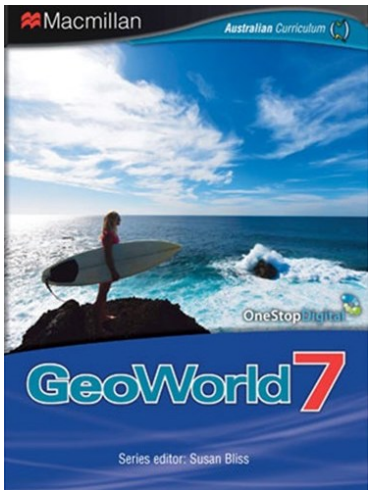

Bliss, S., Chaffer, L. & Reid, G. (2013). GeoWorld7. South Yarra, Vic: Macmillan Education.

chapter 4

Nature of water scarcity and strategies

"Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it. People fight over it. And all people, everywhere and every day, need it."

Mikhail Gorbachev, President of Green Cross International

Aa Geovocab

black water: sewage
blue water: source of supply, such as surface water and groundwater
cloud seeding: process of using substances to artificially create precipitation
economic water scarcity: occurs when a population does not have the monetary means to develop an adequate and reliable supply of water (e.g. an irrigation system and dams)
green water: rainwater directly used and evaporated by non-irrigated agriculture, pastures and forests
grey water: household wastewater
MENA: Middle East and North Africa region, consisting of 12 countries in the Middle East or West Asia in the Arabian Peninsula and Mashriq regions plus eight North African countries located north of the Sahara Desert
physical water scarcity: absolute water shortage occurring when the demand for water is greater than the ability of the land to provide it
qanat: underground irrigation system that uses gravity to distribute water
river basin: catchment area that contributes water to a river system

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An African boy drinks clean water from a pump

The quotation from Mikhail Gorbachev, former President of the USSR, emphasises the importance of water to people. Fresh water is a difficult resource to manage for many reasons. It is shared between places, has competing values and uses, and is highly variable over space and time. Water scarcity and water stress are serious issues in many countries and affect millions of people. Some areas are not water-scarce physically, but do not possess the finance or the technology to access water.

Humans have developed numerous management strategies to overcome water scarcity. Developed nations are more able to deal with water scarcity than developing nations, which regularly suffer from famine as a result.

Think, puzzle, explore

- **Place** How do humans overcome water scarcity at different places and at different scales (local to global)?
- **Space** What is the spatial distribution of water-scarce places?
- **Environment** How do humans impact on water availability and scarcity?
- **Interconnection** Explain the connections between water scarcity and precipitation.
- **Sustainability** How can water scarcity in Australia, West Asia and North Africa be managed sustainably?
- **Scale** What solutions are there for conflicts over water resources on the local, national and global scales?
- **Change** Why does political conflict sometimes result when water is shared between countries?

Geo**skills** in focus

- **Questioning** water scarcity using the inquiry process
- **Evaluating** relevant geographical data on water as a resource
- **Analysing** a variety of primary and secondary sources to identify patterns, relationships and trends at a variety of scales
- **Communicating** the reasons for the variations in water scarcity across the globe
- **Reflecting** the human impacts on a local stream through fieldwork

transboundary (shared) resource: natural resource (e.g. water, air and animals) that is distributed between countries that share the ownership, stewardship and exploitation of such resources

Water Poverty Index: connection between 'water poverty' and 'income poverty'

water scarcity: when water available per person per year in a country falls below 1000 m^3

water stress: when the amount of water available per person per year in a country falls to between 1000 m^3 and 1700 m^3

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4.1 Water scarcity in Africa

In 2013, approximately 450 million people in 29 countries suffered from water shortages. According to the United Nations Environment Programme (UNEP), **water stress** occurs when the amount of water available per person per year in a country falls between 1000 m^3 and 1700 m^3. **Water scarcity** occurs when the water available in a country falls below 1000 m^3. UNEP estimates two out of every three people on Earth will live in water-stressed areas by the year 2025.

The water scarcity index describes the relationship between the water availability of an area and the number of people that can be supported by the water supply. It is expressed as the number of people per flow unit (defined as 1 million m^3 per year). Water scarcity exists when there are between 600 and 2000 people per flow unit. Populations are vulnerable to water stress when there are 100 to 600 people per flow unit. More countries in Africa suffer from water scarcity than any other continent.

Water-poor and water-rich Africa

Africa is the third driest continent after Antarctica and Australia. The continent is home to the Sahara Desert as well as the Kalahari and Namib deserts. The remainder of Africa seems blessed with water resources with large freshwater lakes (e.g. Lake Victoria) and large rivers (e.g. Congo, Nile, Zambezi and Niger). However, rainfall over most of the continent is variable and unreliable.

Approximately 80% of the African population rely on groundwater as a source of drinking water and irrigation. The largest volumes of groundwater are located in Libya, Algeria, Egypt and Sudan. Scientists recently discovered large groundwater aquifers that offer hope for the continent's future water security.

Physical and economic water scarcity

A 2012 *Global Monthly Water Scarcity* report analysed water consumption in 405 **river basins** around the world and found water scarcity impacts on 2.7 billion people for at least one month per year. There are three main reasons:

- Arid regions are often associated with **physical water scarcity** due to their low and unreliable rainfall. Physical water scarcity can also result from the over-consumption of water resources.

4.1.1 Children carry their water containers as they walk towards one of 22 boreholes in the Budiriro District of Harare, Zimbabwe

4.1.2 Predicted fresh water stress and scarcity in Africa and Middle East

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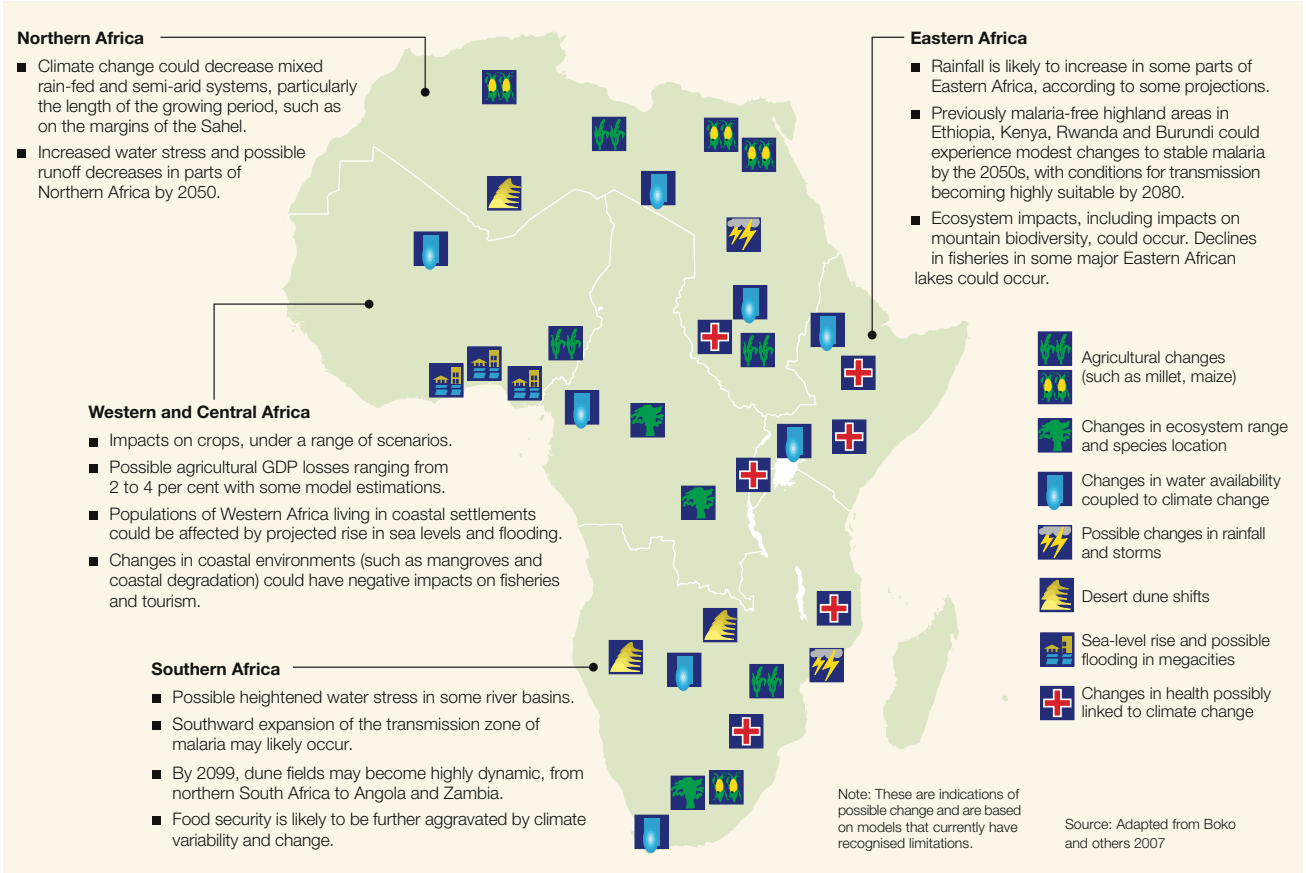
- A population may experience **economic water scarcity**, which is when it doesn't have the means to develop an adequate, reliable supply of water. It can be addressed at the local scale with investment in simple infrastructure (e.g. rainwater collection tanks).
- Climate change presents a challenge to water and food security for most African countries and a severe hurdle to their development. Most sub-Saharan countries are predicted to experience water stress or scarcity by 2025.



