Environmentally-transmitted diseases

Mum, why do I always have to wash my hands after playing outside? What if I couldn't?

Photo by Gaurav Ranjitkar: https://www.pexels.com/photo/a-young-girl-wearing-a-bucket-hat-while-playing-sand-11662602/

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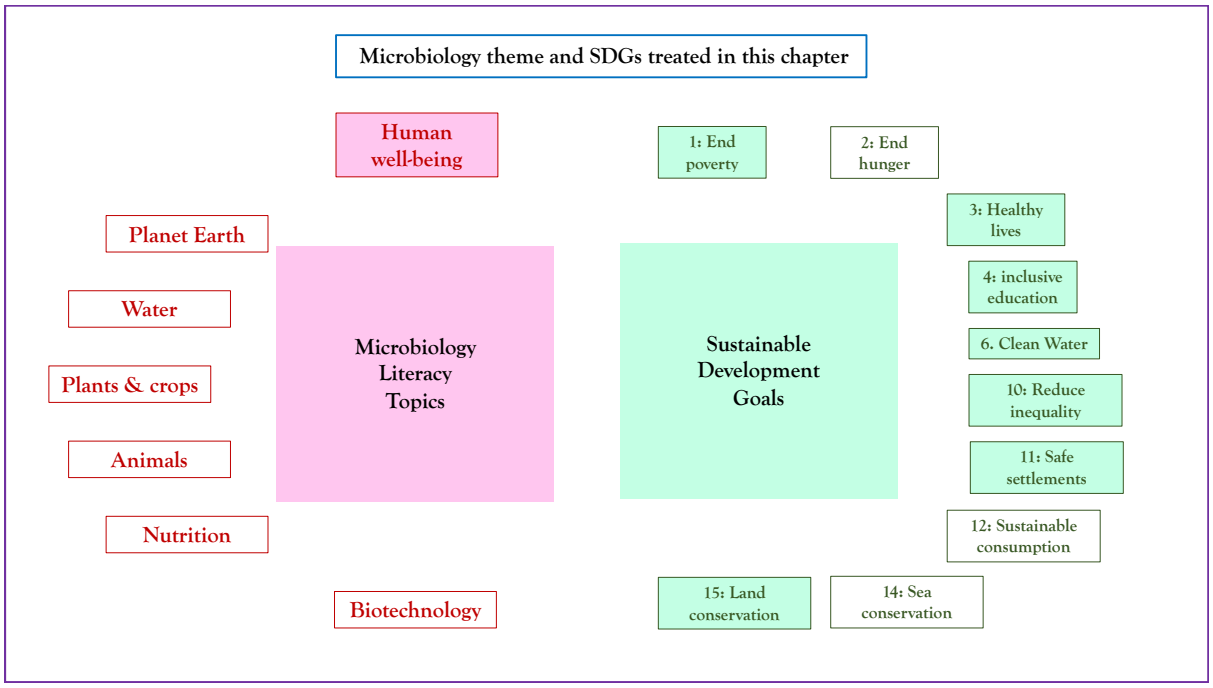
Storyline

Germs that make you sick, known as pathogens, can be spread in numerous ways. You might catch a cold if someone who has one sneezes near you, or you could get sick by eating food that's past its use-by date. Pathogens can also spread through the environment, which is why it's so important to wash your hands after touching the bin or cleaning up after your dog. However, not everyone in the world has access to soap, clean drinking water or toilets. Without these, human and animal faeces can contaminate rivers, soil, or objects that people touch, and pathogens from the faeces can easily make people sick. These pathogens usually cause diarrhoea, which can be especially severe in young children. This is a public health issue in many countries that requires effective improvements to water, sanitation and hygiene. While the transmission of different diseases can be a complicated web of connections between humans, animals and the environment, it is important for scientists to understand these routes so that infections can be prevented.

