisations or generate theories are beyond the scope of this dissertation. The small sample size collected for the feedback questionnaires precludes the use of rigorous statistical analysis common to quantitative methods. The approach was a more qualitative one, to get focused feedback over a short time period with minimal bias. For this reason, close-ended questions, in the form of Likert scales, were used in this research to elicit attitudes and opinions (Mills, Ashford & McLaughlin, 2006). Responses to the open-ended questions were analysed thematically through an iterative process of reading and re-reading data and using any emergent insights to guide critical reflection on the proposed resources (Mills, Ashford & McLaughlin, 2006) in order to pre-empt possible issues while suggesting improvements and opportunities for further research.

3.7 Ethical considerations

Since this project involved the collaboration of participants at different stages, permission to conduct research had to be obtained from the University Research Ethics Committee (UREC). This is the entity responsible to ensure that the principles of ethical research conduct are observed for all research that occurs within the University of Malta. In order to do this all information and permission letters, consent forms and recruitment procedures, for each stage, had to be submitted for review to the respective Faculty Research Ethics Committee (FREC). Details of these

procedures are laid out below, while copies of all permission letters and consent forms used can be found in the Appendix section.

Stage 1: Gathering site information prior to designing the resource pack.

The cooperating institutions were contacted through details that were publicly available on the sites' respective websites. A letter was sent asking for written permission, from the person in charge of the site, such as the General Manager, Director, Head of Department or other, to allow the researcher to visit the site with a designated site responsible person and conduct the interviews.

Before the interviews, the participants were asked to sign the consent form. During the interviews, no data related to the identity of the participants was requested to protect their anonymity. The audio recordings were not transcribed, but stored on a password protected online cloud drive to which only the researcher and the supervisor had access. These were deleted six months after the research was completed. Verbal consent for any photos was sought during the visit as necessary.

Any contact references quoted in the resource pack were kept generalized by pointing to a department, rather than to an individual, for example, human resources, procurement or operations management, to maintain privacy and preserve anonymity. When disseminating results, no specifics of the position occupied by the participant were given. They are referred to solely as: the site responsible persons.

Stage 2: Producing the resource pack and evaluation.

Chemistry teachers from the state, church and independent secondary schools, were recruited to review the resource pack and fill in an online questionnaire. To do this, written permission was sought from the Education Officer for Chemistry, the Head of Department for Chemistry within the Secretariat of Catholic Education and the respective Heads of the independent schools, to act as intermediaries.

A letter was sent to the intermediaries explaining that their responsibility would be to share a link to an online drive, containing the pack and the questionnaire, only with those teachers who express their interest to participate in

the study. This procedure was adopted to protect the anonymity of the teachers, not only in terms of personal details but also details related to school provenience. The only information requested was whether the respondents were employed in a state, church or independent school and how long they have been teaching secondary education Chemistry. Pseudonyms were used in the results section so as not to reveal the participants' identity to protect their interest and prevent any harm.

Throughout both stages, participation was voluntary and any of the participants could opt out of the research at any point without any justification. No information that can be used to identify participants, even if by attribution, was sought or recorded. No inducements, rewards or compensation were offered. The only benefit was indirect and in the long term, by motivating students to follow careers in Science, thereby enriching the scientifically literate workforce.

3.8 Conclusion

This chapter describes the design and implementation of both stages of this project. These stages were similar to those used in education design research methods and included a preliminary research phase, consisting of exploratory visits to potential sites, where data was collected using a semi-structured interview. This was followed by a prototyping or development phase that included producing a resource pack followed by a single evaluative exercise using an online semi-structured questionnaire. In the next chapter, the findings of the evaluation will be presented following a thematic analysis of the questionnaire responses.

4. Results

4.1 Introduction

This chapter provides a summary of the outcomes of Stage 2 of the project, where teachers evaluated the pack and gave their feedback through a questionnaire. This evaluation was characterised by teachers expressing their views on site visits, followed by feedback on the general presentation of the pack and an outlook of the strengths, challenges and recommendations specific to each site visit. Teachers were also given space to express any other opinions and reflections on the project.

4.2 Participant profile

A total of nine responses, out of ten, were received as follows:

- Four (4) from church schools,
- One (1) from an independent school and
- Four (4) from state schools.

Table 4.1 below shows the participants' profile.

Table 4.1: *Profile of school sectors and years of teaching experience for the participants.*

Participants	Sector	Years of Teaching experience
C1	Church	6-14
I2	Independent	1-5
C3	Church	6-14
C4	Church	6-14
C5	Church	6-14
S6	State	6-14
S7	State	15-24
S8	State	6-14
S9	State	6-14

4.3 Teachers' views on site visits

Nearly all respondents (N=8) would consider at least one site visit as coursework. Only one participant would not consider site visits because the assessment criteria proposed in the syllabus are not clear.

Teachers cited various reasons for the potential benefit of site visits. The majority (N= 7) concurred that site visits can encourage students to pursue a career in science as shown in Figure 4.1. One reason given by S6 is that: *"Site visits will place the chemistry in a different context, and the students will be able to better understand its relevance, especially related to different career paths"*. I2 also acknowledges that it is important for students to *"have an idea of what it is like to work in the industry"*. Some, (N=2), also think that site visits may help students achieve their learning outcomes (Figure 4.1).

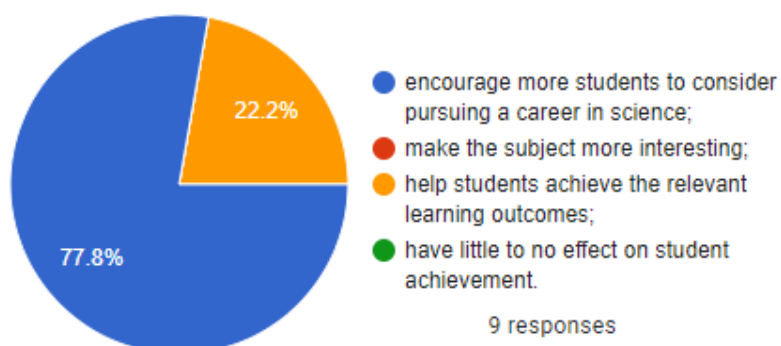


Figure 4.1: Responses to the close-ended question about teachers' views on site visits.

Teachers cited other reasons that focused on how site visits could make chemistry relevant to real-life scenarios. For example, S8 and C1 appreciated that *"the activities will help them [the students] relate chemistry to everyday life"* (S8) because the pack: *"makes the subject much more relevant. It puts theory into real-life applications and gives a reason and a meaning of why students have to study and know certain things - not just to answer an exam question"* (C1). A specific example is given by C4: *"The activities are very much differentiated and very related to the daily use of acids and alkali "* (Farsons pack).

An outcome of linking activities to real-life contexts was that some are *“suitable even for students that do not consider Chemistry as their subject. I think they could learn something interesting for their own use in their everyday life.”* (C1, WSC Luqa Lab). During site visits, students can also experience how particular procedures in chemistry carried out at school, are applied in the industrial context, for instance, C5 mentioned that: *“the students will actually see the use of titration in industry”* (Farsons pack). The activities also made some respondents aware of the importance of chemical reactions in everyday life; C1 pointed out: *“It brings all the theory, patterns of reactions etc. (which most students would say, but ‘why do I need to study this’) into real-life scenarios and it made me even as a teacher appreciate the links behind all the ‘theory’ that we teach”*. Others valued how the resource packs link to local contexts and commended this initiative: *“Well done for including water quality live map with reference to hardness/nitrates/micro-organisms in student guide IA3 (Introductory Activity)- students will really get to know more about the water they use at home!”* (S9, WSC Luqa).

Moreover, site visits were described as making learning Chemistry enjoyable and accessible to students with diverse learning abilities, *“Site visits make learning enjoyable, tangible and accessible to a wide student spectrum - the very meaning of learning chemistry in context from real-life experiences.”* (S9).

4.4 Teachers’ feedback on the resource packs

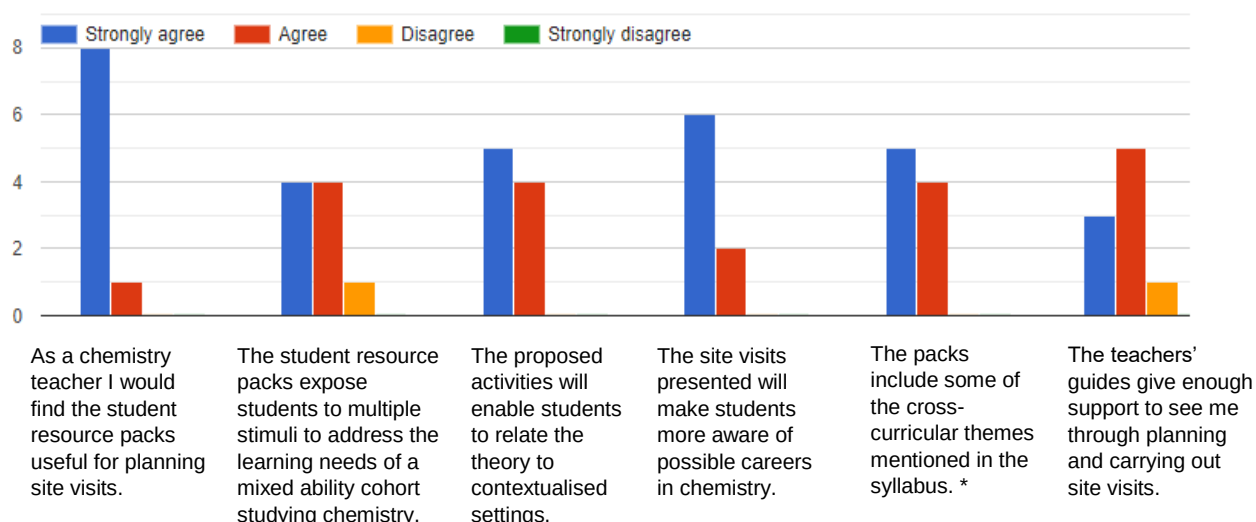
This section summarises the teachers’ evaluations of the resource packs. The focus of the feedback seemed to converge into the following five themes: teachers’ general views on the packs, their presentation and layout, the quality of the activities, challenges, and recommendations. These emerged following a thematic analysis of the responses and are described in sections 4.4.1 to 4.4.5 below.

4.4.1 General views

In general, the teachers’ outlook on the pack was quite positive since most either ‘Strongly Agree’ or ‘Agree’ with the statements shown in Figure 4.2. The packs were, for the most part, seen as useful resources to help teachers organise and plan

site visits since *“ideas given in these booklets can serve as an excellent starting point”* (S6). Some considered the pack *“a very valuable Learning Resource for teachers and students alike”* (S9). The respondents also think that the pack exposes students to multiple stimuli, thereby addressing the needs of mixed-ability classes, and includes some cross-curricular themes mentioned in the syllabus (Figure 4.2).

Most respondents (N= 8) acknowledged that the Teachers’ Guide gives adequate support because *“the teachers’ guide is very informative and well designed.”* (S6) and it also provides *“model answers [which] are very well detailed and well graded for secondary school level students”* (S9). Therefore, the Teachers’ Guide was considered to be *“extremely helpful and will certainly simplify the work for a teacher starting out with organising a site visit”* (S9, referring to the RO site visit as an example).



* Namely: digital literacy; diversity; entrepreneurship; creativity and innovation; citizenship; sustainable development; learning to learn, cooperative learning and literacy.

Figure 4.2: Level of teachers’ agreement with the statements shown.

Some shortcomings were also pointed out; these will be discussed further in section 4.4.4 which reports some challenges teachers foresee with the packs.

4.4.2 Presentation and layout

Overall the teachers rated the general presentation/layout of the resource packs as 'Excellent' (N =5) and 'Good' (N=4) as can be seen in Figure 4.3.



Figure 4.3: Participants' rating of the overall presentation of the packs.

Some of the activities in the packs were described as having an attractive format because they are visual and straightforward and therefore present “a student friendly layout” (C4). The comics style set-up of the ERA pack was found to be especially appealing by some respondents:

“I loved this setup of worksheet with cartoons and dialogues. I think it will be very appealing for most of the students who have just taken up Chemistry at year 9”
(C4)

“The cartoon layout style is amazing/I really like it! This resource connects Chemistry not just with the local context but also with the context of how students learn in everyday life-pictures, cartoons etc.” (S9).

The activities were also found to be well sequenced such that “Students will be very well guided” (S8) into achieving the learning outcomes.

The introduction of newspaper articles in the packs was well received by some respondents as it was found to highlight the importance of learning Chemistry in context: “I loved the last part of relating the topic to newspapers and discussions” (C4). Another participant commented that such articles can be a useful learning resource:

“Excellent primer on concrete/limestone and reference to the concrete quality issue at Mater Dei (PA3). The PA4 activity-falling balconies was so important- the next day

after I read this activity I could not but help observing the sheer number of deteriorating balconies in a well-populated street!” (S9, Solid base)

Two of the participants (S6 and S9) comment positively on the restaurant menu concept because teachers are allowed to *“use the suggested activities or make use of new ones”* (S6). Since the introduction of site visits in the Chemistry syllabus is new to all teachers, such activities were found to be beneficial because: *“the ideas given in these booklets can serve as an excellent starting point”* (S6).

Contrastingly, two of the participants mentioned that the layout of the packs could be improved. Participant C4 contends that some of the activities had lengthy presentations with too much wording and too little spacing between the lines. C1 also argued in favour of more spaces where students can write.

4.4.3 Quality of activities

The general views expressed in section 4.4.1 already give some insight into teachers’ perspectives on the quality of the activities. These views are, to an extent, also apparent in the responses specific to each site visit. For instance, if relevancy to learning outcomes is considered an indicator of quality, then as Figure 4.4 suggests, the activities could be considered of a sufficiently high standard since nearly all teachers described the activities for all site visits as ‘Very relevant’ or ‘Sufficiently relevant’ to the learning outcomes within the syllabus.

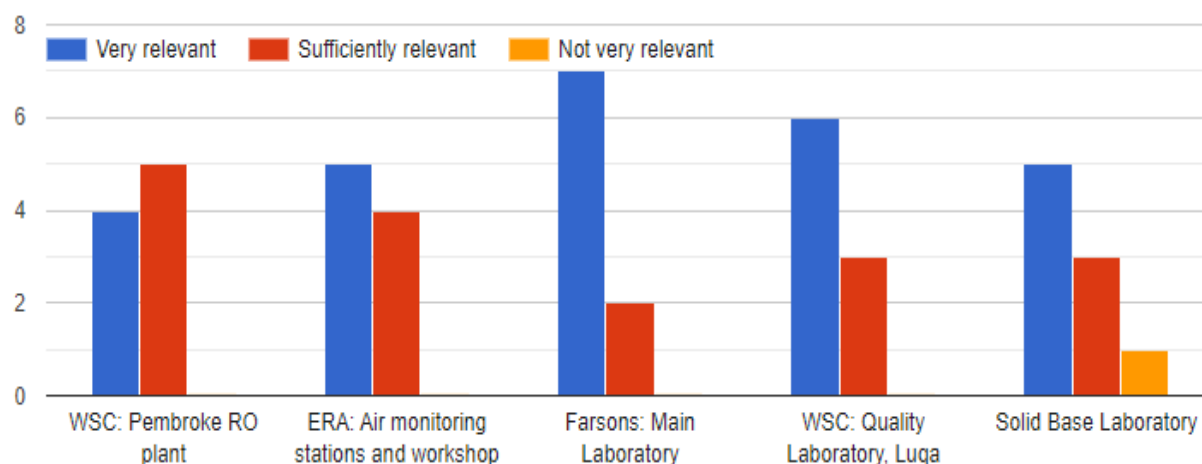


Figure 4.4: Respondent ratings of relevancy of learning outcomes to the activities proposed for each site visit.

In addition, the majority of respondents either “Strongly agree” or “Agree” that the Introductory (IA), Preparatory (PA) and Site (SA) activities can achieve their intended goals (section 3.3.4.1), as shown in Figures 4.5 to 4.7.

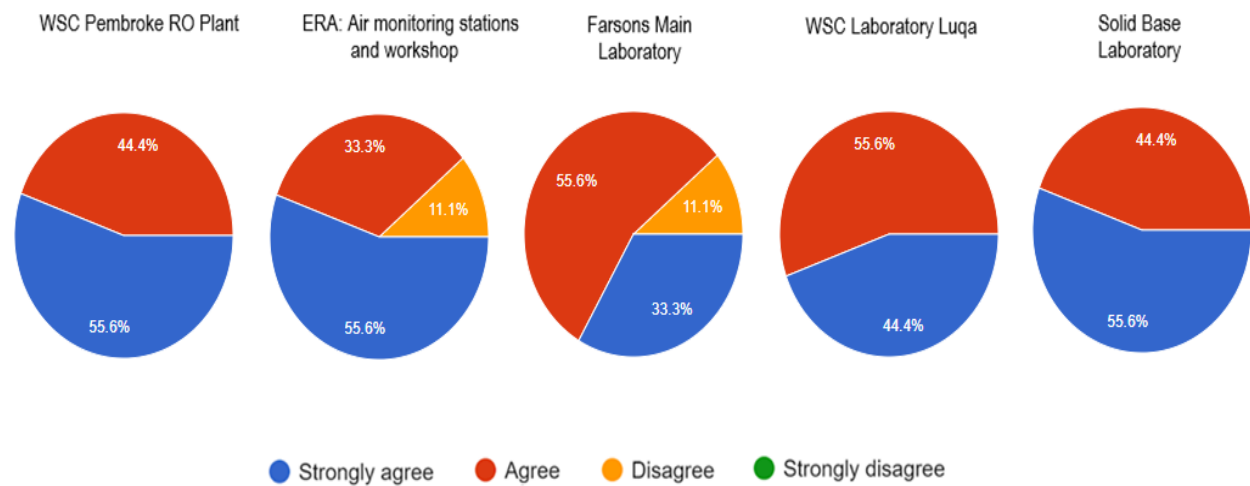


Figure 4.5: Respondents’ level of agreement with how well the Introductory activities introduce the students to the processes occurring at the site and to any relevant general knowledge.

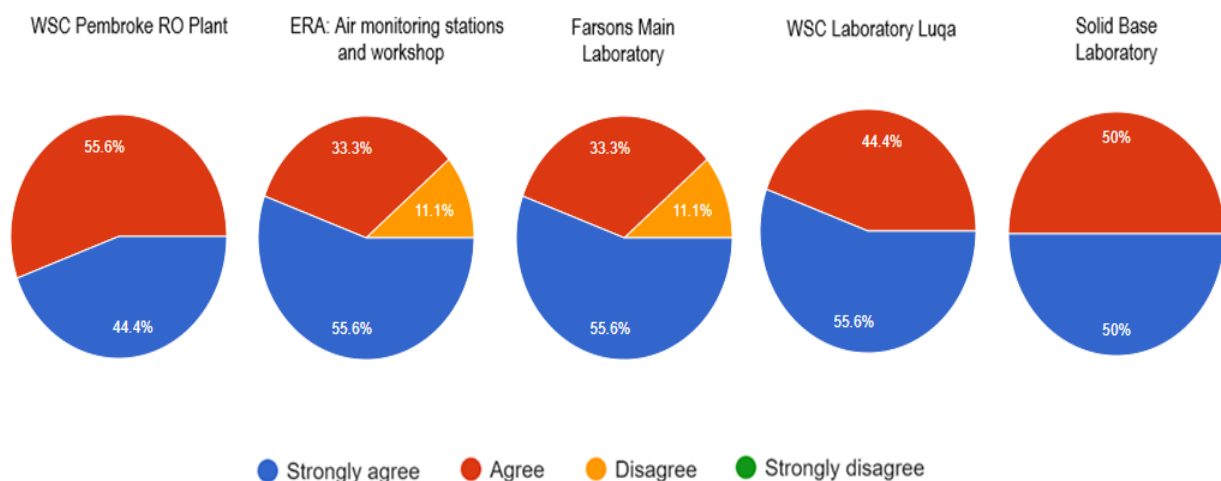


Figure 4.6: Respondents’ level of agreement with how well the Preparatory activities impart to students more in-depth knowledge of processes on the site.

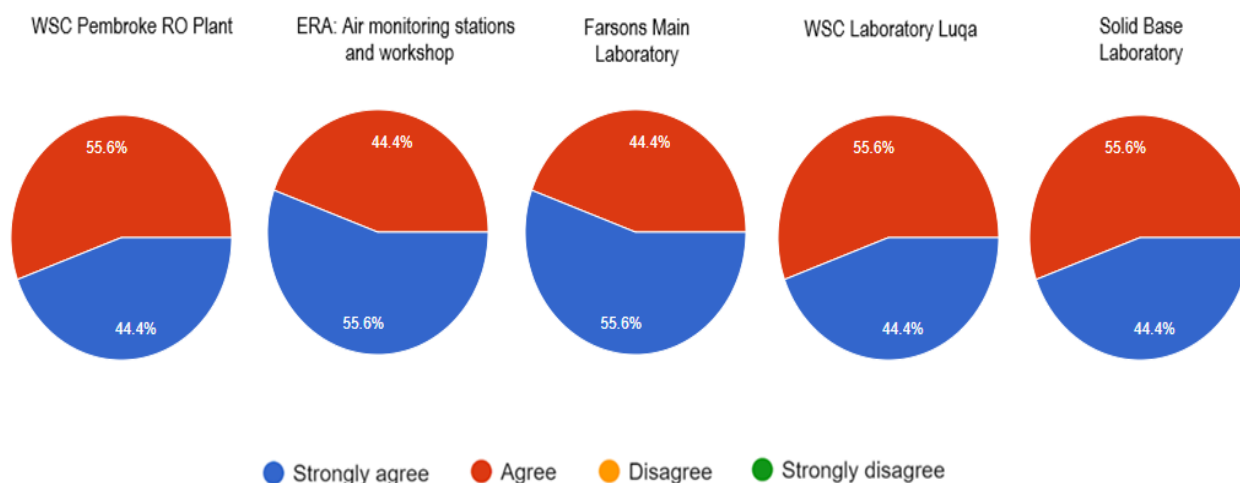


Figure 4.7: Respondents' level of agreement with how well Site activities allow students to sufficiently engage with the environment on site, which could result in significant learning gains.

Similar views were expressed in the open-ended responses; S6 stated that in general the “Introductory and Preparatory activities are very useful and lead well to the site activities” and C1 remarked that the packs are “very well thought and structured” and “it was challenging to come up with a suggestion for improvement at times”. The majority of teachers also thought that the prompts presented in the packs adequately guide students to formulate quality questions (Figure 4.8).

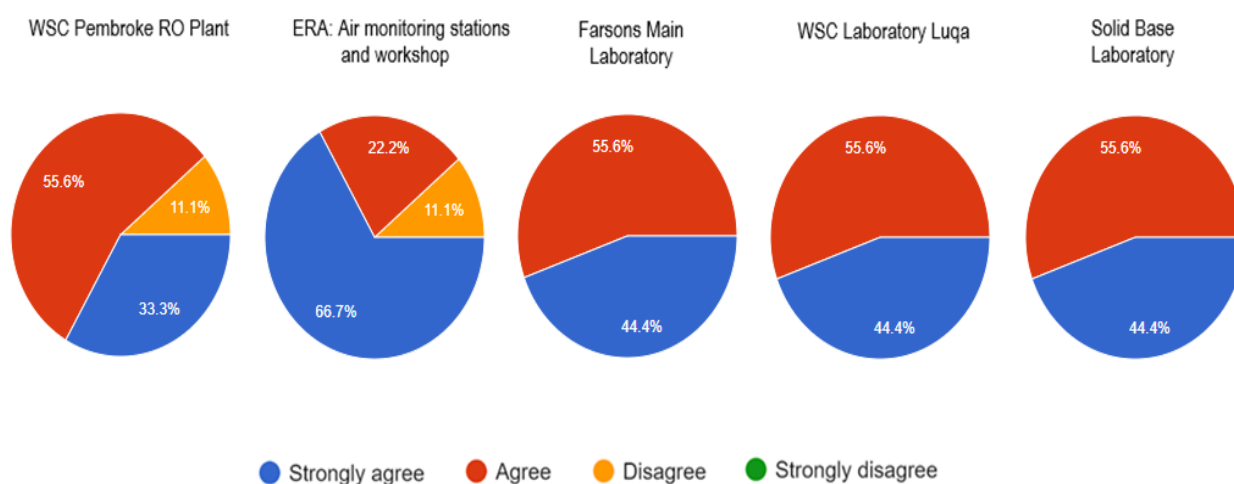


Figure 4.8: Respondents' level of agreement with how adequately the prompts, presented in each pack, guide students into preparing quality questions to ask during the visit.

Other views concerning the quality of the activities can be inferred from replies to the open-ended questions. For example, C1 commented, on more than one occasion, how various concepts link well together and to real-life applications. S9 described one of the online resources as “*a very powerful tool and certain to generate student interest*” (WSC Pembroke). S9 also refers to the Farsons pack as having an “*excellent range of activities*”, that are well-sequenced. Others, C5 and S6, posit that the Farsons activities are good, well guided and link well to each other, while C5 also states, for the WSC Luqa pack, that: “*on the whole, the activities are well prepared*”.

C4 found the Solid Base activities: “*very, very interesting*”, as they provide: “*a lot of chemical setting to the building story, making students appreciate the advantages and disadvantages of concrete and limestone*”, a context C4 was unaware of. Contrariwise, S6 found the Solid base site visit the most limiting and “*hard to relate it effectively to the learning outcomes listed*”. However, for this pack, S6 later commented that the “*First site activity is very well guided and it can be done by students with varied ability*”.

4.4.4 Challenges

In their evaluation, the teachers brought up some challenges they foresee with the proposed activities. These were grouped as follows: level of difficulty, students' prior knowledge, students' behaviour and other concerns.

4.4.4.1 Level of difficulty

In general, the respondents classed the pack activities as being appropriate for most students but might prove challenging to some; only a few perceived some of the packs as 'Easy' or 'Too difficult' (Figure 4.9). Some reasons behind their choices could be inferred from the open-ended responses. For example, according to C5: *"The idea of the schematic diagrams is good. It is something which can be achieved by students with different abilities"* but, contrastingly, S6 stated that: *"For some students filling up the information of flow charts (and schematic diagrams) can be challenging"*. S6 also thought most activities need to be broken down further to be achievable by some students making time constraints an issue. This view was also shared by S9 for the passive diffusion tube activity in the ERA pack.

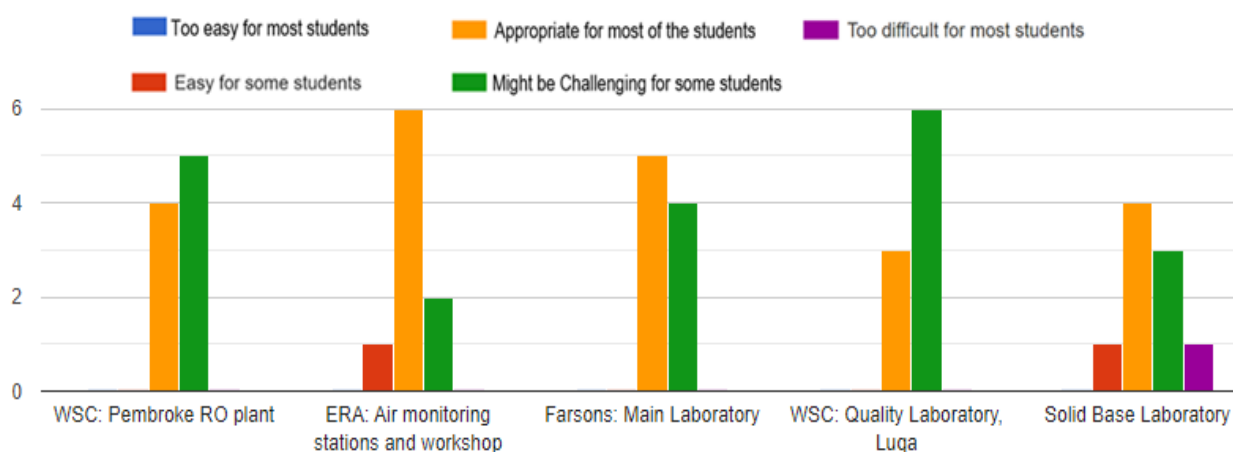


Figure 4.9: The perceived difficulty of proposed activities, for each site.

Other contentions were brought up by C4 and S9, who thought the wording was at times too complex such that some of the English used could “deter students” (C4) and *“Although I found most of the activities interesting, some of them are quite challenging and present too much chemical terms.”* (C4). S9

suggested for some of the recommended articles be paraphrased and/or limited to key information, thereby implying that the wording may be too complex for students at this level. Also, according to C4 and C5, data and graph interpretation could prove difficult for some and *“can decrease the enthusiasm in students”* (C5).

4.4.4.2 Students' prior knowledge

Most of the preparatory activities require students to carry out research and formulate questions to be asked on site. One of the teachers, (S8), thought that students at this level may lack the necessary research and question-formation skills. This, compounded with a lack of experience in paraphrasing and self-reflection, could challenge the success of site visits. C5 seemed to share similar thoughts since rather than come up with more questions: *“Most students will limit their questions and base them solely on the 5 points/ ideas mentioned in the pack”*.

During site visits, students are likely to come across new concepts or ideas. C1 questioned whether students could effectively learn new theoretical knowledge on site or whether this should be covered during classroom Chemistry lessons in preparation for the site visits. Consequently, this teacher thought that: *“it can be challenging to ensure that students have the necessary background knowledge needed prior to linking and be able to discuss certain things as this is a higher order thinking skill. It might be a bit overwhelming for students.”* (C1, WSC Pembroke RO pack). Taking this further, C1 pointed out how addressing this issue inherently makes the planning of lessons related to site visits crucial since the theoretical lessons in class need to be carefully planned and sequenced to complement the preparatory activities, especially when deciding which of the learning outcomes to cover throughout the years.

4.4.4.3 Students' behaviour

Students' behaviour and engagement with onsite activities was another concern that emerged from the feedback. I2 thought that behaviour management on site, especially if the student cohort is large, could be disconcerting: *“The number of students is the most challenging. Some students are difficult to engage or for them*

to behave”. Also: *“Not all students will be engaged. Depends in the cohort you might have. Some students see site visits as a free lesson away from the school setup”* (I2).

4.4.4.4 Other concerns

Some other concerns were voiced by C5 and S6. C5 argues that the amount of work for each site visit varies and therefore difficult to be consistent in terms of standards that need to be adhered to, especially when compared to other coursework modes available in the syllabus. Notwithstanding, C5 added that *“the amount of work required in these site visits is quite reasonable”*. S6 points out that: *“Most of the activities need to be broken down further for students with lower-attainment level, and this would require more time spent on each activity. The length of this whole process can be worrying when trying to integrate it into a new Scheme of Work”*. This teacher proceeded to raise a very important concern about student absenteeism: *“With such a lengthy process leading to the site visit, consideration should be given on how to go about keeping in the loop students who are absent for a part or parts of it”* (S6).

4.4.5 Recommendations

Teachers were asked to put forward some recommendations as part of their feedback. Some proffered ideas on how specific activities within each pack could be improved; others gave suggestions on further activities that could be included within particular site visits. The final part of this section outlines some recommendations for improvement to the pack in general.

WSC Pembroke RO Plant

Starting with the WSC Pembroke RO pack, C4 proposed to include some information on *“how water is obtained in third world countries”*, while S9 suggested that a blending of water preparation activity is done at school as practice for the site activity. S9 would also paraphrase the research article to make it more student-friendly. S6 recommended the use of flashcards to help students who find filling in flowcharts difficult.

ERA: Air monitoring stations and workshop.

In the case of the ERA pack C1, C4 and S9 found the passive diffusion tubes activity interesting and suggested that more information should be included on these tubes. C1 felt that there should be more focus on the impact of pollutants on health and the environment as these provide reasons for the necessity of air quality monitoring. C4 thought that something about possible seasonal trends of pollutants should be added. C4 also emphasised that this pack should offer more guidance for graph interpretation, for instance, by including worked examples, as the way they are presented might confuse some students. S6 adds that extra activities, apart from the Site Walk activity, should be planned to keep students engaged while other groups are visiting the station.

Farsons Main Laboratory

For the Farsons pack, C1 and S9 strongly suggested that theory and practicals with acids, bases and titrations are covered in class first. Since the topic of acids and bases is quite challenging and prone to misconceptions, especially in matters related to pH, concentration and strength of acids and bases, C1 would relish some further guidance on lesson planning for this visit, in particular on how to include some of the introductory and preparatory activities into the classroom theory lessons that tackle the learning outcomes relevant to this pack:

“I would guide teachers on how to go about the 'lesson planning'. I know that this is very subjective. But providing a guide can help set a framework upon which teachers can build and amend according to their teaching”.

WSC Laboratory Luqa

Some parts of the WSC Luqa Laboratory were seen as too complex by S9 and recommended that only key terms or parameters are included in these sections, while reference to spectroscopy should be avoided. S6 advocated for more guidance for students to find information on the WSC website and for introductory activities to be held in pairs or small groups so they are more effective for lower-achieving students. These activities are best done in a computer lab or by giving students access to tablets.

Solid Base Laboratory

Finally, for the Solid Base pack, C1 recommended a 'Maths tip' to be added for the activity involving density. C4 also thought that to avoid long sections of text the information would be best presented in point form, without too much extra detail, and for colourful flowcharts to be included as part of the activities.

General recommendations

As general recommendations, C1 suggested that more spaces, where students can write their notes, are added so all the information related to the site visit is contained within the site visit booklet. According to S6, students should be encouraged to take photos during the visit to help with their recollections of the site. C1 and C4 also felt that good links can be made to certain topics in Biology, for example, osmosis, fermentation and microorganisms:

"Again I would include a link with biology - e.g. ta Barkat sewage treatment plant is also covered in biology- even if it's just a small 'callout' or concept cartoon reminding students that they covered this in biology and how water quality affects health for example-microorganisms and associated diseases." (C1, WSC Luqa).

4.5 Conclusion

This chapter provides a detailed summary of the feedback received from nine secondary school Chemistry teachers, from the state, church and independent school sectors, who participated in Stage 2 of this project. This involved reviewing the pack and evaluating it utilising a questionnaire. The responses were analysed and grouped into two main themes: Teachers' views on site visits and Teachers' feedback on the packs. The latter was categorised further into General views, Presentation and layout, Quality of the activities, Challenges and Recommendations. The next chapter features the researcher's reflections and critique of the emergent themes from the results, followed by some limitations of this study and possible avenues for future research.