4.1.3 Current and predicted impacts of climate change on Africa

Geo**activities 4.1**

Knowledge and understanding

1 What are water scarcity and water stress?
2 'Africa is a land of water contrasts—scarcity and abundance.' Discuss this statement.
3 Distinguish between physical and economic water scarcity.
4 Explain why Africa's water resources are under pressure.

Inquiry and skills

5 Refer to 4.1.2.
  a List five African countries with water projects aimed to decrease water scarcity.
  b Describe the uneven distribution of surface water resources across Africa.
6 Refer to 4.1.3.
  a List the predicted agricultural changes from climate change across Africa as a result of water scarcity.
  b Compare the predicted impacts of climate change between Angola and Egypt.
  c What is the advantage of this map showing the impacts of climate change?
  d Explain how climate change has increased water scarcity in Africa.
7 Investigate the controversy surrounding the Aswan High Dam. List the pros and cons of this project in a table using secondary sources.

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4.2 Water-scarce Africa: conflict and progress

In the Darfur region of Sudan, girls walk eight hours a day to fetch water for their family, whereas in most developed countries a person only has to walk a few metres to turn on a tap. In a developed country an average person uses 400 L of water per day compared to Darfur where 20 people share 400 L of water a day.

Between 2003 and 2009, conflict over race or religion as well as lack of water for nomadic herders contributed to hundreds of thousands of people in Darfur being killed. During 2011 and 2012, severe drought affected the region, resulting in scarce water and poor harvests. As a result famine occurred, tens of thousands of people died and about 1 million fled to neighbouring countries.

Source of conflict

Of the 55 water-scarce countries in the world, 34 are located in Africa. These countries receive annual water supplies below 1000 m^3 per person. By 2050 countries most affected by increasing water scarcity are anticipated to suffer from:

- lower precipitation and higher evaporation as a result of climate change
- frequent droughts
- extreme poverty
- poor yields of agriculture dependent on rainfall
- high population growth.

Climate change is a major threat to the livelihoods of African people. Unless improved water management strategies are implemented,

Wells
Wells were dug in the Turkana region of northwest Kenya. As a result, women do not need to take the 15 km journey in search of water, and hunger and disease have decreased in the village.

Sand and gravel filters
In Kassala in Eastern Sudan, women build sand and gravel filters at the mouth of the haffir. These improve water quality and reduce diseases.

Drip irrigation
In Zimbabwe and Mozambique rain is collected, stored and directed in bursts to the roots of plants. The irrigation system took one hour to set up, water was not wasted as runoff, farms produced more food and money from sales paid for health care and education.

Playpump
In Kipsongo, Kenya, a merry-go-round draws 1400 L of water from a borehole and channels it into a storage tank.

4.2.1 Water projects by Practical Action, an international development charity, help to reduce water scarcity in Africa

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2 billion Africans are anticipated to suffer water scarcity by 2050.

In Africa, water is unevenly distributed across the continent with large quantities wasted and polluted. Despite the existence of large rivers such as the Congo, Nile and Niger, 300 million people live in water-scarce environments. Today, by the time the Nile River runs through Ethiopia, Sudan and Egypt, little water reaches the Mediterranean Sea. With the combined populations of these countries predicted to increase from 150 million today to 340 million in 2050, competition for limited water from the Nile River could become volatile.

As 80% of Africa's rivers and lakes are shared by two or more countries, conflicts over water use are anticipated to increase. The United Nations proposes to establish water use agreements between countries to avoid future conflicts.

Great promises

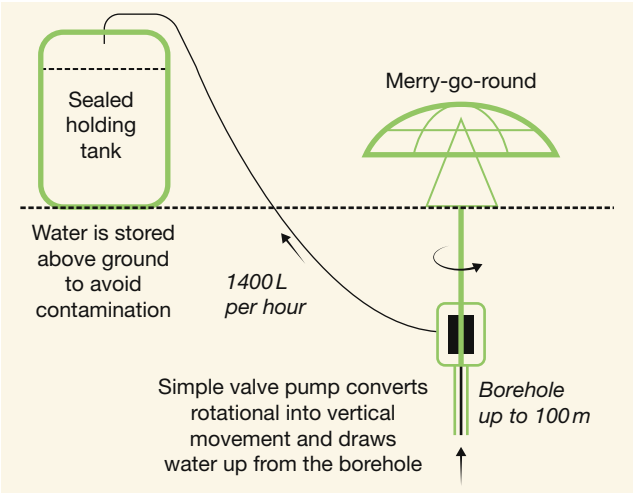
Sub-Sahara Africa contains abundant non-renewable water resources in the form of fossil groundwater formed thousands of years ago. However, lack of irrigation infrastructure and finance mean only 6% of water used in the region is withdrawn from groundwater—of which just 3% is consumed for agriculture.

Groundwater already supplies water to Libya's Great Man-made River (GMR). It is the largest irrigation project in the world, supplying 6 500 000 m^3 of fresh water per day to cities from the Nubian Sandstone Aquifer System fossil aquifer. The recent discovery of a 10 000-year-old underground aquifer in Namibia is anticipated to supply drinking and irrigation water to the country over the next 400 years.

Increased water availability to some sub-Saharan African areas is possible due to low-cost technology; for instance, dung from cows used to generate biogas to pump water to irrigate fields or water-gathering merry-go-rounds.

Geoinfo

- About 30% of Africa's water drains into the Congo Basin, which is inhabited by only 10% of Africa's population.
- Only 6.78% of Sudan's land has access to water, essential for a poor country that is dependent on agriculture.



4.2.2 A merry-go-round is a smart way to increase water availability in Africa

Geoactivities 4.2

Knowledge and understanding

1. Discuss the problems of access to water in Darfur and its impacts on people.
2. Explain why access to water is a threat to the livelihoods of millions of African people now and in the future.
3. Describe how low-cost water technology makes a difference to the lives of people.

Inquiry and skills

4. Refer to 4.2.1 and discuss how Africa's future could improve with sustainable water management strategies.
5. Refer to 4.2.2 and describe how the merry-go-round works to make water more accessible to more people.
6. Explain how water scarcity is both a natural and human-made phenomenon in Africa.
7. *Khotso, Pula, Nala!* (Peace, Rain and Prosperity) is a Basotho greeting. Explain what this greeting means.
8. Water scarcity is a threat to food security in Africa. In groups research the topic and present your findings using PowerPoint or YouTube.
9. Select five African countries and discuss how climate impacts on available surface water. Present your findings as an infographic.
10. Discuss how recently discovered groundwater resources could potentially reduce water scarcity.
11. Brainstorm solutions to freshwater scarcity in Africa as a result of climate change. Should the United Nations do more to help Africa? Provide reasons for your answer.

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4.3 Water-scarce West Asia and North Africa

The arid to semi-arid region covering the Middle East and North Africa (**MENA**) is one of the most water-scarce areas in the world. Countries in the region are experiencing extreme water stress, with Bahrain topping the global list, followed by Libya, Yemen, Egypt and Tunisia. The region's anticipated population growth from 127 million (1970) to 390 million (2015) requires sustainable management of water resources, otherwise scarce water could become a volatile issue among countries.

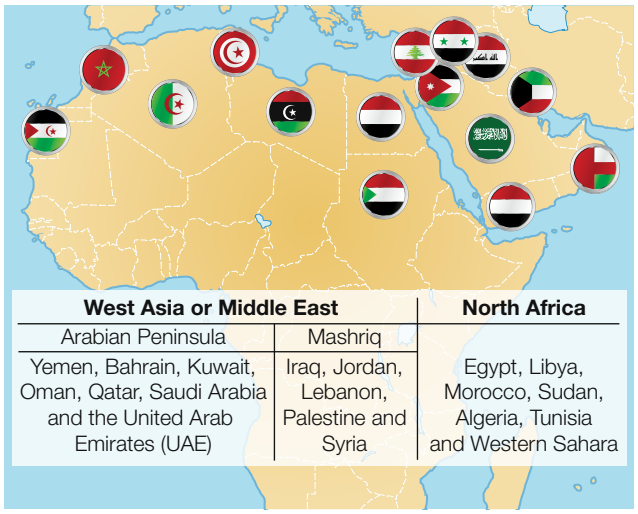
Water connected to wealth

The MENA region (4.3.1) includes:

- 12 countries in the Middle East or West Asia, from the Arabian Peninsula and Mashriq region
- 8 countries located north of the Sahara Desert in North Africa.

Fourteen water-scarce MENA countries consume 500 m^3 of water per person per year compared to the global 7000 m^3. Water consumption within the region is unevenly distributed, with the rich oil-exporting nations such as the United Arab Emirates (UAE) consuming 1600% and Saudi Arabia 951% of water compared with poorer Lebanon's 33%.

The **Water Poverty Index (WPI)** demonstrates a strong connection between 'water poverty' and 'income poverty' as poor people tend to possess less access to clean drinking water and water for irrigation.



