More than holes in the ground:
Lakes created by quarrying and mining

Dad: during the summer, you take us fishing in the lake behind our house. We also enjoy picnics there. You said it used to be a quarry many years ago. How did the ugly quarry turn into our beautiful lake?

The Ubin quarry lake (left) and the Singapore quarry lake (right) in Singapore are important ecosystems that offer scenic views.

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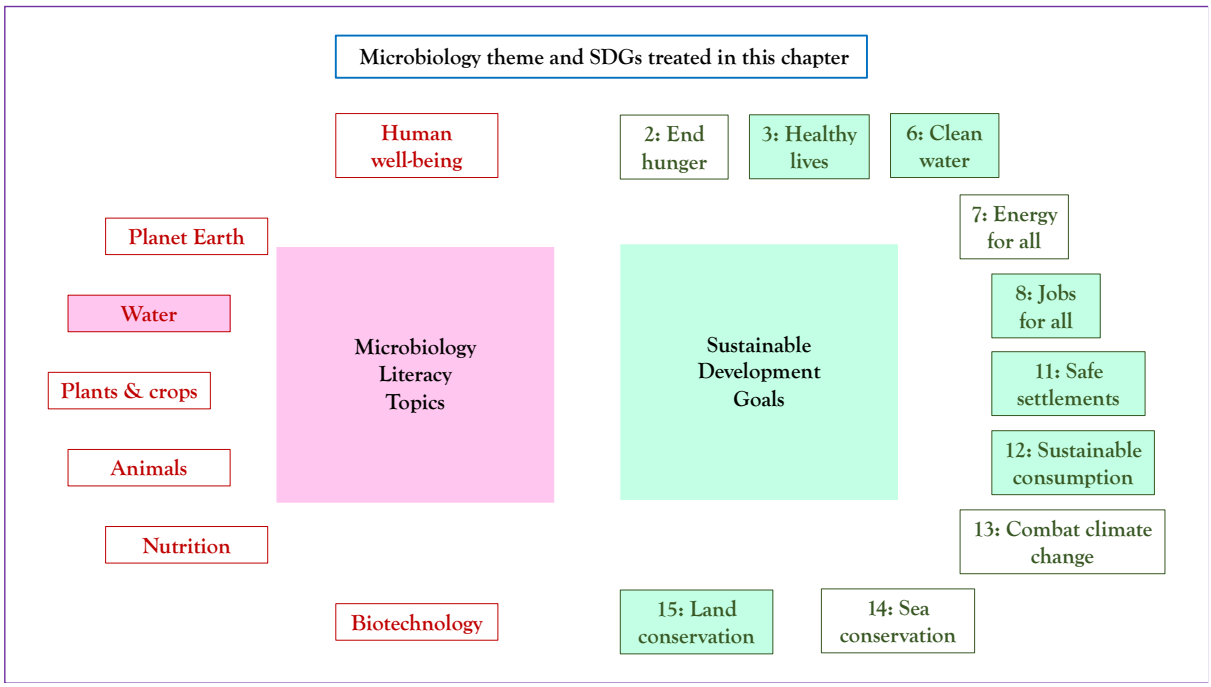
Lakes created by quarrying and mining

Storyline

Quarry lakes are formed at the sites of old quarries, when the abandoned quarry fills with rainwater, water that flows from the land surface, and/or groundwater – water that is found in the cracks and spaces in soil, sand and rock. Over time, quarry lakes become important ecosystems that are habitats for many plants and animals. They are also popular recreation spots for picnicking, fishing, and water sports such as boating. Microorganisms that live in quarry lakes play important roles in many environmental processes and contribute to the transformation of quarry lakes from holes in the ground that are filled with water to beautiful and complex habitats.

The Microbiology and Societal Context

The microbiology: microbial communities; biodiversity; water purification; ecosystems; nutrient cycles. *Sustainability issues:* healthy lives; water management; employment; human settlements; restoration-conservation; terrestrial ecosystems.

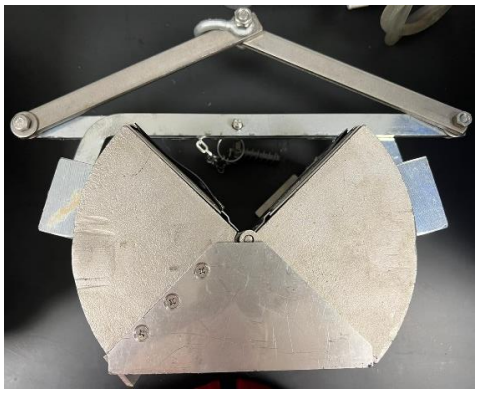


Quarry Lakes: The Microbiology

1. We study the genetic material of microorganisms in the quarry lake to find out who they are and what they are doing there. We often think of microorganisms as the fuzzy mould that grows on bread, or the tiny bacteria that make delicious yoghurt. To study microorganisms such as bacteria, fungi and algae, scientists grow them Petri dishes or culture tubes by providing them with nutrients and suitable conditions for growth. We do this because microbes are small and, unlike say a plant, a single organism represents much too little material to investigate. We need to 'amplify' the organisms under study or their components. We amplify microbial cells by cultivating them, so that one cell becomes millions or billions of identical cells.

However, many microorganisms in environments such as lakes cannot be cultured in the laboratory using the usual methods. One reason for this is that we know little about suitable conditions they need to grow, including what nutrients are required, and how these microorganisms rely on one another's supply of certain chemicals required for their growth in their natural habitats, i.e. what they share with one another. How then do scientists investigate these microorganisms without growing them?