5. Discussion and Conclusion

5.1 Introduction

This project set out to identify potential site visits that could enhance learning and meet the syllabus requirements through education design research, thereby answering the two research questions proposed in section 1.4.1. The results and outcomes of these methods were also used to guide critical introspection on behalf of the researcher to elucidate the strengths of the pack, identify challenges, pre-empt possible issues and propose avenues for improvement. This chapter provides a discussion of the extent to which the project achieved its intended goals. Limitations and opportunities for further research are also discussed.

5.2 Potential Site Visits related to the Chemistry syllabus

The first stage of the project, which consisted of six exploratory visits conducted as described in section 3.3.2, represents the preliminary research phase characteristic of EDR. The findings of this phase were used to answer the first research question:

1. Which sites are available in Malta for educators to visit with their students to meet part of the coursework requirements of the Secondary Education Certificate in Chemistry 2025?

The information compiled from the researcher's experiences during the exploratory visits, outlined in section 3.3.3.1, demonstrates how the local scenario benefits from a number of sites that could be effectively used to meet the site visit coursework requirements of the 2025 Chemistry syllabus. Initially, six potential sites were identified, however, after visiting each site, five were chosen for the pack because what could be learnt from these five sites was very much in line with the learning outcomes of the syllabus. This assertion is corroborated by the teachers' evaluation since nearly all respondents perceived the learning outcomes (LOs) allocated for each of the chosen sites to be relevant (Figure 4.4). Only one teacher thought that the LOs proposed were not very relevant, and this was only in the case

of the Solid Base site. It is worth mentioning that this view contrasted with comments from other educators on the same site.

The five sites chosen for the pack are by no means exhaustive; they are a small representative repertoire of numerous other sites that could be considered for visits to facilitate secondary Chemistry education. If the LOs earmarked for coursework, but not targeted by any of these packs, LO 5, LO 11 and LO 15, are also factored in when searching for sites, then the extent of possibilities is considerably widened.

5.3 Site Visits as opportunities to enhance learning

The second prototyping phase, expected of EDR methods, usually involves developing a solution to an educational problem followed by a process of iterative stages of analysis, design and formative evaluation. The solution proposed in this project involved the design of a resource pack (section 3.3.4) that was submitted for evaluation. Despite the evaluation process being restricted to one cycle, because of time constraints, the quality and rigour of the responses received provided a sound enough basis to effectively answer the second research question:

2. How can these site visits contribute to helping students achieve the subject learning outcomes?

The small sample size of the responses precludes broad generalisations or hypotheses to be made. However, the participants' views on site visits were favourable enough to presume that a good number of Chemistry teachers reacted well to the introduction of site visits as coursework in the Chemistry syllabus. Moreover, the general observations made on the pack and those specific to each visit, despite some shortcomings, were reasonably positive.

The teachers considered the Student Resource pack an excellent starting point for planning site visits. Some also appreciated the restaurant menu concept that allows teachers full agency on how to tailor, sequence and plan their own activities. Even the Teachers' Guides, in their support capacity, got a favourable

response as there was only one respondent who disagreed that they give enough guidance to plan and carry out site visits (Figure 4.2).

The teacher's feedback shows that they consider site visits as opportunities to enhance learning and most acknowledged how the pack activities managed to provide a real and concrete experience to learning, thereby, increasing subject relevance. Secondly teachers found the proposed activities student centred in their approach and target the development of a variety of skills such as research skills, critical thinking, problem-solving and formulation of questions. Therefore, the pack was found suitable enough to help students achieve the subject learning outcomes.

5.3.1 Knowledge contextualisation and relevance

The results in section 4.3 clearly show that teachers recognise a lot of pedagogical potential for site visits and even if one respondent would not consider site visits as coursework, the reasons given concerned issues with understanding the institutional, MATSEC, requirements of standards to be adhered to, and grading, rather than site visits not valued as offering adequate teaching and learning opportunities.

Most of the reasons given for site visits as valuable curricular practices, reported in section 4.3, converge to the premise that site visits give real and concrete context to the knowledge taught in the classroom thereby making the subject objectively and socially relevant. Objective relevance during site visits, where learners get to experience the specific application of theoretical concepts, could be associated with Newton's (1988) treatise on *internal relevance*. Additionally, raising awareness of opportunities for future career paths in chemistry seems to be especially encompassed within teachers' interpretation of relevance, since 77.8% of the respondents gave this as a foreseeable outcome of including site visits in the curriculum (Figure 4.1). Such views are evocative of Newton's (1988) philosophical analysis of *external relevance*, which portrays relevance as making the subject socially relevant. These interpretations of relevance are also congruent with Giamellaro's (2014) understanding of knowledge *contextualisation*. This also ties in nicely with the syllabus' assertion that site visits make science relevant to everyday

life and demonstrate its “social purposes” (MATSEC, 2022, p. 62). The nature of some of the responses received, seem to presume that relevance is therefore crucial to effective learning and deep understanding of concepts in chemistry. It is not clear whether these sentiments, born by Chemistry educators, are suppositions or emanate from personal experience. However, these views compare well with evidence from research:

“A key message is that the learning of chemistry and coming to understand what it means to be a chemist, is better achieved when students learn chemistry by doing ‘real’ chemistry, and doing this chemistry in a ‘real life’ chemistry workplace, working alongside professional chemists. From such experiences students gain a much more sophisticated understanding of chemistry, its nature, its role in industry, and the skills and attributes of a chemist. Such experiences contribute to career clarification, because students know what the working life of a chemist really is – something they found to be very different from traditional stereotypes, and indeed very different from what even they as chemistry students thought it was.”

(Coll, 2015. p. 301)

The precept of relevance, or *contextualisation*, featured quite prominently in teachers’ views on site visits. Seemingly, as inferred from the questionnaire responses, most of the activities presented in the pack also subscribe to these views. For instance, Figure 4.2 shows how all teachers agreed that most of these activities will enable students to relate theory to contextualised settings and will increase student awareness of careers in chemistry: *external relevance*. Also, the fact that most teachers found the proposed activities relevant to the syllabus LOs, as discussed in section 5.3, implies that the activities also impart *internal relevance* to the subject. There are several comments in the responses to open-ended questions, some of which are quoted in section 4.3, that indicate that the pack meets teachers’ expectations in matters related to their perceptions and views on site visits.

The teachers’ preconceptions on site visits and evidence from research quoted in section 2.5.1, communicate the need for an increased use of non-formal learning opportunities to complement learning in formal classroom environments.

5.3.2 Student-centred learning

The resource pack was found to help students achieve the subject learning outcomes because it was student-centred in its approach. Most activities featured topics that are particular to students' circumstances and encountered daily, including socio-scientific issues. According to most respondents, the pack targets mixed-ability students, while all respondents affirm that it includes some cross-curricular themes (Figure 4.2), both of which are syllabus requirements. Additionally, it was necessary for the activities to be attractive and appealing to cater for today's *digital natives* (Prensky, 2001), who learn more easily from graphical and visual representations (Affeldt et al., 2018). The presentation and layout of the pack were well received (Figure 4.3), especially the comics-style presentation of the ERA pack. Reactions to the latter (section 4.4.2), reflect the research findings of Affeldt et al. (2018) on the use of comics in a non-formal Chemistry learning context.

Figures 4.5 to 4.8 clearly indicate that according to most respondents the activities can conceivably attain their intended purposes, detailed in section 3.3.4.1, including facilitating question formulation by the students. Similarly, most of the open-ended responses quoted in 4.4.3, concur that overall the activities are structured and guided enough to generate interest, which would help student performance. In addition, the ratings for the level of difficulty of the activities, Figure 4.9, indicate that the teachers perceived the packs as sufficiently challenging, to entice students out of their comfort zones and into the Vygotskian zone of proximal development (Woolfolk, 2016) or Berger's (2014) "magic-middle", referred to in section 2.3.1, where learning is a joyful and social experience. This might provoke a deeper and lasting understanding of the subject.

5.4 Project limitations

EDR methods require a number of iterative cycles until an optimal solution is found. A limitation of this project is that, because of time constraints, this prototyping or development phase could be conducted only until the first formative evaluation. Therefore, the recommendations teachers proffered as part of their feedback were not implemented in the resource pack. Also, since a student evaluation of the packs was not collected, insights about its potential to facilitate student achievement of

learning outcomes, were only possible from the teachers' responses. Done this way, the assessment of student performance was probably quite accurate, considering that most participants had at least six years of experience teaching Chemistry at secondary level (Table 4.1). Nevertheless, the fact that students did not get to experience the activities themselves, presents another limitation. Similarly, since the pack activities were not attempted in class and no site visits were organised, no feedback could be collected from the teachers, students and even the site guides, after actually experiencing a complete site visit process.

Other limitations were that the pack was restricted to five sites and the site responsible persons were not asked for their views on the resource pack pertinent to their site.

5.5 Opportunities for future research

These limitations present some opportunities for further research. For instance, the pack could be updated with revisions recommended by the teachers and followed by full implementation of one or more site visits as coursework, preferably by schools from each sector. Data could then be collected from teachers and site guides at each stage of the process and, most importantly, even the students can be asked for their feedback. This will allow a more accurate evaluation of the pack and the use of site visits as coursework because it incorporates also 'student voice'. Guided with these new insights, the packs can be further updated and resubmitted for a second evaluation. If necessary, MATSEC can be approached with the outcomes of these studies so future syllabi could be more accommodating for this coursework mode.

A second option could be a project-based study focussed on bringing together Chemistry educators and representatives from the local chemical industry through networking events such as seminars or workshops. Apart from reinforcing bridges between schools and the local scientific community, these events could focus on how more effective use could be made of non-formal learning opportunities. Such programs have been implemented, already for a number of years, in countries like Ireland, Germany and Finland (Affeldt et al. 2017; Garner et al, 2014).

Finally, a study similar to this could explore other local sites that could potentially target also LOs not provided for in this project.

5.6 Reflection

A disheartening obstacle when attempting something novel is not knowing what to expect, which will make it increasingly difficult to organise site visits, especially when they need to be significantly linked to a prescribed curriculum. The researcher's aspiration is to forge the way to an increasing use of site visits by providing fertile ground where ideas can develop and grow to reach new environments, thereby breaching the formal boundaries of the classroom. For this to happen the realities of the classroom and the external scientific community need to come together. This project attempted to do just that. The pack provides an outset, a starting point, for ideas to develop based on contexts external to the classroom, while reducing the compromising uncertainty of previously unexplored milieus. The insights proffered by expert educators served as an evaluation into how feasible site visits could be within the construct of formal schooling.

Starting with the teachers' views on site visits, interestingly these seem to be underpinned, to some extent, by the attributes of setting, behavioural environment, language and background knowledge that, according to Wilson et al. (2015), effective contexts should possess. This already indicates that the participants tend towards mind-sets that favour effective use of the context-based approach in Chemistry. Besides, apart from time concerns, most of the other reasons why educators tend to avoid non-formal learning activities (section 2.5.2), do not seem to be shared by local Chemistry teachers. None of the responses implied that as teachers they do not feel confident enough or lack resources to carry out such visits. Neither were any health and safety issues brought forward. Even if some challenges were pointed out, teachers were quick to provide suggestions. Ostensibly, they were already thinking of ways to personalise these packs to suit their needs, exactly as intended by their underlying restaurant menu concept.

The significance here is that most teachers seem to be very much inclined towards using site visits as coursework. In addition, having had the opportunity to meet and converse with experts in the field, the researcher can quite reliably affirm

that most sites will be very much disposed to receiving our students for visits because they too recognise the potential for students to learn from real and non-formal out-of-school contexts. Failing to do so might be a significant impediment to their science education. In addition, most of them are already used to similar visits in the form of school outings or open days. So, since the mind-set of the teachers seems to align very well with the goodwill of the scientists active in their respective fields, all that remains is a little bit of impetus to get students out of their classrooms and into the several sites available locally where chemistry can transcend its presumed abstractedness to become purposeful, fun and real.

Reflecting on the possibilities for improvement, adding to what the teachers already propositioned (section 4.4.5), a copy of the rubric can be included at the end of each student pack for easier reference. Teachers raised several plausible contributions, focussed on making the tasks more accessible to lower-achieving students. While most of these recommendations are straightforward, such as paraphrasing advanced text or limiting lengthy presentations to key points, other issues concerning time, student behaviour and absenteeism are not as easily resolved. Some teachers, understandably, found disconcerting the prospects of including preparatory activities into the already tight scheme of work schedules, keeping in the loop students who are absent for part of the process and dealing with behaviour issues during the visit. These predicaments are arguably subjective and sensitive to the circumstances of every Chemistry teacher in every school. A multi-faceted approach is probably the best recourse in cases like these, where solutions are arrived at through collaboration between the various stakeholders: teachers, heads and education officers, even if with those from other schools. This kind of collegiality will certainly help mitigate problems.

Finally, as described at the end of each Teachers' Guide, it might be a nice gesture for teachers to encourage their students to prepare a small token of appreciation that could be presented to the guide/s at the end of the visit. Apart from being a sign of gratitude, these simple practices could help build and sustain rapports between the schools and the external scientific community. Such connections are very precious resources which, unfortunately, in Malta, are very much left untapped.

5.7 Conclusion

This study proceeded to answer the research questions through methods characteristic of EDR. Exploratory visits, conducted during the primary phase of the project, disclosed five sites with the potential to meet the requirements of the novel site visits coursework mode, introduced in the MATSEC Chemistry SEC 06 Syllabus, 2025.

A resource pack with learning activities proposed for each site was developed during the second phase and proffered for evaluation by teachers from the state, church and independent school sectors. The pack was found to be relevant to the learning outcomes prescribed by the syllabus. Therefore, the five sites chosen could be considered for coursework.

The evaluation showed that teachers valued site visits as opportunities to enhance learning since they impart objective and social relevance to the theory taught in class. Seemingly, these views were also sufficiently complemented by the activities in the pack. Additionally, the pack was regarded as a useful tool to help teachers plan site visits in non-formal, highly contextualised environments. Most educators agreed that the pack adequately provides for mixed-ability cohorts through a student-centred approach, thereby facilitating the achievement of the learning outcomes by the students.

Analysis of the responses also brought up a number of challenges in the pack, some of which will inherently transcribe into difficulties teachers must overcome when planning and sequencing lessons and others that could negatively impact student performance. While most of these shortcomings could be mitigated by recommendations put forward by the teachers themselves, others may require collaborative practices to safeguard student performance.

Finally, the participants seemed to entertain attitudes that favour the effective use of contexts in Chemistry and were rather unperturbed by most reasons commonly quoted as deterrents to non-formal learning activities. This, coupled with the disposition most sites seemed to have towards such visits, makes this coursework mode very much feasible.

The research questions were thereby answered because the five sites chosen were endorsed by educators as having enough potential to meet the site visit coursework requirements stipulated in the syllabus and the pack was perceived by teachers who participated in this study, as an adequate resource to help students achieve the relevant subject learning outcomes.

5.7.1 Final words (*in prima persona*)

“Learning is the process whereby knowledge is created through the transformation of experience.”

(Kolb, 2015, p. 49)

As a child, I loved taking toys apart to learn what makes them tick. As a young science student, inquisitive and curious as always, I blew up my parents’ washroom. As an adolescent, I loved DIY and the satisfaction of a job well done. As an adult, I still learn more through experience than through anything else. As a father, I enjoy reliving these experiences with my daughter, even if I tend to stay away from washrooms nowadays.

Think about anything you learned about through the descriptions of another. Maybe a book, a movie, a village in the mountains or a lake in the wilderness. Pick one you got to experience in person and reflect on how this experience transformed your previous knowledge. For better or for worse, your perceptions, expectations and emotions inevitably changed because of this experience.

Montessori once said that the hands are the instruments of intelligence because the hands allow you to experience what could otherwise only be described. It is said that concepts in Chemistry are too abstract and beguiling in their apprehension. Many Chemistry teachers have probably maintained this impression. While this sentiment is understandable, experiencing chemistry in real life will inevitably transform this damaging proclivity that too often taints the subject and obstructs the learner from the awe and lustre of the knowledge contained within.

As a researcher I propounded these views into my study, trying to reveal to teachers what was naturally gifted to me. Theoretical knowledge is but the tip of the

iceberg. To know more, to understand more, a deep dive into the cold uninviting water is necessary as only so can one indulge in the magnificence of it all. For the cautious, however, a cursory look below the surface is sometimes needed before, reassured by the reaching hand of the intrepid, they can witness the breath-taking transformation of experience.

I was pleasantly surprised by how well the teachers reacted to the prospect of site visits as learning opportunities. I dare say some were even commendably relieved at discovering that what they teach in class actually has a purpose. Ultimately I believe all of us still possess that inner child prodding us to get our hands dirty; all we have to do is open the classroom door.

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APPENDICES

APPENDIX A: Stage 1 Research Instrument: Semi-structured interview

Introduction:	
Interview questions	Prompt questions
Describe briefly the main operation of the site.	Which types of chemical processes are used on site? One of the learning outcomes students would need to achieve is: [relevant subject learning outcome]. How can students learn about this during a site visit of this plant? Which tests are carried out in the lab to ensure quality? Describe some measures implemented in your lab standard operating procedures to ensure fair and accurate testing. Is any type of research related to Chemistry carried out? Are you thinking of developing new products? Is any research being carried out at the moment?
How do you deal with the waste generated at this site (if applicable)?	Do you try to recover any other products from the waste in order to make the process sustainable? Do you treat any waste in order to prevent damage to the environment?
Logistics:	
How should teachers go about organising the site visit?	Who should teachers contact should they choose this site for one of their visits? Who will take them around? Is there anyone in charge of educational tours? Would students have the opportunity to talk to the key scientists on site? Are there any particular dates, within the scholastic year, when it would be better for site visits? Are there any instances when site visits are not at all possible? What is the maximum number of students that you can have on a site visit? Which age groups can visit the site? How long will the students' tour last?

How accessible is the site?	Can all parts of the visit be accessed by students with physical disabilities, in particular wheelchair access? Are there any particular safety considerations teachers and students need to be aware of?
Other considerations:	Are there on site or within a short walking distance: Toilet facilities students can use? Recreational areas for lunch break?
Activities:	As part of the visit students will be encouraged to write questions about the site after carrying out some research prior to the visit. Would you allow some question time from the students? Would you consider/allow the setting up of one onsite activity the students can participate in to engage them while encouraging a deeper understanding of subject related content? If not, would you consider having a set of handouts where students can do follow up activities in the school lab in relation to this visit?
During the Site Tour:	
Which specific parts of this site are most relevant to the subject learning outcome/s mentioned previously?	Which would be the most important aspects of the operation educators should focus on? Which sections should students be particularly encouraged to focus on in order to learn and understand the main chemical processes carried out on site?
Conclusion:	
What is your opinion of the introduction of site visits as an integral aspect of the chemistry curriculum?	Do you think they are conducive to a deeper understanding of the subject? How important is their role in motivating students to pursue a career in science? So which qualifications are required to work here in science related careers?

APPENDIX B: Research Instrument Stage 2: Semi-structured questionnaire (online)

Chemistry in context: A Guide to Site Visits in Secondary Education Chemistry

Dear participant,

You are being invited to review the attached resource pack about potential site-visits relevant to secondary education chemistry and fill in this questionnaire. Your feedback will be used to guide critical reflection on the proposed resources in order to pre-empt possible issues while suggesting improvements and opportunities for further research.

It is recommended to fill in the sections relevant to each pack immediately after it is reviewed.

Teachers' views on site visits

Question 1:

i) How long have you been teaching chemistry at secondary level?

1-5 years

6-14 years

15-24 years

25+ years

ii) Do you teach Chemistry in a:

State School?

Church School?

Independent School?

Question 2:

Choose ONE that best mirrors your opinion on site visits

The inclusion of site visits as part of the 2025 curriculum will: (*Tick only one*)

- ☐ encourage more students to consider pursuing career in science;
- ☐ make the subject more interesting;
- ☐ help students achieve the relevant learning outcomes;
- ☐ have little to no effect on student achievement.

Question 3:

i) Would you consider presenting at least one site visit as part of the SEC coursework?

YES

NO

ii) Are there any reasons for your reply, in addition to those mentioned in Question 2 above?

Teachers' general outlook on the packs

Question 4:

Please indicate your level of agreement with the following statements

	Strongly Agree	Agree	Disagree	Strongly Disagree
As a chemistry teacher I would find the student resource packs useful for planning site visits.				
The student resource packs expose students to multiple stimuli to address the learning needs of a mixed ability cohort studying chemistry.				
The proposed activities will enable students to relate the theory to contextualized setting's.				
The site visits presented will make students more aware of possible careers in chemistry				
The packs include some of the cross-curricular themes mentioned in the syllabus*				
The teachers' guides give enough support to see me through planning and carrying out site visits.				

* Namely: digital literacy; diversity; entrepreneurship; creativity and innovation; citizenship; sustainable development; learning to learn, cooperative learning and literacy.

Question 5:

When answering this question consider the general structure of the packs in terms of:

- the activities being categorised as: Introductory, Preparatory and Site activities,
- how well they adhere to the sections and rubric stipulated in the SEC 06 syllabus (2025) for the site visit report,
- aesthetic presentation,
- other similar considerations.

How would you rate the overall general presentation/layout of the resource packs?	Excellent	Fair	Poor
---	-----------	------	------

Teachers' feedback on the packs specific to each site visit

Question 6:

In the table below, rate your perceived difficulty level of proposed activities, respective to each site visit as compared to the level of students you are currently teaching chemistry.

Mark only one per row.	Too easy for most students	Easy for some students	Appropriate for most of the students	Might be challenging for some students	Too difficult for most students
WSC:Pembroke RO plant					
ERA: Air monitoring stations and workshop					
Farsons: Main Laboratory					
WSC: Quality Laboratory, Luqa					
Solid Base Laboratory					

Question 7:

How relevant are the activities proposed for each site visit to the learning outcomes allocated in the respective resource pack?

Mark only one per row.	Very Relevant	Sufficiently Relevant	Not very relevant
WSC: Pembroke RO plant			
ERA: Air monitoring stations and workshop			
Farsons: Main Laboratory			
WSC: Quality Laboratory, Luqa			
Solid Base Laboratory			

WSC Pembroke RO plant.

QUESTION 8:

This question is intended to collect feedback specific to the WSC Pembroke RO plant Student Resource Pack and Teachers' Guide.

- i) The Introductory activities are well designed to introduce the students to the processes occurring at the site and to any relevant general knowledge, without which important aspects of the site visit might be lost.

Strongly Agree	Agree	Disagree	Strongly Disagree
----------------	-------	----------	-------------------

- ii) The Preparatory activities are well designed to give students more in-depth knowledge of processes on the site.

Strongly Agree	Agree	Disagree	Strongly Disagree
----------------	-------	----------	-------------------

- iii) The Site activities allow students to sufficiently engage with the environment on site, that could result in significant learning gains.

Strongly Agree	Agree	Disagree	Strongly Disagree
----------------	-------	----------	-------------------

iv) The prompts presented through this pack adequately guide students into preparing quality questions to ask during the visit.

Strongly Agree	Agree	Disagree	Strongly Disagree
----------------	-------	----------	-------------------

v) Discuss any strengths and/or challenges you foresee for the proposed activities.

vi) Any recommendations? (You can also include any comments regarding the Teachers' guide here)

QUESTIONS 9 to 12:

These were the same as Question 8 above but intended to collect feedback specific to the other packs:

ERA: Air monitoring stations and workshop - Question 9

Farsons: Main Laboratory - Question 10:

WSC: Quality Laboratory, Luqa - Question 11

Solid Base Laboratory - Question 12

Conclusion

Question 13:

Are there any other general comments/suggestions you would like to make?

Your feedback and participation are much appreciated.

THANK YOU!

APPENDIX C: Stage 1: Information Letter sent to sites considered for the exploratory visits.

[Date]

Information letter

Dear Sir/Madam,

My name is Adrian Vella and I am a student at the University of Malta, presently reading for a Masters in Teaching and Learning in Science and Chemistry. I am presently conducting a project based study for my dissertation titled: **Chemistry in context: A Guide to Site Visits in Secondary Education Chemistry**; this is being supervised by Dr Doreen Mizzi. This letter is an invitation to participate in this study. Below you will find information about the study and about what your involvement would entail, should you decide to take part.

The aim of my study is to explore some sites that are related to the subject of chemistry and that are available for visits by secondary chemistry students. A resource pack will then be designed which will focus on any related chemical aspects taking place in this site. The purpose of this resource pack will be to eventually help chemistry educators decide which sites to visit with their students in order to meet part of the coursework requirements of the Secondary Education Certificate in Chemistry 2025 Syllabus. Your participation in this study would help contribute to a better understanding of which site visits should be included in the resource pack and how they can help students achieve the prescribed learning outcomes. Any data collected from this research will be used solely for purposes of this study.

Should you choose to participate, you will be asked to participate in an interview, which may be audio recorded with your consent, and take me on a guided tour of the site you are responsible for. This will require approximately 1 hour of your time. Data collected will be anonymized and only myself and my supervisor will have access to it. Participation in this study is entirely voluntary; in other words, you are free to accept or refuse to participate, without needing to give a reason. You are also free to withdraw from the study at any time, without needing to provide any explanation and without any negative repercussions for you. Should you choose to withdraw, any data collected from your interview will be deleted.

If you choose to participate, please note that there are no direct benefits to you. Your participation does not entail any known or anticipated risks.

Please note also that, as a participant, you have the right under the General Data Protection Regulation (GDPR) and national legislation to access, rectify and where applicable ask for the data concerning you to be erased. All data collected will be erased within six (6) months of completion of the study.

A copy of this information sheet is being provided for you to keep and for future reference.

Thank you for your time and consideration. Should you have any questions or concerns, please do not hesitate to contact me by e-mail

[REDACTED]; you can also contact my supervisor via email:

[REDACTED].

Sincerely,

Adrian Vella

[REDACTED]

Dr Doreen Mizzi

[REDACTED]

APPENDIX D: Stage 1: Permission Letter

[Addressee name]

[Address]

[Date]

Request for permission to conduct research at your site

Dear [title and name of recipient],

My name is Adrian Vella and I am a student at the University of Malta, presently reading for a Masters in Teaching and Learning in Science and Chemistry. I am presently conducting a project based study for my dissertation titled **Chemistry in context: A Guide to Site Visits in Secondary Education Chemistry**. This study aims to explore sites that secondary education Chemistry teachers could visit with their students. A resource pack will then be designed which will focus on any related chemical aspects taking place in this site. These site visits will become part of the coursework requirements in 2025. This project is being conducted under the supervision of Dr Doreen Mizzi.

I am hereby seeking your permission to meet your designated responsible person for a guided tour of your site. My data collection methods will also involve an interview, which together with the site tour should last approximately one hour.

Participation will be entirely voluntary and participants will be free to withdraw at any point, without any repercussions. Data collected will be anonymized and only myself and my supervisor will have access to it.

Should you require further information, please do not hesitate to contact me or my supervisor; both our contact details are provided below.

Thank you for your kind consideration of this request.

Sincerely,

Adrian Vella

[Redacted Signature]

Dr Doreen Mizzi

[Redacted Signature]

Office: [Redacted]

APPENDIX E: Stage 1: Participant's Consent Form

(signed by site responsible person).

Chemistry in context: A Guide to Site Visits in Secondary Education Chemistry

I, the undersigned, give my consent to take part in the study conducted by Adrian Vella. This consent form specifies the terms of my participation in this research study.

1. I have been given written and/or verbal information about the purpose of the study; I have had the opportunity to ask questions and any questions that I had were answered fully and to my satisfaction.
2. I also understand that I am free to accept to participate, or to refuse or stop participation at any time without giving any reason and without any penalty. Should I choose to participate, I may choose to decline to answer any questions asked. In the event that I choose to withdraw from the study, any data collected from me will be erased.
3. I understand that I have been invited to participate in qualitative data collection by means of an interview and where the researcher has to be taken on a guided tour to explore the possibility of the site I am responsible for to be proposed as a site-visit in order to help students achieve prescribed learning outcomes in secondary education chemistry. I am aware that this will take approximately 1 hour. I understand that the guided site tour and the interview are to be conducted in a place and at a time that is convenient for me.
4. I understand that my participation does not entail any known or anticipated risks.
5. I understand that there are no direct benefits to me from participating in this study. I also understand that this research may benefit others by: facilitating the teaching of chemistry in secondary schools.
6. I understand that, under the General Data Protection Regulation (GDPR) and national legislation, I have the right to access, rectify, and where applicable, ask for the data concerning me to be erased.
7. I am aware that, if I give my consent, the interview will be audio recorded and converted to text as it has been recorded (transcribed).
8. I understand that all data collected will be erased within six months of completion of the study.
9. I have been provided with a copy of the information letter and understand that I will also be given a copy of this consent form.
10. I am aware that, if I give my consent, extracts from my interview may be reproduced in these outputs, either in anonymous form, or using a pseudonym [a made-up name or code – e.g. respondent A].
11. I am aware that, if I give my consent, the identity of the organisation I represent will be revealed in publications, reports or presentations arising from this research, and responses I provide may be quoted directly or indirectly.
12. I am aware that my identity and personal information will not be revealed in any publications, reports or presentations arising from this research.

I have read and understood the above statements and agree to participate in this study.

Name of participant: _____

Signature: _____

Date: _____

Adrian Vella

Dr Doreen Mizzi

Office: _____

APPENDIX F: Stage 2: Information Letter inviting teachers to review the pack.

This was shared by the Education Officer (Chemistry) acting as intermediary for state schools. Similar letters were sent to the Head of Department for Chemistry within the Secretariat of Catholic Education, for church schools, and to the respective heads of the independent schools

Information letter

Dear Sir/Madam,

My name is Adrian Vella and I am a student at the University of Malta, presently reading for a Masters in Teaching and Learning in Science and Chemistry. I am presently conducting a project based study for my dissertation titled **Chemistry in context: A Guide to Site Visits in Secondary Education Chemistry**; this is being supervised by Dr Doreen Mizzi. This letter is an invitation to participate in this study. Below you will find information about the study and about what your involvement would entail, should you decide to take part.

The aim of my study is to explore some sites related to the subject of chemistry and that are available for visits by secondary chemistry students. A resource pack has been designed that focuses on any chemistry related aspects taking place in five (5) sites. The purpose of this resource pack will be to eventually help chemistry educators decide which sites to visit with their students in order to meet part of the coursework requirements of the Secondary Education Certificate in Chemistry 2025. Your participation in this study would help contribute to a better understanding of how these site visits can help students achieve the prescribed learning outcomes. Any data collected from this research will be used solely for purposes of this study.

Should you choose to participate, you will be asked to review the resource pack and fill in an online questionnaire. This will require approximately 60 minutes of your time.

Data collected will be anonymized and only myself and my supervisor will have access to it.

Participation in this study is entirely voluntary; in other words, you are free to accept or refuse to participate, without needing to give a reason. You are also free to withdraw from the study at any time, without needing to provide any explanation and without any negative repercussions for you. Should you choose to withdraw, any data collected from your questionnaire will be deleted.

If you choose to participate, please note that there are no direct benefits to you. Your participation does not entail any known or anticipated risks. Please note also that, as a participant, you have the right under the General Data Protection Regulation (GDPR) and national legislation to access, rectify and where applicable ask for the data concerning you to be erased. All data collected will be erased within six (6) months of completion of the study.

A copy of this information sheet is being provided for you to keep and for future reference.

Kindly inform the Education Officer for Chemistry, [REDACTED]
[REDACTED], if you want to participate in this study so he
will share the relevant files and links.

Thank you for your time and consideration. Should you have any questions or
concerns, please do not hesitate to contact me by e-mail

[REDACTED]; you can also contact my supervisor via email:
[REDACTED] or office telephone number: [REDACTED].

Sincerely,

Adrian Vella

[REDACTED]

Dr Doreen Mizzi

[REDACTED]

APPENDIX G: Authorisation to carry out this research in state schools



GOVERNMENT OF MALTA
MINISTRY FOR EDUCATION
DIRECTORATE FOR RESEARCH, LIFELONG
LEARNING AND EMPLOYABILITY

Tel: 25982743

researchandinnovation@ilearn.edu.mt

PERMISSION TO CONDUCT RESEARCH STUDY

Date: 28th September 2021

Ref: R09-2021 904

To: Education Officer - Chemistry

From: Director

Title of Research Study: *Chemistry in context: A Guide to Site Visits in Secondary Education Chemistry.*

The Directorate for Research, Lifelong Learning and Employability would like to inform that approval is granted to **Adrian Vella** to conduct the research in State Schools according to the official rules and regulations, subject to approval from the Ethics Committee of the respective Higher Educational Institution.

The researcher is committed to comply with the General Data Protection Regulation (GDPR) and will ensure that these requirements are followed in the conduct of this research. The researcher will be sending letters with clear information about the research, as well as consent forms to all data subjects and their parents/guardians when minors are involved. Consent forms should be signed in all cases particularly for the participation of minors in research.

For further details about our policy for research in schools, kindly visit www.research.gov.mt.

Thank you for your attention and cooperation.

Claire Mamo

MA Ed (Open)

Research Support Teacher

Directorate for Research, Lifelong Learning and Employability

f/ Alex Farrugia

Director

Directorate for Research, Lifelong Learning and Employability

Great Siege Road | Floriana | VLT 2000

 | www.education.gov.mt



MINISTRY FOR EDUCATION

MINISTERU GĦALL-EDUKAZZJONI
MINISTRY FOR EDUCATION

APPENDIX H: Authorisation to carry out this research in church schools.

Authorisations from independent schools are not shown to protect their anonymity.

Segretarjat għall-Edukazzjoni Nisranija
16, Il-Mall, Furjana FRN 1472
Num. ta' Tel. 27790060



Secretariat for Catholic Education,
16, The Mall, Floriana FRN 1472
Tel. No. 27790060

The Head
All Secondary Church Schools

9th June 2022

Mr Adrian Vella, currently reading for a Masters Degree in Teaching and Learning in Science and Chemistry at the University of Malta, requests permission to distribute online questionnaires to All Chemistry Teachers of years (9, 10, 11) at the above mentioned schools.

The Secretariat for Catholic Education finds no objection for Mr Adrian Vella, to carry out the stated exercise subject to adhering to the policies and directives of the schools concerned.



Rev Dr. Charles Mallia
Delegate for Catholic Education

APPENDIX I: Rubric for Site Visits as coursework provided in the Chemistry SEC 06 syllabus.