West Asia or Middle East		North Africa
Arabian Peninsula	Mashriq	
Yemen, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE)	Iraq, Jordan, Lebanon, Palestine and Syria	Egypt, Libya, Morocco, Sudan, Algeria, Tunisia and Western Sahara

4.3.1 MENA countries

New water: desalinisation

As the MENA region contains few large rivers, most water is obtained from shallow aquifers, deep fossil aquifers, treated wastewater and desalinated water.

- *Aquifers*—these are a major source of fresh water in Saudi Arabia (95%) and Tunisia (73%) as well as for irrigation in Libya (90%). The over-exploitation of groundwater resulted in seawater entering and polluting aquifers in Morocco and Lebanon. Excessive use of groundwater also caused the land to collapse, which has meant depressions in the ground 50–100 km in diameter across the region.
- *Treated wastewater*—Egypt, Syria, the UAE and Saudi Arabia reuse 94% of the region's wastewater, with Egypt accounting for 73%.
- *Desalinated water*—approximately 60% of the world's desalination capacity resides in oil-rich Gulf States. Saudi Arabia, the UAE and Kuwait use 79% of the region's desalinated water with Saudi Arabia accounting for 42%.

Poorer countries without oil depend on agriculture as a major source of income, and they are unable to afford expensive desalination technology without the assistance of international organisations, governments and non-government organisations.

Future scenario

In the MENA region, by 2050, available water per capita is anticipated to decrease by 50% as a result of climate change. Climate change is expected to cause a:

- 10–25% decrease in precipitation
- 5–10% decrease in soil moisture
- 10–40% decrease in runoff
- 5–20% increase in evaporation.

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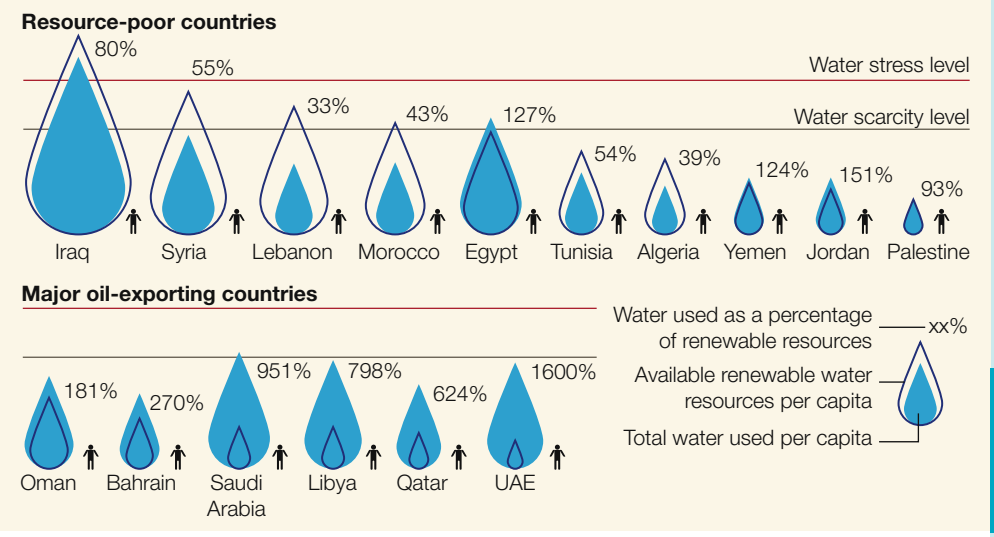
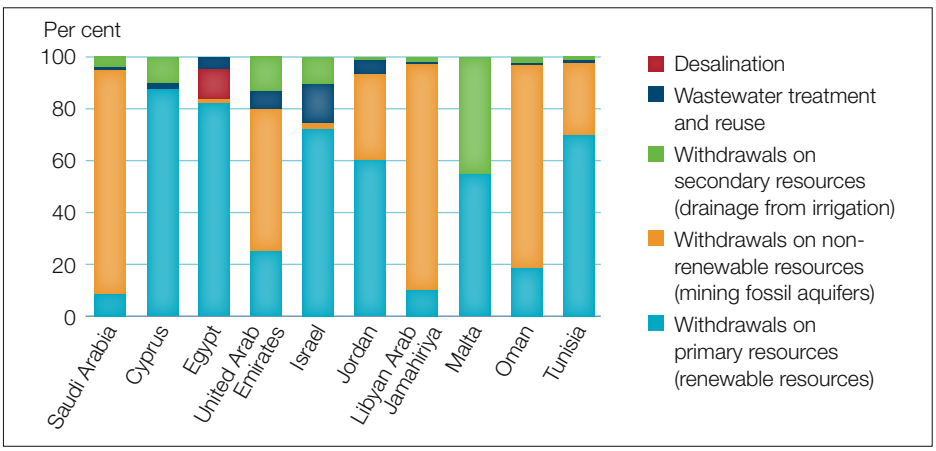
The greatest impact of climate change will be on food production as 85% of water is allocated to irrigating crops. As a precaution to water shortages, MENA countries already import food from wetter places (this is referred to as 'virtual water', see chapter 5), and have purchased land in wetter places to grow food (Qatar has land in Kenya and Saudi Arabia has land in Ethiopia). The issue of securing and maintaining water supplies remains a challenge.



4.3.2 Water use of MENA residents



4.3.3 Sources of water for MENA

Geoinfo

In Kuwait and the UAE, aquifers are used to store fresh water to prevent the risk of water scarcity during droughts.

Geoactivities 4.3

Knowledge and understanding

1 List the countries in the MENA region.
2 Discuss the advantages of access to water in oil-rich countries compared to resource-poor countries.
3 Describe the three main sources of water in the MENA region and their advantages and disadvantages.

Inquiry and skills

4 Refer to the text, 4.3.1 and Google Earth.
  a List three countries in the Middle East and three in North Africa experiencing 'extremely high' water stress.
5 Refer 4.3.2.
  a Name the countries overusing their water resources.
  b Compare water use in resource-poor and oil-wealthy countries. Do you think this is fair? Give reasons for your answer.
6 Refer to 4.3.3.
  a Which countries obtain most water from: desalination, primary renewable resources, mining fossil aquifers, wastewater treatment and drainage from irrigation?
  b Calculate the percentage of water from desalination in Malta, Israel and Egypt.
  c Draw Saudi Arabia's sources of water as a pie graph.
7 In groups discuss how the most water-stressed nations on Earth are in the MENA region. Add increasing populations, food and energy costs, and trouble seems inevitable. In groups discuss whether the Middle East is running into a storm (see Geolinks).

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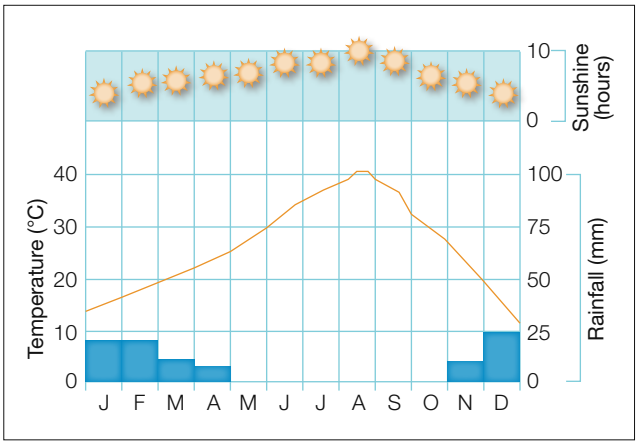
4.4 Water crises in West Asia

Over 70% of West Asia experiences water scarcity. Although most people possess access to clean drinking water, it is unreliable in poorer countries and in low-income urban areas. For example, in Syria's capital, Damascus, water is available 12 hours a day and in Jordan's capital, Amman, residents receive water one day a week. By contrast, the UAE contains wealthy gated communities with huge pristine pools, and the city of Dubai boasts indoor ski slopes and dancing water fountains to entertain tourists. The overuse of scarce water is unsustainable in Dubai as it receives only 88 mm/year from precipitation and loses 2000 mm/year from evaporation and transpiration each year.

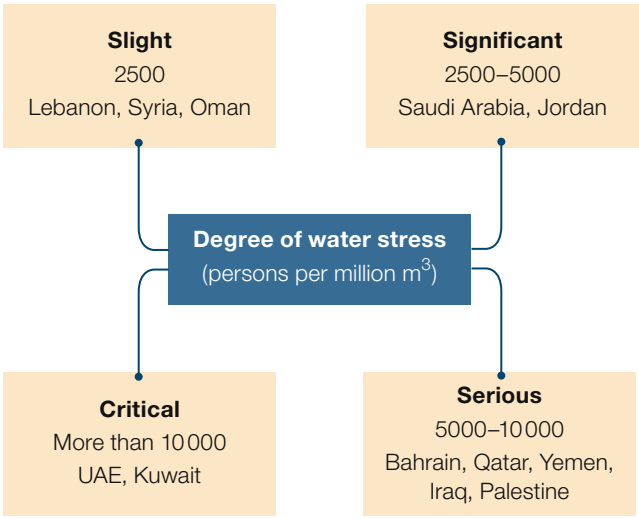


4.4.1 Climate graph for Dubai—a city with low precipitation

Water use in the UAE is 24 times larger than its annual renewable water. Additionally, water per capita is 550 L per person per day—three times greater than the global average. Population growth, luxury lifestyles of oil-rich families, and lack of conservation programs has resulted in unsustainable use of water. As a result, the UAE is experiencing critical water stress, but to address this it has built 70 desalination plants—66% of which are in Abu Dhabi and 18% in Dubai.