The Microbiology and Societal Context

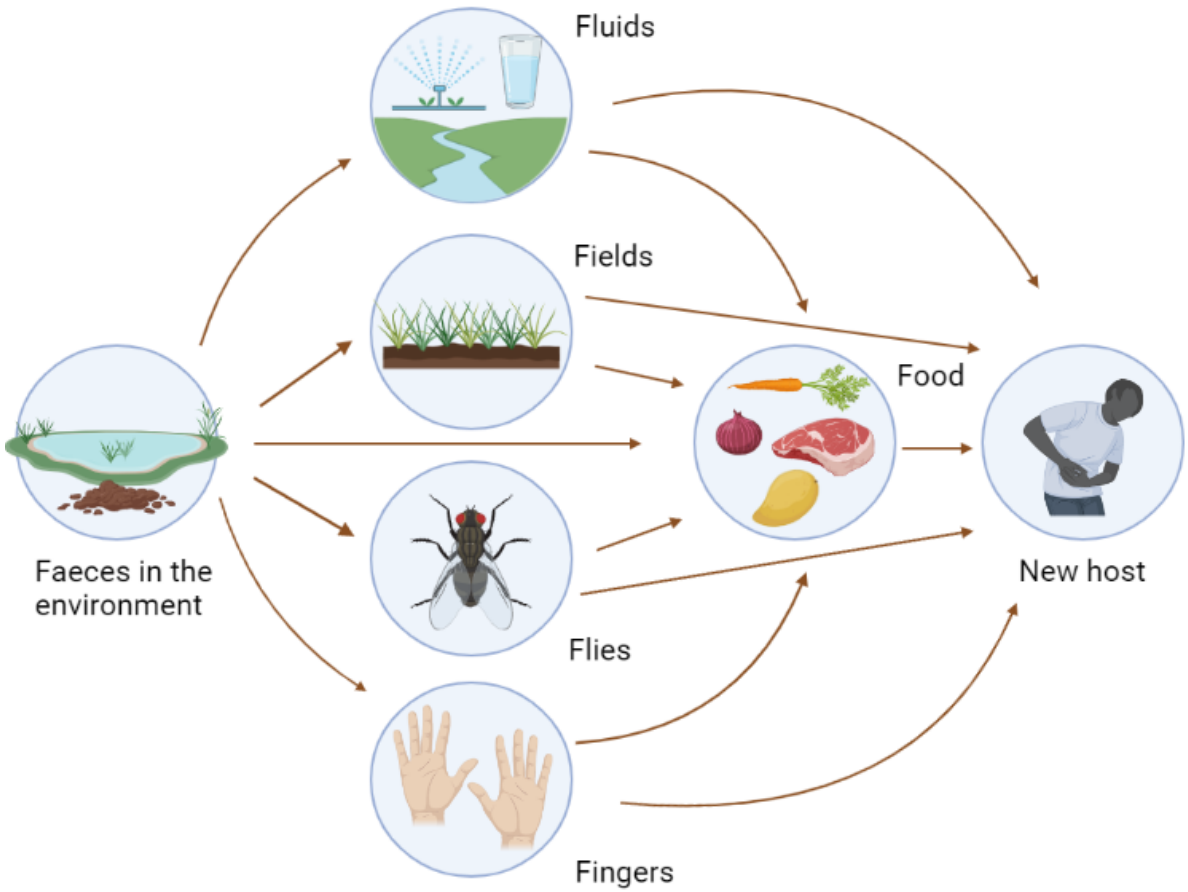
The microbiology: enteropathogens; faecal-oral route; plant, animal and human health; public health; sanitation; hygiene; diarrhoeal disease; environmental contamination. *Sustainability issues*: poverty; health; education; clean water; inequality; safe settlements; land conservation.



Environmentally-transmitted diseases: The Microbiology

1. ***Infectious diseases can spread in many different ways, including through the environment.*** Most known microorganisms on the planet are not pathogenic to humans: less than 1% cause infectious disease in people. This doesn't sound like much, but this is approximately 1400 different species of human pathogens that can cause disease. Infectious diseases can spread from one person to another through several different routes: respiratory pathogens are usually breathed in from droplets in the air after a cough or sneeze, while other diseases can be spread through direct contact with the skin or blood of an infected person.