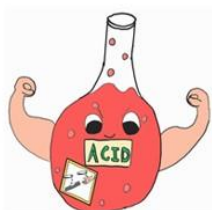
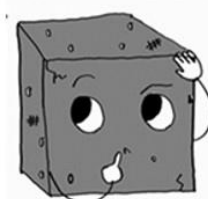
SEC 06 SYLLABUS (2025): CHEMISTRY

Marking Criteria: Site Visit

MARKING CRITERIA – Site Visit		
Maximum 100 marks		
Date, Title & Aim (0 – 10 marks)		
0 – 3 marks	4 – 6 marks	7 – 10 marks
Title is missing.	Title is incomplete.	Title includes the full name of the site and the location where the visit took place.
Date is missing.	Date is missing.	Date of site visit.
A limited description of the aim/s and objective/s of the site visit is given.	A partial description of the aim/s and objective/s of the site visit.	Aim/s and objective/s of the visit clearly stated.
Preparatory Activities (0 – 20 marks)		
0 – 6 marks	7 – 12 marks	13 – 20 marks
No/minimal background information about the scientific aspects relevant to the site visit.	Limited background information about the scientific aspects relevant to the site visit.	Background information about the scientific aspects relevant to the site visit.
No/minimal number of questions to ask the relevant practitioner/s.	Few or not so relevant questions the students would be asking the practitioner/s on site.	Relevant questions the students would be asking the practitioner/s on site.
No/minimal outline of activities to be carried out.	An incomplete and/or incoherent outline of activities to be carried out.	A thorough outline of the activities to be carried out.
Site Details (0 – 10 marks)		
0 – 3 marks	4 – 6 marks	7 – 10 marks
No/minimal description of the location.	An incomplete and/or incoherent description of the location.	A complete description of the location.
No/incorrect map/plan of the site.	An incomplete map/plan of the site.	A detailed map/plan of the site.
No/incorrect history of the site.	An incomplete history of the site.	A brief history of the site.
The main purpose of the site is not stated.	The main purpose of the site is not clearly stated.	The main purpose of the site is clearly stated.
Precautions and Safety Considerations (0 – 10 marks)		
0 – 3 marks	4 – 6 marks	7 – 10 marks
No/minimal list of potential hazard/s and the precautionary measures taken to reduce them is presented.	An incomplete list of potential hazard/s and the precautionary measures taken to reduce them is presented.	A comprehensive list of potential hazard/s and the precautionary measures taken to reduce them is presented.
Site Activities (0 – 20 marks)		
0 – 6 marks	7 – 12 marks	13 – 20 marks
No/minimal description of the activities carried out on site.	Incomplete description of the activities carried out on site.	Detailed description of the activities carried out on site.

Communication of Outcomes (0 – 10 marks)		
0 – 3 marks	4 – 6 marks	7 – 10 marks
No/poor communication of outcomes to the questions prepared by the students.	Good communication of outcomes to the questions prepared by the students.	Comprehensive communication of outcomes to the questions prepared by the students.
Discussion, Evaluation, Reflection & References (0 – 20 marks)		
0 – 6 marks	7 – 12 marks	13 – 20 marks
No/poor discussion, evaluation and/or interpretation of the outcomes achieved or information collected with respect to the aim/s and objective/s set.	A good discussion, evaluation and/or interpretation of the outcomes achieved or information collected with respect to the aim/s and objective/s set.	A comprehensive discussion, evaluation and/or interpretation of the outcomes achieved or information collected with respect to the aim/s and objective/s set.
No/minimal self-reflection/s on the experience of the site visit including good practices, possible improvements and alternative activities.	Superficial self-reflection/s on the experience of the site visit including good practices, possible improvements and alternative activities.	Thorough self-reflection/s on the experience of the site visit including good practices, possible improvements and alternative activities.
No sources cited listed.	Incomplete list of sources cited and/or presented inconsistently.	All sources cited in the report are listed in full in a basic format.

THE RESOURCE PACK



Subject Focus 2: Substances from the Earth: Aquatic environments

Site Visit



Pembroke RO Plant

Student Resource Pack

Subject Focus 2:

Substances from the Earth: Aquatic environments

Site Visit: Water Services Corporation (WSC) Pembroke RO plant

Target Learning Outcomes

Learning Outcome 3:

I can describe the solvent action of water including the impact of water hardness.

3.1a Identify sources of potable water and their management in Malta.

3.2a Present ideas that water is a very precious resource in the world and a potential source of conflict.

3.3a Relate ideas based on research about why water is a very precious resource.

3.2b State criteria of purity for water. (Limited to melting point, boiling point and conductivity.)

3.1e Explain that sea water contains dissolved charge ions that form crystals on evaporation

3.3f Explain the properties of ionic compounds (limited to solubility, mpt/bpt and electrical conductivity in different states.

3.1m Explain why water softening is important in hard water areas by referring to the local scenario.

3.1n Name desalination techniques that can be used to create demineralised water from seawater.
(*Limited to distillation and reverse osmosis.*)

3.2n Describe how simple distillation and reverse osmosis are used to produce demineralised water from impure water.

3.3n Evaluate desalination techniques that can be used to produce demineralised water from seawater.
(*Limited to distillation and reverse osmosis.*)

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

Introduction



By referring to the WSC website and from your day to day experiences, list the three main sources of potable water in Malta:

1. _____
2. _____
3. _____

"Groundwater production, however, is not enough to meet demand which means that the Corporation has to convert seawater into high-purity drinking water"

<https://www.wsc.com.mt/about-us/water-production-distribution/>

How does WSC convert seawater into drinking water?
Where are these sites located?



Introductory Activities (IA)

IA1: Research Task

"The long-term deterioration in the quality of groundwater required the introduction of desalinated water to achieve the required quality (potability) levels which has forced the WSC to increase RO water production."

<https://www.wsc.com.mt/about-us/water-production-distribution/>

Discuss:

Why is the quality of groundwater in Malta deteriorating?

Do some research (online or otherwise) to find answers to this question.

You can use the following article.

Hartfiel, L., Soupir, M., & Kanwar, R. S. (2020). Malta's Water Scarcity Challenges: Past, Present, and Future Mitigation Strategies for Sustainable Water Supplies. *Sustainability*, 12(23), 9835. MDPI AG. Retrieved from <http://dx.doi.org/10.3390/su12239835>

It is rather advanced at this level, but even just reading the abstract the introduction and the conclusion can be very insightful.

For those who are interested in reading further, this article touches on other very sensitive issues that could be brought up as questions during your site visit:

- Unrecovered water and environmental impact.
- Future of fresh water supply in Malta.
- Threat of water scarcity.
- Management of potable water.
- Sources of freshwater and their sustainability.

Your teacher may recommend other sources of information on this issue.

IA2: Water Quality

Visit: <https://www.wsc.com.mt/>

Click on: VIEW LIVE MAP
In the Menu bar on left:

Click on 'Control room'

Choose 'Water Quality'

You can access water quality information for each locality shown on the map of the Maltese islands, as described in the website prompt below:

Water quality information

The 'Water Quality' map option shows detailed water quality information for every locality in the Maltese Islands. Place the mouse cursor on the desired locality and click. The information will be displayed on the right-hand side of your screen. To select another locality, click on a new locality.

Click on a locality and the following table will be displayed:

The  button will call up some information on each parameter. Read through some of these and compare the conductivity values at different localities, including the ones where you live.

Choose five localities and take note of the parameters circled in **RED**, namely: Conductivity, Total Hardness and Nitrates, by filling them out in Table 1 below.

VIEW LIVE MAP

REPORT AN ISSUE

SMS ALERT

LEARN & SAVE

Menu

Customer Reports

Control Room

Road Works

Water Quality

New Water Dispensers

Map

Abnormal Consumption

WSC PV Panels

Map of Maltese Islands

Water Quality

Qawra WOZ: 2

Collection Date 17-Jan-2022

TURBIDITY 0.17 N.T.U

CONDUCTIVITY 1815 $\mu\text{S cm}^{-1}$

TEMP (ON SITE) 16.2 °C

TEMP 15 °C

pH 7.55

TOTAL HARDNESS 330 mg/L CaCO_3

CALCIUM HARDNESS 160 mg/L CaCO_3

MAGNESIUM HARDNESS 170 mg/L CaCO_3

CALCIUM 64 mg/L Ca

MAGNESIUM 41 mg/L Mg

NITRATES 41.53 mg/L NO_3^-

AMMONIA <0.15 mg/L NH_4^+

NITRITES <0.0210 mg/L NO_2^-

TOTAL COLIFORMS Not Detected

E.coli Not Detected

FAECAL ENTEROCOCCI Not Detected

Disclaimer

Table 1

Collection Date	Locality	Conductivity $\mu\text{S/cm}$	Total Hardness mg/L CaCO_3	Nitrates mg/L NO_3^-

Salinity

One major concern of Maltese fresh water is salinity.

Salinity does not refer to the concentration of NaCl only, **but to the concentrations of all salts dissolved in water.**



a. Give examples of ions commonly present in Maltese fresh waters.

b. A property of ionic compounds is that they are usually soluble in water.
Mention one other property that is consequence of this.

This last property is widely used to check for salinity in a water sample by measuring the conductivity.

Conductivity

Conductivity is a measure of the ability of an aqueous solution to conduct electricity. This ability depends on the presence of ions; their total concentration and valency. It is, therefore, a good indication of the total amount of minerals (anions and cations) present in a sample of water.

Therefore, the higher the concentration of ions dissolved in water, the higher the conductivity.

c. Is this relation between the Conductivity and concentration of hardness + nitrates observed in Table 1? _____

d. Which other two important ions are not shown in WSC’s water quality tables but could account for any differences? _____

How is conductivity measured?



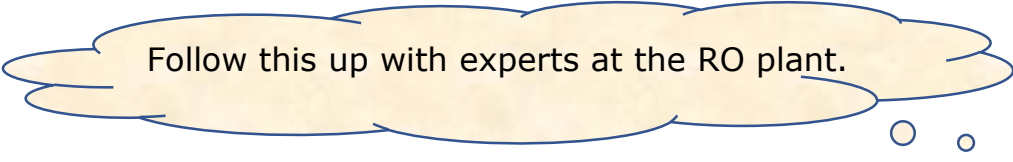
Conductivity is measured using electronic instruments that can measure the current passing through a sample of water. The amount of current that flows through the sample is proportional to the total concentration of ions dissolved in the sample. The meters are calibrated to convert these current measurements into the units of conductivity:

$\mu\text{S/cm}$	OR	mS/cm
microSiemens per cm		milliSiemens per cm

IA3: Discussion

Analyse again the conductivity values for various localities.

- a. Is the water quality, on average, the same all over Malta and Gozo, or does it vary between localities?
- b. From the values deduce which localities are likely to be receiving mostly reverse osmosis water and which are receiving groundwater.
- c. Could there be any link to how close they are to the RO plants?
- d. WSC ensures that all the quality parameters of tap water over Malta and Gozo are within the acceptable, safe ranges. Notwithstanding, how does the fact that you could be receiving better or inferior water quality than other localities make you feel? Is this an issue of social justice?



Follow this up with experts at the RO plant.

The Site Visit

It is now time to visit the site with the experts! Before you go have a look at the next section and remember to **PATE**:

- Participate,
- Ask questions,
- Take photos and notes,
- ENJOY!



Date	
Title	
Aims and objectives	

PA1: Desalination by Reverse Osmosis

Research Task

Desalination is the process of removing salts or other minerals and contaminants from seawater, brackish water, and wastewater effluent. It is an increasingly common solution to obtain fresh water for human consumption and for domestic/industrial utilization.

Do some research on the process of desalination by reverse osmosis before your site visit. You can use the following videos, but feel free to use any other information you can access and understand.

<https://www.youtube.com/watch?v=vkDNYZXZ7Fo>

https://www.youtube.com/watch?v=4RDA_B_dRQ0

https://www.youtube.com/watch?v=-_sr7mzhVsE

https://www.youtube.com/watch?v=iY_f_9NWiYA

Below are some important points you can use to focus your questions before your visit. Ask these questions to your guides and learn from their answers.

- What osmosis is, and how is this process reversed in desalination plants to reduce salinity.
- The role of the membranes.
- Volumes of potable water and brine produced from the RO plant you are visiting.
- Disposal of reject water (brine) and any related environmental implications.
- Energy recovery systems.
- Conductivities of the feed, brine and product water.

PA2: Prepare your questions



Based on what you have learned so far, as a group, propose 3 questions you would like to ask the experts at the reverse osmosis plant during your visit.

Some ideas you may use to formulate your questions:

- ✓ Tackling issue of localities receiving inferior water quality.
- ✓ Percentages of water recovered and lost during the RO process.
- ✓ Unrecovered water and environmental impact.
- ✓ Future of fresh water supply in Malta.
- ✓ Threat of water scarcity.

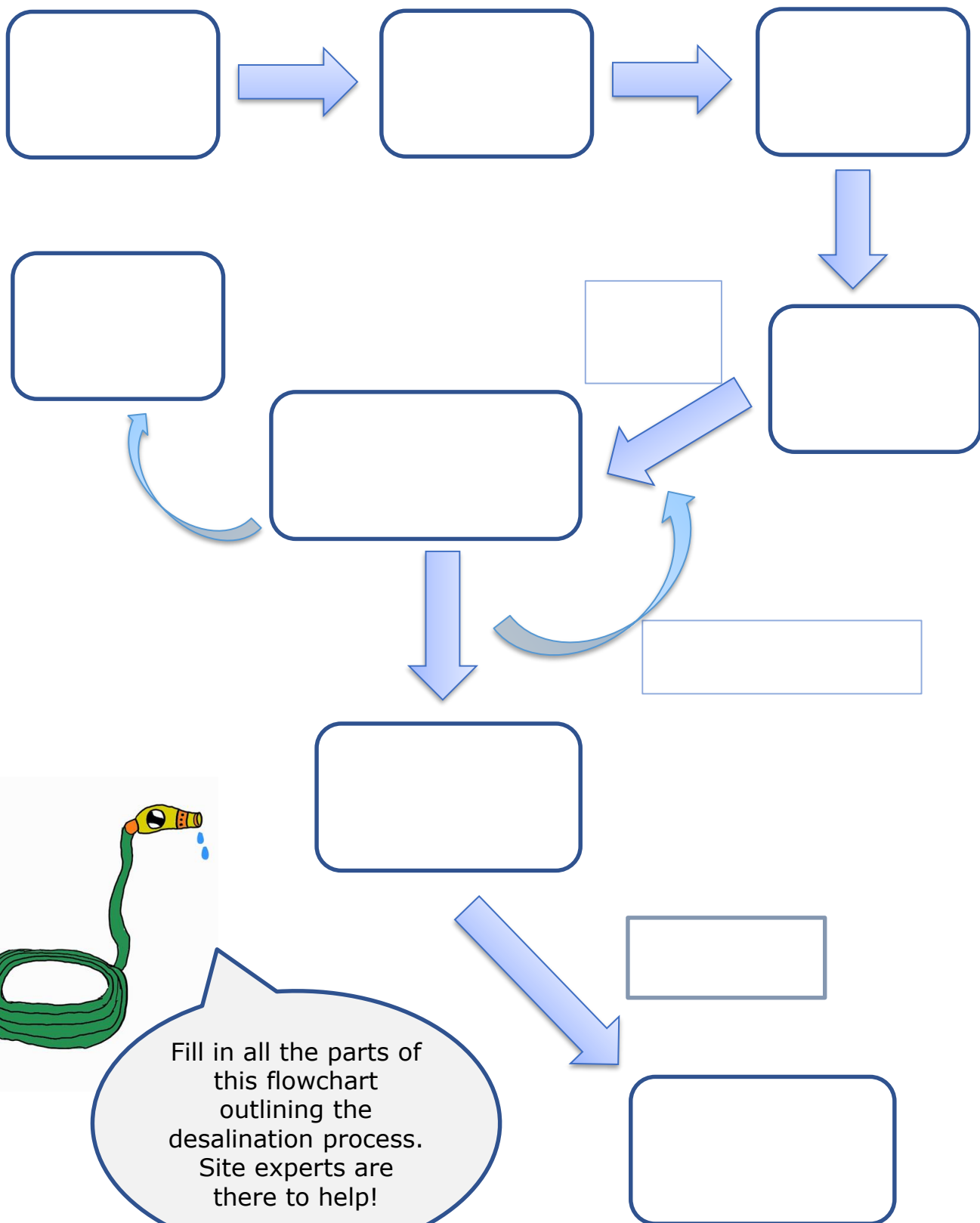
Here is one way you can organise your questions and answers:

Question:	
Answer: (Notes)	

Site details	
Description of location	
History	https://www.wsc.com.mt/about-us/our-history/
Purpose of site	
Precautions and Safety Considerations <i>(Potential hazards and safety considerations noticed on site)</i>	

Site Activities (SA)

SA1: Flowchart showing the conversion of sea water into potable water

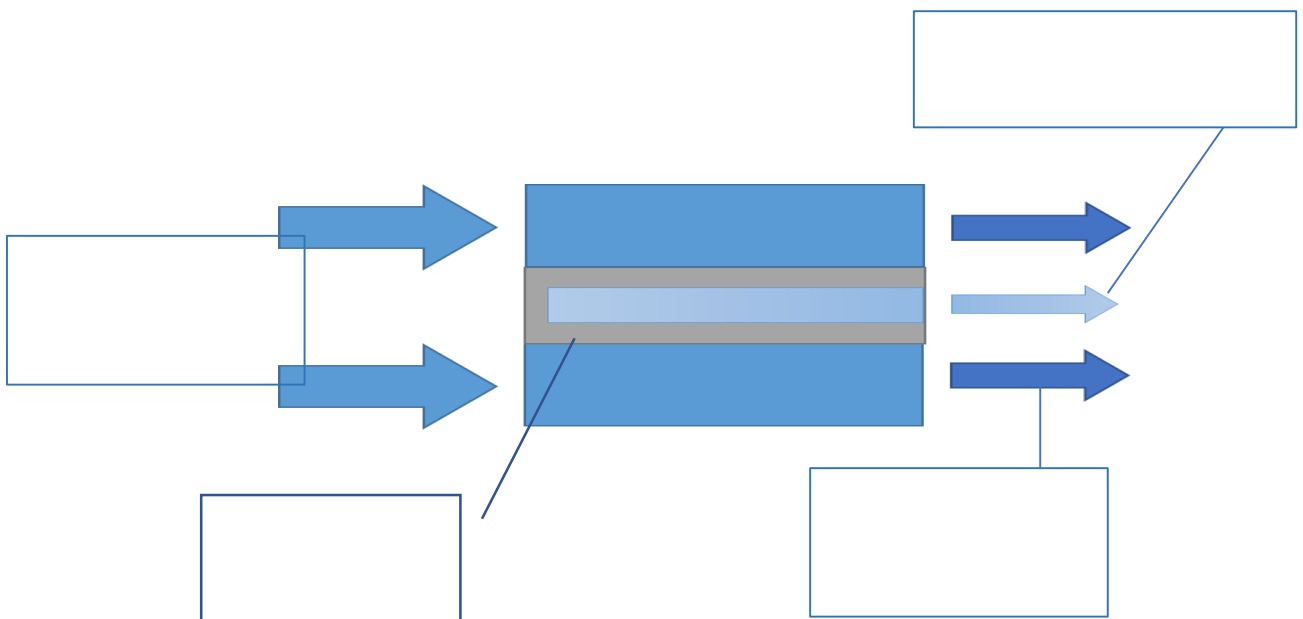


SA2: Membrane Schematic

The below is a basic schematic of an RO membrane similar to the ones used in the local RO plants. Consider including this in your report while adding labels showing:

- ✓ the different water types
- ✓ the respective typical conductivities
- ✓ percentage volume of water flowing at each stage.

On site you will meet engineers who can help you fill these in and possibly even draw more accurate diagrams.



SA3: Preserving membranes and pipes: the role of pH and Hardness

Reverse Osmosis membranes are the lifeline of our country since they produce all the extra fresh water necessary to meet our demand: a demand which cannot be met by natural processes alone.

This fresh water needs to be delivered to our taps safely and efficiently, for convenient use. This is done through a huge network of underground pipes that the Water Services Corporation is responsible for.

The membranes and pipes are crucial to the security of water supply and very expensive to purchase, install and maintain. It is therefore imperative to extend their lifetime as much as possible through proper care. Ironically both are susceptible to damage caused by the same water that flows through them.

Among other factors, two important parameters the WSC RO plants need to constantly monitor and control are pH and hardness. For example if the pH of the feed sea water (the water entering the membranes) is above a certain level, the membranes will be irreparably damaged and need to be replaced at considerable costs and production downtimes.

If the pH of the output product fresh water is below a certain level, then the pipes delivering the water will be damaged causing losses and shortages to certain locations.

Hardness has a role too and is linked to pH. Learn more about this and discover how RO engineers use chemistry to control these factors thereby preserving these critical components and ensuring adequate water supply.

Interact with the experts to help you on your quest for knowledge and fill in the table below.

	pH level	How is the pH controlled	Consequences if pH is out of range
Treated Feed water (from the sea)			
Treated Fresh water output			

SA4: Reverse Osmosis vs Distillation

Compare and contrast the two methods on the basis of:

Process	Reverse Osmosis	Distillation
Fresh water recovery ➤ How effective is the process in recovering the fresh (potable) water? ➤ How easy is it to recover the fresh water? ➤ What can be done to ensure maximum recovery?		
Energy ➤ How energy demanding is the process? ➤ Is it sustainable? ➤ Can it be made sustainable?		
Time ➤ How long does it take to produce fresh water? ➤ Can it be easily controlled and carried out at any time?		
Other		

Ask the experts at the RO plant to help you compare these two processes. Distillation was used in the past, nowadays not any more. Why?

SA5: Mixing waters to improve quality

News: The Ta' Qali to Pembroke Tunnel

L-aħħar fażi tax-xogħlijiet tal-mina taħt l-art bejn Pembroke u Ta' Qali għal ilma aħjar

[The final stages of works on the Pembroke to Ta Qali underground tunnel for improved water quality]

<https://www.wsc.com.mt/l-ahhar-fazi-tax-xoghlijiet-tal-mina-taht-l-art-bejn-pembroke-u-ta-qali-ghal-ilma-ahjar/> Posted on October 1, 2021 at 1:29 pm.

Malta will see an overhaul of the distribution and blending system. A large underground tunnel was drilled from Pembroke RO to Ta' Qali Group of reservoirs. Through this 9.4 km tunnel a 1,200mm diameter main pipe was installed to convey desalinated water to the reservoirs at Ta' Qali to increase Ta' Qali's blending potential. Another 800mm pipe will convey blended water back to the central part of the island, where a centralized hub feeding via gravity and booster pumps will supply quality water to consumers effectively and efficiently.

While on-site, consider an activity where you blend tap water (with a high conductivity) with RO water in different ratios and check how conductivities change in each case. Discover what kind of ratios WSC are aiming for and any reasons behind their choice (more info on: <https://www.wsc.com.mt/fireworks-chemicals-tap-water-no-cause-for-alarm/>).

Tabulate your results in a table such as the one below (the two blends shown are sufficient).

Conductivity: RO Water		Conductivity: Tap Water Locality: Attard (example)	
µS/cm		µS/cm	
Volume Tap Water [ml]	Volume RO Water [ml]	Ratio Tap / RO %	Final conductivity
		30 / 70	
		40 / 60	

Take with you a bottle of tap water from a locality with high conductivity. Use the online water quality tables from the WSC website to decide who will bring a tap water sample.

Below are some points to help you focus the discussion in your report:

- ✓ How effective is blending in improving water quality?
- ✓ Which blend is WSC currently using? Why?
- ✓ Which blend is WSC aiming for? Why?

Communication of outcomes

In your report it is important to describe your findings. In this section use the notes you took during the visit to help you to:

- answer any questions you asked the scientists.
- communicate any other information collected during the visit, for example: data from any measurements taken, any results or data shared with you by the scientists, any chemical or physical changes observed during experiments carried out on site, any unexpected findings etc.

The table below is one way you can organise your notes/information. However use whatever other method/means you are comfortable with.

Name of activity:	Example:
Scope:	<i>(What to I want to learn? Example:</i>
Outcomes:	<i>(What did I actually learn?):</i>

Discussion, Evaluation, Reflection and References

Discussion

- What did you learn from this site visit?
- Which learning outcomes did you achieve?
- Interpret any results, data or other information collected by: relating findings to expectations and any conclusions arrived at.

Evaluation

- Did you encounter any difficulties, challenges during the visit?
- Are there any improvements or alternate activities you can suggest?

Reflection

- "[Malta] has been facing and will continue to face water stress and scarcity in the coming years, receiving the designation as the most water stressed country in Europe." [Quoted from article in IA1]
- Before this site visit, were you aware of how serious the threat of water scarcity in Malta is?
 - Can we solve Malta's water crisis just by producing more fresh water through desalination?
 - Is water preservation a social responsibility or something only the authorities need to worry about?
 - Describe some lifestyle changes you are willing to implement to reduce water use.
 - Any other reflections you would like to add?

References

List any sources cited or referred to.

Subject Focus 2: Substances from the Earth: Aquatic environments

Site Visit



Pembroke RO Plant

Subject Focus 2: Substances from the Earth: Aquatic environment

Site Visit: Water Services Corporation (WSC) Pembroke RO Plant

Learning Outcome 3:

I can describe the solvent action of water including the impact of water hardness.

3.1a Identify sources of potable water and their management in Malta.

3.2a Present ideas that water is a very precious resource in the world and a potential source of conflict.

3.3a Relate ideas based on research about why water is a very precious resource.

3.2b State criteria of purity for water. (Limited to melting point, boiling point and conductivity.)

3.1e Explain that sea water contains dissolved charged ions that form crystals on evaporation

3.3f Explain the properties of ionic compounds (limited to solubility, mpt/bpt and electrical conductivity in different states.

3.1m Explain why water softening is important in hard water areas by referring to the local scenario.

3.1n Name desalination techniques that can be used to create demineralised water from seawater.

(Limited to distillation and reverse osmosis.)

3.2n Describe how simple distillation and reverse osmosis are used to produce demineralised water from impure water.

3.3n Evaluate desalination techniques that can be used to produce demineralised water from seawater.

(Limited to distillation and reverse osmosis.)

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

General Site information

Water Services Corporation

Head Office, Triq Hal Qormi, Hal Luqa
LQA 9043

Freephone: 8007 6400

Email: customer care@wsc.com.mt

Pembroke Reverse Osmosis Plant

<https://goo.gl/maps/NNho2fAJL85vTZxt7>



How to contact:

Use the general contact details on WSC website: <https://www.wsc.com.mt/contact-us/>

Send an email request or fill in the online form clearly specifying your position, intent and school details, especially the site you are considering for a visit.

Otherwise call the corporation asking for the Public Relations Officer (PRO). Ask the PRO to give you direct contact details of the responsible person of the site you intend to visit.

Logistical Considerations: Pembroke RO

Tour Duration
(approx., not including travel time)

2 hours

Recommended number of students:

16 maximum, split in two groups.

Safety considerations

No access allowed to dangerous areas. Health and safety officers would have carried out a risk assessment for the planned route.

Only closed shoes allowed (no heels).

Possibility of loud background noise. Check in advance, especially if there are students who are particularly susceptible.

Availability during scholastic year	All year, any time during school hours. Prior appointment necessary.
Access to students with disabilities	Limited wheel chair access to certain areas.
Facilities:	
Restrooms	Yes
Lunch/recreational areas	Yes
Lecture room	Yes
Student pack resources:	
Introductory Activities (IA)	IA1: Research Task IA2: Water Quality IA3: Discussion IA4: Extension: Global water scarcity
Preparatory Activities (PA)	PA1: Desalination by Reverse Osmosis PA2: Prepare your questions
Site Activities (SA)	SA1: Process Flowchart SA2: Membrane Schematic SA3: Caring for membranes and pipes: the role of pH and Hardness SA4: Reverse Osmosis vs Distillation SA5: Mixing waters to improve quality

The Student Resource pack: answers and some guidelines

Rationale:

This pack is not prescriptive. Contrarily, its underlying intention is to provide an outset for the introduction of site visits as coursework. The activities include a variety of resources encompassed within diverse teaching modes spanning traditional, practical and critical approaches. Teachers are encouraged to use whichever resources they deem most pertinent to the contexts they are operating in such as the level of class competence, resources available at school, scheme of work schedules and other such factors typical of the teaching profession.

The pack is modelled around the concept of a restaurant menu, whereby patrons choose their meals depending on their mood and preferred tastes. In fact, the pack's quintessential goal is to spur teachers into eventually creating their own personalised site related resources by either choosing which activities to use or reorganizing them in a different sequence, while adding their own content. Teachers could consider amending the resources to target outcomes related to the site visit. The pack includes various activities that are also suggestive of ideas for lesson planning and other coursework modes: fieldwork, investigations, project based and laboratory practicals.

Activities:

The activities are divided into three categories:

Introductory Activities (IA):

Designed to introduce the students to the processes occurring at the site and to any relevant general knowledge, without which important aspects of the site visit might be lost.

Preparatory Activities (PA):

Designed to get students more in-depth knowledge of processes on the site, possibly encouraging a more critical approach especially in matters related to socio-scientific issues. Some include school based practical activities.

Site Activities (SA):

These are activities that can be carried out on site. These were designed around what the author has experienced during the site evaluation visits. Please appreciate that the guides may be unaware of these activities. Teachers need to liaise with the site responsible people, well in advance, on what activities are possible at the time. It is imperative to discuss in detail the planned activities focusing on any procedures the students will be carrying out and availability of resources on site: equipment, consumables, supervising personnel and venue. Health and safety issues also need to be considered.

Preparing quality questions:

One requirement for site visits in the SEC 06 chemistry syllabus (2025) is for students to prepare questions to ask to the site experts. Therefore, all activities are designed to cater for this prerequisite. Ideally students should use the included prompts to guide their research in order to formulate quality, focused questions to ask during their site visit. For example, instead of asking: 'What is reverse osmosis?' a better question could be: 'How is the natural process of osmosis reversed in this plant?' This would indicate to the scientists that the students have prepared themselves well because they are keen on learning. This, in turn, could transcribe into a more positive disposition of the site experts towards the students, thereby making the experience more fruitful and rewarding to all actors.

It is advisable to share the questions with the site guides before the visit so they can plan the tour accordingly, thereby further bolstering the learning efficacy of the site visit.

The final report:

The general layout of the pack is structured around the rubric presented in the syllabus SEC 06 (2025) document, to facilitate the students' report writing. The teachers should discuss with the students, either as a class or in groups, which of the activities to include in their final report. The rubric stipulates that a set of preparatory and site activities need to be described in the report.

Introduction:

(Assessment Criteria: 3.1a Identify sources of potable water and their management in Malta.)

By referring to the WSC website and from your day to day experiences, list the three main sources of potable water in Malta:

1. Groundwater
2. Purification of seawater
3. Imported water/ bottled water

How does WSC convert seawater into drinking water? Where are these sites located?

Reverse Osmosis.

At time of writing WSC had four sites: Pembroke, Cirkewwa, Ghar Lapsi and Qala (Gozo)

(<https://www.independent.com.mt/articles/2021-06-07/local-news/Gozo-s-first-Reverse-Osmosis-expected-to-become-operational-by-end-of-year-6736234132>)

Introductory Activities (IA)

IA1: Research Task

(Assessment Criteria:

3.1a Identify sources of potable water and their management in Malta.

3.3a Relate ideas based on research about why water is a very precious resource.)

This activity centres around a research publication and intends to show students how scientific knowledge is propagated, while guiding them towards milieus for retrieving reliable, factual and objective sources of scientific knowledge. For instance, this article was published by a university in the USA and can be considered relatively unbiased by local influences and contentions. A copy is included in the appendix with text thought to be most relevant highlighted:

Hartfiel, L., Soupir, M., & Kanwar, R. S. (2020). Malta's Water Scarcity Challenges: Past, Present, and Future Mitigation Strategies for Sustainable Water Supplies. *Sustainability*, 12(23), 9835. MDPI AG. Retrieved from <http://dx.doi.org/10.3390/su12239835> .

Since the article is rather long and advanced, below are some recommendations:

- ✓ In groups: allow the class 15-20minutes to read the Abstract, Introduction and Conclusion.
- ✓ Use other, more concise, resources that are relevant to issues discussed in the article: resources that are possibly more aligned to the level of students in the classroom. For example, the following article published in the Times of Malta (2/06/2021):

"Freshwater: Securing our future"

(<https://timesofmalta.com/articles/view/freshwater-securing-our-future.876182>)

maybe be considered an abridged version of the research article.

(This article is also used in **IA4: Extension: Global water scarcity**)

Each group could prepare a short presentation, write-up, video, infographic, charts, awareness/activist leaflet etc., focusing on one or more of the main points listed in the resource pack.

IA2: Water Quality

(Assessment criteria:

3.2b State criteria of purity for water. (Limited to melting point, boiling point and conductivity.)

3.1e Explain that sea water contains dissolved charged ions that form crystals on evaporation

3.3f Explain the properties of ionic compounds (limited to solubility, mpt/bpt and electrical conductivity in different states.)

An activity that can be used to introduce the concepts of salinity and conductivity while resolving common misconceptions associated with these two terms. It also demonstrates how basic theoretical concepts learnt in class are applied in real life contexts. This activity gives students skills for retrieval and analysis of online data.

Salinity:

- By referring to the water quality tables, give examples of ions commonly present in Maltese fresh waters:

Cations	Anions
Ca^{2+}	CO_3^{2-}
Mg^{2+}	NO_3^-
NH_4^+	NO_2^-

- b. A property of ionic compounds is that they are usually soluble in water. Mention one other property that is consequence of this.

They conduct electricity when they are dissolved in water.

Conductivity:

- c. Is this relation between the Conductivity and concentration of hardness + nitrates observed in Table 1?
Depends on the data the students choose to analyse. There maybe instances where this relation is not clear.
- d. Which other two ions are not shown in the tables but could account for any differences? Sodium (Na^+) and chloride (Cl^-).

Extension question:

Why is monitoring of these ions in local groundwater important?

It is important to monitor these as since Malta is an island, groundwater can be contaminated by seepage of seawater into the aquifers.

IA3: Discussion

(Assessment criteria:

3.1a Identify sources of potable water and their management in Malta.

3.1m explain why water softening is important in hard water areas by referring to the local scenario.)