Water for narcotics

Agriculture accounts for 93% of water consumed in Yemen. The population's demand for water has led to the creation of 14 000 private wells, which has lowered groundwater levels in the basin of Sana, Yemen's capital, by 3–6 m a year. Approximately 40% of the groundwater used for agriculture is consumed by a narcotic plant called Qat. The production of a daily bag of Qat requires 500 L of water. Despite scarce water, poor farmers find it more profitable to produce Qat as it brings in 2.6 million rials per hectare compared to fruit, which returns 0.55 million rials per hectare. As a result the area cultivated for Qat has grown from 8000 ha in 1970 and is anticipated to grow to 140 000 by 2015.



4.4.2 Water-stressed countries in West Asia

Sustainable strategies needed

Environmental problems resulting from poor water management costs West Asian countries 0.5–2.5% of GDP every year. During the past 30 years West Asia's agricultural subsidies expanded farming, and as a result excessive use of water. Poor irrigation practices, such as sprinkler systems, waste 30–50% of water, deplete groundwater and increase salinity. Water pollution from sewage, fertilisers, pesticides and toxic waste has reduced available drinkable water. High nitrates in Gaza's coastal wells and tannery waste in the Barada River in Syria are unhealthy for people and marine species. Waterborne diseases, such as diarrhoea, are the second highest cause of death among children in the region. Sustainable water management strategies are required for improved wellbeing of the population.

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4.4.3 Renewable water and share by sector

Country	Renewable water (m^3 per capita)		Share of withdrawals by sector (%)		
	1990	2025	Domestic	Industry	Agriculture
Jordan	224	91	29	6	65
Saudi Arabia	156	49	6	3	91
Syria	4391	161	7	10	83
Yemen	214	72	5	2	93

Geoinfo

Jordan shares the Jordan and Yarmouk rivers with Syria and Israel, leaving Jordan only a small amount of water.

4.4.4 Sustainable water management strategies

4.4.5 Qatar is considering using desert seawater greenhouses, which involves pumping seawater to an arid location and then using it to humidify and cool the air. It is evaporated by solar heating and distilled to produce fresh water. The remaining humidified air is expelled from the greenhouse to improve growing conditions for outdoor plants

Geoactivities 4.4

Knowledge and understanding

1 Explain the link between oil and water.
2 Discuss why West Asia is considered a water-scarce region.
3 'Some countries are more water greedy than others.' Explain this statement.
4 Discuss the problems of water quantity and quality in West Asia.

Inquiry and skills

5 Refer to 4.4.1.
  a Calculate the total precipitation for Dubai.
  b In which season does rain fall?
  c Explain why the country is referred to as hot and arid.
6 Refer to 4.4.2.
  a List the degree of water stress experienced in the UAE, Iraq, Jordan and Oman.
  b Explain what is meant by 'water-stressed countries'.
7 Refer to 4.4.3.
  a Which country experienced the greatest decline in water per person?
  b Most water is used for agriculture. What is the average percentage of water used for agriculture in the five countries?
  c Discuss the changes in water availability per person from 1990 to 2025 and why there will be less water per person.
8 Refer to 4.4.4 and 4.45 and discuss how water availability could improve in West Asia despite increased population and use.
9 Research why countries sharing water supplies with other countries are at risk of conflict using secondary sources. Present your findings as a Prezi.

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4.5 Reducing scarcity: blue, green, grey and black water

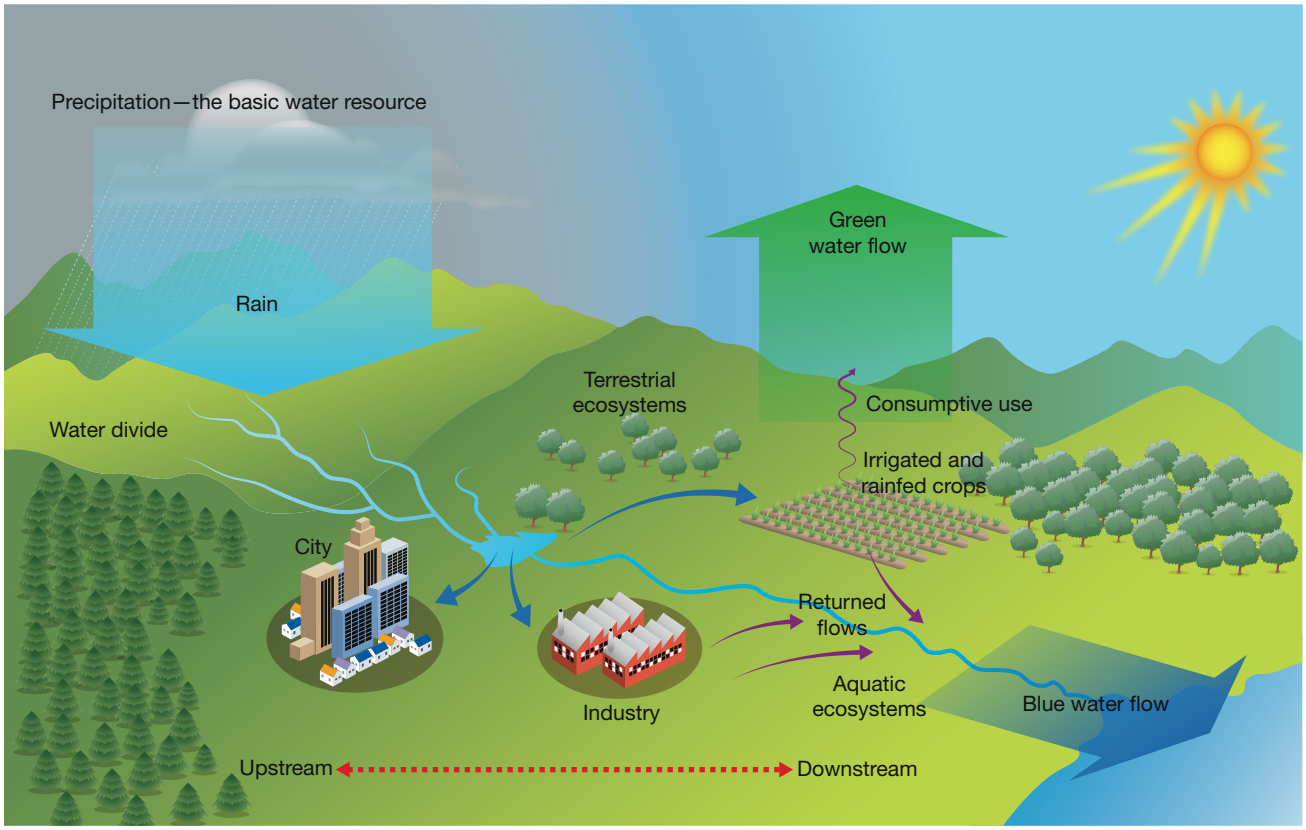
Improved understanding of different types of water—blue, green, grey and black—could reduce water scarcity in the future. Swedish scientist Malin Falkenmark was the first to classify the world's limited freshwater resources into two catagories—blue and green water—based on how water is consumed in the water cycle. This enables comparisons to be made regarding fresh-water usage around the world and how it could be better managed.

Types of water

Blue water is defined as surface water and groundwater that has the potential to be consumed as a drink or used in the production of foods and consumer goods. It includes runoff as well as water in storages such as wetlands, streams, lakes, dams and groundwater aquifers. Until recently, scientists focused on blue water resources in an attempt to access more water.

Green water is the rainwater stored as soil moisture, which supports terrestrial ecosystems. It is the water in the plant root zone that does not flow into groundwater aquifers, rivers or lakes. Natural vegetation depends on green water, which is eventually evaporated or transpired through the leaves of plants. Accessing green water as a resource has become a priority in managing water in recent years. Worm farms have increased water retention in soil—500 000 worms burrowing into half a hectare of soil can create a drainage system equal to 600 m of 15 cm pipe. Their tunnels break up the soil and provide a path for water to flow and reach the roots, saving irrigated water.