Many pathogens are also environmentally transmitted, meaning they come from, or pass through, the environment when spreading to an uninfected person. For some pathogens, this can be through direct contact with soil or water where the pathogen naturally lives. Many other pathogens are passed on through drinking water or food when it is contaminated with human or animal faeces. This is known as the faecal-oral route of pathogen transmission: pathogens from faeces are transferred to the mouth of a new person through water or food, or the pathogens end up on hands, surfaces or objects because of contact with infected faeces. Most of the diseases transmitted this way are diarrhoeal diseases, because they infect the gut and are shed in the faeces of an infected person or animal.



Faecal-oral route of pathogen transmission. Diarrhoea-causing pathogens are often present in human or animal faeces in the environment. They reach new hosts through a wide range of routes, including via water, soils, food, flies, and fingers. Water, sanitation, and hygiene (WASH) improvements decrease disease transmission by reducing faecal contamination in the environment (e.g. providing toilets) or reducing exposure to pathogens (e.g. providing clean water sources).

2. ***Diarrhoeal disease is a significant public health issue that can be caused by a multitude of different pathogens.*** You might have experienced "gastro" or "stomach flu" before, perhaps with diarrhoea, if you ate something bad or caught it from someone at school who was sick. You can usually prevent yourself from getting sick by washing your hands regularly and cooking food properly. For people living in places without safe drinking water, basic toilets, handwashing facilities with soap or adequate medical care, these enteric diseases can be very severe. Unfortunately, there are still about half a million children under the age of five worldwide who die from diarrhoeal disease each year, primarily in low to middle income countries.

There are several different viruses, bacteria, protists and worms that can cause diarrhoeal disease, with some examples listed below. These pathogens are called enteropathogens, as they infect the gut. Each of these enteropathogens can be transmitted through the faecal-oral route, so they can follow complicated pathways between animals, contaminated water and soil, objects and surfaces, and people. These pathogen transmission pathways can be interrupted by water, sanitation and hygiene (WASH) interventions: things like clean drinking water, toilets and hand-washing. When these are inadequate, such as in informal settlements, diarrhoeal disease is a significant issue.

Some examples of enteropathogens
Viruses
Norovirus
Rotavirus
Adenovirus
Sapovirus
Bacteria
Escherichia coli
Salmonella enterica
Shigella flexneri
Campylobacter spp.
Vibrio cholerae
Protists and worms
Giardia lamblia
Cryptosporidium parvum
Hookworm
Whipworm

3. ***London's outbreak of cholera in 1854 is a classic example of the development of public health knowledge and sanitation.*** One of the most famous examples in the history of public health microbiology is the 1854 Broad Street cholera outbreak in London. Cholera is a particularly severe diarrhoeal disease caused by *Vibrio cholerae*, which can cause death within hours due to rapid loss of water from the body.

In 1854, it was commonly believed that disease spread by "miasma", or bad air, so it was not known how cholera spread. London had suffered several cholera outbreaks, because there was not yet a sewer system in this area and sewage was overflowing from cesspits and into the River Thames.

The medical doctor John Snow had recently proposed that cholera spread through contaminated water. When the Broad Street outbreak occurred, he mapped the locations of people who had died, showing that they were clustered around a particular water pump on Broad

Street. He said: "On proceeding to the spot, I found that nearly all the deaths had taken place within a short distance of the pump... The result of the inquiry then was that there had been no particular outbreak or prevalence of cholera in this part of London except among the persons who were in the habit of drinking the water of the above-mentioned pump-well." After he persuaded city officials to remove the pump handle, so that the pump could no longer be used, the outbreak rapidly subsided: the infection chain had been broken, the pathogen transmission pathway had been interrupted.

This event made the importance of water-borne diseases known, influencing public health and sanitation infrastructure from then on.

4. ***Public health interventions are crucial for preventing the spread of environmentally-transmitted disease.*** Like the identification of the Broad Street Pump, it is just as important today for scientists to understand where infectious diseases come from and how they are spread. This helps them to design ways to prevent transmission, which is more effective than treating or curing the disease in a large number of infected people.