Learners are guided into a critical analysis of the water quality data for various localities. It should quickly become evident that certain localities have conductivity values up to ten times lower than others. Students are asked to come up with their own ideas about this situation while slowly guiding them into what could constitute socio-scientific issues (SSI) of equality and social justice. Below are some points that could be used to channel the discussion:

- Everyone pays the same water rates, so everyone is entitled to the same water quality.
- A case of unfair distribution and inequality of sharing public water resources among taxpayers.
- Extra costs incurred by people in high conductivity areas because of reduced lifetime of water heaters, mixer taps, shower heads etc., and the need to install, privately funded, filters or ROs (added costs).

- Problems with taste such that households revert to purchase costly bottled water and associated environmental implications: higher carbon footprint needed for production and transport, volume of plastic waste generated etc.

The Water Services Corporation took this situation very seriously and invested heavily to rectify it:

<https://www.independent.com.mt/articles/2021-10-01/local-news/WSC-Pembroke-Ta-Qali-tunnel-final-breakthrough-6736237178>

This activity could be used as a case study to show how SSI spurred a revolution in distribution infrastructure of potable water locally.

For a more critical approach:

- Is such an expenditure justified? Should it have gone elsewhere: building of more RO plants or other projects to make Malta's water infrastructure more sustainable?

IA4: Extension: Global Water Scarcity

(Assessment criteria:

3.2a Present ideas that water is a very precious resource in the world and a potential source of conflict.

3.3a Relate ideas based on research about why water is a very precious resource.)

This activity aims to make students aware of the imminent, but yet rather under acknowledged, threat of global water scarcity. Student can research this subject by reading online articles or watching documentaries such as:

<https://www.youtube.com/watch?v=C65iqOSCZOY>

<https://www.youtube.com/watch?v=RjsThobqq7Q>

Case studies California, the Amazon, Cape Town :

<https://www.youtube.com/watch?v=J9tF4vEHjaE>

<https://www.youtube.com/watch?v=XPCaM9Rzzbs>

<https://www.youtube.com/watch?v=vB68xvRb2T4>

For a concise description of how precarious the local situation is, they can refer to the following article published in the Times of Malta (2/06/2021):

"Freshwater: Securing our future"

<https://timesofmalta.com/articles/view/freshwater-securing-our-future.876182>

This article raises a number of issues that concern and disquiet us as Maltese citizens:

- Sustainable extraction of fresh water while respecting the country's ecological boundaries.
- Uncontrolled overexploitation and contamination of groundwater reserves.
- Malta's core water challenge is water mismanagement.
- Illegal boreholes.
- The poor status of groundwater will continue to worsen unless decisive action is taken.

Points to guide your class discussion:

- ✓ Are the issues leading to water shortages in Malta similar to those in other countries?
- ✓ Which practices use up fresh water the most? What can be done to limit their use?
- ✓ Can the world's water crisis be solved just by producing more fresh water through desalination?
- ✓ Is this technology easily available to all countries? Which countries are already suffering from severe water shortages?
- ✓ How crucial were community efforts and social responsibility important to delay severe drought in places like Cape town and California?
- ✓ Do you think the Maltese are willing to take on some of the sacrifices these countries had to make?

Points to encourage students to discuss with the site experts:

- ✓ Can the science behind reverse osmosis alone resolve the water crisis?
- ✓ Are oil spills a significant threat to our RO plants and, as a consequence, our fresh water supply?
- ✓ What recommendations would you propose to local politicians and decision makers to mitigate the threat of water scarcity?

Each group could prepare a short presentation, write-up, video, infographic, chart, awareness/activist leaflet, painting, model etc., focusing on one or more of the main points listed.

Preparatory Activities (PA)

PA1: Desalination by Reverse Osmosis

(Assessment criteria:

3.1n Name desalination techniques that can be used to create demineralised water from seawater.

(Limited to distillation and reverse osmosis.)

3.2n Describe how simple distillation and reverse osmosis are used to produce demineralised water from impure water.)

Prior to the site visit students can watch videos listed in this activity in order to understand the natural process of osmosis and how it is reversed by artificial means, to understand the basic principles taking place at the RO plant. This activity includes prompt questions to help students prepare the necessary questions to be asked during the site visit.

During their research, students could also start filling in the section for 'Site details' in their packs

PA2: Prepare your questions

Here students are given time to consolidate what they have learnt into questions which they will be asking during the visit as a group.

Site Activities (SA)

(Assessment criteria:

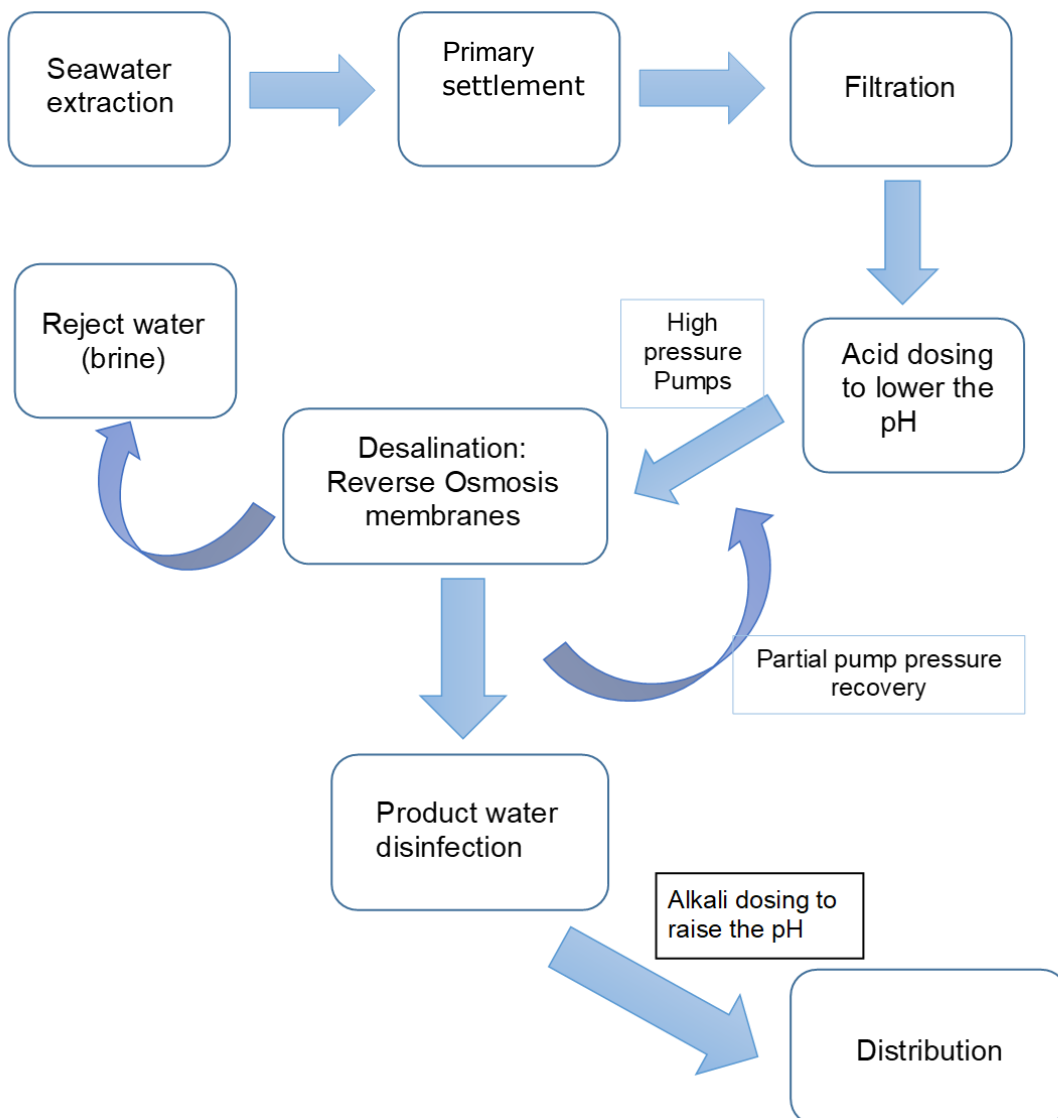
3.1n Name desalination techniques that can be used to create demineralised water from seawater.
(Limited to distillation and reverse osmosis.)

3.2n Describe how simple distillation and reverse osmosis are used to produce demineralised water from impure water.

3.3n Evaluate desalination techniques that can be used to produce demineralised water from seawater.
(Limited to distillation and reverse osmosis.))

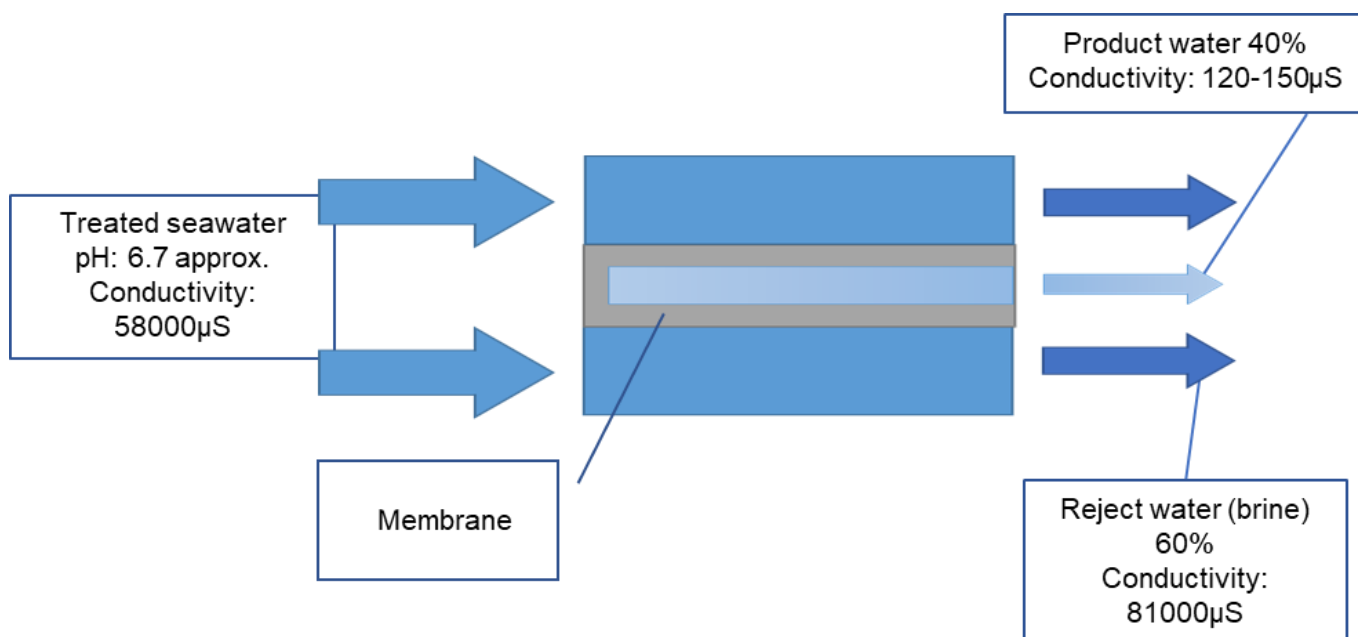
SA1: Flowchart showing the conversion of sea water into potable water

Whilst on site, with the help of the guide, students will be asked to complete this flowchart which explains the various stages involved in converting seawater to potable water. *(Idea: students might add their own photos from the site visit showing each stage.)*



SA2: Membrane Schematic

Whilst on site, with the help of the guide, students will be asked to complete this schematic which outlines how freshwater is produced from seawater inside the membranes by reverse osmosis.



SA3: Preserving membranes and pipes: the role of pH and Hardness.

In order to preserve membranes and pipes, acids and alkalis are added at different stages in the process as explained in the table below.

	pH level	How is the pH controlled	Consequences if pH is out of range
Treated Feed water (from the sea)	6.7 – 6.8	Acid dosing	If pH is too high, scaling will occur on the RO membranes, due to precipitation of calcium carbonate mostly (calcium hardness). This damages (blocks) the membranes.
Treated Fresh water output	9.1	Alkali dosing (calcium hydroxide)	The pipes through which product water is pumped to the consumers are ductile iron cement lined. If the pH is too low (acidic) the water will eat the lining thereby damaging the pipes.

SA4: Reverse Osmosis vs Distillation

(Assessment criteria:

3.3n Evaluate desalination techniques that can be used to produce demineralised water from seawater. (Limited to distillation and reverse osmosis.))

By completing this table students will evaluate the two desalination techniques: reverse osmosis and distillation in terms of efficiency of the process, the energy required and time taken to complete the process. This activity could be carried out in a lecture or board room with the help of the site experts.

SA5: Mixing waters to improve quality

A large underground tunnel is being constructed from RO Pembroke to Ta Qali reservoir, so that water from the RO can be blended with groundwater to improve water quality. During this hands on activity students will simulate this process by mixing tap and RO water in different ratios to determine how the conductivity is affected in each case. The implications of this process, such as the lowering of hardness and groundwater salinity, can be discussed in the students' report.

Concluding remarks

As a final thought and recommendation, it would be a nice gesture for the students to prepare a small token of appreciation that could be presented to the guide/s at the end of the visit. This should be something relevant to the site and that the students produced during their activities, for example a leaflet or infographic raising awareness about Malta's water challenges. Students with a penchant for artistic or literary expression might even present a painting or read out a poem or a short essay related to the subject.

Apart from being a sign of gratitude, these simple practices could help build and sustain rapports between the schools and the external scientific community. Such connections are very precious resources which unfortunately, in Malta, are very much left untapped.



My Environment



Environmental Assessment



Environmental Permitting



Environmental Compliance and
Enforcement

Subject Focus 1: Substances from the Earth: The Atmosphere

Site Visit



Student Resource Pack

Adrian Vella MTL (SCI)

Your Map to Success

Learning Outcome 2: At the end of the programme, I can describe and explain the properties of gases that may be found in air and how to prepare them in the lab.

2.1o Relate the emission of the pollutants present in air to human activities.

2.2o Describe how the amount of certain gases and particulates in the environment may increase due to combustion reactions.

2.3o Explain how the amount of certain gases and particulates in the environment may increase due to combustion reactions and natural causes.

2.2r Explain environmental effects of pollutants.

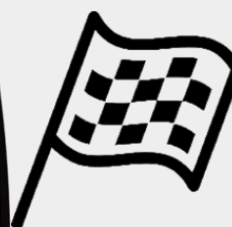
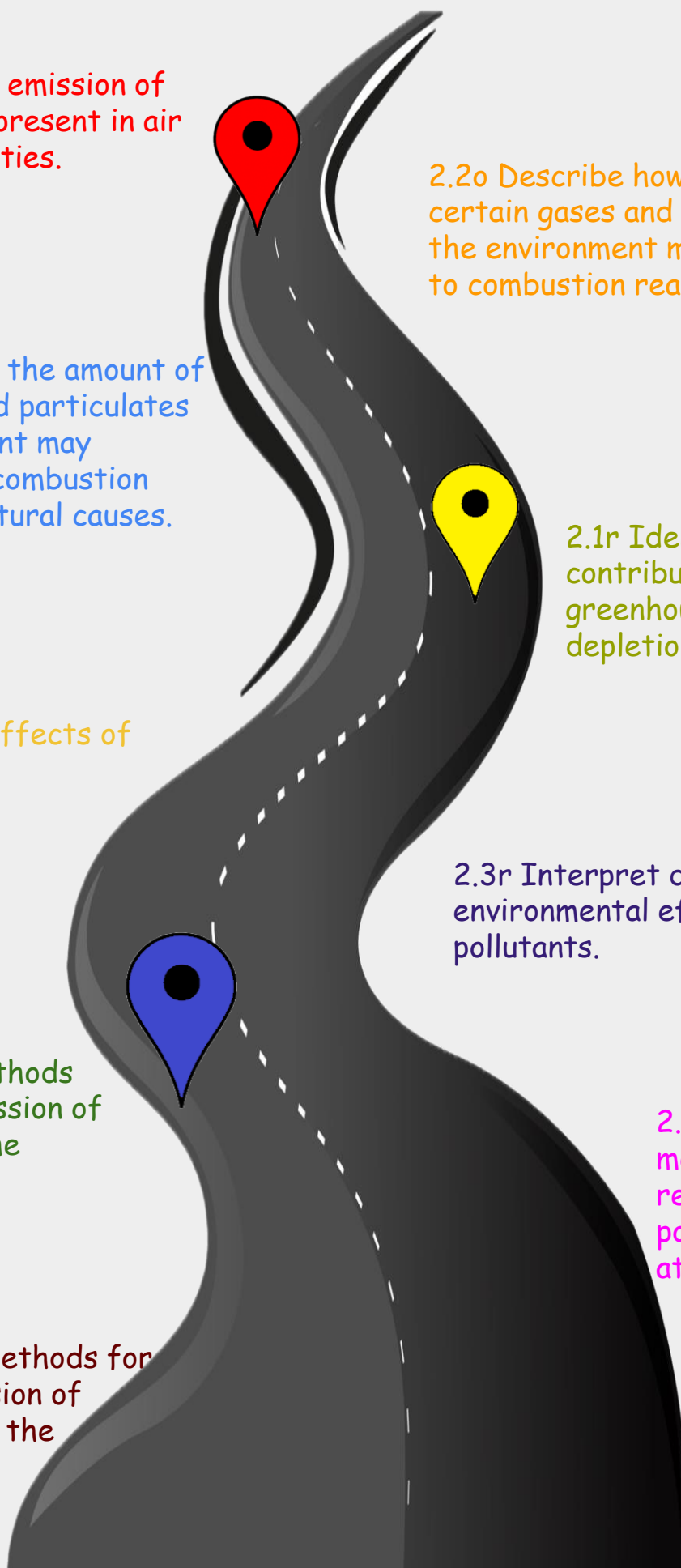
2.1r Identify gases that contribute towards the greenhouse effect, ozone depletion and acid rain.

2.3r Interpret data regarding environmental effects of some pollutants.

2.1s Identify methods for reducing emission of pollutants into the atmosphere.

2.2s Describe methods for reducing emission of pollutants into the atmosphere.

2.3s Discuss methods for reducing emission of pollutants into the atmosphere



Introduction

Hey, guess what this site visit will be about?

A few days before the visit....

Easy, Air pollution!

Indeed. I wonder what gave this away!

And **after** have a look at this website:

era.org.mt/#

Let's get to it then. **Start** by watching this video:

www.youtube.com/watch?v=oCdSYPgtr_8

Introductory Activities (IA)

IA1: About ERA

What is E.R.A.?

What is their Mission? *(you can quote directly here)*

Explain what you understand by 'Environment'

What do you understand by the word 'Sustainable'?

How do you think ERA tries to 'safeguard' the Air environment?

Now let's
answer some
questions...



IA2: Air Quality

Now you need to decide what you would like to discover more about during the site visit.

Really! In that case it might be wise to learn more about ERA and its operations.



Good idea. The website below is a good place to start.

And while you're at it, think about any questions you want to ask during your visit



Air Quality and National Emissions

era.org.mt/era-topic-categories/air-quality-and-national-emissions/

Try searching for articles on local newspapers related to air quality too!

Important links on this site:

era.org.mt/topic/ambient-air-quality/

era.org.mt/topic/real-time-air-quality-network/

era.org.mt/topic/sources-and-health-effects-of-air-pollution/

era.org.mt/air-quality-widget/

Questions:

PA1: Which Site?



ERA have multiple stations that are continuously monitoring the air quality in their surrounding environment.

Using Google Maps, scout a bit the area of where each station is located. Think about pollution sources and sinks in the vicinity, as well as other factors such as seasonal variations in traffic.

- Which sites experience the most/least air pollution? (*Predict giving reasons*).
- Choose a site to visit (Keep in mind logistic issues: time of day, distance from school, and traffic conditions to get there). Give reasons for your choice.

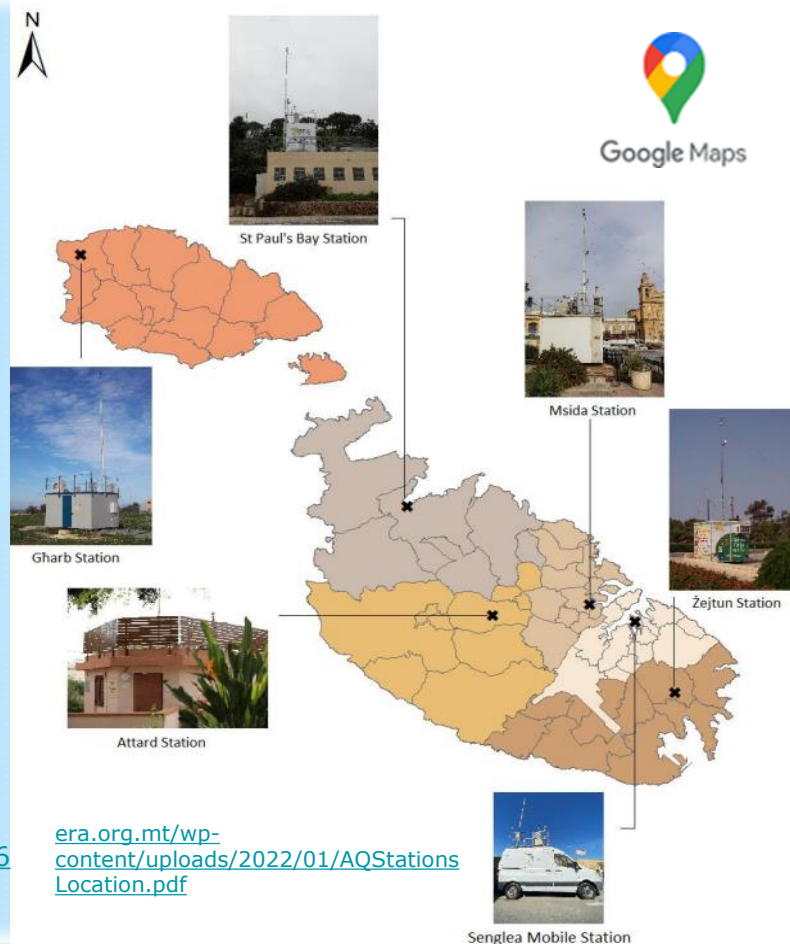
Attard: <https://goo.gl/maps/xJbwCaduLDMkoYEZ8>

Gharb: <https://goo.gl/maps/pP33Kram3qddWjGz7>

Msida: <https://goo.gl/maps/ZzdrECCrH4wddHTH7>

St Paul's Bay: <https://goo.gl/maps/uRqQoB4EYJ9qjflB6>

Zejtun: <https://goo.gl/maps/Ep25LDQ6MApmBGsH8>



STUDY
Requested by the ENVI committee



Sampling points for air quality

Representativeness and
comparability of measurement
in accordance with Directive
2008/50/EC on ambient air quality
and cleaner air for Europe



Policy Department for Economic, Scientific and Quality of Life Policies
Directorate General for Internal Policies
Authors: Christian NAGL, Wolfgang SPANGL, Iris BUEBAUM
PE 631 055 - March 2019

EN

[www.europarl.europa.eu/RegData/etudes/STUD/2019/631055/IPOL_STU\(2019\)631055_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2019/631055/IPOL_STU(2019)631055_EN.pdf)

How did ERA choose these sites? Their decisions were not just random. They had to adhere to criteria specified by the EU. The document shown here (pg 24), states that the measurements must specifically be made in:

- areas with the highest concentrations of pollutants and where it is likely for the population to be directly exposed for significant time periods;
- areas which are representative for the exposure of the general population.

Discuss what these could mean and why the site you chose above could meet these criteria.

Propose a new site to ERA that could qualify for an air monitoring station.

In Site activity SA2 you have the opportunity to discuss your ideas with ERA. I encourage you to do so!



PA2:

Passive Diffusion Tubes

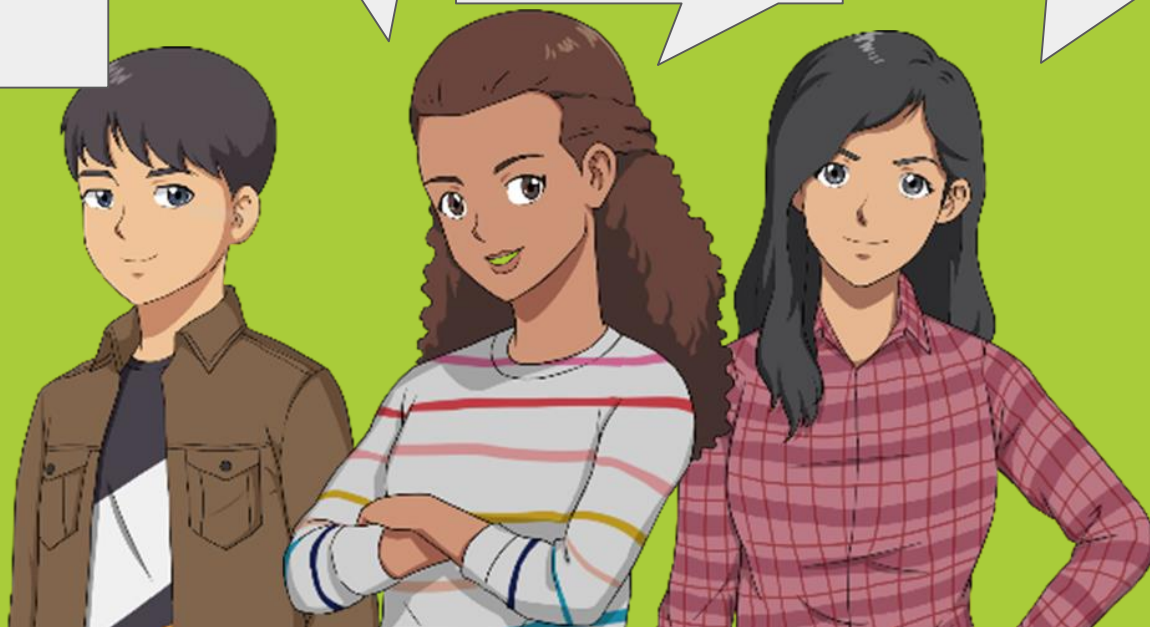
Start here:

<https://era.org.mt/topic/passive-diffusive-tube-network/>

Next look at the NO₂ data presented here, especially 2020.

Then have a go at the questions on the next pages.

OR you may want to consider the project idea in **PA4**.....



Which areas in Malta and Gozo persistently have higher/lower levels of NO₂?

Can you suggest reason/s for this?

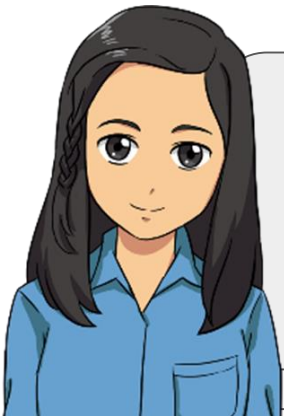
Examine carefully the results of 2020 compared to other years. What do you notice?

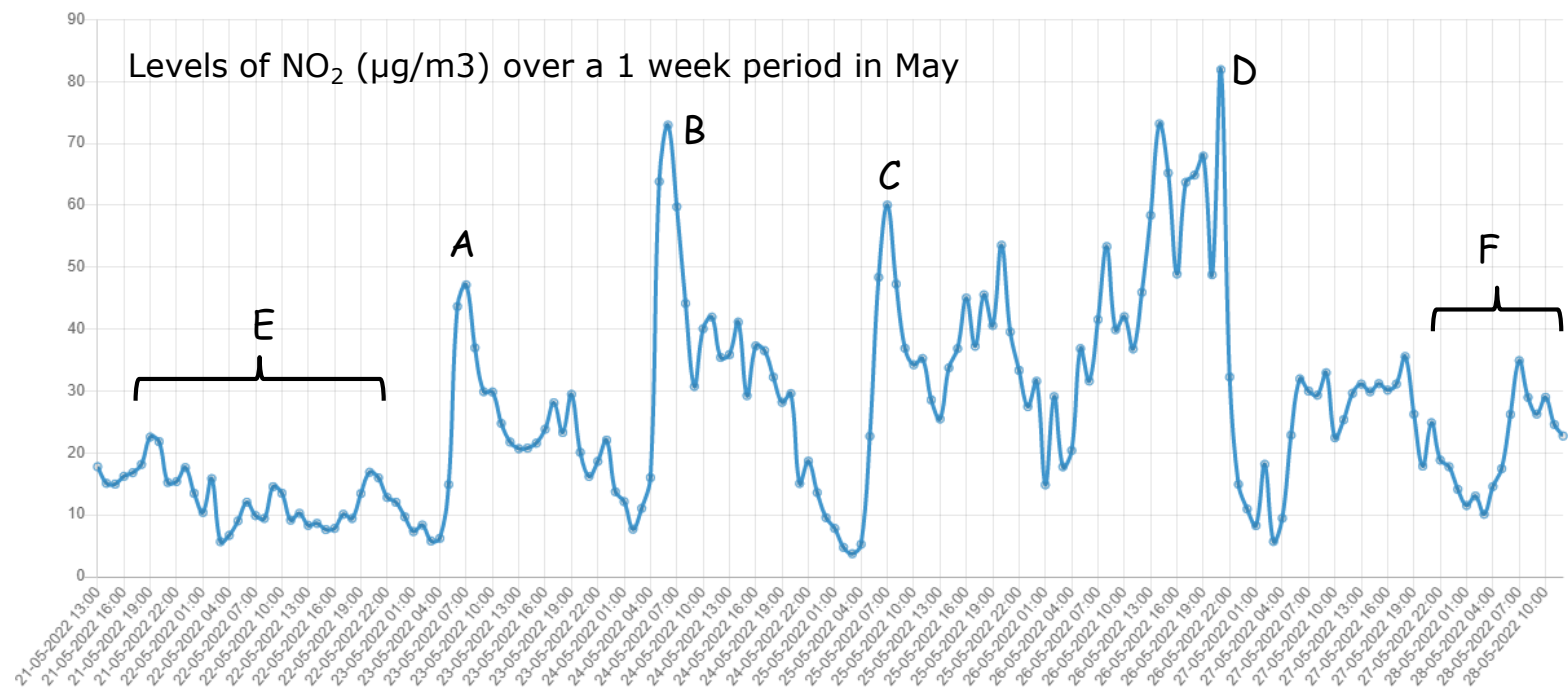
Can you suggest an explanation?



Based on this data what can you conclude about air pollution and human activities?

(Mention which human activity is mostly responsible for this.)





Give possible reasons for the position of peaks labelled:

A, B and C:

D:

Why are there no such peaks in the sections labelled E and F?



Suggest three ways to reduce peaks A, B, C and D.



In chapter 6 of the document referred to in PA1, there is a list of measures other countries took to reduce pollution. Make a list of three measures you think are also possible in Malta. Do you feel up to asking ERA why certain measures have not been implemented yet?

Measure #1: _____

Measure #2: _____

Measure #3: _____



PA3: Extension Passive Diffusion Tubes: The Challenge

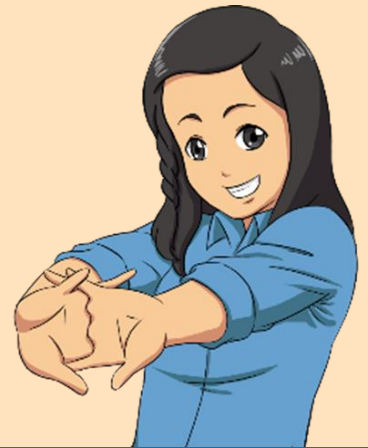
We don't want you to get bored!



I read somewhere that ERA are supplying these tubes even to schools!



Wow! Wouldn't it be great to know what the air quality is like in our school?



Sure is! I say we talk to the guys at ERA during our visit and let's do this.

Passive Diffusion Tubes look something like this. They are very easy to use.



Once ERA supply these you need to set them up in suitable shelters such as the ones shown here. These would need to be prepared by you.



The tubes will have to be returned after a number of days to ERA for analysis.

Think about what you would need to ask scientists at ERA should you decide to take up this project.



Where to locate the tubes.
The correct procedure to set them up.
How to collect and return the tubes.
Dimensions of the shelter, etc.....

PA4: Prepare your questions

Based on what you have learned so far, as a group, propose 3 questions you would like to ask the experts during your visit.

[illegible]

I would like to know more about....

[illegible]

The Site Visit



It is now time to visit the site with the experts! Before you go have a look at the following sections that are designed to help you write your report and....

....remember to **PATE**:
Participate,
Ask questions,
Take photos and notes,
ENJOY!



Date	
Title	
Aims and objectives	

Adrian Vella
MTL (SCI)

SA1:

Site Walk

When you arrive on the site spend some minutes walking around and sketch a map.

On it label:
Sources of air pollution and things that can mitigate the effects of air pollution.



You can draw your map here!



What else is important?
E.g. Gases emitted from
each source....

Any visible effects
of pollution?

Anything else?

SA2:

Siting the Stations



This is a photo of the station in Gharb, Gozo. There doesn't seem to be much pollution here!



There are no monitoring stations in my locality. I wonder why...

Neither where I live... So aren't we part of the 'general population?'

I am sure there is a rational explanation for this. We read about this in the EU document mentioned in class during PA1.

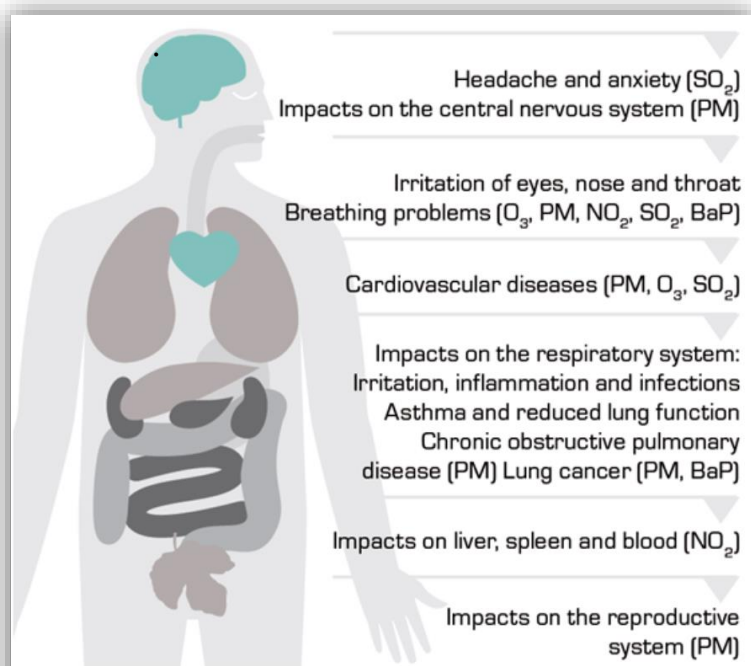
You should discuss this with ERA during the visit to understand why the site you are visiting was chosen and not some other place!