Both blue and green water differ from **grey water**, which is polluted water. Grey water is household wastewater from baths, showers,



4.5.1 Blue and green water in the water cycle

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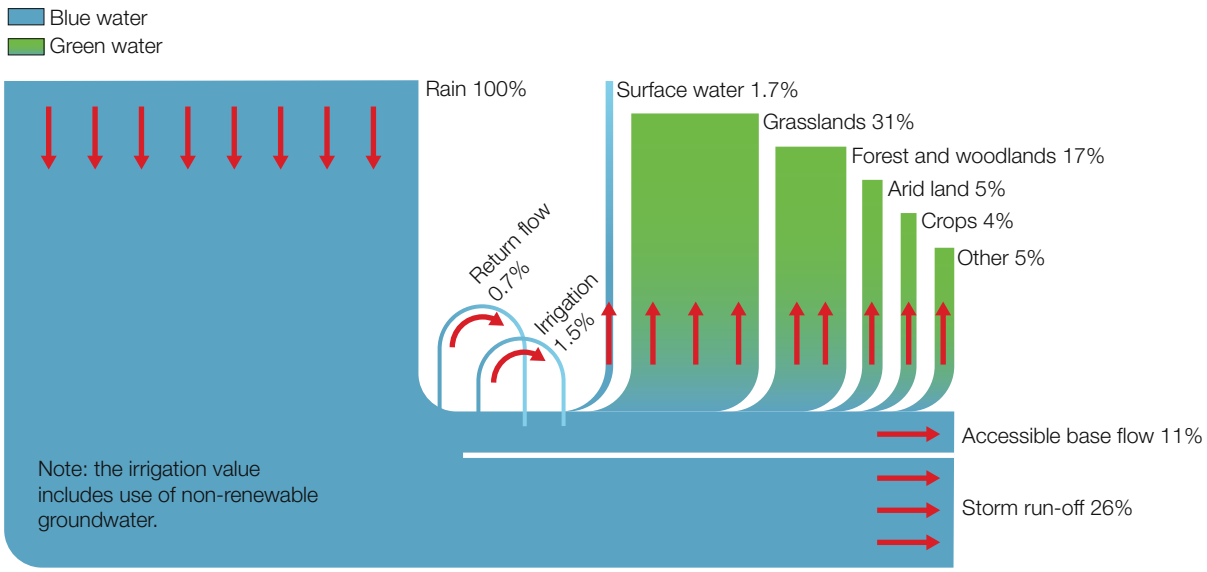
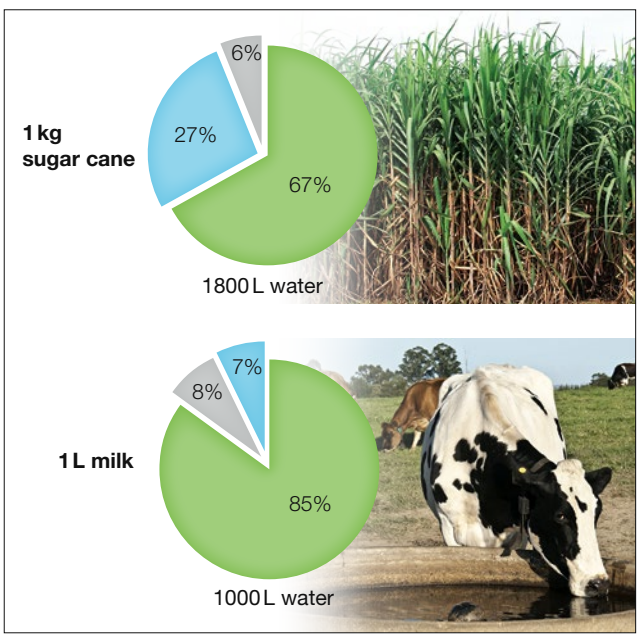


4.5.2 Green and blue water: global flows

wash basins and laundries. It contains soap and anything else that washes off people and clothes. It does not include sewage (which is called **black water**) and water from dishwashers and kitchen sinks. Today, grey and black water are increasingly being used after pollutants have been removed.

Spatial variations

The proportions of blue and green water are different in each region of the world. Environmental water flow is the proportion of blue water that is necessary for the functioning of aquatic ecosystems. Comparisons between regions are possible because the precipitation is always used as a base figure (100%) and rainwater is partitioned into blue water and green water as percentages. Therefore, regardless of the annual precipitation of an area, it is possible to measure the major components of each part of the water cycle and compare them with anywhere else on Earth. This is a useful tool in water management.



4.5.3 Blue, green and grey water used in food production

Geoactivities 4.5

Knowledge and understanding

1 Explain the difference between blue and green water.
2 According to Falkenmark, how does green water compare with blue water?
3 Why is green water important to natural vegetation?
4 Explain how it is possible to compare blue water and green water in different regions.
5 Explain how worms reduce the need for soil water.

Inquiry and skills

6 Refer to 4.5.1 and explain the flows of blue and green water in the water cycle.
7 Refer to 4.5.2.
  a What is the total percentage of global green and blue water flow?
  b Name two uses of blue water that return water.
  c What percentage of blue water is surface water?
  d What percentage of blue water is storm runoff?
8 Refer to 4.5.3 and discuss the use of different types of water for different foods. Present this information using ICT.

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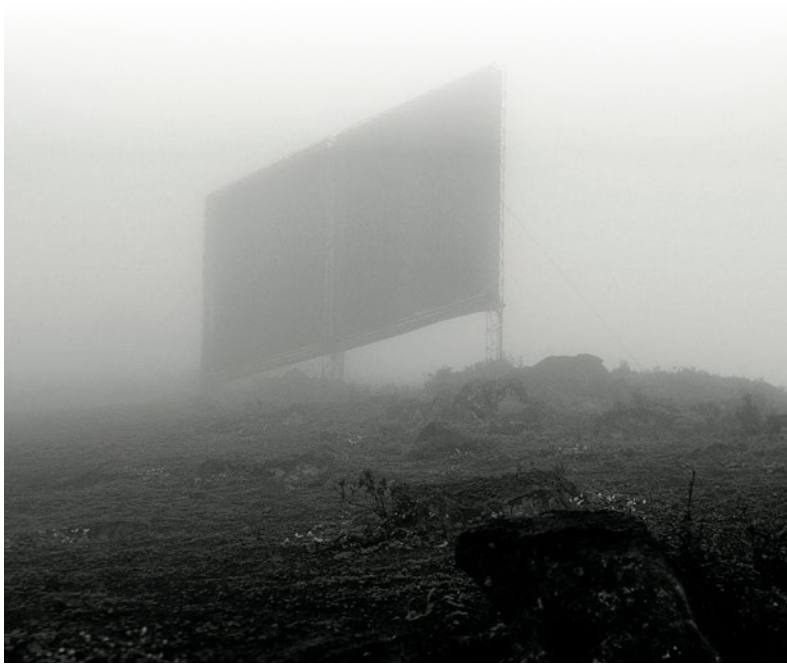
4.6 Water-supply strategies

Supplying water to people in areas that are water-scarce has always been a challenge. However, modern technology has literally produced water out of thin air with fog harvesting, cloud seeding and AirDrop. Maybe, one day, through technology, floods and droughts will be eradicated.

Solar energy solution

In 2011, Australia inventor Edward Linacre won an award for designing a low-tech atmospheric water-harvesting system called the AirDrop Irrigation System. The system has a solar-powered turbine that draws air underground into a network of pipes. Once there, the moisture condenses and collects in underground tanks that are not affected by evaporation. A submersible pump then circulates the water directly to the roots of plants through a sub-surface irrigation system, which limits evaporation losses. This ingenious system has great potential for providing water for people, crops and animals in water-scarce areas.

Aussie inventor Edward Linacre with his AirDrop Irrigation System



4.6.1 Nylon mesh screens are used to harvest water from fog in Peru

Fog harvesting

Fog is defined as a mass of water vapour condensed into tiny droplets near Earth's surface. Scientists believe that ancient cultures used piles of stones to harvest fog and mist to supplement their water supplies. The first modern fog collection installation was in 1987 in Chile. The remote fishing village of Chungungo erected vertical mesh nets to capture the fogs—traditionally known as camanchacas—that roll off the Pacific in the arid coastal regions of Chile and Peru from June to November. On some days 100 000 L could be stored or piped to the village for use in drinking and irrigation.

Fog harvesting is used in several countries, including Nepal and South Africa. In Kenya, the Gabbra people have little access to permanent water sources, but in the misty area of Hurri Hills, water condenses on the branches of eucalyptus trees and trickles down the trunk. A plastic sheet is tied around the base of the trees to collect the water. Families harvest this water and place it in tanks for storage. This simple technology provides 1000 L of water in two hours.

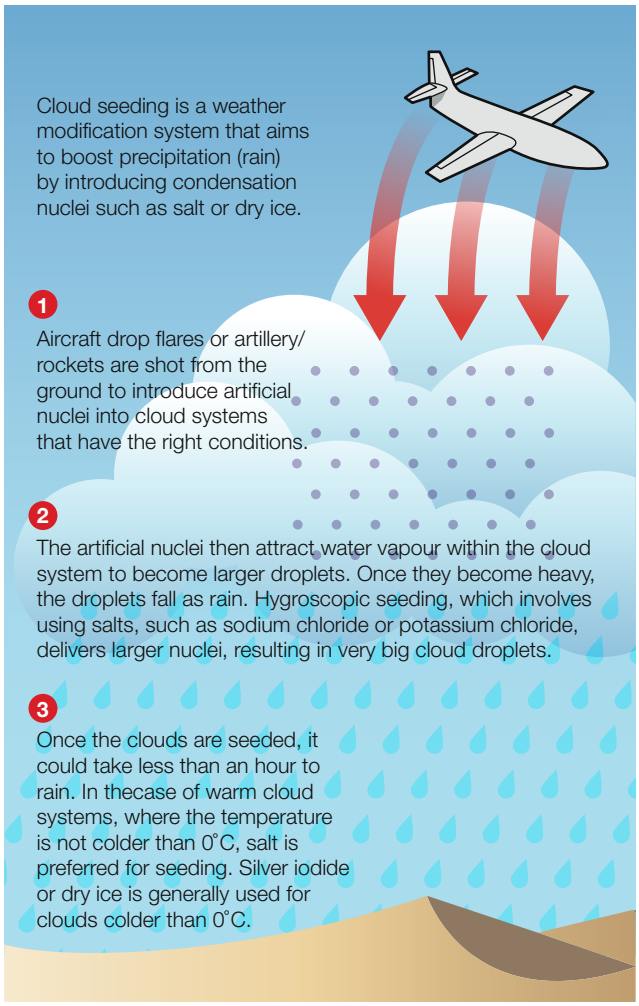
ISBN 978 1 4202 3263 9

Cloud seeding

Cloud seeding is the introduction of substances into Earth's atmosphere in an attempt to produce rain. Chemicals such as salt, dry ice or silver iodide are used to create a surface for condensation to occur in moist skies. Many countries use this technology, foremost of which is China. Australia has used cloud seeding since 1947. Examples include increasing rainfall over Tasmanian hydroelectric dams and increasing snowfall over the Snowy Mountains. However, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) states that cloud seeding is only effective under certain weather conditions and it cannot be used to break droughts because at those times the skies have little moisture. The environmental effects of the chemicals used in cloud seeding are yet to be determined.