In cities and towns within high-income countries, this is usually achieved by a sewerage system, wastewater treatment plants and treatment of harvested drinking water: infrastructure influenced by the work of people like John Snow. Flushing toilets, clean water and the ability to wash your hands regularly are probably things you would take for granted.

Public health improves in an informal settlement in Batua, Indonesia with infrastructure built for the Revitalising Informal Settlements and their Environments (RISE) program. The newly constructed bridge reduces contact of residents to contaminated water, especially during flooding events. The plants and microbes in the small constructed wetland help to filter pathogens and nutrients as part of a decentralised sanitation system. These measures are intended to improve the health of the environment and in turn the health of people.

However, there are still billions of people in the world that lack these things, many of them in living in informal settlements in low to middle income countries. In smaller rural villages, building toilets, introducing household-level water filtration and chlorination and providing soap can make a big difference. But in densely populated informal settlements, the

environment can be so contaminated and infrastructure so lacking that new approaches are required to properly interrupt the connections between humans, animals and the environment. For example, the Revitalising Informal Settlements and their Environments (RISE) Program is a research program that began in 2017 that involves scientists from Australia, UK, USA, Indonesia and Fiji. Using nature-based infrastructure like constructed wetlands in conjunction with wastewater recycling and rainwater harvesting, RISE is working to improve water management and the quality of water and sanitation in informal settlements without these facilities. By targeting not only drinking water and sanitation, but the reduction of contamination in the environment, programs like RISE are aiming to break the cycle of faecal-oral transmission. These programs recognise that the health of humans, animals and the environment are interconnected and must be simultaneously addressed to prevent disease. This concept is known as One Health.

5. ***Many other diseases can be transmitted through the environment.*** Diarrhoeal diseases that spread due to inadequate water quality and sanitation remain a major public health issue, but there are also many other examples of infectious diseases that can be spread through the environment. Diseases such as dengue virus, yellow fever, malaria and leishmaniasis are spread via a vector, which is a living organism (like a mosquito or sandfly) that transmits disease from an infected host to a new host. These vector-borne diseases can be transmitted between people, or from animals to humans (zoonosis).

Another example of a current initiative in disease prevention is the World Mosquito Program, where scientists are investigating ways to infect mosquitoes with *Wolbachia,* a bacterium that naturally occurs in insects. *Wolbachia* competes with viruses like dengue and yellow fever inside the mosquito, which makes it much harder for the mosquitoes to transmit them to people.

The RISE Program and World Mosquito Program are just two examples of active scientific research in the prevention of environmentally-transmitted diseases. However, there is also much yet to learn about how some diseases are spread. For example, Buruli ulcer is a rare but severe flesh-eating disease caused by *Mycobacterium ulcerans.* Curiously, it occurs almost exclusively in Southeast Australia and in West Africa. It is thought to be transmitted through bodies of water where it may naturally live, perhaps via mosquitoes or aquatic insects, but it remains unknown exactly how this bacterium spreads. Just as was with *Vibrio cholerae*, identifying the transmission pathways of *Mycobacterium ulcerans* is necessary to be able to develop appropriate public health measures to reduce disease transmission.

We have come a long way since the Broad Street Pump, but recognition of the crucial role of the environment as a source of infections, and development of the principles of One Health, have been essential to gaining new insights into the transmission and prevention of many infections.

Relevance for Sustainable Development Goals and Grand Challenges

- **Goal 1 – End poverty:** Many infections having an environmental origin result from inadequate water and sanitation infrastructure, which are usually associated with poverty. Reducing poverty will improve sanitation and hygiene, and result in a reduction in such diseases. Disease in adults decreases the time spent in gainful employment and hence in earning capacity. Disease in children reduces the time spent in education and hence negatively impacts career trajectories, which also reduces earning capacity in adulthood. Environmental infections therefore perpetuate poverty, and hence turn the vicious circle of poverty-hygiene-environmental infections. Interrupting infection transmission pathways will reduce poverty.