Don't forget to propose the site/s you came up with in PA1. See what the experts at ERA think about your choices!



SA3: Which pollutants?

Station Location: _____



The major effects of air pollution on human health. Source: Nagl, Spangl & Buxbaum (2019); Sampling

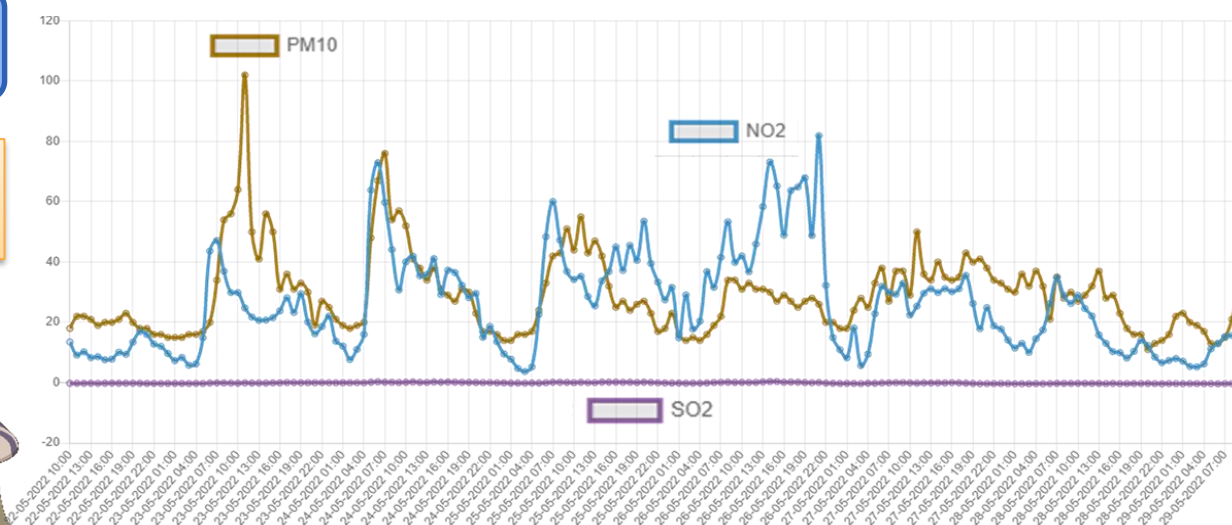
On this figure circle the pollutants being monitored at this station. Choose 3 and fill in the table below with the help of your guide.

era.org.mt/topic/sources-and-health-effects-of-air-pollution/

Pollutant	Human source	Natural Source

Reading the Data:

Sure looks complicated!



And why is SO_2 always zero; should we keep monitoring it?

Indeed! But look closely. There is huge PM10 peak, but the general pattern follows that of NO_2 . I wonder....

Explore these and other questions with ERA. Look at fresh data from the station you are visiting. Discuss and LEARN!!!

Site details	
Description of location	
History	
Purpose of site	
Precautions and Safety Considerations <i>(Potential hazards and safety considerations noticed on site)</i>	

Back in school.....



In your report it is important to describe your findings. In this section use the notes you took during the visit to help you to:
answer any questions you asked the scientists...

... and communicate any other information collected during the visit, for example: data from any measurements taken, any results or data shared with you by the scientists, any chemical or physical changes observed during experiments carried out on site, any unexpected findings etc.



Discussion, Evaluation, Reflection and References

Discussion

- What did you learn from this site visit?
- Which learning outcomes did you achieve?
- Interpret any results, data or other information collected by: relating findings to expectations and any conclusions arrived at.

Evaluation

Did you encounter any difficulties, challenges during the visit?



Are there any improvements or alternate activities you can suggest?

Write about them in your report.

Reflection



These questions and concerns may help guide you in your **reflections**.
Anything else you want to add?

By car, bus or bike?

Could it be the reason that I have asthma?

I have to do something....

Is it as bad as they say?

Not my problem!

References

List any sources cited or referred to.

Taking it further....

Why not consider taking this experience further and keep in touch with ERA by taking up the tubes project



Or invite one of their scientists to show them what your school is doing to reduce air pollution



It has been great going on this journey with you!

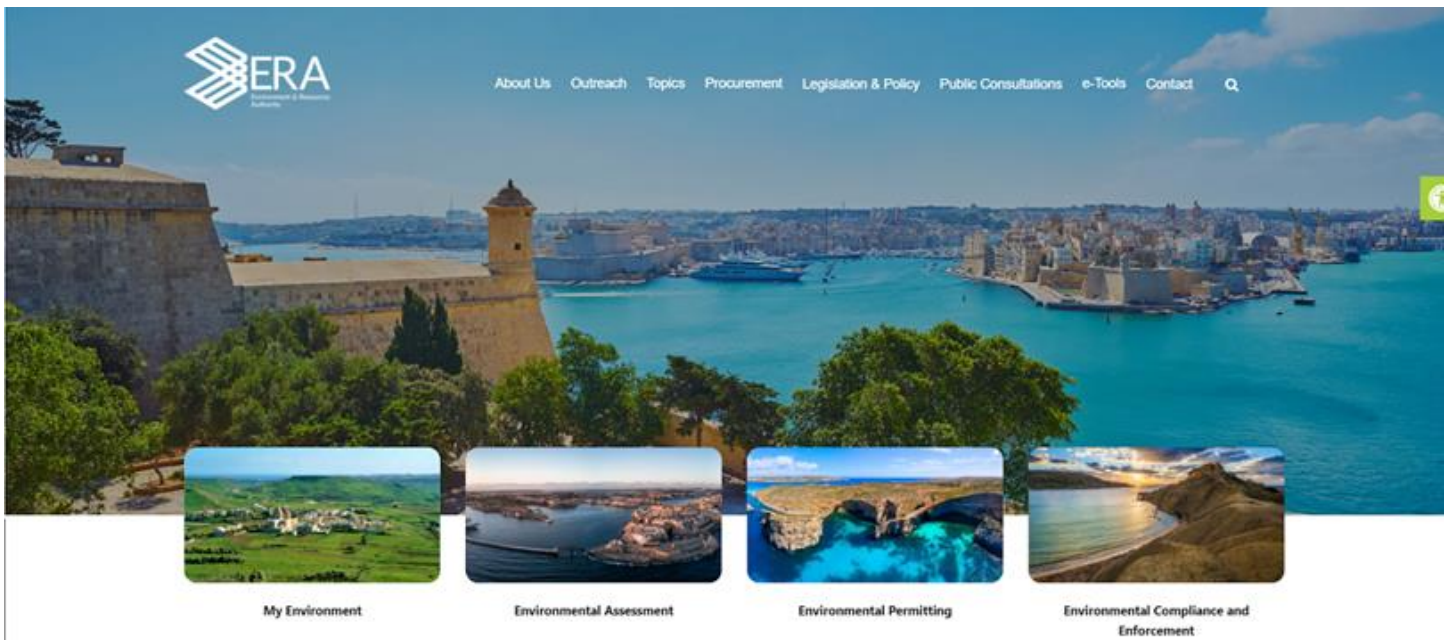
We hope you learnt a lot from this experience..

..not just about pollution but also about career opportunities,

and working on research together as a team.

In the meantime we wish you best of luck in your studies. Hope to see you again soon.





Subject Focus 1: Substances from the Earth: The Atmosphere

Site Visit



Teachers' Guide

Subject Focus 1:

Substances from the Earth: The Atmosphere

Site Visit: ERA Air Quality

Target Learning Outcomes

Learning Outcome 2:

At the end of the programme, I can describe and explain the properties of gases that may be found in air and how to prepare them in the lab.

2.1o Relate the emission of the pollutants present in air to human activities.

2.2o Describe how the amount of certain gases and particulates in the environment may increase due to combustion reactions.

2.3o Explain how the amount of certain gases and particulates in the environment may increase due to combustion reactions and natural causes.

2.1r Identify gases that contribute towards the greenhouse effect, ozone depletion and acid rain.

2.2r Explain environmental effects of pollutants.

2.3r Interpret data regarding environmental effects of some pollutants.

2.1s Identify methods for reducing emission of pollutants into the atmosphere.

2.2s Describe methods for reducing emission of pollutants into the atmosphere.

2.3s Discuss methods for reducing emission of pollutants into the atmosphere.

General Site information	
Environment and Resources Authority Hexagon House Spencer Hill Marsa, MRS 1441 Tel: 2292 3500 Emails: Human resources: hr.era@era.org.mt General: info@era.org.mt	Locations: 1. Workshop: https://goo.gl/maps/erKh8tSRFrWFPYb17 2. One of the Air monitoring stations: (<i>as at time of writing</i>) Gharb (Gozo), Msida, St Paul's Bay, Attard, Zejtun and Senglea (mobile). era.org.mt/wp-content/uploads/2022/01/AQStationsLocation.pdf
How to contact: Call or send an email to human resources, as per contacts given above (double check the website in case of changes). Alternatively fill in the Customer Care enquiry form on the website. Always include your position as science educator, contact details and explain clearly your intentions. Start communications early, at least three months before the visit.	
Logistical Considerations: ERA: Air monitoring stations and workshop. (This site visit might require transport to two different locations)	
Tour Duration (approx., not including travel time)	2 hours
Recommended number of students:	16, in groups of 4
Safety considerations	Some stations are located in areas with heavy traffic.
Availability during scholastic year	All year, any time during school hours

Access to students with disabilities	Depends on site. Check with ERA whether the planned site has adequate access.
Facilities:	
Restrooms	Depends on site
Lunch/ recreational Areas	Available at most sites, but check before.
Lecture/board room	Available at the headquarters; subject to availability at time of visit.
Student pack resources:	
Introductory Activities (IA)	IA1: About ERA IA2: Air Quality
Preparatory Activities (PA)	PA1: Which Site? PA2: Passive Diffusion Tubes PA3: Extension: Passive Diffusion Tubes: The Challenge PA4: Prepare your questions
Site Activities (SA)	SA1: Site Walk SA2: Siting the Stations SA3: Which pollutants? <i>Optional</i> SA4: The weight of pollution

The Student Resource pack: answers and some guidelines

Rationale:

This pack is not prescriptive. Contrarily, its underlying intention is to provide an outset for the introduction of site visits as coursework. The activities include a variety of resources encompassed within diverse teaching modes spanning traditional, practical and critical approaches. Teachers are encouraged to use whichever resources they deem most pertinent to the contexts they are operating in such as the level of class competence, resources available at school, scheme of work schedules and other such factors typical of the teaching profession.

The pack is modelled around the concept of a restaurant menu, whereby patrons choose their meals depending on their mood and preferred tastes. In fact, the pack's quintessential goal is to spur teachers into eventually creating their own personalised site related resources by either choosing which activities to use or reorganizing them in a different sequence, while adding their own content. Teachers could consider amending the resources to target outcomes related to the site visit. The pack includes various activities that are also suggestive of ideas for lesson planning and other coursework modes: fieldwork, investigations, project based and laboratory practicals.

Activities:

The activities are divided into three categories:

Introductory Activities (IA):

Designed to introduce the students to the processes occurring at the site and to any relevant general knowledge, without which important aspects of the site visit might be lost.

Preparatory Activities (PA):

Designed to get students more in-depth knowledge of processes on the site, possibly encouraging a more critical approach especially in matters related to socio-scientific issues. Some include school based practical activities.

Site Activities (SA):

These are activities that can be carried out on site. These were designed around what the author has experienced during the site evaluation visits. Please appreciate that the guides may be unaware of these activities. Teachers need to liaise with the site responsible people, well in advance, on what activities are possible at the time. It is imperative to discuss in detail the planned activities focussing on any procedures the students will be carrying out and availability of resources on site: equipment, consumables, supervising personnel and venue. Health and safety issues also need to be considered.

Preparing quality questions:

One requirement for site visits in the SEC 06 chemistry syllabus (2025) is for students to prepare questions to ask to the site experts. Therefore, all activities are designed to cater for this prerequisite. Ideally students should use the included prompts to guide their research in order to formulate quality, focused questions to ask during their site visit. For example, instead of asking: 'Why did you choose this site for air quality monitoring?', a better question could be: 'How does this site meet the criteria specified in the Directive 2008/50/EC on ambient air quality and cleaner air for Europe?'. This would indicate to the scientists that the students have prepared themselves well because they are keen on learning. This, in turn, could transcribe into a more positive disposition of the site experts towards the students, thereby making the experience more fruitful and rewarding to all actors.

It is advisable to share the questions with the site guides before the visit so they can plan the tour accordingly, thereby further bolstering the learning efficacy of the site visit.

The final report:

The general layout of the packs is structured around the rubric presented in the syllabus SEC 06 (2025) document, to facilitate the students' report writing. The teachers should discuss with the students, either as a class or in groups, which of the activities to include in their final report. The rubric stipulates that a set of preparatory and site activities need to be described in the report.

Introduction

(Assessment criteria

2.1o Relate the emission of the pollutants present in air to human activities.

2.2o Describe how the amount of certain gases and particulates in the environment may increase due to combustion reactions.

2.3o Explain how the amount of certain gases and particulates in the environment may increase due to combustion reactions and natural causes.

2.1r Identify gases that contribute towards the greenhouse effect, ozone depletion and acid rain.

2.2r Explain environmental effects of pollutants.

2.3r Interpret data regarding environmental effects of some pollutants.)

Introductory Activities (IA)

IA1: About ERA

An introduction to the purpose and responsibilities of the Environmental Resources Authority.

What is E.R.A? The Environmental Resources Authority, a government entity responsible for regulation of matters related to the environment.

What is their mission? To safeguard the environment for a sustainable quality of life, by promoting and instilling sound environmental management.

Explain what you understand by 'Environment'? (There are various; the one proffered here, from the Cambridge dictionary is concise and easy to understand by students at this level): The air, water, and land in or on which people, animals, and plants live.

What do you understand by the word 'Sustainable'? Practices causing, or made in a way that cause, little or no damage to the environment and therefore able to continue for a long time.

How do you think ERA tries to 'safeguard' the Air environment? ERA monitors air quality in a number of locations over Malta and Gozo. It uses this data and other research based evidence to advise the Government on environmental policy-making.

IA2: Air Quality

In this activity students can explore in more depth ERA's purpose, responsibilities and operations, specific to safeguarding the air environment. Students are encouraged to start putting forward some questions based on their research.

Preparatory Activities (PA)

PA1: Which Site?

(Assessment Criteria:

2.1o Relate the emission of the pollutants present in air to human activities.

2.2o Describe how the amount of certain gases and particulates in the environment may increase due to combustion reactions.

2.3o Explain how the amount of certain gases and particulates in the environment may increase due to combustion reactions and natural causes.)

Students are given some ownership over the visit as they are encouraged to decide which of the sites they want to visit. This decision should not be taken randomly, but they have to weigh out a number of factors and agree, as a class, on the best way forward. In the process they can use an online tool (Google Maps) to gather data and make predictions related to potential pollution sources and sinks.

Pollution sink

Vehicle for removal of a chemical or gas from the atmosphere-biosphere-ocean system, in which the substance is absorbed into a permanent or semi-permanent repository, or else transformed into another substance. A carbon sink, for example, might be the ocean (which absorbs and holds carbon from other parts of the carbon cycle) or photosynthesis (which converts atmospheric carbon into plant material). Sinks are a fundamental factor in the ongoing balance which determines the concentration of every greenhouse gas in the atmosphere. If the sink is greater than the sources of a gas, its concentration in the atmosphere will decrease; if the source is greater than the sink, the concentration will increase.

(Source: <https://www.eea.europa.eu/help/glossary/gemet-environmental-thesaurus/pollution-sink>)

In the second part of this activity, which is also a prequel to SA2, students can learn about the EU directives ERA had to comply with when choosing the sites: [www.europarl.europa.eu/RegData/etudes/STUD/2019/631055/IPOL_STU\(2019\)631055_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2019/631055/IPOL_STU(2019)631055_EN.pdf).

Based on what they learn they are encouraged to propose a new site that could qualify for an air monitoring station. Their choice can be discussed with the experts during the site visit (SA2).

PA2: Passive Diffusion Tubes

(Assessment Criteria:

2.1o Relate the emission of the pollutants present in air to human activities.

2.2o Describe how the amount of certain gases and particulates in the environment may increase due to combustion reactions.

2.3o Explain how the amount of certain gases and particulates in the environment may increase due to combustion reactions and natural causes.

2.1r Identify gases that contribute towards the greenhouse effect, ozone depletion and acid rain.

2.2r Explain environmental effects of pollutants.

2.3r Interpret data regarding environmental effects of some pollutants.

2.1s Identify methods for reducing emission of pollutants into the atmosphere.

2.2s Describe methods for reducing emission of pollutants into the atmosphere.

2.3s Discuss methods for reducing emission of pollutants into the atmosphere.)

Here students can learn about ERA's Passive Diffusion Tube (PDT) network which constitutes an important part of their air monitoring capabilities. In this activity the focus is on the data acquired by the tubes and its analysis in pre and post COVID scenarios, rather than on the tubes themselves. If there are students who show interest in the tubes they can be referred to **PA3** which is an extension activity that can be also taken up as a project or fieldwork.

The questions are intended to bring about a discussion as opposed to a Q&A exercise. The points below can serve as a framework for the discussion:

Which areas in Malta and Gozo [persistently](#) have higher/lower levels of NO₂? Can you suggest reason/s for this?

Usually industrial areas and major main roads due to increased anthropogenic activities that involve combustion of fossil fuels. A major contributor is vehicular traffic, that generates a substantial amount of NO₂. *(This can be taken further to discuss the environmental impact of these emissions.)*

Examine carefully the results of 2020 compared to other years. What do you notice? Can you suggest an explanation?

It is evident that levels are drastically reduced due to COVID lockdown measures. An increase should be noted in subsequent years as the measures were slowly lifted.

Based on this data what can you conclude about air pollution and human activities? *(Mention which human activity is mostly responsible for this.)*

The COVID pandemic has provided an unprecedented situation which made unequivocal the link between human activities and air pollution. This is an extension of the first question, but here the reasons are supported beyond doubt with scientific evidence. The following peer reviewed article further supports these claims: Fenech, S., Aquilina, N. J., & Vella, R. (2021). COVID-19-related changes in NO₂ and O₃ concentrations and associated health effects in Malta. *Frontiers in Sustainable Cities*, 1.

Figure 1



A,B and C: Morning rush hours. Recurring between 7-9am.

Why are there no such peaks in the sections labelled E and F?

Weekends, therefore no rush hour.

Suggest three ways to reduce peaks A, B, C and D.

In the final part of this activity students are encouraged to think about possible mitigation measures at national policy level. They are referred to an official EU document that gives examples of policies other European countries implemented. They can share ideas on whether some of these are feasible in Malta.

PA3: Extension: Passive Diffusion Tubes the Challenge

This activity is intended for students who want to participate in one of ERA's school air quality monitoring programs. ERA can supply the tubes and their holders (shelters). However, the task of building the shelters can be taken up by the students themselves. The PDT are small tubes that contain chemicals to absorb a particular type of pollutant (e.g. NO₂). These are placed in appropriate shelters in strategic locations for a number of days. They are then collected and sent, by ERA, to laboratories for analysis of the pollutant concentrations. Students who want to take this up as a project are encouraged to liaise with ERA scientists to get more information on how to build the shelters, locate the tubes and organise logistics. ERA can also send their scientists to the school to share their knowledge, not just about the tubes, but on all environment related matters.

PA4: Prepare your questions

Here students are given time (and space) to consolidate what they have learnt into questions which they will be asking during the visit as a group. Probably students will have formulated different questions in the previous activities. Here they get to decide which three they think are most relevant and are about issues they want to learn more about.

Site Activities (SA)

(Assessment Criteria:

2.1o Relate the emission of the pollutants present in air to human activities.

2.2o Describe how the amount of certain gases and particulates in the environment may increase due to combustion reactions.

2.3o Explain how the amount of certain gases and particulates in the environment may increase due to combustion reactions and natural causes.

2.1r Identify gases that contribute towards the greenhouse effect, ozone depletion and acid rain.

2.2r Explain environmental effects of pollutants.

2.3r Interpret data regarding environmental effects of some pollutants.

2.1s Identify methods for reducing emission of pollutants into the atmosphere.

2.2s Describe methods for reducing emission of pollutants into the atmosphere.

2.3s Discuss methods for reducing emission of pollutants into the atmosphere.)

SA1: Site Walk

The air monitoring stations are rather small in size so students can only access them in small groups (max 4). This activity is designed to keep the rest of the groups busy. They are asked to continue the site assessment they started in **PA1** in more detail. Since they are now physically on the site, they can sketch a map, which could also be made into a chart or infographic, showing potential sources and sinks of pollution in the vicinity of the station. This activity could help them in writing their discussion by describing air pollution sources that the air monitoring station is detecting.

SA2: Siting the Stations

This activity is a continuation of **PA1**, where students can better understand the criteria that need to be met when choosing locations for the stations by interacting with the ERA scientists. These criteria are laid out by EU directives and are the same for all EU countries. This could be considered as an application of the principles of fair testing over a large scale; only so can air quality data be compared between countries. Students are reminded to discuss whether the site/s proposed in **PA1** can indeed qualify for an air monitoring station.

SA3: Which pollutants?

Here students need to discover which pollutants are monitored on the site they are visiting and list at least one human and one natural source for three of them. Some answers are given below but these are not exhaustive:

Pollutant	Human source	Natural Source
Nitrogen dioxide (NO ₂)	Car exhaust	Lightning strikes
Sulfur dioxide (SO ₂)	Burning of fossil fuels such as coal and heavy fuel oil (HFO).	Volcanoes
Particulate matter (PM)	Incomplete combustion of fossil fuels	Sea salt, sand

While undergoing this task they can learn about some of the health implications for each pollutant.

Note:

This link contains information about sources of Benzo(a)pyrene (BaP):
<https://www.umweltbundesamt.de/en/topics/air/air-pollutants-at-a-glance/benzoapyrene-in-particulate-matter#emission-sources>

Finally, they are given a sample of real data, taken from the ERA website, that they can discuss with the experts on site. The peaks are of particular interest. NO₂ has already been discussed in **PA2** but can be addressed in more detail with the scientists. The peak in PM is usually due to sand from the Sahara Desert and the guides can explain how they correct for these events when analysing PM data. Finally, the reasons behind the very low levels of SO₂ can be discussed; one being the switch from coal and HFO to natural gas power stations. Live data can possibly be called up on site or later at the ERA workshop and similarly discussed and analysed.

Optional: not in students' pack.

SA4: The weight of pollution.

This activity can be done at the ERA workshop in Marsa. Here they have a state-of-the-art system (figure 2) to weigh the particulate filters used to measure Particulate Matter (PM: PM10, PM2.5). The system is mostly automated but analytical balances are available for some students to weigh the filters themselves and take reading at the microgram level. Filters are weighed before being installed at the air monitoring sites. Here they are inserted into calibrated pumps that aspirate measured volumes of air through the filters. Any PMs are collected on the filters (as seen in the background of figure 3) and after reweighed at the workshop. The difference is the weight of the PM. The per unit volume reading is obtained by dividing the PM weight by the aspirated volume of air that is set on the pump. Readings are usually given in $\mu\text{g}/\text{m}^3$. Students can be guided into collecting some data in a table such as the below:

Location	Date	Weight before (filter only) [μg]	Weight after (filter+PM) [μg]	Weight of PM [μg]

There are a number of precautions that need to be observed, for example humidity and temperature control as these will affect the readings. Students should be encouraged to take a note of one or two of these.

The workshop also has access to live data from all the monitoring stations. The scientists are sure to bring up graphs showing some interesting pollution events that will be discussed during the visit.

Concluding remarks

As a final thought and recommendation, it would be a nice gesture for the students to prepare a small token of appreciation that could be presented to the guide/s at the end of the visit. This should be something relevant to the site and that the students produced during their activities, for example a leaflet or infographic raising awareness about Malta's air quality challenges. Students with a penchant for artistic or literary expression might even present a painting or read out a poem or a short essay related to the subject.

Apart from being a sign of gratitude, these simple practices could help build and sustain rapports between the schools and the external scientific community. Such connections are very precious resources which unfortunately, in Malta, are very much left untapped.

Figure 2



Figure 3



Subject Focus 2:

Substances from the Earth: Aquatic environments

Site Visit



Quality Control Laboratory

Student Resource Pack

Target Learning Outcomes

Learning Outcome 4:

I can describe the chemical properties of acids, bases and salts

4.1a Use indicators and the pH scale to distinguish between acidic, alkaline and neutral solutions.

4.2a Classify a substance as acid, base or alkali.

4.3a Explain the difference between strong and weak acids/alkalis.

4.2f Apply acid-base concepts to the real world. (*E.g. In terms of solutions to environmental issues such as acid rain, neutralisation of acid soils and excess stomach acidity.*)

4.3f Investigate acid-base concepts in real life applications.

Learning Outcome 7:

At the end of the programme, I can describe how substances dissolved in water can be identified and how their concentration can be measured.

7.2h Conduct an acid/base titration using step by step instructions. (Limited to hydrochloric acid, sulfuric acid, with sodium hydroxide, potassium hydroxide and sodium carbonate.)

7.3h Conduct an acid/base titration to determine the concentration of a given solution. (E.g. hydrochloric acid, sulfuric acid, nitric acid, ethanoic acid with sodium hydroxide, potassium hydroxide and sodium carbonate.)

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

IA1: About Farsons.

"Established since 1928, the Group is engaged in the brewing, production and sale and distribution of branded beers and beverages, the importation, wholesale and retail of food and beverages including wines and spirits....."

www.farsons.com

Task 1:

Browse through the Farsons website and make a list of four brands of products that are produced (not imported) by Farsons:

1. _____
2. _____
3. _____
4. _____

Mention one ingredient common to all of these products: _____

Task 2:

Think about at least three resources that are needed for Farsons to manufacture these products. Discuss some effects of each on the air, aquatic and land environments of the planet (the first one has been done for you).

Resource	Air	Water	Land
Factory and warehouse buildings	Emissions of CO ₂ , dust and other pollutants.	To produce concrete and other building materials.	Mining and quarrying for cement production, stone and other: marble, granite, iron etc.

Task 3:

Have you ever thought of human beings as important resources in industry? Think about any business sector and the role of humans in each. Humans (and animals) are different than most other resources mentioned above because they have rights. Have a quick read through the following document on the website to understand how Farsons safeguards the rights of its employees: www.farsons.com/en/human-rights.

(Focus on pg1: the two broad categories of human rights and pg2&3: activities to promote and ensure the human rights of all the company's stakeholders.)

IA2: Living with Acids and Bases.

Watch: www.youtube.com/watch?v=r3hirzIWILM

Which of the acids and bases in the table are present in the items shown below. (Some items may contain more then one acid/base). Research if necessary....

Sodium hypochlorite	Lactic acid	Ammonia	Acetic acid
Citric Acid	Calcium Carbonate	Hydrochloric Acid	Calcium hypochlorite
Phosphoric Acid	Sodium Hydroxide	Carbonated Water	Sodium hydrogen carbonate

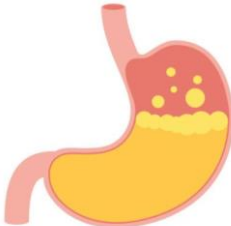




















Which of the items in bold are:

Acids:

Bases:

The Site Visit

It is now time to visit the site with the experts!
Before you go have a look at the next section and remember to:

Participate, **A**sk questions, **T**ake photos and notes, **E**NJOY!



Date	
Title	
Aims and objectives	

Preparatory Activities (PA)

PA1: Strong acids/weak acids, a practical approach.

Aim: To compare the strength of two acids: Hydrochloric Acid vs Ethanoic Acid

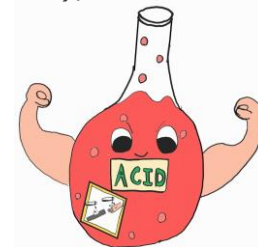
Apparatus:

Test tube rack, test tubes x2, beakers 100cm³ x2, glass rod, measuring cylinder 10ml, Dropping pipettes.

Chemicals: :

Ethanoic acid solution 0.05 moldm⁻³ (15 cm³), Hydrochloric acid solution 0.05 moldm⁻³ (15 cm³), Sodium carbonate solution 0.4 moldm⁻³ (50cm³), Universal indicator solution and Chart (pH1-14).

Procedure: Adapted from: edu.rsc.org/experiments/the-acidic-reactions-of-ethanoic-acid/462.article



(Observe usual health and safety precautions)

1. Set up a test tube rack containing two test tubes.
2. Into one of the test tubes place 5cm³ of ethanoic acid solution (0.05 moldm⁻³).
3. Into the other tube place 5cm³ of hydrochloric acid (0.05 moldm⁻³).
4. Add two drops of full-range universal indicator solution to one of the ethanoic acid tubes and note the pH.
5. Add two drops of full-range universal indicator solution to one of the hydrochloric acid tubes and note the pH.
6. Place about 0.5 cm depth of sodium carbonate (0.4 moldm⁻³) solution in a small beaker.
7. Use a dropping pipette to add one drop of sodium carbonate solution to the ethanoic acid tube which contains the indicator. Stir the tube with a glass rod and note any observations. Continue to add drops until the pH is neutral. Count the number of drops you have used.
8. Repeat '7' for the tube containing hydrochloric acid.

Results: Collect your data including any observations in the table below.

Test			
Ethanoic acid			
Hydrochloric acid			

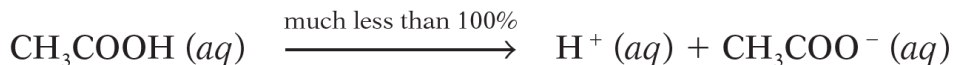
Discuss: Which acid was stronger? Explain how you arrived at this conclusion. Mention two precautions necessary to ensure fair testing. Include also any relevant chemical equations.

PA2: Strong and weak, acids and alkalis

What happens when acids dissolve in water:



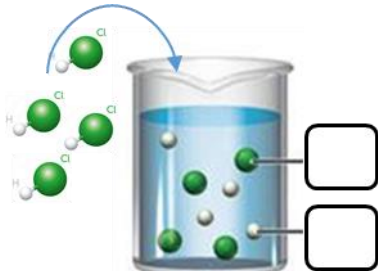
→ All the molecules of hydrogen chloride ionise in solution.



→ Only some of the molecules of ethanoic acid ionise in solution.

Which of the two is a strong acid: _____? Weak acid: _____?

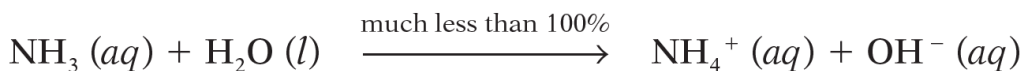
Label the anions and cations of hydrochloric acid:



Figures from: brainly.com

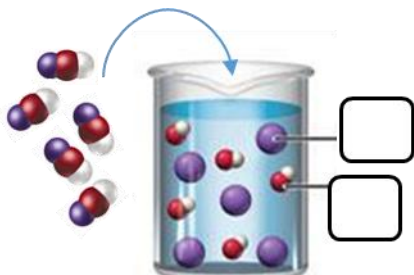
Draw a similar diagram for a weak acid:

Similarly when alkalis dissolve in water:



Which of the two is a strong alkali: _____, weak alkali: _____?

Label the anions and cations of sodium hydroxide:



Figures from: brainly.com

Draw a similar diagram for a weak alkali:

PA3: Conductivity matters?

Conductivity

Conductivity is a measure of the ability of an aqueous solution to conduct electricity. This ability depends on the presence of ions and their concentration. The higher the concentration of ions dissolved in water, the higher the conductivity.

How is conductivity measured?

Conductivity is measured using electronic instruments that can measure the current passing through a sample of water. The amount of current that flows through the sample is proportional to the total concentration of ions dissolved in the sample. The meters are calibrated to convert these current measurements into the units of conductivity:

$\mu\text{S/cm}$	OR	mS/cm
microSiemens per cm		milliSiemens per cm



Ask the lab technician to prepare 0.1mol dm^{-3} solutions of the acids and alkalis shown in the table below. Test the pH of each solution at school. Take these solutions with you during the site visit (refer to SA1) to complete the table.

Acid	pH	Conductivity Units: _____	Base	pH	Conductivity Units: _____
Hydrochloric acid: Conc: 0.1mol dm^{-3}			_____: Conc: 0.1mol dm^{-3}		
Ethanoic acid Conc: _____			Ammonia Conc: _____		

What is the relation between conductivity and strength of acids/ alkalis? Give a reason for your answer.

In this experiment the concentration of each solution was kept constant. Predict what happens to the conductivity if a lower concentration of each solution is used. Give a reason for your answer.

PA4: Acids and Alkalis: pH matters?

Analyse the two tables below:

Concentration of Sodium hydroxide (mol dm^{-3})	pH
0.001	11.00
0.01	12.00
0.1	13.00

Concentration of Ammonia soln (mol dm^{-3})	pH
0.001	10.00
0.01	10.63
0.1	11.13

Which of the two is a: strong alkali: _____, weak alkali: _____.

Are there instances when the pH of the weak alkali is **higher** than that of the strong one? _____.

Is pH, alone, a suitable parameter to classify an alkali as strong or weak? Explain.

Similarly for acids:

Concentration of hydrochloric acid (mol dm^{-3})	pH
0.001	3.00
0.01	2.00
0.1	1.00

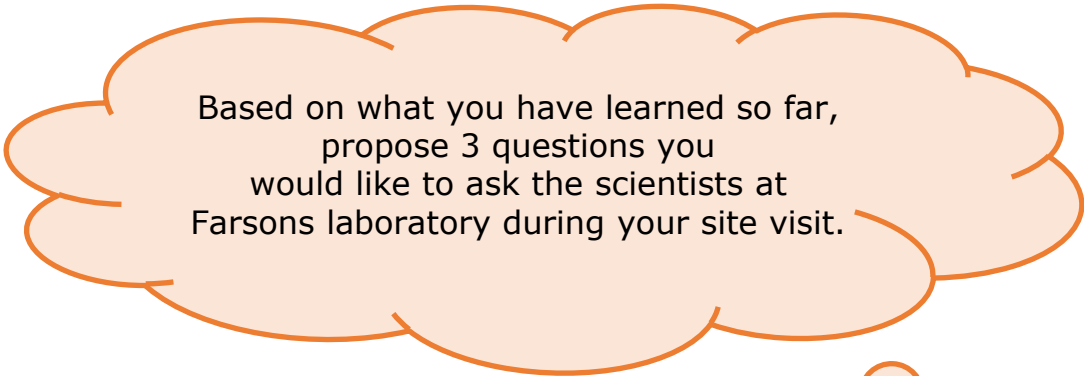
Concentration of ethanoic acid (mol dm^{-3})	pH
0.001	3.87
0.01	3.37
0.1	2.87

Which of the two is a: strong acid: _____, weak acid: _____.