In 2011, Swiss researchers from the University of Geneva successfully used a technology called laser-assisted water condensation to create minute water droplets. While these were too small to fall as rain, the technique has possibilities for the future.

People dream of controlling the weather, and maybe one day—through technology—this dream may become a reality.



4.6.2 Cloud seeding is also called artificial rain-making

Geoinfo

China has the largest cloud seeding program in the world. In 2009 the Beijing Meteorological Bureau claimed to have successfully created rain after using 18 jets and 432 rockets to seed clouds.

Geoactivities 4.6

Knowledge and understanding

1 List the strategies used to increase water supplies in water-scarce areas.
2 Describe how water can be captured from fog and mist.
3 List the factors necessary for fog harvesting.
4 Explain how the Gabbra people collect water.

Inquiry and skills

5 Refer to 4.6.1.
  a Explain the process of collecting fog.
  b List the advantages and disadvantages of collecting water by fog harvesting.
6 Refer to the text and 4.6.2.
  a Describe the process of cloud seeding.
  b According to CSIRO, how effective is cloud seeding?
7 Refer to the article and discuss how water is produced using sustainable energy sources such as the AirDrop Irrigation System.
8 Investigate the cloud seeding program in China. Write a report of its effectiveness.
9 Choose a country that uses fog harvesting and write an evaluation of the effectiveness of this technology in supplying water. Include location maps and photos. Present your findings as an oral report or Prezi.

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4.7 Reducing scarcity: dams and qanats

Not all human settlements are fortunate enough to possess a reliable, adequate and easily accessible nearby source of quality fresh water. To secure sufficient water, humans have built structures such as dams and qanats to harness the distribution of the precious resource. Developed nations have significant investment in water infrastructure and therefore better access to water than poorer countries.

Human beavers: dams and reservoirs

Beavers are well known for building dams to regulate their environment. Humans also construct dams across streams and rivers to collect and store surface water from the catchments for later use. Dams and reservoirs also reduce flooding. The water is used for domestic supply, irrigation of crops, hydroelectricity generation, recreation and providing environmental flow to maintain the health of the ecosystem downstream from the dam. Water is distributed from artificial storages (sometimes called reservoirs) via channels, pipelines, aqueducts and natural waterways.

Large dams are classified as those with walls greater than 15 m high. The numbers and average size of large dams have been steadily growing over the past 50 years, especially in Asia. More than half of the world's major rivers are now dammed. China has more major dams than any other country, including the world's largest dam, the Three Gorges Dam. Spain, the USA and Japan also have more than 1000 large dams each.

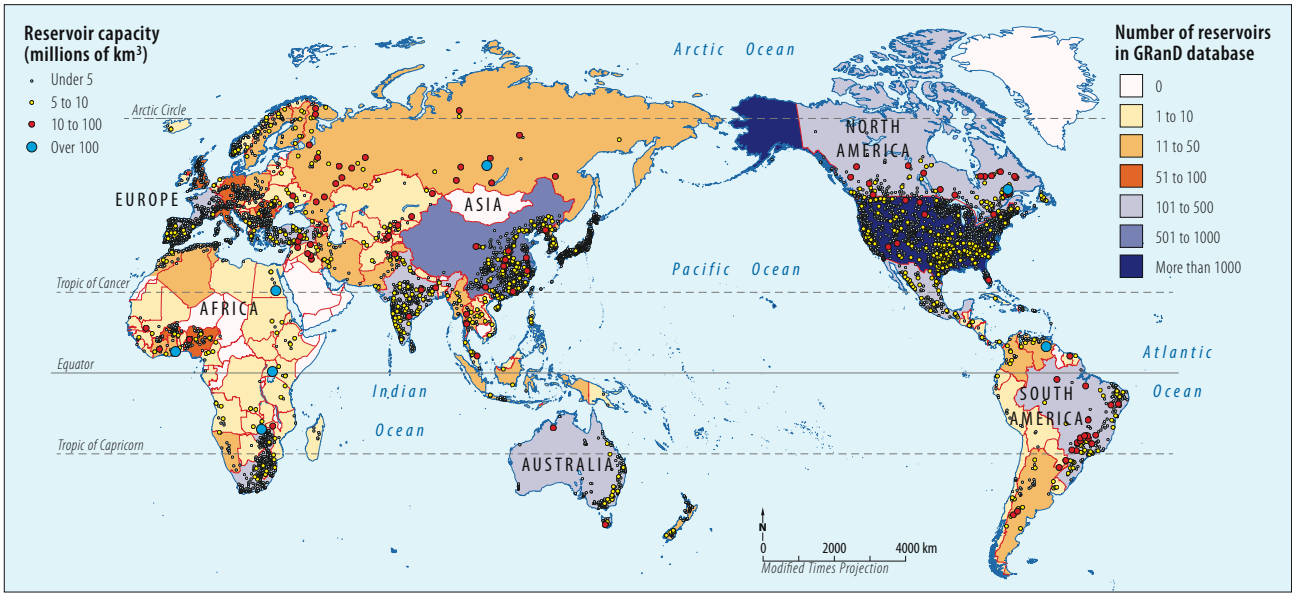
While dams provide significant benefits, they are also controversial. Problems include loss of productive farmland, loss of nutrients deposited by rivers on the floodplain, and reduction of freshwater biodiversity.

Geoinfo

Australia has about 500 large dams and many thousands of farm dams.

Human moles: qanats

The qanat underground irrigation system was developed in ancient Persia more than 3000 years ago. The Farsi word 'qanat' means 'water channel'. (In Arabic, the term is 'falaj'.) This unique gravity-based system spread throughout the world and



4.7.1 Damming the world (data from the Global Reservoir and Dam [GRanD] database)

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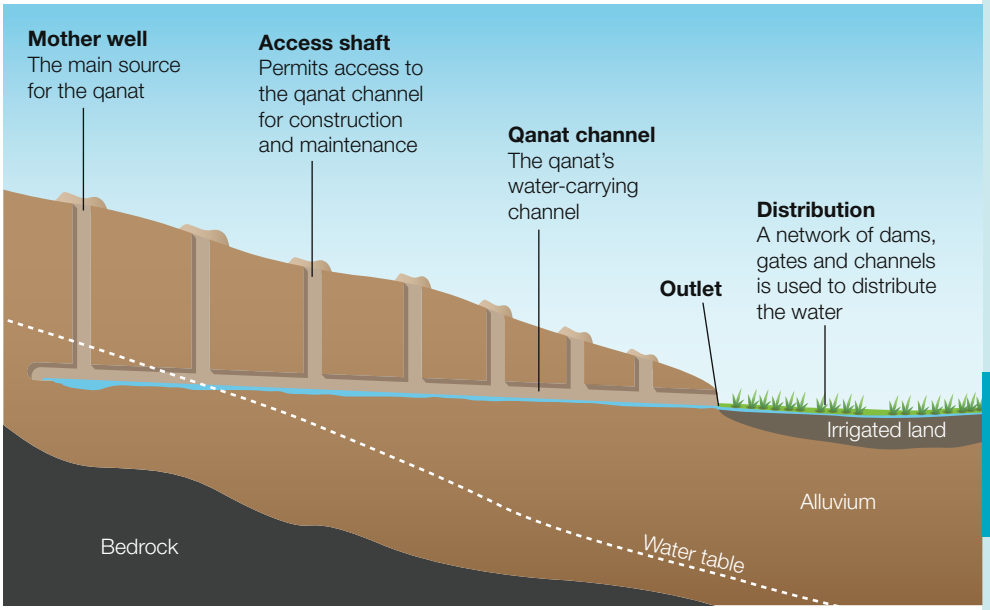
still operates today. Historically, much of the population in the arid regions of Asia and North Africa depended on qanat technology for fresh, reliable water.