To study such microorganisms, scientists turn to their genetic material. The genetic material, either DNA or RNA, provides clues to their identity and functions. But most samples also only yield tiny amounts that cannot be directly analysed, so these also need to be amplified. After extracting genetic material from microorganisms in the quarry lake water and sediment, scientists amplify the genes using a molecular biology technique called Polymerase Chain Reaction (PCR). By sequencing the genes and comparing them to sequences from other microorganisms, scientists can deduce the species of microorganisms that live in the lake and their possible roles.



Sediment from the bottom of quarry lakes is collected using a sediment grab. It has two jaws which close and grab sediment when it is lowered to the lake bottom.

Water from quarry lakes is collected using a water sampler designed for collecting water from water bodies such as lakes.

2. Different types of microorganisms are present in the water and sediment of the quarry lake. As a result of the vastly different characteristics of water and sediment, distinct types of microorganisms are found in these habitats.

Water close to the surface is directly exposed to sunlight while little sunlight reaches the sediment at the bottom of the lake. There is also more oxygen in water compared to sediment – as a result of mixing by the currents and wind. Hence, photosynthetic microorganisms such as algae that require light to grow and microorganisms that are not affected by oxygen are commonly found in water. On the other hand, sediment provides a conducive habitat for microorganisms such as anaerobic bacteria as oxygen is toxic to these bacteria.

Microorganisms in water such as bacteria are collected by passing water through filters, which function as sieves. Scientists then extract and study the genetic material of the microorganisms trapped on the filters.

Sediment provides a dark and low oxygen habitat for many microorganisms to thrive.

Scientists measure the biodiversity of ecosystems in terms of richness and evenness. Species richness is the number of species within a defined region while species evenness is a measure of how evenly species are distributed in a community. Species evenness is highest when all species in a community are equally abundant. In a study that we conducted to investigate the microbial communities in quarry lakes in Singapore, we have found that the microbial

communities in sediment are more diverse than in water, with a greater number of species of microorganisms found in sediment than water.

3. Microorganisms living in the quarry lake purify the water and contribute to the health of the ecosystem. Microorganisms in the water and sediment of lakes play important roles in various environmental processes, such as producing oxygen via photosynthesis, decomposing organic matter such as tree leaves, as well as breaking down toxic chemicals such as pesticides in the environment. For example, scientists found that microorganisms in the water and sediment from a sand and gravel quarry were able to degrade acrylamide, a chemical used in many industries such as construction and mining, that can cause cancer. In our study, bacteria that can transform metals to less toxic forms and degrade organic matter were abundant in quarry lake sediment, while photosynthetic bacteria such as cyanobacteria were found in the water. Hence, microorganisms in lakes created by quarrying and mining are vital for breaking down harmful contaminants that are left behind by these activities, as well as recycling nutrients in organic compounds in faeces and the remains of plants and animals.

Relevance for Sustainable Development Goals

Microorganisms in lakes created by quarrying and mining are relevant to a number of the UN's Sustainable Development Goals, including

- **Goal 3. Healthy lives.** Many abandoned quarries may, after restoration and removal of any legacy pollutants, become lakes and areas of natural beauty that serve as recreational sites for local residents. As such, they provide opportunities for exercise, relaxation, de-stressing, social activities and re-bonding with family, friends and nature, all of which contribute to personal and collective wellbeing, and hence good health.
- **Goal 6. Ensure availability and sustainable management of water and sanitation for all**, which includes the protection of water-related ecosystems. Microorganisms are key drivers of environmental processes in aquatic habitats and if we understand how they contribute to the health of such ecosystems, we can better conserve and protect these habitats for future generations.
- **Goal 8. Employment for all.** Larger lakes and restored areas may be used for commercial leisure activities, like sailing, wind surfing, paddle boarding, etc., and the provision of food and drink, all of which provides local employment.
- **Goal 11. Safe settlements.** Lakes and recreational areas constitute elements of 'green and public spaces' that should be available to 'settlements', especially in urban areas.
- **Goals 12 and 15. Sustainable practices and Land conservation.** Restoring quarries to natural environments is an essential component of sustainable production and land conservation, and microbes and their activities play key enabling roles in restoration.

Potential Implications for Decisions

1. ***Individual***
    a. Where shall we go for a picnic today?
2. ***Community policies***
    a. Restoration of local legacy quarries and mining sites to create recreation areas of natural beauty
    b. Monitoring and maintenance of local restored quarries

3. ***National policies***
    a. Restoration of legacy quarries and mining sites nationally to create recreation areas of natural beauty
    b. Legislation for owner-restoration of quarries and mining sites following closure

Pupil Participation

1. ***Pupil stakeholder awareness***

What can I do to conserve and protect quarry lake ecosystems?
Possible answers: pick up litter, do not throw rubbish into the lakes which may disrupt the microorganisms there etc.

The Evidence Base, Further Reading and Teaching Aids

Kumar A, Ng DHP, Wu Y and Cao B (2019). Microbial community composition and putative biogeochemical functions in the sediment and water of tropical granite quarry lakes. Microb Ecol 77:1–11.

Guezennec A-G, Michel C, Ozturk S, Togola A, Guzzo J, Desroche N (2015). Microbial aerobic and anaerobic degradation of acrylamide in sludge and water under environmental conditions – case study in a sand and gravel quarry. Environ Sci Pollut Res 22: 6440–6451.

https://www.ebparks.org/parks/quarry_lakes/default.htm

Glossary

Anaerobic: requiring an absence of oxygen
Aquatic: relating to water
Contaminant: substance that is harmful to living things
Decomposition: process by which dead material is broken down into simpler substances
Ecosystem: geographic area where plants, animals and other living things interact with one another
Groundwater: water that is found underground in the cracks and spaces in soil, sand and rock
Habitat: natural environment of an animal, plant, or other living thing
Photosynthesis: process by which green plants and other living things such as algae use sunlight to produce nutrients from carbon dioxide and water
Toxic: containing poisonous materials