Are there instances when the pH of the weak acid is **lower** than that of the strong one? _____.

Is pH, alone, a suitable parameter to classify an acid as strong or weak? Explain.

PA5: Prepare your questions.



Some ideas you may use to formulate your questions:

- ✓ Quality checks: ensuring accurate and reliable results.
- ✓ Checking that all analytical instruments are working properly.
- ✓ Handling and disposing of chemical waste from the laboratory.
- ✓ Qualifications required to work in this laboratory.
- ✓ Keeping records of the test results. Their implications for production and other processes in the factory.
- ✓ Examples of important tests carried out on a particular product and how they influence their production.
- ✓ Applications related to acid/base concepts in their factory.
- ✓ The company’s attitude towards caring and sustaining the environment.

Here is one way you can organise your questions and answers:

Question:	
Answer: (Notes)	

Site details	
Description of location	
History	
Purpose of site	
Precautions and Safety Considerations <i>(Potential hazards and safety considerations noticed on site)</i>	

SA1: pH and conductivity meters: calibration and use.

Ask the laboratory personnel to show you how pH and conductivity meters are first calibrated and then used to take readings of samples. Observe closely how each meter is used.



- Write two precautions that are necessary for accurate readings.
- Measure the pH and conductivity of the solutions prepared in PA4 and complete the table.
- Explain any conclusions based on the data you collect. Compare them with your predictions.
- Ask the lab scientists why pH and conductivity are important for their operations.

SA2: Meet the rest of the crew.

Below are some of the instruments used by Farsons laboratory for chemical analysis. Learn more about them and ask your guide for a demo if possible. You will notice most of them have calibration labels. **Questions anyone?.....**



We do shake and spin, but we NEVER do laundry! How bitter is that?!



Our tests are colourful and very useful!



Alcohol is my game, but getting drunk is lame, so I don't!



As sweet as sugar, that's me!

SA3: Titrimetric analysis: a reality show.

The food and beverage industry is not an easy one. The products need to be tasteful and appealing to sell, while adhering to very strict regulations to guarantee quality and safety for the customers. Contaminated food products can cause serious illness and even death.

Titration is very frequently used in the food industry to check for numerous parameters, such as acid, base, salt and sugar content, in the raw materials and final products.

Task 1:

The Farsons laboratory also carries out a number of titrations, some of which are listed below. Ask the lab scientists about these in order to complete the table. *(the last row has been left empty on purpose!)*

	Titrant (burette)	Sample (conical flask)	Indicator	Colour change
Chlorides				
Alkalinity				
Acid/Base				

Task 2:

This lab also has an automatic titrator: an instrument that can carry out titrations automatically. It does not use an indicator for the end point, but a sensor. Curious? Ask for a demo when there....

Task 3:

This lab does not carry out only tests related to their food and beverage production. The lab also monitors the factory’s waste water and cleaning processes. Some production machines use acid or alkalis for cleaning. What if the concentration of the cleaning solution is not correct? What if the cleaning solution is not rinsed out properly? All of this is monitored by the elegant burettes shown here.

How? Why not go and find out? Or better yet, try a titration yourself and discuss with the scientists what advice you should pass on to the production department. *(Take note of any results).*



Communication of outcomes

In your report it is important to describe your findings. In this section use the notes you took during the visit to help you to:

- answer any questions you asked the scientists.
- communicate any other information collected during the visit, for example: data from any measurements taken, any results or data shared with you by the scientists, any chemical or physical changes observed during experiments carried out on site, any unexpected findings etc.

The table below is one way you can organise your notes/information. However use whatever other method/means you are comfortable with.

Name of activity:	Example:
Scope:	<i>(What to I want to learn? Example:</i>
Outcomes:	<i>(What did I actually learn?):</i>

Discussion, Evaluation, Reflection and References

Discussion

- What did you learn from this site visit?
- Which learning outcomes did you achieve?
- Include some examples of how acids/base concepts are used in everyday life.
- Interpret any results, data or other information collected by: relating findings to expectations and any conclusions arrived at.

Evaluation

- Did you encounter any difficulties, challenges during the visit?
- Are there any improvements or alternate activities you can suggest?

Reflection

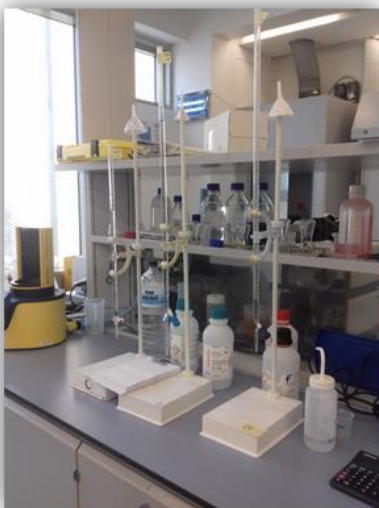
- How environmentally conscious is the site you visited?
- How important is the knowledge of chemistry to Farsons: the quality of their products, production processes and their business?
- What could happen if lab results are compromised?
- Do you see yourself working in such a laboratory?
- Any other reflections you want to make?

References

List any sources cited or referred to.

Subject Focus 2: Substances from the Earth: Aquatic environments

Site Visit



Quality Control Laboratory Teachers' Guide

Target Learning Outcomes

Learning Outcome 4:

I can describe the chemical properties of acids, bases and salts

4.1a Use indicators and the pH scale to distinguish between acidic, alkaline and neutral solutions.

4.2a Classify a substance as acid, base or alkali.

4.3a Explain the difference between strong and weak acids/alkalis.

4.2f Apply acid-base concepts to the real world. (*E.g. In terms of solutions to environmental issues such as acid rain, neutralisation of acid soils and excess stomach acidity.*)

4.3f Investigate acid-base concepts in real life applications.

Learning Outcome 7:

At the end of the programme, I can describe how substances dissolved in water can be identified and how their concentration can be measured.

7.2h Conduct an acid/base titration using step by step instructions. (Limited to hydrochloric acid, sulfuric acid, with sodium hydroxide, potassium hydroxide and sodium carbonate.)

7.3h Conduct an acid/base titration to determine the concentration of a given solution. (E.g. hydrochloric acid, sulfuric acid, nitric acid, ethanoic acid with sodium hydroxide, potassium hydroxide and sodium carbonate.)

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

General Site information	
SIMONDS FARSONS CISK PLC The Brewery Mdina Road, Zone 2 Central Business District Birkirkara CBD 2010 Tel: +356 2381 4114	Location: https://goo.gl/maps/L3LNmwrRe5FUESSH7 
How to contact: Use the general contact details on the company website: https://www.farsons.com/ Call and ask for the Head of Quality or Laboratory Manager. Introduce yourself and the school and express your intention to organise a site visit at their lab.	
Logistical Considerations:	
Tour Duration (<i>approx., not including travel time</i>)	2 hours
Recommended number of students:	15
Safety considerations	Students are to bring their own laboratory coats, gloves and safety spectacles if they intend to carry out some tests on site.
Availability during scholastic year	All year, any time during school hours unless the laboratory is undergoing audits. Prior appointment necessary.
Access to students with disabilities	Good. Wheelchair access to all areas.
Facilities:	
Restrooms	Yes

Lunch/ recreational Areas	A kitchenette and the canteen are available for lunch breaks
Lecture room	Boardrooms are available but need to be booked in advance.
Student pack resources:	
Introductory Activities (IA)	IA1: About Farsons. IA2: Living with Acids and Bases.
Preparatory Activities (PA)	PA1: Strong acids/weak acids, a practical approach. PA2: Strong and weak, acids and alkalis. PA3: Conductivity matters? PA4: Acids and Alkalis: pH matters? PA5: Prepare your questions.
Site Activities (SA)	SA1: pH and conductivity meters: calibration and use. SA2: Meet the rest of the crew. SA3: Titrimetric analysis: a reality show.

The Student Resource pack: answers and some guidelines

Rationale:

This pack is not prescriptive. Contrarily, its underlying intention is to provide an outset for the introduction of site visits as coursework. The activities include a variety of resources encompassed within diverse teaching modes spanning traditional, practical and critical approaches. Teachers are encouraged to use whichever resources they deem most pertinent to the contexts they are operating in such as the level of class competence, resources available at school, scheme of work schedules and other such factors typical of the teaching profession.

The pack is modelled around the concept of a restaurant menu, whereby patrons choose their meals depending on their mood and preferred tastes. In fact, the pack's quintessential goal is to spur teachers into eventually creating their own personalised site related resources by either choosing which activities to use or reorganizing them in a different sequence, while adding their own content. Teachers could consider amending the resources to target outcomes related to the site visit. The pack includes various activities that are also suggestive of ideas for lesson planning and other coursework modes: fieldwork, investigations, project based and laboratory practicals.

Activities:

The activities are divided into three categories:

Introductory Activities (IA):

Designed to introduce the students to the processes occurring at the site and to any relevant general knowledge, without which important aspects of the site visit might be lost.

Preparatory Activities (PA):

Designed to get students more in-depth knowledge of processes on the site, possibly encouraging a more critical approach especially in matters related to socio-scientific issues. Some include school based practical activities.

Site Activities (SA):

These are activities that can be carried out on site. These were designed around what the author has experienced during the site evaluation visits. Please appreciate that the guides may be unaware of these activities. Teachers need to liaise with the site responsible people, well in advance, on what activities are possible at the time. It is imperative to discuss in detail the planned activities focusing on any procedures the students will be carrying out and availability of resources on site: equipment, consumables, supervising personnel and venue. Health and safety issues also need to be considered.

Preparing quality questions:

One requirement for site visits in the SEC 06 chemistry syllabus (2025) is for students to prepare questions to ask to the site experts. Therefore, all activities are designed to cater for this prerequisite. Ideally students should use the included prompts to guide their research in order to formulate quality, focused questions to ask during their site visit. For example, instead of asking: 'What is conductivity?' a better question could be: 'Why is conductivity testing important in your lab?' This would indicate to the scientists that the students have prepared themselves well because they are keen on learning. This, in turn, could transcribe into a more positive disposition of the site experts towards the students, thereby making the experience more fruitful and rewarding to all actors.

It is advisable to share the questions with the site guides before the visit so they can plan the tour accordingly, thus further bolstering the learning efficacy of the site visit.

The final report:

The general layout of the pack is structured around the rubric presented in the syllabus SEC 06 (2025) document, to facilitate the students' report writing. The teachers should discuss with the students, either as a class or in groups, which of the activities to include in their final report. The rubric stipulates that a set of preparatory and site activities need to be described in the report.

Introductory Activities (IA)

IA1: About Farsons.

A short introduction to the site and its purposes.

Task 1 asks students to list some brands that are manufactured at Farsons. Learners are familiar to a number of these already example: Kinnie, Cisk, San Michel, Elan, Aquadot etc. The common ingredient is water.

Task 2 gets students to think about the enormous environmental impact of industry, even if for seemingly benign objectives such as food and beverage production. Some of the resources that could be included in the table here are:

Resource	Air	Water	Land
Production machinery	Indirect emissions of CO ₂ , particulate matter and other pollutants due to high consumption of electricity.	Washing and rinsing for decontamination. Waste water generation.	Extraction of rare metals and others for manufacturing the machinery. Use of raw materials such as plastic, carton etc needed for production. Waste generation.
Transport vehicles	Emissions of CO ₂ , particulate matter and other pollutants (also for vehicle manufacture)	Indirect: acid rain. Run off oil and fuel road spills.	Extraction of metals and other ores for vehicle manufacture. Road infrastructure.
Office related equipment	Indirect emissions of CO ₂ , particulate matter and other pollutants (electricity)	Manufacture of paper, electronics, wood needed for furniture.	Extraction of rare metals and others for electronics manufacture. Deforestation (furniture manufacture). Toxic waste generation: ink cartridges, toners etc.

Task 3 focuses on humans as underlying resources in all industrial and business ventures. Sometimes employees are taken for granted at the workplace and treated as machines. This activity attempts to make students aware that humans have rights, notwithstanding that they are being paid a salary. Eventually, when they themselves will be employers or employees, they have to realise that for civil business practices (and society in general) to thrive these rights must be safeguarded and respected. This task uses Farsons as a case study to introduce learners to concepts related to workplace rights and ethical business conduct.

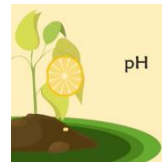
IA2: Living with Acids and Bases.

(Assessment Criteria:

4.2f Apply acid-base concepts to the real world. (E.g. In terms of solutions to environmental issues such as acid rain, neutralisation of acid soils and excess stomach acidity.)

4.3f Investigate acid-base concepts in real life applications.)

NOTE: The suggested video: www.youtube.com/watch?v=r3hirzIWILM offers a concise and clear explanation on the role of acids and bases in everyday life. It has one shortcoming @54s where it says pH of soil can be raised using lime, referring to limestone or other lime compounds. However, it shows 'lime' as the juice of the lime fruit being added which is actually acidic. It is important to point this out to the students. Some online research is expected for this activity.



Calcium carbonate



Sodium hydrogen carbonate



Sodium hypochlorite



Calcium hypochlorite



Sodium hydroxide



Hydrochloric acid



Ammonia



Carbonated water
Phosphoric acid
Citric acid



Carbonated water
Citric acid



Lactic acid
Acetic acid (found in vinegar)
Citric acid

Which of the items in bold are:

Acids: Carbonated water (Carbonic acid)

Bases: Ammonia, sodium hypochlorite, calcium hypochlorite, calcium carbonate, sodium hydrogen carbonate

Preparatory Activities (PA)

(Assessment Criteria:

4.1a Use indicators and the pH scale to distinguish between acidic, alkaline and neutral solutions.

4.2a Classify a substance as acid, base or alkali.

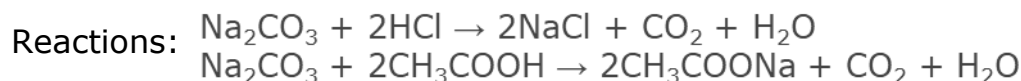
4.3a Explain the difference between strong and weak acids/alkalis.)

PA1: Strong acids/weak acids, a practical approach.

A hands-on activity to introduce students to the concept of strong and weak acids. The misconception that pH is a measure of acid strength starts being addressed. This is expanded upon in subsequent activities.

Observations:

The hydrochloric acid will show pH = 1, and the ethanoic acid will show pH = 3. Only a few drops of sodium carbonate solution will be needed to neutralise the acids as the alkaline solutions are eight times more concentrated than the acids. The hydrochloric acid will fizz strongly with the sodium carbonate solution, whereas for ethanoic acid the fizzing will be detectable but less vigorous.

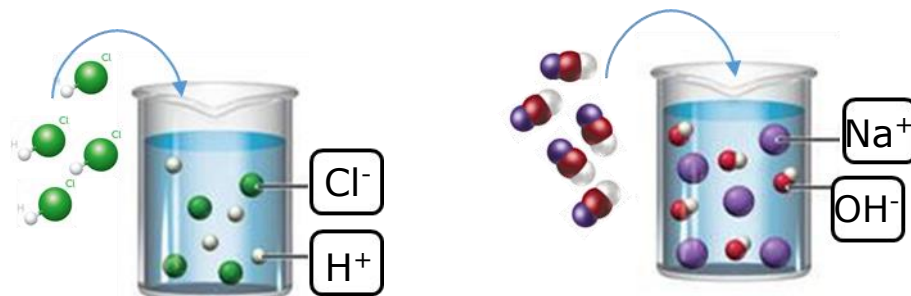


More information on:

<https://edu.rsc.org/experiments/the-acidic-reactions-of-ethanoic-acid/462.article>

PA2: Strong and weak, acids and alkalis

An activity to introduce students to the concept of how the degree of ionisation determines the strength of acids and alkalis. When drawing diagrams, similar to the below, for the weak acid and alkali, students should show a number of molecules or formula units that remain unionised inside the beaker.

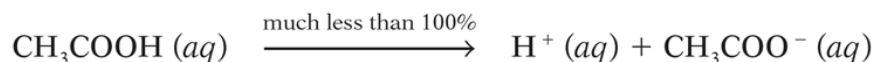


The intention is to allow students to better visualise what is being described in the previous statements:

Acids:



→ All the molecules of hydrogen chloride ionise in solution.

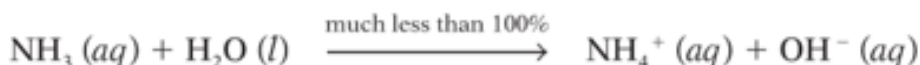


→ Only some of the molecules of ethanoic acid ionise in solution.

Alkalis:



→ All of the dissolved NaOH (an ionic solid) exists as ions in solution.



→ Only some of the ammonia molecules form ions.

PA3: Conductivity matters?

This activity builds on the previous (**PA2**) and explores the concept of strong/weak acids and alkalis using conductivity measurements. Since conductivity increases with the concentration of ions dissolved in water, it follows that the conductivity of strong acid/alkali solutions should be higher than those of their weaker counterparts, providing the test solutions are of the same concentration. This is because strong acids and alkalis ionise completely therefore releasing more ions, in the solution, that can conduct electricity.

Students are introduced to this concept in this preparatory activity and will have the opportunity to experience it hands-on in a follow-up site activity (**SA1**).

PA4: Acids and Alkalis: pH matters?

This activity addresses misconceptions related to strengths of acids and bases and 'pH'. Students are guided to arrive at the conclusion that pH varies according to the concentration of the acid/base solutions. Therefore, to compare relative strength, the concentration of solutions being tested must be the same. The notion that pH is a function of the concentration of H^+ ions is thereby gently introduced, even if not explicitly mentioned.

Analyse the two tables below:

Concentration of Sodium hydroxide (mol dm^{-3})	pH	Concentration of Ammonia soln (mol dm^{-3})	pH
0.001	11.00	0.001	10.00
0.01	12.00	0.01	10.63
0.1	13.00	0.1	11.13

Which of the two is a: strong alkali: NaOH, weak alkali: Ammonia solution

Are there instances when the pH of the weak alkali is **higher** than that of the strong one? Yes, 0.1 mol dm^{-3} ammonia > pH than 0.001 mol dm^{-3} NaOH.

Is pH, alone, a suitable parameter to classify an alkali as strong or weak? Explain.

No, as the concentration of the solutions must be considered too. To compare relative strength using pH the concentration of the solutions must be the same.

Similarly for acids:

Concentration of hydrochloric acid (mol dm^{-3})	pH	Concentration of ethanoic acid (mol dm^{-3})	pH
0.001	3.00	0.001	3.87
0.01	2.00	0.01	3.37
0.1	1.00	0.1	2.87

Which of the two is a: strong acid: HCl, weak acid: Ethanoic acid.

Are there instances when the pH of the weak acid is **lower** than that of the strong one? Yes, 0.1 mol dm^{-3} ethanoic acid < pH than 0.001 mol dm^{-3} HCl.

Is pH, alone, a suitable parameter to classify an acid as strong or weak? Explain.

No, as the concentration of the solutions must be considered too. To compare relative strength using pH the concentration of the solutions must be the same.

PA5: Prepare your questions

Here students are given time to consolidate what they have learnt into questions which they will be asking during the visit as a group.

Site Activities (SA)

(Assessment Criteria

4.1a Use indicators and the pH scale to distinguish between acidic, alkaline and neutral solutions.

4.2a Classify a substance as acid, base or alkali.

4.3a Explain the difference between strong and weak acids/alkalis.

4.2f Apply acid-base concepts to the real world. (*E.g. In terms of solutions to environmental issues such as acid rain, neutralisation of acid soils and excess stomach acidity.*)

4.3f Investigate acid-base concepts in real life applications.)

SA1: pH and conductivity meters: calibration and use.

Students are given the opportunity to use professional lab equipment that is not available in schools. They can also appreciate that readings given by this instrumentation, no matter how expensive and advanced, need to be constantly checked against reference standards to adhere to good quality control protocols. They can also substantiate their understanding of strong and weak acids and alkalis (PA3) through a hands-on activity.

SA2: Meet the rest of the crew.

Students experience what it feels like to work in a real life laboratory as they are sent on a quest to discover the various tests carried out and the equipment used. Photos and riddles are included to make the quest more interesting. The equipment they see here invariably differs from that which they are used to in school.

	The orange instrument is a flask shaker, while the grey instruments are centrifuges. These are used in the bitterness test for beer; a very important parameter in beer production.
	These black boxes are manual photometers and are used to determine the concentration of a parameter by comparing the colour, formed after addition of a reagent, with a standard. It is used for a number of applications including testing levels of chlorine in potable and/or pool water.

	This instrument measures percentage alcohol in beverages and estimates their calorific value.
	This is a bench refractometer. It can measure the refractive index of a sample. The refractive index of beverages is influenced by, for example, sugar. So this instrument is often used to determine the sugar content (% Brix).

SA3: Titrimetric analysis: a reality show.

This onsite activity demonstrates the use of titration as an important quality control technique.

Task 1 encourages students to ask about details of titrations that are carried out in order to fill the table. The 'sample' column refers to the type of samples that are tested with a particular titration set-up for example: chlorides in bottled water, alkalinity of boiler feed water, residual acid in cleaning solutions. The last row has been left empty for students to ask further. This can be filled in for sugars in juice titration, amongst others. In task 2 they can observe how the titration procedure can be made more efficient through the use of an automatic titrator. Finally, in task 3, they may also try their hand at titrating real samples and give advice based on their results. This enhances the school learning experience as the context here is real, in contrast to the laboratory simulated scenarios.

Concluding remarks

As a final thought and recommendation, it would be a nice gesture for the students to prepare a small token of appreciation that could be presented to the guide/s at the end of the visit. This should be something relevant to the site and that the students produced during their activities, for example a leaflet or infographic raising awareness about Malta's environmental challenges. Students with a penchant for artistic or literary expression might even present a painting or read out a poem or a short essay related to the subject.

Apart from being a sign of gratitude, these simple practices could help build and sustain rapports between the schools and the external scientific community. Such connections are very precious resources which unfortunately, in Malta, are very much left untapped.

Subject Focus 2: Substances from the Earth: Aquatic environments

Site Visit



Water Quality Laboratory

Student Resources

Adrian Vella (MTI SCI)

Subject Focus 2: Substances from the Earth: Aquatic environments

Site Visit: Water Services Corporation (WSC) Water Quality Laboratory

Target Learning Outcomes

Learning Outcome 7:

I can describe how substances dissolved in water can be identified and how their concentration can be measured.

7.2c Identify cations present in solutions.

7.2d, 7.3d Identify anions present in solutions.

7.3h Conduct an acid/base titration to determine the concentration of a given solution.

Learning Outcome 3:

I can describe the solvent action of water including the impact of water hardness.

3.1a Identify sources of potable water and their management in Malta.

3.1e Explain that sea water contains dissolved charged ions that form crystals on evaporation

3.2b State criteria of purity for water. (Limited to melting point, boiling point and **conductivity**.)

3.3f Explain the properties of ionic compounds

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

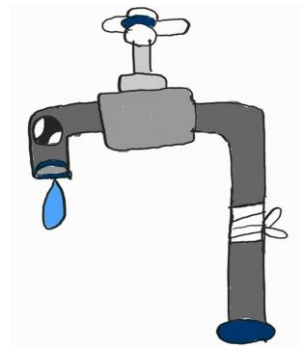


Responsible for the complete drinking and waste water cycle in the Maltese Islands.

<https://www.wsc.com.mt>

One way the Water Services Corporation (WSC) shoulders this responsibility is by producing and distributing good quality tap water, suitable for human consumption.

The aim of this site visit is to learn about how the laboratories at WSC assure that the tap water reaching our homes is of potable quality, day after day....



Introduction

The WSC Laboratory

The WSC Laboratory tests both potable and wastewater. It analyses a diverse array of parameters ranging from conductivity, pH and turbidity, to titrimetric analysis of hardness, chlorides and *COD. It also carries out UV/VIS spectrophotometric analysis for nitrates, sulfates, ammonia and also the more complex Atomic Absorption Spectrophotometric analysis of heavy metals."

(Excerpt from: 'Services provided by THE WSC LABORATORY' wall display at the entrance to their water analysis laboratories)

*COD: *Chemical Oxygen Demand*, an indirect measurement of the amount of organic matter in a sample.

Quality Assurance

The quality and safety of the water produced by WSC is constantly checked by their laboratory. Every year over 5100 samples are collected upon which approximately 54,500 physical, chemical and bacteriological tests are carried out.

Introductory Activities (IA)



IA1: Water testing

Read through the information given in this link (download also the accreditation scope document) and other parts of the WSC website:

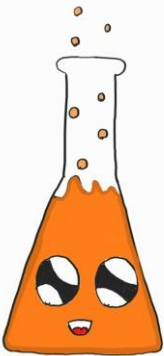
<https://www.wsc.com.mt/facilities/laboratory>

Find out what tests are being carried out by WSC and list some of them in the table below.

WSC analyse two main categories of water samples. Which are they?

--	--

Do you recognise any of the laboratory techniques WSC use to analyse for some of the water quality parameters? List these down below and keep them in mind for later. *(Feel free to include one technique you never heard of and may want to learn more about).*



Question ideas:

There are a number of terms and laboratory techniques you may not be familiar with and may want to learn more about during your site visit. Take a note of them and decide whether to include them in the questions you need to formulate before the visit.

(For example: Accreditation, ISO 17025, bacteriological testing, Atomic Absorption Spectrophotometric analysis, ICPMS)

IA2: Quality control

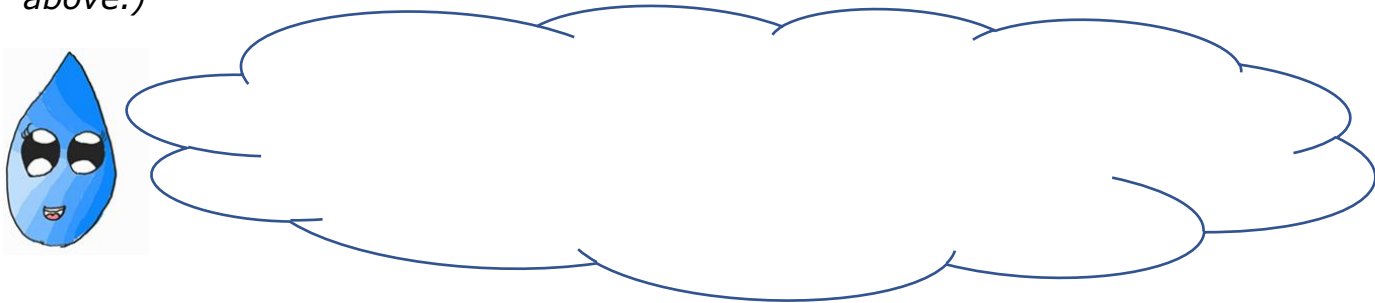
Extending the practice of three readings.....



WSC employs a number of ways to ensure quality in their labs, some of which are mentioned below:

Proficiency testing	Inter-lab comparisons	Blind samples	Internal sample checks
Method witnessing	Instrument calibrations	Technician training	Repeatability

It might be interesting to learn about some of these during your site visit. Formulate a question to learn more about quality. (*Decide whether you want to make the question general or specific to one or two of the methods mentioned above.*)



IA3: Water Quality

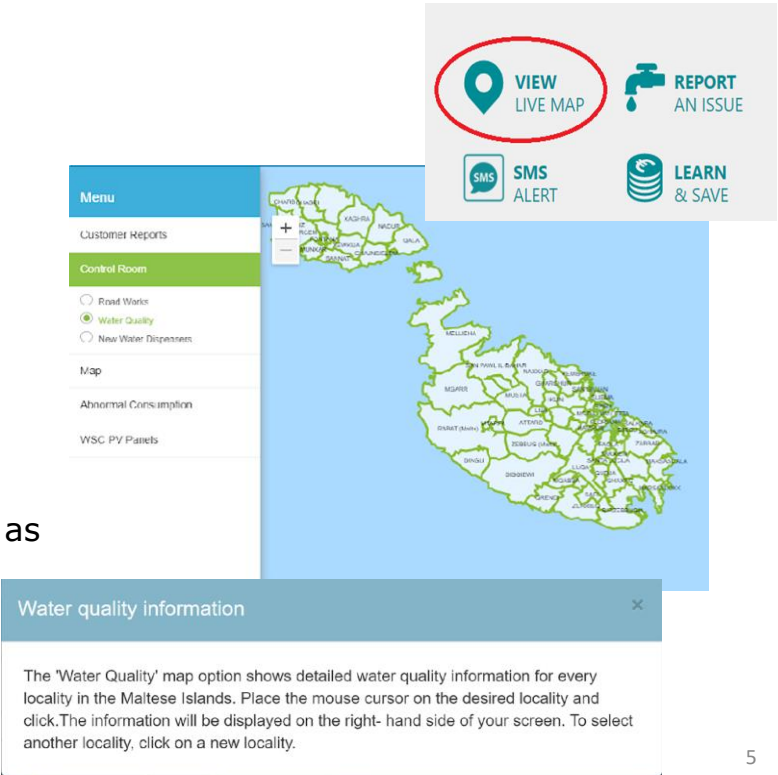
Visit: <https://www.wsc.com.mt/>

Click on: VIEW LIVE MAP
In the Menu bar on left:

Click on 'Control room'

Choose 'Water Quality'

You can access water quality information for each locality shown on the map of the Maltese islands, as described in the website prompt below:



Once you click on a locality the following table will be displayed:

The  button will call up some information on each parameter.

Read through some of these and discuss in class possible sources of these parameters in our tap water.

Water Quality	
Qawra WQZ: 2	
Collection Date	17-Jan-2022
TURBIDITY	0.17 N.T.U
CONDUCTIVITY	1815 $\mu\text{S cm}^{-1}$
TEMP (ON SITE)	16.2 °C
TEMP	15 °C
pH	7.55
TOTAL HARDNESS	330 mg/L CaCO_3
CALCIUM HARDNESS	160 mg/L CaCO_3
MAGNESIUM HARDNESS	170 mg/L CaCO_3
CALCIUM	64 mg/L Ca
MAGNESIUM	41 mg/L Mg
NITRATES	41.53 mg/L NO_3^-
AMMONIA	<0.15 mg/L NH_4^+
NITRITES	<0.0210 mg/L NO_2^-
TOTAL COLIFORMS	Not Detected
E.coli	Not Detected
FAECAL ENTEROCOCCI	Not Detected

Hardness:	
Nitrates/Nitrites/ Ammonia:	
Microorganisms:	

Choose five localities (including where you live) and take note of the parameters circled in **RED**, namely:
Conductivity, Total Harness and Nitrates, by filling them out in Table 1 below.

Table 1

Collection Date	Locality	Conductivity $\mu\text{S/cm}$	Total Hardness mg/L CaCO_3	Nitrates mg/L NO_3^-

Salinity

One major concern of Maltese fresh water, is salinity. Salinity does not refer to the concentration of NaCl only, **but to the concentrations of all salts dissolved in water.**

- a. By referring to WSC’s water quality tables, give examples of ions commonly present in Maltese fresh waters.

Cations	Anions

- b. A property of ionic compounds is that they are usually soluble in water.
Mention one other property that is a consequence of this.
-
- This last property is widely used to check for salinity in a water sample by measuring the conductivity.
- Conductivity**
- Conductivity is a measure of the ability of an aqueous solution to conduct electricity. This ability depends on the presence of ions; their total concentration and valency. It is, therefore, a good indication of the total amount of minerals (anions and cations) present in a sample of water.
- Therefore, the higher the concentration of ions dissolved in water, the higher the conductivity.
- c. Is this relation between the Conductivity and concentration of hardness + nitrates observed in Table 1?
-
- d. Which other two ions are not shown in WSC’s water quality tables but could account for any differences? Why is monitoring of these ions in local groundwater important?
-
-
-

How is conductivity measured?

Conductivity is measured using electronic instruments that can measure the current passing through a sample of water. The amount of current that flows through the sample is proportional to the total concentration of ions dissolved in the sample. The meters are calibrated to convert these current measurements into the units of conductivity:

$\mu\text{S/cm}$	OR	mS/cm
microSiemens per cm		milliSiemens per cm



The Site Visit

It is now time to visit the site with the experts!
Before you go have a look at the next section and remember to **PATE**:

- Participate,
- Ask questions,
- Take photos and notes,
- ENJOY!



Date	
Title	
Aims and objectives	

Preparatory Activities (PA)

PA1: Understanding conductivity in practice 1

Collect a number of water samples:

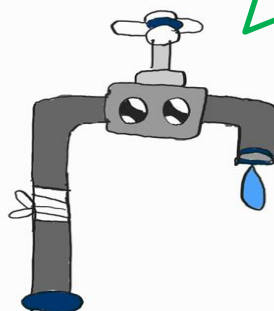
Tap water, bottled water, distilled water, water from a well or run off rain water from Buskett, Chadwick lakes etc.

In your group, predict the conductivity for each sample and sort them out in one of the tables below:

Very low conductivity <50 $\mu\text{S}/\text{cm}$	Low Conductivity 100 - 500 $\mu\text{S}/\text{cm}$	Medium Conductivity 500 - 1500 $\mu\text{S}/\text{cm}$	High Conductivity >1500 $\mu\text{S}/\text{cm}$
Sample name	Sample name	Sample name	Sample name

Using a conductivity meter take readings for the various water samples and collect your results in the table below (include headers and units).

Before you throw away your samples you may want to have a look at Site Activities (SA) 1 and 2!



Discuss your results.

Why did you make this prediction?

How do the readings compare with your predictions?

Compare the readings and explain why the samples have different conductivities.

PA2: Understanding conductivity in practice 2

(Apparatus: Conductivity meter, balance and some common salts as, for example, listed below)

On the teacher's bench you can find the following salt samples:

Magnesium sulfate, Sodium chloride, Potassium nitrate, Sodium carbonate.

As a group, choose one of these salts and carry out the investigation below:

1. Take the conductivity reading of a 200ml sample of distilled water.
2. Dissolve approx. 5g of your salt and measure the conductivity.
3. Add another 5g and take another measurement.
4. Repeat until 20g of salt have been added in total.
5. In each case work out the concentration of salt solution in mg/L.
6. Record your results in the table below and plot a suitable graph.