A qanat starts in the foothills with the construction of a vertical shaft (called a mother well) to access the water table. Being a subterranean system, qanats have the advantage of low evaporation losses—critically important in an arid environment. The flow of water from the water table is relatively constant through the year, which provides water security. The Iranians are understandably proud of their qanats, which still provide water in deserts thousands of years after their construction. Modern-day exploitation of aquifers by large-scale deep-well pumping threatens groundwater sustainability, but in comparison the qanat system is an efficient and sustainable water system.

Recently, many qanats have fallen into disrepair with young people being reluctant to perform the difficult and dangerous underground work involved in building and maintaining them.



4.7.2 Cross-section showing how a qanat works

4.7.3 Aerial view of qanat access shafts in Xinjiang Uygur Autonomous Region, China

Geoactivities 4.7

Knowledge and understanding

1 What are the advantages of dams and reservoirs?
2 Explain why the global numbers and average size of dams have been increasing.
3 List the problems associated with dams.
4 Distinguish between qanats and deep-well pumping.

Inquiry and skills

5 Refer to 4.7.1.
  a List the number of reservoirs in the GRanD database in Australia, China and Saudi Arabia.
  b Explain the advantages of water reservoirs for future food production.
6 Refer to 4.7.2.
  a Explain how qanats work.
  b List the advantages of qanats over dams.
  c Investigate the countries that use qanats. Name and locate these on a world map. Give reasons for the spread of qanats to these areas.
7 Research and write a brief report on the positive and negative impacts of the Three Gorges Dam. Present your research as a Prezi based on analysis of data and information collected.

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4.8 Damming the Mekong River

The 4350 km long Mekong River is the world's twelfth longest river. It is a transnational river flowing from the Tibetan Plateau in China through Myanmar (Burma), Laos, Thailand and Cambodia to its delta in Vietnam. Many millions of people rely on the Mekong for their survival. It is one of the world's largest freshwater fisheries, with many of the 700 species endangered. Twenty new hydropower dams are planned for the Mekong. Dam construction threatens the livelihood of more than 60 million people downstream as well as the survival of freshwater ecosystems.

Mekong River Commission

The Mekong River Commission (MRC) is an intergovernmental body responsible for looking after the sustainable management and development of the shared water resources of Laos, Cambodia, Thailand and Vietnam. Under an agreement between these countries, signed in 1995, the host country needs to notify the governments of the other countries of any proposed dam projects. China and Myanmar (Burma) are not members of the MRC. The MRC has been criticised as being unable and unwilling to influence China's dam-building policy. It also attracted recent criticism and protests over the controversial Xayaburi Dam in Laos.

4.8.1 The Dachaosan Dam in Yunnan province, China

4.8.2 Giant barb—the 'king of fish' in the Mekong River. This fish species has become severely threatened due to water pollution, river traffic and especially overfishing

China dams the Mekong

About 16% of the Mekong's total annual flow comes from China, but this contributes to 40% of the dry season flow for downstream countries. China refuses to join the MRC and has built four dams in Yunnan province on the Upper Mekong. It is planning another seven for its huge hydropower needs. In 2012, China commissioned Nuozhadu—its fifth hydropower dam in Yunnan province. About 43 000 people have to be relocated for its construction. According to scientists, the Chinese dams are already altering the natural flood–drought cycle of the river and decreasing the natural, nutrient-rich silt load of the river. They are also affecting the survival of fisheries and migratory fish species, and the livelihoods of millions of people who depend on fisheries and irrigated rice crops for their food security.

Geoinfo

The First Thai–Lao Friendship Bridge crosses the Mekong River at the international border. The bridge cost $60 million and was funded by the Australian government as aid to Laos. It was completed in 1994.

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4.8.3 The damming of the Mekong River

Lower Mekong dams

In the Lower Mekong Basin another 11 dams are proposed to generate hydropower. The first is the controversial Xayaburi Dam—a test case for the 1995 MRC agreement. Laos is one of the world's least-developed countries, and it plans to use revenue from Xayaburi and other dams to increase its economic development.

The Vietnamese Government fears salt water will intrude into the fertile, low-lying Mekong delta area, ruining productive agricultural land already threatened by rising sea levels. In 2012, Vietnamese President Truong Tan Sang warned of increasing international tensions over water. Sang said: 'Dam construction and stream adjustments by some countries in upstream rivers constitute a growing concern for many countries and implicitly impinges on relations between relevant countries'.

Geoactivities 4.8

Knowledge and understanding

1 List geographical facts to outline the importance of the Mekong River in South-East Asia.
2 Describe what China is doing in the Upper Mekong.
3 Explain how dams in the Lower Mekong are a challenge to the MRC's 1995 agreement.
4 Explain why Vietnam is concerned about dams and stream adjustments upstream on the Mekong.

Inquiry and skills

5 Using 4.8.3 list the economic and social effects of dams on China, Laos, Thailand, Cambodia and Vietnam.
6 Research the impacts of Mekong River dams on the food security of the region. What is likely to happen as more dams are built and sea levels rise as a result of climate change?
6 Reflect on your learning and propose actions for a sustainable Mekong River.

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4.9 Transboundary water: conflict over scarce water

The uneven distribution of accessible fresh water leads to competition between human uses (agriculture, industry, mining and domestic) and environmental flows, as well as conflict or cooperation between states and countries.

Transboundary resource

Water is a **transboundary resource** that does not respect political boundaries. Water flows under the influence of gravity, not governments. Very few international boundaries follow natural watercourses. Surface water and groundwater flow across borders. Consequently, when humans extract water for their needs from upstream, it has an impact on water availability downstream, such as in the Mekong River, Nile River, Tigris–Euphrates rivers, Murray–Darling rivers and the Xingu River in the Amazon Basin. Increasingly, upstream countries are building dams and other water projects to obtain regional influence or develop their water resources at the expense of weaker countries downstream. Because this affects people and the environment, the result is either conflict or cooperation on a range of scales—local, regional, national and global.

The sustainable management of shared freshwater resources invariably involves political conflict or cooperation. The social and economic needs of people, communities and nations depend upon reliable access to sustainable water resources in terms of quality and quantity.

4.9.1 The Nile Basin

Conflict or cooperation

According to US intelligence experts, water scarcity has the potential to destabilise countries in North Africa, the Middle East and South Asia. In these places, populations are rising and water supplies are declining as a result of climate change and poor water management strategies. In 2012, then US Secretary of State Hillary Clinton said: 'As the world's population continues to grow, demand for water will go up but our fresh water supplies will not keep pace. These difficulties will increase the risk of instability within and between states. Within states they could cause some states to fail. And between and among states, you could see regional conflicts among states that share water basins be exacerbated and even lead to violence.'

Over the past 60 years, there have been more than 200 water treaties negotiated between countries. There were 1228 cooperative events and 507 conflict events. Of the 37 cases that reported violence, 30 were in the Middle East.

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Belo Monte Dam

The Belo Monte Dam complex in Brazil will be the world's third-largest hydroelectric project, generating electricity for the nation's rapidly growing economy. It will have the potential to power 23 million households. The $16 billion project involves more than 100 dams and hydroelectric projects throughout the Amazon Basin in Brazil, Ecuador, Peru, Colombia and Bolivia. Environmentalists caution that should these dams be built, resource extraction will follow, leading to loss of the Amazon's forests and the transformation of its great rivers into a series of reservoirs. Around 12 000 people will need to be relocated.

4.9.3 Belo Monte Dam

4.9.2 Indigenous people protesting the Belo Monte Dam project at the Rio+20 Conference in Brazil in 2012. They say the dam will destroy their livelihoods along the Xingu River.

Geoinfo

The Danube River, and its tributaries, is the world's most transnational river system, flowing through 20 European countries and providing water for more than 80 million people.

Geoactivities 4.9

Knowledge and understanding.

1 Explain how water is a transboundary resource.
2 Explain how water can be a source of conflict or cooperation between countries.

Inquiry and skills

3 Refer to 4.9.1 and research the conflicts surrounding scarce water in the Nile River, which are interconnected with population, environment, climate, politics and land use. Discuss the interconnections using geographical terminology.
4 Refer to 4.9.2 and 4.9.3. Describe the causes and anticipated consequences of the construction of the Belo Monte Dam in Brazil as a photo story.

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4.10 Fieldwork: waterway health check

Waterway health check

Make notes on each category on a separate sheet

Site information

Name of wetland/waterway:

If unnamed, what is the closest town, suburb or road?

Location:

Provide sufficient details so that you or someone else using your directions can return to exactly the same spot to repeat your rating.

Date:

Weather:

Has it rained in the last 24 hours?

(If yes, was it heavy rain?):

Area being rated:

Create a simple site map using a road directory or local plan. Mark in features that might affect your waterway. Mark in where you made your rating.

Provide enough detail so that when you repeat your rating you're examining the same area. For example, you might look at an area 50 m on either side of the waterway, stretching up and down the waterway as far as you can see.

CATEGORY 1 Land use

Walk around the area surrounding your waterway. Record land uses that you see or land uses you're aware of in the local area.

Create a list of places where water comes from that flows into your waterway.

Rating Category 1

0. Lots of industry nearby, most of land cleared, soil bare, environment disturbed
1.
2. Some industry, some land cleared
3.
4.
5. Some commercial, recreational and residential land use
6.
7.
8.
9.
10. No human use at all; in its natural state

YOUR RATING ☐

What's the land being used for around your waterway?