- **Goal 3 – Healthy lives:** Prevention of disease is a critical component to healthy human lives. Environmentally-transmitted diseases including diarrhoeal disease, vector-borne diseases and zoonotic diseases are major causes of death and poor health, especially in children under the age of 5.
- **Goal 4 – Ensure quality education for all:** Disease reduces in-school time and negatively impacts the quality of education acquired. Environmental infections constitute the major contribution to childhood disease in low income countries. Interrupting transmission pathways will improve education of those children affected, quantitatively and qualitatively.
- **Goal 6 – Clean water and sanitation:** The management of water and sanitation is the most important aspect of preventing diarrhoeal disease. With inadequate sanitation, faeces from humans and animals can contaminate water supplies. Contaminated water used for drinking, washing, preparing food or watering crops has the potential to transmit pathogens to humans, continuing the cycle of infectious disease. Clean drinking water, appropriate sanitation, and supplies and education to enable good hygiene are critical in the prevention of diarrhoeal disease.
- **Goal 10 – Reduce inequality among countries:** Environmental infections are particularly prevalent in low income countries, and hence a significant component of inequality among countries. Interrupting transmission pathways will reduce inequalities.
- **Goal 11 – Safe settlements:** Both urban and rural informal settlements face significant challenges with water and sanitation management. Developing cost-effective and sustainable infrastructure is integral to upgrading such settlements and improving residents' health and wellbeing.
- **Goal 15 – Protect terrestrial ecosystems:** Rivers and other bodies of water used for drinking, washing or agricultural irrigation are sources of environmental diseases that can be reduced by improvements to sanitation and water management. In addition, expansion of agricultural land and human settlements, and deforestation, reduce natural habitats of wildlife and bring humans into closer and more frequent contacts with wildlife. This in turn facilitates the transmission of animal diseases to humans - zoonotic infections – such as coronavirus, salmonellosis , and rabies. Protection of terrestrial ecosystems, increasing forest systems and reducing human contact with wildlife, will reduce zoonotic infections.

Pupil participation

1. ***Discussion topic***: Class discussion on the different ways that diseases could spread via the environment.

2. ***Pupil stakeholder awareness***
    a. What sorts of things do you do in your daily life that prevent you from getting sick?
    b. How might diseases still spread in places with clean drinking water and flushing toilets?
    c. Are all microorganisms in the environment bad for humans?

3. Exercises
    a. Design a new invention that could help to prevent disease in communities without clean water or toilets.

The evidence base, further reading and teaching aids

Microbiology by numbers: https://www.nature.com/articles/nrmicro2644
Ways infectious diseases spread https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/conditions/infectious+diseases/ways+infectious+diseases+spread
Water, Sanitation and Hygiene https://www.unicef.org/wash
One Health Basics: https://www.cdc.gov/onehealth/basics/index.html
The RISE Program: https://www.rise-program.org/
Cholera in Victorian London: https://www.sciencemuseum.org.uk/objects-and-stories/medicine/cholera-victorian-london; https://www.ph.ucla.edu/epi/snow/snowcricketarticle.html
Vector-borne diseases https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases
Zoonoses https://www.who.int/news-room/fact-sheets/detail/zoonoses
World Mosquito Program https://www.worldmosquitoprogram.org/
Understanding the transmission of Mycobacterium ulcerans: A step towards controlling Buruli ulcer https://doi.org/10.1371/journal.pntd.0009678

Glossary

Enteropathogen – a pathogen that infects the human gut.
Informal settlement – an area of housing that has not been legally or formally built, where living conditions may be poor. Also referred to as slums or shanty towns, though these are more negative terms.
One Health – the concept of interconnected human, animal and environmental health.
Vector – a living organism that carries disease from one infected host to new host. Most vectors are insects such as mosquitoes or flies.
WASH – Water, Sanitation and Hygiene.
Zoonosis – an infectious disease that has been transmitted from an animal to humans.