Mass of salt [g]	Concentration of salt [mg/L]	Conductivity $\mu\text{S}/\text{cm}$
0		
5		
10		
15		
20		

1. What ions (positive and negative) are present in your solution?
2. Why are these ions influencing your conductivity readings?
3. What can you conclude about the relation between concentration of salt and conductivity?
4. Compare your findings with those of the other groups. Do all salts affect conductivity in the same way? Try to explain any differences.

PA3: Acceptable levels of water quality: who decides?

“Malta is one of the most water-stressed countries within the EU. Its potable water is a blend of desalinated seawater and groundwater sources. This blend is continuously monitored to ensure that its quality is compliant with the **EU Drinking-Water Directive 98/83/EC**. One of the major requirements of this Directive is that the potable water supplied to the consumers is safe for their health.”

Excerpt from: <https://www.wsc.com.mt/purilma/>

Do some research about this drinking water directive. You can access the official document from the EU official website:

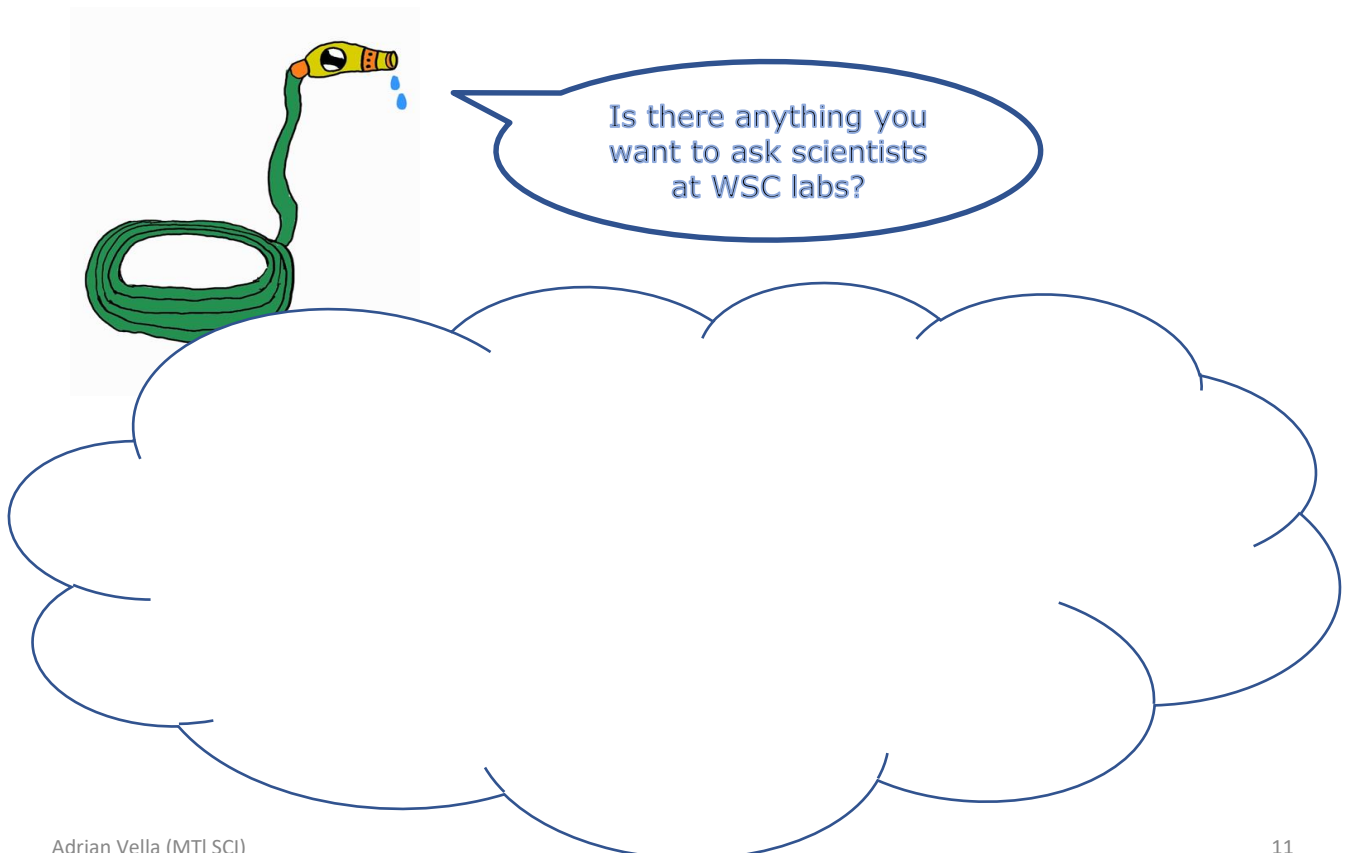
<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020L2184&from=EN>

What is this directive?

What obligations does it set out for EU countries?

Compare some of the parameter values in the WSC water quality tables to those specified in this Directive (Pages 34 – 43). Does Maltese tap water measure up well with these levels or can we do better?

Research any adverse implications to health if concentrations are higher than stipulated levels for these parameters.



PA4: Prepare your questions



Prepare 3 questions you would like to ask scientists at the water quality laboratories of WSC during your site visit.

You can use any of the questions you thought about in the activities carried out so far....

Some ideas you may use to formulate your questions:

- Testing for parameters in the water quality tables: chemicals and equipment used, procedures etc.
- Sample collection and handling.
- Waste disposal of reagents.
- Quality concerns: ensuring that all the results for all the thousands of tests carried out are always reliable: day, after day, after day, after day.....
- Comparing levels of local water parameters to the limits of the EU drinking water directives and how any issues are being addressed.

Here is one way you can organise your questions and answers:

Question:	
Answer: (Take some notes)	

PA5: Extension: New Water from wastewater!

With the help of EU endorsed funds*, Malta, through WSC, has invested in technologies to produce:

“New Water” [which] is highly polished reclaimed water, which can be used for agriculture, industry, landscaping and other applications.

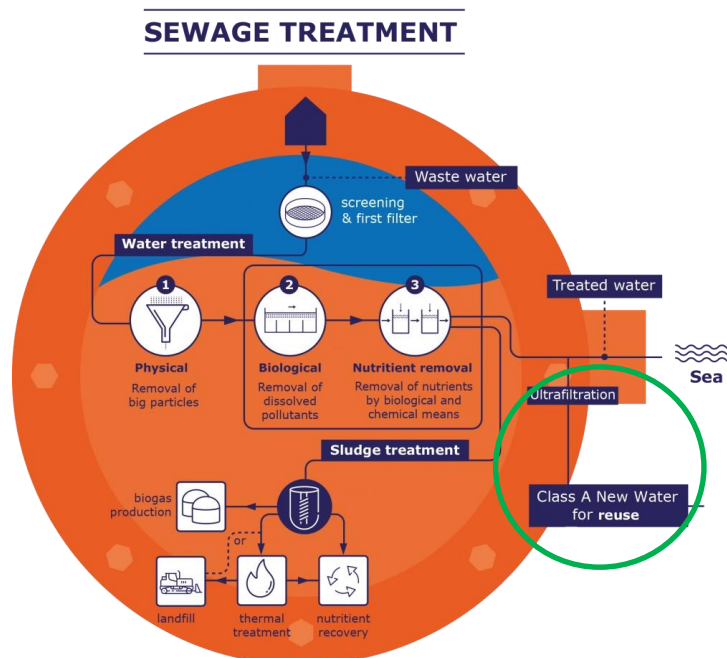
<https://www.wsc.com.mt/information/new-water/>

Simply put ‘New Water’ is water reclaimed from wastewater (sewage) after it undergoes a number of treatment processes. So it is necessary to understand what happens to wastewater in Malta first.

Up until a few years ago wastewater used to be dumped as raw (untreated) sewage directly into the sea. This sewage caused ample pollution along parts of the coastline (try searching online for photos and videos showing this). Now sewage is being treated by a number of waste treatment plants, also operated by WSC, before being discharged into the sea and this:

“has eliminated the coastline pollution in Kalkara, Xgħajra, Marsascula and Marsaxlokk thereby upgrading the bathing water quality.”

You can read more about this here: <https://www.wsc.com.mt/about-us/wastewater/>.

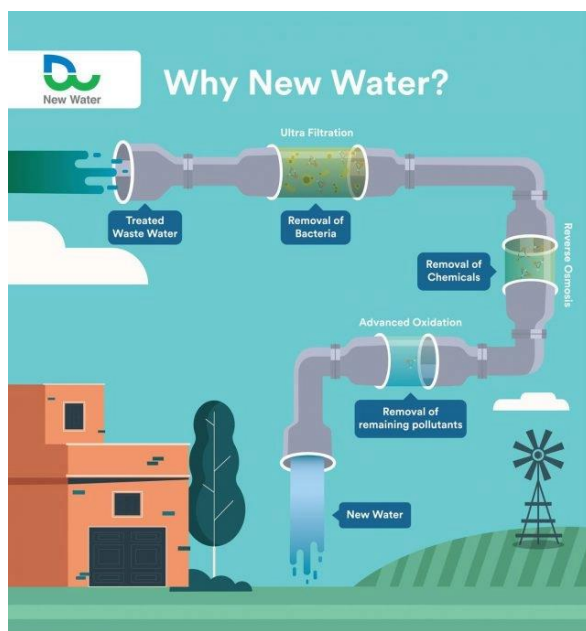


* <https://eufundsmalta.gov.mt/content/supply-highly-polished-tertiary-treated-water-agricultural-use>

WSC has taken this process a step further. Part of the treated wastewater is diverted to tertiary water polishing plants, as shown in the green circle on page 13 (Sewage treatment), to produce this 'New Water'.

You can read more about this here:

<https://www.wsc.com.mt/information/new-water/>



Reliability

New Water is treated waste water thoroughly filtered using a tertiary treatment process. This results in the production of high quality water which is safe for the environment and for use by the agricultural, industrial and landscaping sectors.

For more information on New Water kindly visit www.wsc.com.mt/information/new-water/



Now, read through the following links:

<https://timesofmalta.com/articles/view/freshwater-securing-our-future.876182>

<https://www.wsc.com.mt/two-major-milestones-for-malta-in-the-water-sector>

and take note of figures referring to:

- volumes of water produced by RO plants,
- volumes of 'New Water' produced from sewage treatment plants,
- costs of building RO and New Water plants and
- water used up in agriculture.

Debate these two statements:

'New Water' projects should be prioritised as they are a sustainable means of reducing the demand on Malta's potable water sources for agricultural use.

Investment in RO plants makes more sense as they can produce good quality potable water that can also be used for agriculture.

Site details	
Description of location	
History	https://www.wsc.com.mt/about-us/our-history/
Purpose of site	
Precautions and Safety Considerations <i>(Potential hazards and safety considerations noticed on site)</i>	

Site Activities (SA)

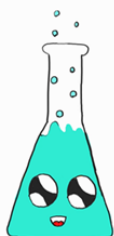
SA1: pH and conductivity meters: calibration and use

Ask the laboratory personnel to test your samples collected in 'PA1' for pH and conductivity using their meters. Observe how each meter is used.

- Write two precautions that are necessary for accurate readings.
- Draw simple diagrams labelling the main features of each instrument.
- Compare the use of a digital pH meter with universal indicator or pH paper.

SA2: Onsite testing of parameters

At the WSC labs you have the opportunity to test the water samples collected in 'PA1' for parameters listed in their website quality tables. You get to use equipment not usually available in schools, such as the auto burette shown in photo.



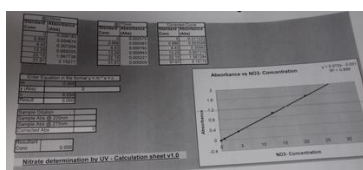
(Due to time restrictions a maximum of five samples per class visit is recommended.)

Decide which samples you want to take with you and what to test for. Make sure to take note of any reagents and equipment used for the tests.



Prepare table/s of results where you can collect and share your data.
(Each sample should include pH, conductivity and one other parameter).

The photos below show how some of these tests are carried out. Learn more about this during your visit. The scientists are there to help!

A photograph of a laboratory notebook showing a table of results. The table has columns for Sample, Date, Time, pH, Conductivity, and other parameters. The data is organized into rows for different samples.

SA3: Laboratory testing competence

In 'IA1' you were asked to list down some tests carried out by WSC mentioned on their website. While on your visit make a list of tests that are described by the guide. They could be the same from 'IA1' or others. Also take note of the names of some of the equipment used for these tests.

The riddles below may help you on your quest for knowledge during this activity!

What I do, you also did at school, but I am faster and my results more reliable 😊!
What am I? What do I measure at WSC?



Eating and drinking are strictly prohibited in a lab, and yet here you can see a box of brand new wine glasses in the background! Are the scientists celebrating something?



Detecting many things at once keeps my passion burning at 6000K. Learn about me at the WSC water quality labs.....



My business is a style of rock music.

SA4: A question of taste!



www.wsc.com.mt/purilma/

PURILMA

Research and innovation:

The Quality, Research & Development section at WSC has teamed up with the Food Sciences and Nutrition department of the University of Malta and has secured funding for project **Purilma**. Its aim was to carry out a study of various water disinfection technologies and assess among other things, the following:

1. chemical reactions and creation of secondary by-products as a result of disinfection technologies being used.
2. organoleptic implications (taste & odour) in a scientific non-subjective way.

In Malta, chlorination (addition of chlorine) is the process adopted by WSC to disinfect the distributed potable water. Over the past years, the use of such disinfectant in the production and distribution of drinking-water has provided satisfactory results. At appropriately controlled levels (as low as 1.0 mg/l) chlorine is effective and safe for public health. Unfortunately, even in these low doses, the use of chlorine has some disadvantages:

- 1) it is easily detected in form of taste and odour,
- 2) other species commonly present in Maltese tap water can:

➤ influence the perceived chlorine taste

➤ react with chlorine to form by-products which may cause health issues and degrade the quality of water. Read for example:

<https://timesofmalta.com/articles/view/maltas-tap-water-linked-to-fifth-of-bladder-cancer-cases.763824>



Investigate:

- What 'other species' can influence the perceived chlorine taste and how?
- What are these 'by-products' that could adversely effect health?
- How is WSC tackling these issues through their project Purilma?
- Did their research yield any promising results or conclusions?

Communication of outcomes

In your report it is important to describe your findings. In this section use the notes you took during the visit to help you to:

- answer any questions you asked the scientists.
- communicate any other information collected during the visit, for example: data from any measurements taken, any results or data shared with you by the scientists, any chemical or physical changes observed during experiments carried out on site, any unexpected findings etc.

The table below is one way you can organise your notes/information. However use whatever other method/means you are comfortable with.

Name of activity:	Example:
Scope:	(What to I want to learn? Example:
Outcomes:	(What did I actually learn?):

Discussion, Evaluation, Reflection and References

Discussion

- What did you learn from this site visit?
- Which learning outcomes did you achieve?
- Interpret any results, data or other information collected by: relating findings to expectations and any conclusions arrived at.

Evaluation

- Did you encounter any difficulties, challenges during the visit?
- Are there any improvements or alternate activities you can suggest?

Reflection

"Today, one simply opens a tap and clean, safe water is always available upon demand."

<https://www.wsc.com.mt/about-us/our-history/>

- Based on your experiences during the site visit, comment on the efforts and what costs are behind this statement.
- How much does WSC rely on the science of chemistry, to ensure 'clean, safe water'? Is this knowledge important to our health?
- How do you think this knowledge was acquired?
- Any other reflections you want to make?

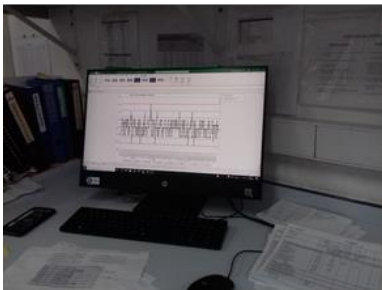
References

List any sources cited or referred to.

Subject Focus 2:

Substances from the Earth: Aquatic environments

Site Visit



Water Quality Laboratory

Teachers' Guide

Subject Focus 2: Substances from the Earth: Aquatic environment

Site Visit: Water Services Corporation (WSC) Laboratory

Target Learning Outcomes

Learning Outcome 7:

I can describe how substances dissolved in water can be identified and how their concentration can be measured.

7.2c Identify cations present in solutions.

7.2d, 7.3d Identify anions present in solutions.

7.3h Conduct an acid/base titration to determine the concentration of a given solution.

Learning Outcome 3:

I can describe the solvent action of water including the impact of water hardness.

3.1a Identify sources of potable water and their management in Malta.

3.2b State criteria of purity for water. (Limited to melting point, boiling point and **conductivity**.)

3.3f Explain the properties of ionic compounds

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

General Site information	
Water Services Corporation Head Office, Triq Ħal Qormi, Ħal Luqa LQA 9043 Freephone: 8007 6400 Email: customercare@wsc.com.mt	Water Quality Laboratory Contact Details Tel: 22443271 Email: wsc.laboratory@wsc.com.mt https://goo.gl/maps/2Dbox9F3iyrpohMo7 
How to contact: Contact the laboratory directly using the contacts given above (double check the website in case of changes). Ask for the laboratory manager and explain your intentions.	
Logistical Considerations: Water Quality Laboratory, Luqa	
Tour Duration (approx., not including travel time)	2 hours
Recommended number of students:	30, in groups of 10
Safety considerations	Students to bring their own laboratory coats, gloves and safety spectacles if they intend to carry out water tests on site.

Availability during scholastic year	All year, any time during school hours unless the laboratory is undergoing audits. Prior appointment necessary.
Access to students with disabilities	Good; wheelchair access to all areas.
Facilities:	
Restrooms	Yes
Lunch/ recreational Areas	Yes
Lecture/board room	Yes
Student pack resources:	
Introductory Activities (IA)	IA1: Water testing IA2: Quality control IA3: Water quality
Preparatory Activities (PA)	PA1: Understanding conductivity in practice 1 PA2: Understanding conductivity in practice 2 PA3: Acceptable levels of water quality: who decides? PA4: Prepare your questions PA5: Extension: New Water from wastewater!
Site Activities (SA)	SA1: pH and conductivity meters: calibration and use. SA2: Onsite testing of parameters SA3: Laboratory testing competence SA4: A question of taste!

The Student Resource pack: answers and some guidelines

Rationale:

This pack is not prescriptive. Contrarily, its underlying intention is to provide an outset for the introduction of site visits as coursework. The activities include a variety of resources encompassed within diverse teaching modes spanning traditional, practical and critical approaches. Teachers are encouraged to use whichever resources they deem most pertinent to the contexts they are operating in such as the level of class competence, resources available at school, scheme of work schedules and other such factors typical of the teaching profession.

The pack is modelled around the concept of a restaurant menu, whereby patrons choose their meals depending on their mood and preferred tastes. In fact, the pack's quintessential goal is to spur teachers into eventually creating their own personalised site related resources by either choosing which activities to use or reorganizing them in a different sequence, while adding their own content. Teachers could consider amending the resources to target outcomes related to the site visit. The pack includes various activities that are also suggestive of ideas for lesson planning and other coursework modes: fieldwork, investigations, project based and laboratory practicals.

Activities:

The activities are divided into three categories:

Introductory Activities (IA):

Designed to introduce the students to the processes occurring at the site and to any relevant general knowledge, without which important aspects of the site visit might be lost.

Preparatory Activities (PA):

Designed to get students more in-depth knowledge of processes on the site, possibly encouraging a more critical approach especially in matters related to socio-scientific issues. Some include school based practical activities.

Site Activities (SA):

These are activities that can be carried out on site. These were designed around what the author has experienced during the site evaluation visits. Please appreciate that the guides may be unaware of these activities. Teachers need to liaise with the site responsible people, well in advance, on what activities are possible at the time. It is imperative to discuss in detail the planned activities focussing on any procedures the students will be carrying out and availability of resources on site: equipment, consumables, supervising personnel and venue. Health and safety issues also need to be considered.

Preparing quality questions:

One requirement for site visits in the SEC 06 chemistry syllabus (2025) is for students to prepare questions to ask to the site experts. Therefore, all activities are designed to cater for this prerequisite. Ideally students should use the included prompts to guide their research in order to formulate quality, focused questions to ask during their site visit. For example, instead of asking: 'What is proficiency testing?', better questions could be: 'What information do you get from proficiency testing results?', 'What do you do with this information', 'How do you choose which proficiency testing programs to participate in?'. This would indicate to the scientists that the students have prepared themselves well because they are keen on learning. This, in turn, could transcribe into a more positive disposition of the site experts towards the students, thereby making the experience more fruitful and rewarding to all actors.

It is advisable to share the questions with the site guides before the visit so they can plan the tour accordingly, thereby further bolstering the learning efficacy of the site visit.

The final report:

The general layout of the packs is structured around the rubric presented in the syllabus SEC 06 (2025) document, to facilitate the students' report writing. The teachers should discuss with the students, either as a class or in groups, which of the activities to include in their final report. The rubric stipulates that a set of preparatory and site activities need to be described in the report.

Introductory Activities (IA)

IA1: Water testing

An introduction to the purpose of the WSC laboratory.

Below is a non-exhaustive list of tests carried out by WSC. You can ask students to include the formulae of any, complex or otherwise, ions they are familiar with as revision. The analytical techniques are included as extra information for the teacher and not expected of the students.

Refer also to accreditation scope document which can be accessed from WSC website:

<https://nab.gov.mt/en/Documents/Accredited%20Cabs/001%20-%20WSC%20-%20Accreditation%20Scope.pdf>

Chemical oxygen demand (COD)	Nitrate (UV/VIS)	Fluoride (UV/VIS)	Conductivity
Total Hardness (Titrimetric)	Chlorides (Titrimetric)	Sulfates (UV/VIS)	Ammonia (UV/VIS)
Turbidity	pH	Microbiological	Biological Oxygen Demand (BOD)
Sodium	Boron (UV/VIS)	Heavy metals (Atomic Absorption Spectrophotometry AAS)	Potassium (Atomic Absorption Spectrophotometry AAS)

The two main categories of water analysed at WSC lab:

Potable water	Waste water
---------------	-------------

IA2: Quality control

(Assessment criteria: 1.1b Discuss the importance of fair (objective) testing in science.)

Students' ideas of ensuring validity of results are probably limited to repeated readings, fair testing and possibly, use of a control. The aim of this activity is to help students realise that in real life laboratories, concerns with quality extended far beyond these. Quality control and assurance are fundamental to the operation of any analytical laboratory for a number of reasons. Students can learn about some of them by asking appropriate questions.

Remember to allow enough time for the students to research one or two quality control procedures in detail so they can formulate a question that focuses on a specific aspect of the method.

IA3: Water Quality

(Assessment criteria:

3.2b State criteria of purity for water. (Limited to melting point, boiling point and conductivity.)

3.1e Explain that sea water contains dissolved charged ions that form crystals on evaporation

3.3f Explain the properties of ionic compounds (limited to solubility, mpt/bpt and electrical conductivity in different states.)

An activity that can be used to introduce the concepts of salinity and conductivity while resolving common misconceptions associated with these two terms. It also demonstrates how basic theoretical concepts learnt in class are applied in real life contexts. This activity gives students skills for retrieval and analysis of online data.

Hardness:	Mostly from the globigerina limestone sedimentary rock that features prominently in Maltese geology. Rain water percolates through this rock into the aquifers becoming hard in the process as it dissolves minerals from rocks, particularly calcium, magnesium carbonate and manganese.
Nitrates/Nitrites/ Ammonia:	Excessive use of fertilizer that leach into the aquifers.
Microorganisms:	Contamination from leaking sewage pipes or illegal dumping of contaminated waste. Algal blooms from eutrophication.

Salinity:

- a. By referring to the water quality tables, give examples of ions commonly present in Maltese fresh waters:

Cations	Anions
Ca^{2+}	CO_3^{2-}
Mg^{2+}	NO_3^-
NH_4^+	NO_2^-

- b. A property of ionic compounds is that they are usually soluble in water. Mention one other property that is a consequence of this.

They conduct electricity when they are dissolved in water.

Conductivity:

- c. Is this relation between the Conductivity and concentration of hardness + nitrates observed in Table 1?

Depends on the data the students choose to analyse. There maybe instances where this relation is not clear.

- d. Which other two ions are not shown in WSC's water quality tables but could account for any differences? Why is monitoring of these ions in local groundwater important?

Sodium (Na^+) and chloride (Cl^-). It is important to monitor these as since Malta is an island, groundwater can be contaminated by seepage of seawater into the aquifers.

Preparatory Activities (PA)

PA1: Understanding conductivity in practice 1

PA2: Understanding conductivity in practice 2

(Assessment criteria:

3.2b State criteria of purity for water. (Limited to melting point, boiling point and conductivity.)

3.3f Explain the properties of ionic compounds.)

Two activities that allow students to deepen their understanding of the theory explored in previous activities through practical work. They also suggest possibilities for fieldwork or laboratory practicals.

PA3: Acceptable levels of water quality: who decides?

An activity designed to expose students to socio-scientific issues related to water quality. Access to good quality water is a basic human right that is highly regarded and legally enforced in Europe. Learners are further encouraged to be critical in their analysis of water quality data.

PA4: Prepare your questions

Here students are given time to consolidate what they have learnt into questions which they will be asking during the visit as a group.

PA5: Extension: New Water from wastewater!

This activity attempts to stimulate debate regarding local investments into projects related to sustainability. Students are asked to adopt a critical stance in defending their own proposal against another. This activity would be very suited also for the RO plant visit. The arguments may be rather complex and teacher intervention is encouraged. Below are a few prompt ideas:

- Wastewater can be safely dumped into the sea once treated and RO plants can produce potable water from seawater. Given that RO plants cost roughly the same (if not a bit less) as New Water plants, why invest in the latter?
- Desalination of water through RO is safer and less demanding than producing lower class 'New Water' that has limited applications, such as agriculture. Also any dangerous substances that may escape New Water filtration technology can end up in local agricultural produce.
- Dumping wastewater into the sea, even if treated, is still a source of pollution of the aquatic environment. With New Water projects, up to a third of the wastewater can be reclaimed, thereby reducing coastal pollution.
- It would be a waste to use potable quality water for agricultural when plants can thrive with lower quality reclaimed water.

Site Activities (SA)

SA1: pH and conductivity meters: calibration and use

Students have the opportunity to use professional field/lab equipment that is not available in schools. They can also appreciate that readings given by this instrumentation, no matter how expensive and advanced, need to be constantly checked against reference standards to adhere to good quality control protocols.

SA2: Onsite testing of parameters

(Assessment criteria:

7.2c Identify cations present in solutions.

7.2d, 7.3d Identify anions present in solutions.

7.3h Conduct an acid/base titration to determine the concentration of a given solution.)

Students have the opportunity to use professional laboratory equipment (under supervision) that is not available in schools. They can use an automatic burette to test for hardness or a UV/VIS spectrophotometer to measure for nitrates or fluorides. They might even get to see more sophisticated equipment in action such as an atomic absorption spectrophotometer (AAS) to detect heavy metals, or a gas chromatograph (GC) for pesticide analysis or petroleum hydrocarbon analysis.

It is imperative for teachers to liaise closely with the laboratory technicians, informing them of the intended tests, so everything is ready for the students during the visit. It is important that health and safety protocols are well understood and observed for the sake of student safety.

SA3: Laboratory testing competence

This activity extends 'IA1' to real life. Students are sent on a quest to discover the various tests carried out and the equipment used. Photos and riddles are included to make the quest more interesting.

SA4: A question of taste!

Students are introduced to rather unusual tests on water: taste. Unusual because taste cannot be objectively measured, but is subject to an individual's perception of how water should taste to be described as pleasant. Chemical species present in the water tend to exacerbate the problem:

High levels of calcium hardness in water make the pH more alkali and this amplifies sense of chlorine. So even if chlorine is present at normal levels, if the hardness is high people may still complain that their tap water tastes of chlorine. Chlorine reactions with other species in water are also influenced by pH, creating by-products that are adverse to health such as trihalomethanes (THMs). So high levels of water hardness coupled with chlorine disinfection can deteriorate water quality if not closely monitored. Learn how WSC is tackling these issues and taking all possible measures to ensure the quality of Maltese tap water.

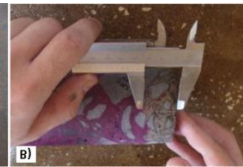
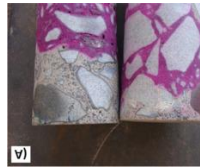
Concluding remarks

As a final thought and recommendation, it would be a nice gesture for the students to prepare a small token of appreciation that could be presented to the guide/s at the end of the visit. This should be something relevant to the site and that the students produced during their activities, for example a leaflet or infographic raising awareness about Malta's water challenges. Students with a penchant for artistic or literary expression might even present a painting or read out a poem or a short essay related to the subject.

Apart from being a sign of gratitude, these simple practices could help build and sustain rapports between the schools and the external scientific community. Such connections are very precious resources which unfortunately, in Malta, are very much left untapped.

Subject Focus 3: Substances from the Earth: The Land

Site Visit



Student Resource Pack

Target Learning Outcomes

Learning Outcome 8:

I can describe how different rocks contain important substances, their extraction, chemical nature, responsible use and environmental impact.

8.1a State uses of limestone.

8.2a Describe the use of limestone in industry.

(Including the manufacture of quicklime and slaked lime. As an aggregate in construction.)

8.2b Investigate simple physical properties of substances used in buildings and relate them to their use.

(E.g. density, heat and electrical conductivity of limestone, concrete, wood, steel and aluminium.)

8.3b Investigate the chemical properties of substances used in buildings and relate them to their use.

(Limited to action of acids and water on limestone, concrete, wood, steel and aluminium)

8.2c Describe the economic and environmental impact of open quarrying of stone.

8.3c Debate the economic and environmental impact of open quarrying of stone.

8.1d Identify metals that are found free in nature or that are extracted from certain minerals found in rocks.

(Limited to iron from haematite and aluminium from bauxite as well as the very few metals found as elements in the ground e.g. gold and platinum.)

8.1g Describe methods that prevent rusting.

8.2g Investigate the conditions needed for iron to rust.

8.3g Investigate the effectiveness of various rust prevention techniques in different situations.

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

Introduction: About Solid Base

Visit the Solid Base Laboratory website:

<http://www.solidbasemalta.com/index.html>

to learn about some services this lab offers to its clients.

In particular watch the Corporate presentation video (<https://www.youtube.com/watch?v=SGA0m4KjTxs>) and/or download the Corporate brochure.

List four materials this lab offers testing services for:

1. _____
2. _____
3. _____
4. _____

In which industry are the above materials being used in this case?

From which environment are most of these materials being extracted from?

For the purposes of this site visit we will be focusing on three materials:



Limestone



Cement



Steel

These materials are major components of the second most used material in the world: **concrete.**

Introductory Activities (IA)

IA1: A primer on Concrete

Concrete is an artificial stone and the most widely used building material. It is often confused with cement. Make sure you understand the difference between cement and concrete by watching the following video:

<https://www.youtube.com/watch?v=BTCubpLQTZc>

or reading the following article:

<https://kids.britannica.com/students/article/concrete/273771>

List four main components required to make concrete:

1. _____
2. _____
3. _____
4. _____



What about Steel?

Steel is used to reinforce concrete structures.

In this case the steel is referred to as rebar (short for: reinforcing bar).

Watch the following (or other) videos showing how rebar is used with concrete:

<https://www.youtube.com/watch?v=aWtn-GyFuiU>

https://www.youtube.com/watch?v=wxO-5oj5_wM

Construction is one of the most important steel-using industries, accounting for more than 50% of world steel demand.

(Read more: <https://worldsteel.org/steel-by-topic/steel-markets/buildings-and-infrastructure/>)

Where does all the iron to make steel come from?

IA2: A primer on Limestone

We have seen how cement is a key ingredient in concrete as without it the mixture cannot harden. Cement is a fine mineral powder usually grey in colour. One of the most important raw materials for producing cement is **limestone**. Up until a few years ago, limestone was still used extensively for construction in Malta. Nowadays, not so much. Limestone is a type of naturally occurring sedimentary rock and needs to be quarried from the land for use.



a. Discuss:

The economic and environmental impact of limestone quarrying in Malta. What can be done to mitigate this impact?

The following can guide your discussion:

- Use Google Earth to look for satellite images of quarries in Malta and Gozo. Assess their impact on the environment.
- <https://www.bbc.co.uk/bitesize/guides/z6gqmsg/revision/4>
- <https://tvmnews.mt/en/news/use-of-maltese-limestone-has-decreased-as-it-is-backbreaking-work-says-stonemason/>



b. Debate

Locally the building industry has switched to the use of concrete and bricks (also made from concrete). Was this a wise choice?

Here are some points to think about for your discussion:



- Strength of limestone slabs (eg xorok) vs concrete.
- Stone craftsmanship.
- Height of buildings.
- Quarrying and environmental implications.
- Buildings close to the sea.
- Workability of concrete.

Anything you want to ask the site experts you will be meeting?

<https://timesofmalta.com/articles/view/watch-arte-documentary-tackles-maltas-paradise-of-concrete.876665>

The Site Visit

It is now time to visit the site with the experts!
Before you go have a look at the next section and remember to

Participate, **A**sk questions, **T**ake photos and notes, **E**NJOY!



Date	
Title	
Aims and objectives	

Preparatory Activities (PA)

PA1: The chemistry of limestone: The Limestone Cycle

Learn more about the limestone cycle and uses of limestone from your textbooks or other resources. The following links lay it all out clearly and concisely:

<https://www.bbc.co.uk/bitesize/guides/z6gqmsg/revision/2>
(scroll to pg 3 and 4)

<https://www.youtube.com/embed/KzzRYSyQCA8>

The cycle consists of the three equations below. Write down balanced chemical equations including the state symbols.

1. calcium carbonate $\rightarrow$ calcium oxide + carbon dioxide

2. calcium oxide + water $\rightarrow$ calcium hydroxide

3. calcium hydroxide + carbon dioxide $\rightarrow$ calcium carbonate + water

Which of reactions 1, 2 and 3:

i. Is a thermal decomposition reaction? ____

ii. Is a metal oxide with water reaction? ____

If the product of this reaction is dissolved in water, how would it effect litmus paper? Why?

iii. Is a neutralisation reaction? ____

Why can it be classified as a neutralisation reaction?

Write down the chemical names and formulae of the following compounds in reaction referred to in (iii):

	Name	Formula
Acid		
Base		
Salt		

These three reactions of the limestone cycle underlie the:

- ✓ process of making cement,
- ✓ chemistry of concrete hardening process,
- ✓ the deterioration and spalling of concrete structures.

These various 'lime' compounds of calcium are often referred to by their layman's names as follows:

Calcium carbonate is found naturally in (and often referred to as) **limestone**.

Calcium oxide is also known as **quicklime**.

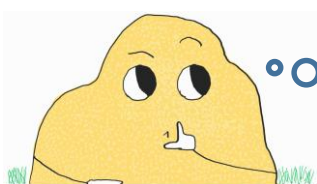
Calcium hydroxide is also known as **slaked lime**.

Calcium hydroxide dissolves in water to form a basic solution called **lime water**.

Calcium hydroxide is only slightly soluble in water and therefore it quickly becomes saturated; calcium hydroxide particles then become suspended in water to form **milk of lime**.



'**Xaħx**' is the Maltese word for limestone sand, often used as an aggregate in construction. It was mentioned in a previous [video](#).



What does 'xaħx' look like?
What is an aggregate?
How is xaħx used as an aggregate?



Ask about this during your site visit!

PA2: Building habitats but destroying others....

Consider this quote from a research article related to the cement industry:

"Global industrialization and urbanization processes enabled a diverse cement production boom over the past three decades, as cement is the most important building construction material. Consequently, the cement industry is the second-largest industrial CO₂ emitter (~25% of global industrial CO₂ emissions) globally." (Chen et al., 2022, p. 1)*

Watch this video on how is cement made:

<https://www.youtube.com/watch?v=Tpc9d7ESw38>

Which of the reactions in the limestone cycle is partly responsible for cement production to be classified as the "second-largest industrial CO₂ emitter".

Mention one other process in the production of cement that releases large volumes of carbon dioxide.

Do some research on the use of concrete globally. The articles and videos below give much insight on the issue:

<https://www.theguardian.com/cities/2019/feb/25/concrete-the-most-destructive-material-on-earth>

<https://www.bbc.com/news/science-environment-46455844>

<https://www.youtube.com/watch?v=UmnFTffYM3w>

Discuss:

How is concrete affecting our planet's Air, Water and Land Environments?

*Chen, C., Xu, R., Tong, D., Qin, X., Cheng, J., Liu, J., ... & Zhang, Q. (2022). A striking growth of CO₂ emissions from global cement industry driven by new facilities in emerging countries. *Environmental Research Letters*.

€30 million required to repair inferior quality concrete at Mater Dei

"....although the concrete in Malta should have been made of hard rock (*tal-qawwi*), it turns out that the concrete used to build the hospital was made of concrete mixed with soft globigerina limestone (*tal-franka*). The tests carried out on the columns show that while their strength should have been Grade **C30**, many of the tests yielded different results, with the strength of the columns in the Emergency ward registering at a mere **C18**."

"..all the blocks at Mater Dei were built with concrete which is less than Grade **C30**. The structures in Block D are at Grade **C23**, which is much lower than the stipulated requirement of **C30**."

tvmnews.mt/en/news/e30-million-required-to-repair-inferior-concrete-at-mater-dei/

Task 1:

Sort the items shown according to how hard you predict each is to break.

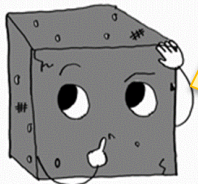


Task 2:

Are any items difficult to sort? Propose a set-up that could be used to measure the force necessary to break each item.

Solid Base have special instruments that can measure the compressive force (N) needed to break a sample cube of concrete. This instrument actually measures the **pressure** (force per unit area: N/mm^2) at which the cubes break (*the same size of cube is used for all samples. Why?*). This number defines the grade ('C' rating) of concrete. The higher the number, the stronger and the better the quality of the concrete. Example: C30 concrete will break at 30N/mm^2 .

Task 3: Research and list some applications for the different grades of concrete.



Why does '*tal-franka*' aggregate produce lower quality concrete than '*tal-qawwi*'?

What else affects the quality of concrete?

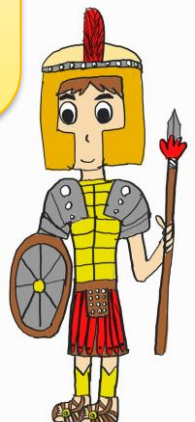
Anything else you want to ask the experts please do!

Checkout how strong my friends are in site activity: **SA1!**

Did you know....

Roman concrete was the best concrete EVER!
But we kept our mix secret, even from you guys!!

www.youtube.com/watch?v=Gxni8PnOTtY



PA4: Carbonation (*the chemistry of falling balconies!*)

'It was like a bomb exploding' - the danger of balcony collapses



<https://timesofmalta.com/articles/view/it-was-like-a-bomb-exploding-the-danger-of-balcony-collapses.899888>

What is rusting? (Explain using a chemical equation.)

Imagine a piece of iron rod that is undergoing a rusting reaction. The volume of this rod increases as a result of this reaction. Why?

Previously we mentioned how rebar is used to reinforce concrete structures. Rebar is made of steel (which is an alloy of iron and carbon). When this rusts, its volume will increase. Since concrete is very brittle, this increase in volume will cause it to crack, severely damaging the structure (spalling).

Discuss:

Is there any evidence of rust in the picture above?
Could this be what caused the balcony to collapse and very nearly kill someone?

What could be the fate of this bridge if no maintenance is carried out?

<https://www.independent.com.mt/articles/2018-08-17/local-news/Marsa-Qormi-intersection-flyover-structurally-safe-Infrastructure-Malta-6736194980>



The question is....

...if rebar is totally immersed in hard concrete why does it rust?

You have learned about how rusting is a reaction with oxygen (in air) and water. Concrete is a porous substance and gases like oxygen and water vapour can diffuse into it especially at the surface. However rusting of rebar occurs mostly due to a process known as carbonation. First we need to understand a bit about the hardening process of concrete.

The binding agent (the substance that 'glues' all the aggregates: the gravel, sand and other additives) is cement. As we have seen in previous videos, water is necessary for the cement to be activated and for the hardening process to start.

When water is added to cement a number of chemical reactions, known as hydration reactions (reaction with water), begin. Now, the chemistry of the concrete hardening process is rather complex and involves a number of minerals such as:

- Calcium silicates (containing silicon dioxide)
- Calcium aluminates (containing aluminium oxide)
- Calcium aluminoferrites (containing aluminium and iron oxides)

When these minerals react with water, they undergo crystallisation process where crystals start growing and merging into each other producing a very strong, hard structure: concrete. One reason (among others) why this happens is because the water bonds with the minerals as water of crystallisation, a process you are familiar with. This is a simplified way of understanding how concrete hardens.

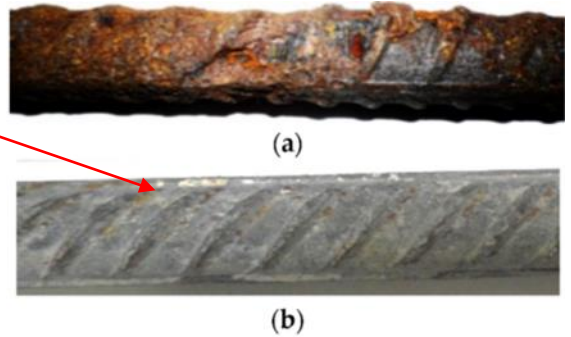
In previous activities you have learned that an important constituent of cement is calcium oxide, which is produced as a result of limestone being heated to high temperatures during the cement production process (*which reaction was this?*).

Give the reaction of calcium oxide in cement when water is added:

What kind of pH would you expect the product of this reaction to be? _____
(Research the typical pH values of concrete).

What colour change would you expect of phenolphthalein indicator if it came into contact with this product? _____.

This kind of alkaline pH in concrete ensures that a passivation layer (the grey layer in 'b') is formed on the rebar that protects it against corrosion (rusting, as in photo 'a').



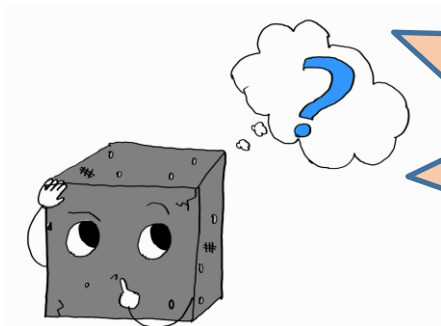
Problems start when carbon dioxide in air, diffuses into concrete structures causing: Carbonation.

Which of the limestone cycle reactions do you think occurs?

CO₂

Predict what happens to the pH of concrete when it reacts with CO₂.
Give a reason for your answer.

How would this affect phenolphthalein indicator?

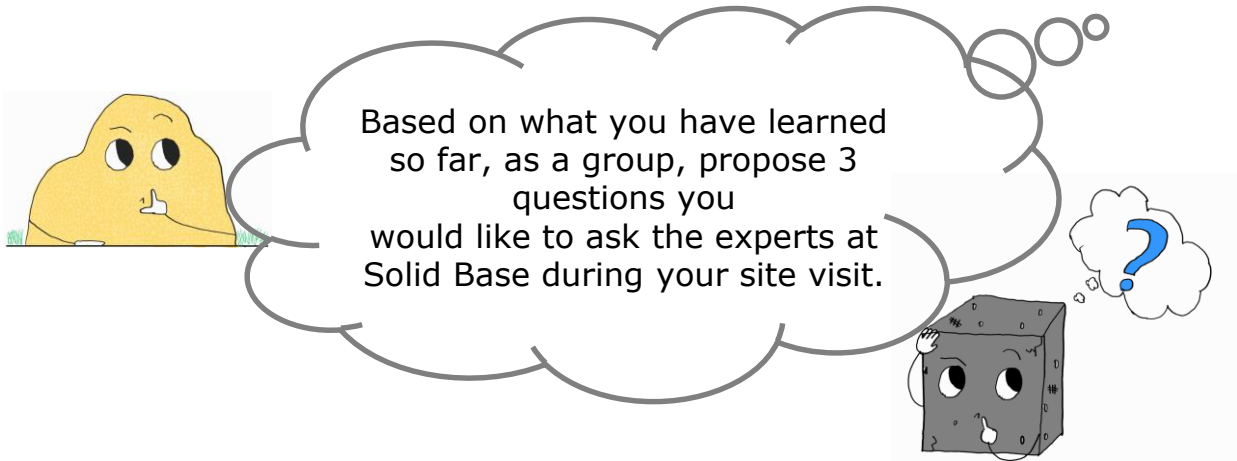


What happens to the rebar when the pH of concrete changes because of CO₂?

What happens to the concrete?

For answers you need to complete Site Activity: SA2!

PA5: Prepare your questions



Some ideas you may use to formulate your questions:

- ✓ The use of aggregates and concrete mix design.
- ✓ Measuring the strength of concrete: good vs inferior concrete mixes.
- ✓ Steel reinforcement.
- ✓ Quarrying land for limestone and other minerals in Malta.
- ✓ Limestone vs concrete in Malta.
- ✓ Construction, the environment and sustainability.
- ✓ Cement and global warming.
- ✓ Alternatives to cement.

Here is one way you can organise your questions and answers:

Question:	
Answer: (Notes)	

Site details	
Description of location	
History	
Purpose of site	
Precautions and Safety Considerations <i>(Potential hazards and safety considerations noticed on site)</i>	

SA1: How strong is concrete?



Concrete is classified in grades (C10/C20/C25/C30 etc) according to how strong it is after 28 days from being poured.

The equipment shown here, is used by Solid Base Laboratory to measure the strength of sample concrete blocks. Site technicians can demonstrate the use of this equipment.



You can also decide to try an experiment:

Aim: To investigate the relationship between concrete strength and density.

Results: *(the square brackets are for the units)*

Mass of block []	Volume of block []	Density of block []	Compressive strength []

Observe how the strength varies with how dark the grey of the blocks is. Try to explain this.

Use this activity to learn about and understand:

- The units used to measure concrete strength.
- Why is the test usually performed after 28 days.
- Which of the reactions in the limestone cycle is important in the concrete hardening process.
- What affects the density and strength of concrete.
- How are these measurements used to classify concrete.
- Why is it important to classify concrete according to its strength.

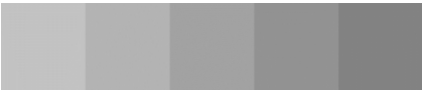
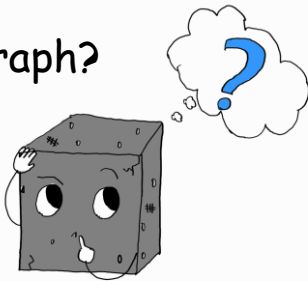
Conclusion:

Is there a relationship between concrete strength and density? Explain.

Volume of a cube...

Density = ?/?

Graph?

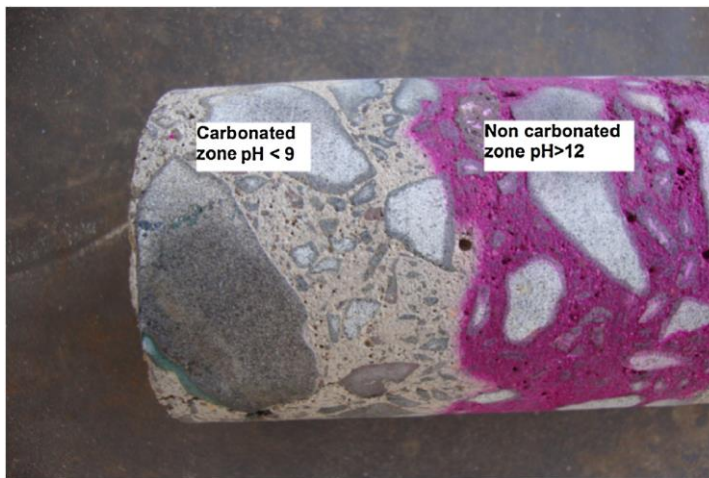


SA2: A spoonful of CO₂, makes the balcony go down..... solving the case

In **PA4** (pg 11), the chemistry behind carbonation was discussed. Below are some of the key words used during the activity:

Phenolphthalein, passivation layer,
rebar corrosion, pH values and spalling.

Learn about how all these are linked and how carbonation is tested for at Solid Base Laboratory. The picture below is a clue.



<https://www.sciencedirect.com/science/article/pii/S2214509516300493>

Task:

1. Ask the lab technicians for a demo.
2. Observe and take note of the apparatus used.
3. Write a procedure, in point form, describing the process.

In your report:

Write a short discussion explaining how carbonation may severely damage concrete structures; include any relevant chemical equations (**PA1**, pg 7).

Acid rain can have a similar effect on concrete. Explain, including at least one chemical equation that is relevant.

Suggest ways by which concrete structures can be protected.

Conclusion:

Explain what could have caused the balcony/parts of the bridge to collapse.

Communication of outcomes

In your report it is important to describe your findings. In this section use the notes you took during the visit to help you to:

- answer any questions you asked the scientists.
- communicate any other information collected during the visit, for example: data from any measurements taken, any results or data shared with you by the scientists, any chemical or physical changes observed during experiments carried out on site, any unexpected findings etc.

The table below is one way you can organise your notes/information. However use whatever other method/means you are comfortable with.

Name of activity:	Example:
Scope:	<i>(What to I want to learn? Example:</i>
Outcomes:	<i>(What did I actually learn?):</i>

Discussion, Evaluation, Reflection and References

Discussion	➤ What did you learn from this site visit? ➤ Which learning outcomes did you achieve? ➤ Interpret any results, data or other information collected by: relating findings to expectations and any conclusions arrived at.
Evaluation	➤ Did you encounter any difficulties, challenges during the visit? ➤ Are there any improvements or alternate activities you can suggest?
Reflection	"Being prominently used, steel and concrete industries are dominating among the construction industries leading to symbolic damage to the environment." (Mehra et al., 2022, p. 1)* ➤ Were you aware of the huge environmental impact of concrete? ➤ Economies built around: construction or the environment? ➤ Are there any solutions? Is a totally 'green' construction industry possible? ➤ Any other reflections you want to make?
References	List any sources cited or referred to.

*Mehra, S. et al. (2022). Impact of Construction Material on Environment. In: Malik, J.A., Marathe, S. (eds) Ecological and Health Effects of Building Materials. Springer, Cham.

Subject Focus 3: Substances from the Earth: The Land

Site Visit



Teachers' Guide

Subject Focus 3: Substances from the Earth: The Land

Site Visit: Solid Base Laboratory

Learning Outcome 8:

I can describe how different rocks contain important substances, their extraction, chemical nature, responsible use and environmental impact.

8.1a State uses of limestone.

8.2a Describe the use of limestone in industry.

(Including the manufacture of quicklime and slaked lime. As an aggregate in construction.)

8.2b Investigate simple physical properties of substances used in buildings and relate them to their use.

(E.g. density, heat and electrical conductivity of limestone, concrete, wood, steel and aluminium.)

8.3b Investigate the chemical properties of substances used in buildings and relate them to their use.

(Limited to action of acids and water on limestone, concrete, wood, steel and aluminium)

8.2c Describe the economic and environmental impact of open quarrying of stone.

8.3c Debate the economic and environmental impact of open quarrying of stone.

8.1d Identify metals that are found free in nature or that are extracted from certain minerals found in rocks.

(Limited to iron from haematite and aluminium from bauxite as well as the very few metals found as elements in the ground e.g. gold and platinum.)

8.1g Describe methods that prevent rusting.

8.2g Investigate the conditions needed for iron to rust.

8.3g Investigate the effectiveness of various rust prevention techniques in different situations.

Learning Outcome 1:

At the end of the programme, I can demonstrate an understanding of how chemistry works and is communicated.

General Site information	
Solid Base Laboratory Handaq Industrial Estate Qormi, QRM4000 Tel: +356 21492807 Email: info@solidbasemalta.com	Location: https://goo.gl/maps/ffGCqvZjwmUUerT49 
How to contact: Use the general contact details on the company website: http://www.solidbasemalta.com/ Call and ask for the Quality Manager. Otherwise send an email expressing your intent and school details.	
Logistical Considerations:	
Tour Duration (approx., not including travel time)	2 hours
Recommended number of students:	15
Safety considerations	Since the laboratory carries out tests for the construction sector, part of its function involves handling of bulky samples such as concrete blocks, aggregate and drilled core samples, and also the use of heavy testing equipment and machinery. Nevertheless, the laboratory is well equipped and organised to handle these safely, so no particular safety concerns were noted. Furthermore, the guides will make sure that any machinery that could pose some risk will be switched off.
Availability during scholastic year	All year, any time during school hours. Prior appointment necessary.

Access to students with disabilities	Limited wheel chair access to some areas.
Facilities:	
Restrooms	Yes
Lunch/ recreational Areas	A boardroom could be used for lunch break.
Lecture room	Yes
Student pack resources:	
Introductory Activities (IA)	Introduction: About Solid Base IA1: A primer on Concrete IA2: A primer on Limestone
Preparatory Activities (PA)	PA1: The chemistry of limestone: The limestone cycle PA2: Building habitats but destroying others.... PA3: Quality matters PA4: Carbonation (<i>the chemistry of falling balconies!</i>) PA5: Prepare your questions
Site Activities (SA)	SA1: How strong is concrete? SA2: A spoonful of CO₂, makes the balcony go down: solving the case

The Student Resource pack: answers and some guidelines

Rationale:

This pack is not prescriptive. Contrarily, its underlying intention is to provide an outset for the introduction of site visits as coursework. The activities include a variety of resources encompassed within diverse teaching modes spanning traditional, practical and critical approaches. Teachers are encouraged to use whichever resources they deem most pertinent to the contexts they are operating in such as the level of class competence, resources available at school, scheme of work schedules and other such factors typical of the teaching profession.

The pack is modelled around the concept of a restaurant menu, whereby patrons choose their meals depending on their mood and preferred tastes. In fact, the pack's quintessential goal is to spur teachers into eventually creating their own personalised site related resources by either choosing which activities to use or reorganizing them in a different sequence, while adding their own content. Teachers could consider amending the resources to target outcomes related to the site visit. The pack includes various activities that are also suggestive of ideas for lesson planning and other coursework modes: fieldwork, investigations, project based and laboratory practicals.

Activities:

The activities are divided into three categories:

Introductory Activities (IA):

Designed to introduce the students to the processes occurring at the site and to any relevant general knowledge, without which important aspects of the site visit might be lost.

Preparatory Activities (PA):

Designed to get students more in-depth knowledge of processes on the site, possibly encouraging a more critical approach especially in matters related to socio-scientific issues. Some include school based practical activities.

Site Activities (SA):

These are activities that can be carried out on site. These were designed around what the author has experienced during the site evaluation visits. Please appreciate that the guides may be unaware of these activities. Teachers need to liaise with the site responsible people, well in advance, on what activities are possible at the time. It is imperative to discuss in detail the planned activities focusing on any procedures the students will be carrying out and availability of resources on site: equipment, consumables, supervising personnel and venue. Health and safety issues also need to be considered.

Preparing quality questions:

One requirement for site visits in the SEC 06 chemistry syllabus (2025) is for students to prepare questions to ask to the site experts. Therefore, all activities are designed to cater for this prerequisite. Ideally students should use the included prompts to guide their research in order to formulate quality, focused questions to ask during their site visit. For example, instead of asking: 'What is rebar?' a better question could be: 'Why does rebar help reinforce concrete structures?' This would indicate to the scientists that the students have prepared themselves well because they are keen on learning. This, in turn, could transcribe into a more positive disposition of the site experts towards the students, thereby making the experience more fruitful and rewarding to all actors.

It is advisable to share the questions with the site guides before the visit so they can plan the tour accordingly, thus further bolstering the learning efficacy of the site visit.

The final report:

The general layout of the pack is structured around the rubric presented in the syllabus SEC 06 (2025) document, to facilitate the students' report writing. The teachers should discuss with the students, either as a class or in groups, which of the activities to include in their final report. The rubric stipulates that a set of preparatory and site activities need to be described in the report.

Introduction: About Solid Base

Solid Base Laboratory is probably not very well known in the chemistry education communities. This activity or video introduces teachers and students to the kind of testing this lab specialises in.

Answers:

List four materials this lab offers testing services for:

1. Aggregate
2. Concrete
3. Soil
4. Asphalt

In which industry are the above materials being used in this case? Construction

From which environment are most of these materials being extracted from? Land

Introductory Activities (IA)

IA1: A primer on Concrete

(Assessment Criteria:

8.1d Identify metals that are found free in nature or that are extracted from certain minerals found in rocks. (Limited to iron from haematite and aluminium from bauxite as well as the very few metals found as elements in the ground e.g. gold and platinum.

8.2b Investigate simple physical properties of substances used in buildings and relate them to their use. (E.g. density, heat and electrical conductivity of limestone, concrete, wood, steel and aluminium.))

Students will learn about the difference between cement and concrete while slowly introducing an awareness on how demanding the production of concrete and the construction are on the environment.

Answers:

List four main components required to make concrete:

1. Cement
2. Sand
3. Gravel
4. Water

Where does all the iron to make steel come from?

From ore deposits in rock such as haematite.

IA2: A primer on Limestone

(Assessment criteria:

8.1a State uses of limestone.

8.2a Describe the use of limestone in industry.

(Including the manufacture of quicklime and slaked lime. As an aggregate in construction.)

8.2c Describe the economic and environmental impact of open quarrying of stone.

8.3c Debate the economic and environmental impact of open quarrying of stone.)

Some points that may be used to spur the discussion/debate:

- Quarries can be reused as landfills for construction (or other) waste.
- Articles about reuse of limestone:

Recycled limestone will soon be available as a building material

<https://timesofmalta.com/articles/view/recycled-limestone-will-soon-be-available-as-a-building-material.898699>

and

https://www.um.edu.mt/_data/assets/pdf_file/0005/264965/KD01SBXRecons titutedStone.pdf

- Limestone can be quarried and immediately used. Cement production requires quarrying of materials and very energy intensive refining processes in plants.
- Limestone is finite and cannot meet Malta's demands indefinitely. Cement can be imported and so the local environment is not affected that much.
- Concrete is much easier to use for building.
- Bigger buildings and towers can be built using concrete because they can withstand large forces and concrete is more workable. Limestone slabs cannot withstand such weight so the construction industry is replacing limestone with concrete. Is this a wise choice?
- The construction industry (local context) should be diminished at the expense of the economy it generates; the environment (green areas) is more important. Are all these new buildings really necessary?

Preparatory Activities (PA)

(Assessment criteria:

8.1a State uses of limestone.

8.2a Describe the use of limestone in industry. (Including the manufacture of quicklime and slaked lime. As an aggregate in construction.

8.2c Describe the economic and environmental impact of open quarrying of stone.

8.3c Debate the economic and environmental impact of open quarrying of stone.)

PA1: The chemistry of limestone: The Limestone Cycle

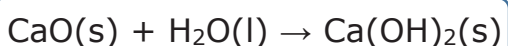
Students can learn about the chemical reactions that are important in the production of cement, hardening of concrete and deterioration of concrete structures. These will be expounded upon in the upcoming activities. The names of common lime compounds are clearly laid out as they are often used interchangeably. The activity is also a revision exercise on past topics.

Answers:

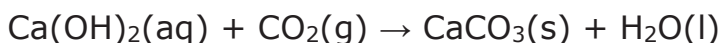
1. calcium carbonate → calcium oxide + carbon dioxide



2. calcium oxide + water → calcium hydroxide



3. calcium hydroxide + carbon dioxide → calcium carbonate + water



Which of reactions 1, 2 and 3:

- i. Is a thermal decomposition reaction? 1

- ii. Is a metal oxide with water reaction? 2

If the product of this reaction is dissolved in water, how would it affect litmus paper? Why?

It would change red litmus to blue since calcium hydroxide releases hydroxide ions (OH⁻) in solution, which makes the solution alkali.

- iii. Is a neutralisation reaction? 3

Why can it be classified as a neutralisation reaction?

An acidic gas (CO₂) is reacting with a base (Ca(OH)₂), in solution, to give salt and water only.

Write down the chemical names and formulae of the following compounds in this reaction:

	Name	Formula
Acid	Carbon dioxide	CO ₂
Base	Calcium hydroxide	Ca(OH) ₂
Salt	Calcium carbonate	CaCO ₃

PA2: Building habitats but destroying others

This activity intends to raise awareness of the problems the global cement production boom is causing. The focus is mainly on the cross curricular themes of global warming, the environment and sustainability, but it also links some of the impacts to the chemical reactions of limestone.

Below are some ideas to prompt the discussion:

- Link to Aquatic and Air Environments.
- Research about water needed for the production of concrete in view of the global water scarcity crisis.
- Carbon dioxide emissions from cement production and global warming.
- Land use for quarrying and destruction of natural habitats.

Answers:

Which of the reactions is partly responsible for cement production to be classified as the "second-largest industrial CO₂ emitter". $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

Mention one other process in the production of cement that releases large volumes of carbon dioxide. Very high temperatures are needed for this reaction to occur. These are generated through burning of fossil fuels, a process which releases CO₂.

PA3: Quality matters

This activity is a prequel to **SA1**. Students are introduced to the concept of quality of concrete by means of a controversial case study concerning the concrete used to build Mater Dei.

Task 1 calls on prior knowledge to sort a number of objects according to their hardness. Most students would be aware of the kind of force necessary to break an egg or a walnut, for instance. However, for some of the items (walnut, hazelnut and ice) this comparison is not straightforward.

Task 2 appeals to the learners' creativity to design a set-up that could help them sort the problematic items. The objects can be made available to the students to

aid their designs. They could then compare these to the actual instrument shown in **SA1** or on-site.

Task 3 encourages to research and list some applications for the different grades of concrete. There are a number of sites from where to access this information, for example:

- <https://mastermixconcrete.co.uk/news/different-types-of-concrete-strengths-and-their-uses/>
- <https://www.concreteideas.com/concrete-grade/>

You will come across 'M' ratings for concrete strength (M10, M20 etc). At this level they can be considered to be similar to the corresponding 'C' ratings.

List of typical applications for some concrete grades. (Mix ratio -> cement : sand : coarse aggregate)

C10 Mix ratio: 1:3:6	Suitable for commercial and domestic projects including: Floors, Garden walls, non-load-bearing walls, drainage works, foundations for steps, trench filling, bedding for footings, roads.
C20 Mix ratio: 1:1.5:3	Suitable for domestic purposes such as floors and foundations if the structure weight is light. This strength of concrete is also suitable for internal floor slabs, garages, driveways and workshop bases. Also: patio paving, shed bases, house extensions, internal flooring, garages, foundations, walls, light agricultural slab.
C30 Mix by design	Also known as: reinforced cement concrete (RCC)* as it includes embedded rebar. This is another factor that affects concrete quality and strength and should be pointed out to the students. Used for slabs, beams, footings and columns for structures that are slightly heavier. It can also be used for paths and roadways as it is weather-resistant and can take the weight of road traffic. Also: bases, paving, reinforced concrete construction foundations, external parking, hard standing areas, access roads for vehicles, driveways. * https://engineeringcivil.org/articles/concrete/reinforced-cement-concrete-rcc-simple-explanation-significance/
C40 Mix by design	Used in commercial construction sites to create foundations and beams to provide structural support and roads. Withstands chemical corrosion so can also be used as pre-stressed concrete, beams, footings, slabs, pressurized concrete girders, RCC columns and pressurized beams. Typically used for: ironworks, roadworks, foundations, support beams, harsh environments, septic tanks, agricultural yards, piling.

The activity also guides students into formulating questions.

Roman concrete: it offers some general knowledge about the historical origins of concrete. The information given in the video is very relevant, even to this day.

PA4: Carbonation (*the chemistry of falling balconies!*)

(Assessment criteria:

8.1g Describe methods that prevent rusting.

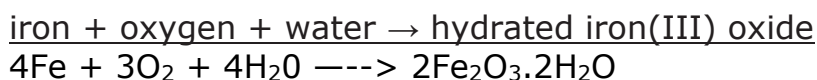
8.2g Investigate the conditions needed for iron to rust.

8.3g Investigate the effectiveness of various rust prevention techniques in different situations.)

The phenomenon of carbonation is introduced through a case study. Calcium hydroxide in concrete makes the pH highly alkaline and this creates a passivation layer on the rebar, protecting it from corrosion. Carbon dioxide from the air reacts with the hydroxide and lowers the pH. This can jeopardise the passivation layer and the rebar can eventually become exposed and susceptible to corrosion. When this happens, the increase in volume of the rebar will cause the brittle concrete to spall with devastating results. The depth of carbonation is tested with a pH indicator: phenolphthalein, as explained further in **SA2**.

Answers:

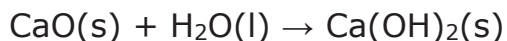
- What is rusting? (Explain using a chemical equation.)



- Imagine a piece of iron rod that is undergoing a rusting reaction. The volume of this rod increases as a result of this reaction. Why?

This happens because oxygen and water combine with the iron.

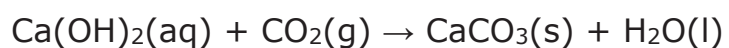
- Give the reaction of calcium oxide in cement when water is added:



- What kind of pH would you expect the product of this reaction to be? >7 (alkali)
(Research the typical pH values of concrete). (Between 12.5 and 13)
- What colour change would you expect of phenolphthalein indicator if it came into contact with this product? Colourless to Pink.

Since carbon dioxide is present in air, it too diffuses into concrete structures.

- Which of the limestone cycle reactions do you think occurs?



- Predict what happens to the pH of concrete when it reacts with CO_2 .
Give a reason for your answer.

The pH decreases as CO_2 is an acidic oxide, so it reacts with the hydroxide in the concrete.

- How would this affect phenolphthalein indicator?
If the pH becomes low enough it will change from pink to colourless.

PA5: Prepare your questions

Here students are given time to consolidate what they have learnt into questions which they will be asking during the visit as a group.

Site Activities (SA)

8.2b Investigate simple physical properties of substances used in buildings and relate them to their use.

(E.g. density, heat and electrical conductivity of limestone, concrete, wood, steel and aluminium.)

8.3b Investigate the chemical properties of substances used in buildings and relate them to their use.

(Limited to action of acids and water on limestone, concrete, wood, steel and aluminium)

SA1: How strong is concrete?

TO BE CARRIED OUT UNDER CONSTANT TECHNICAL SUPERVISION

Here students have a unique opportunity to carry out a practical activity on concrete blocks to relate their density with compressive strength.

Safety Advice:

The blocks should be handled only by the technicians as they can be rather heavy. Students should limit themselves to taking length measurements and recording data from the test instruments.

Concrete is sampled in standard cubes the volume of which is easily calculated by measuring the sides of the cube (L^3 or $L \times B \times H$).

The weight of each block can be measured using balances at the laboratory and the density calculated using $\text{Density} = \text{Mass}/\text{Volume}$.

The blocks are then put into the testing machine which will apply pressure (compressive force) to the blocks and measure the point at which they break.

Students can plot these crush test readings against the density.

Results should show that the higher the density, the greater the strength of concrete. Students should also be encouraged to ask about what affects the density of concrete.

One factor is the ratio of cement added. The more cement there is, the stronger the concrete. Predictions can be made by observing the colour of the blocks. Darker shades of grey usually indicate higher cement ratios in the mix, and therefore stronger concrete. They may use the chart below to assess how 'grey' the blocks are. Another factor is the type of aggregate and additives used. If necessary, ask the site scientists for more information.



SA2: A spoonful of CO₂, makes the balcony go down: solving the case

This activity is a continuation of 'PA4', where students can observe how carbonation is tested for and its effects in real life (hopefully without having to experience real life falling balconies!). The test involves spraying a concrete sample with phenolphthalein. As photos on the pack depict, carbonated zones remain colourless because of reduced pH, while the non-carbonated areas show up as pink. The scientists can then measure the depth of carbonation to decide what action needs to be taken.

Certain preventive measures can stop carbonation from going deeper and reaching the rebar. Such measures include painting or coating the concrete. There may be other techniques that the students can learn about by asking the experts at Solid Base Laboratory.

Students are asked to write a short report. For the discussion they are prompted to extend this effect to include acid rain. The chemical equation(s) expected in this case is that of calcium hydroxide (in concrete) with either sulfuric acid or nitric acid (from acid rain).

Concluding remarks

As a final thought and recommendation, it would be a nice gesture for the students to prepare a small token of appreciation that could be presented to the guide/s at the end of the visit. This should be something relevant to the site and that the students produced during their activities, for example a leaflet or infographic raising awareness about Malta's environmental challenges. Students with a penchant for artistic or literary expression might even present a painting or read out a poem or a short essay related to the subject.

Apart from being a sign of gratitude, these simple practices could help build and sustain rapports between the schools and the external scientific community. Such connections are very precious resources which unfortunately, in Malta, are very much left untapped.