CATEGORY 2 Litter

Make notes on the type of litter floating on or in the water or on the surrounding land. (Include natural litter such as leaves sticks and animal faeces.)

If litter seems to collect in one particular area, take a photo of that area each time you monitor your waterway so you can compare litter buildup.

Rating Category 2

0. Lots of human litter such as car bodies, tyres, plastics and cans, oily films and/or excessive algae growth.
1.
2. A lot of human litter, cans, plastics or algae.
3.
4.
5. Some human litter such as garden rubbish and plastics
6.
7.
8. One or two pieces of human litter, and local vegetation such as leaves floating in the water
9.
10. No human use at all; preserved in its natural state

YOUR RATING ☐

What kind of litter is found in your waterway, and how much is there?

CATEGORY 3 Pipes and drains

Look for pipes, drains or trenches leading into your waterway. Examine what's coming out of them (by smell and sight: don't touch or taste), record how many there are and make notes on what you think they're there for.

Without touching the discharge from the pipes, figure out a method of calculating what the volume of any discharge is.

Rating Category 3

0. A number of pipes from industry and/or sewage treatment and/or urban stormwater.
1.
2. Some pipes or trenches
3.
4.
5. No pipes from industry, but some urban stormwater drainage
6.
7.
8. No pipes or drains
9.
10.

YOUR RATING ☐

What are the pipes and drains bringing to your waterway?

CATEGORY 4 Extra structures/ modifications

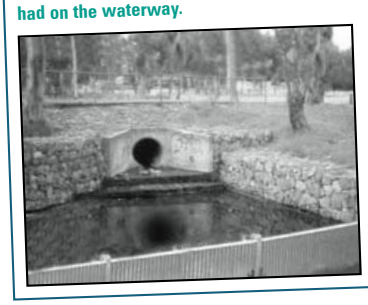
In addition to pipes and drains, record the presence of other artificial structures such as weirs, concrete banks, piers or any artificial modification of the water flow.

Describe what effect you think these structures have had on the waterway.

Rating Category 4

0. A number of artificial structures, large modification of natural flow
1.
2. Some artificial structures or some flow modification
3.
4.
5. No concrete structures or minimal modification of water flow
6.
7.
8. No extra structures or artificial modifications
9.
10.

YOUR RATING ☐



Stormwater filters such as shown here are designed to catch litter that might accumulate in other areas.

Fieldwork is an essential part of the study of geography. It is a means to understanding geographical environments and their sustainable management. Fieldwork enables you to plan an inquiry by collecting, evaluating, analysing and interpreting information.

Investigate the health of your local creek, stream, lake or wetland with this Waterways Health Check.

At the end of the fieldwork, communicate what you have learnt by using maps, graphs, statistics and photo-graphs. Your research can be presented orally, as a report, or using multi-media, such as PowerPoint or Prezi. Back in the classroom, reflect on what you have learnt and consider future action.

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CATEGORY 5

Smell

Sit by the waterway and record any smells. Take a sample of water and record its smell (don't taste it). A strong natural smell in wetlands and estuaries should be recorded as 6 or more.

Take a sample of water in a glass jar and ask other people how they would judge the smell. Is it the water that smells or something else at the waterway?

Rating Category 5

0. Very strong, unnatural chemical smell
1.
2. Strong unnatural smell
3.
4.
5. Stronger decaying smell or slight unnatural smell
6.
7.
8. Very slight smell, perhaps natural decay
9.
10. No smell / natural smell

YOUR RATING ☐

The water is clear but doesn't smell very nice!

CATEGORY 6

Water clarity

Collect a water sample in a clear container. Hold it up to the light. Record how clear the sample is.

If your water sample is murky, allow it to stand for a couple of days. Do particles settle out of it, causing it to become clearer?

Rating Category 6

0. Milky brown or green colour with particles and scum. You can hardly see through it!
1.
2. Cloudiness and/or greenish colour, with some particles or film
3.
4.
5. Some colour and particles
6.
7.
8. A little colour
9.
10. Colourless and clear as tap water

YOUR RATING ☐

It's looking good!

CATEGORY 7

Vegetation

Look at the banks and the land extending from the waterway. Note if the vegetation is natural or introduced, and if the soil is eroded or stable.

Using flora books or consulting local experts, learn the names of your local plants. Create a list of species growing around your waterway.

Rating Category 7

0. Lots of introduced plants, much clearing, bare ground, pasture, extensive erosion
1.
2. Mixed plants, much clearing, large eroded areas
3.
4.
5. Mixed native and introduced plants. Some clearing. Small corridor of vegetation. Some minor erosion.
6.
7.
8. Mainly native plants. Natural vegetation extends up to 30 m from water, no erosion
9.
10.

There's vegetation around but the banks themselves are eroded and appear unstable.

YOUR RATING ☐

CATEGORY 8

Invertebrate animals

(insects, crustaceans, molluscs and so on)

Sit by your waterway and look for invertebrate animal activity. Run a scoop net through the water and see if you can catch insects or other invertebrates.

Scrape up the first centimetre of sediment with a tin. Put it into an ice cream container and wash it with lots of water. Draw any animals you find.

Rating Category 8

0. No invertebrate animal life visible at all
1.
2. Only one or two types of animal life visible (probably snails leeches or worms)
3.
4.
5. Fewer than five types of animals found
6.
7.
8. At least seven types of animals found
9.
10. Many types of animals found including insect larvae and nymphs

YOUR RATING ☐

Run a scoop net through the water and see what you catch.

CATEGORY 9

Vertebrate animal life

(birds, reptiles, fish, amphibians and mammals)

Sit by your waterway and look for vertebrate animal activity. Note both the variety and number of birds. Look for fish, listen for frogs and record any animal tracks

Using bird books, learn the names of birds around your waterway and compile a list. Keep a chart of what birds are around at what times of year.

Rating Category 9

0. No vertebrate animal life visible at all
1.
2.
3. One type of animal life (birds)
4.
5.
6. Two types of animals found
7.
8.
9.
10. Many types of vertebrate animals found

YOUR RATING ☐

What birds are using the waterway near you?

Total score

Source: www.waterwatch.org.au

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Geothink

21st century water challenges and solutions

Providing adequate, safe fresh water for a rapidly expanding population is an increasing challenge, especially in developing countries. Climate change is also exacerbating the problems of water scarcity. The following graphic and newspaper article outline some of the major challenges related to water scarcity.

ACCESS TO DRINKING WATER

783 000 000
people don't have access to safe fresh water

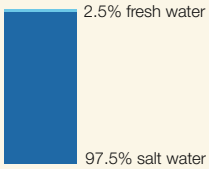
40%
concentrated in Sub-Saharan Africa

TOTAL VOLUME OF WATER AVAILABLE

The total volume of water on Earth is
1.424.192.640 km³

30% is mostly found underground

70% of the planets fresh water is frozen in the icecaps of Antarctica and Greenland



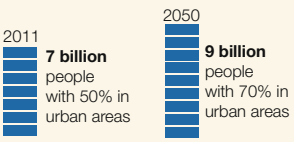
HUMAN WATER NEEDS

2-4 L
The daily drinking water requirement per person is 2–4 litres

2000+L
It takes 2000 to 5000 litres of water to produce one person's daily food

DEMOGRAPHIC BOOM AND URBANISATION

1 second = 2 more people
Every second, the urban population grows by 2 people



HEALTH

36 000 000
people die each year from water–related disease

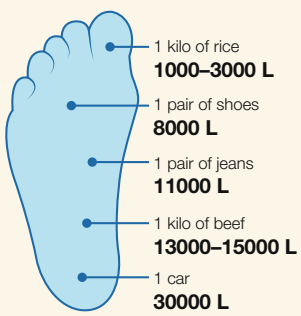
CLIMATE

4 billion
4 billion people may be facing water scarcity or flooding; that is, half of the global population

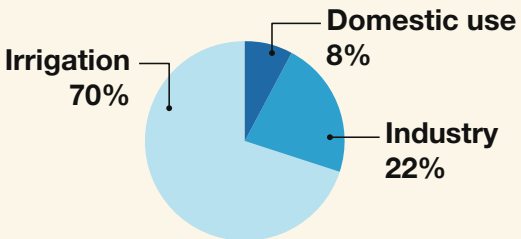
<100 litres
993 million city inhabitants may be living with less than 100 litres of fresh water to satisfy their basic needs

2 billion m³
2 billion m³ of water a year: this would be the fresh water deficit to meet actual irrigation, industry and domestic needs

WATER FOOTPRINT



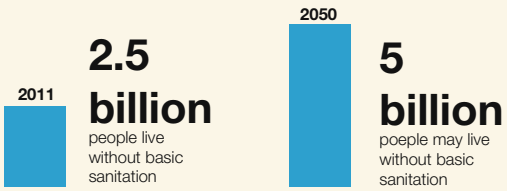
FRESH WATER USE BY SECTOR



DESALINATION

2%
of fresh water will be produced via desalination by 2015

WASTEWATER TREATMENT



4.11.1 Water: 21st century challenges

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Inquiry and skills

1 Refer to 4.11.1.
   a What will the world's population be in 2050, and what percentage will live in urban areas?
   b By 2050 how many million city dwellers may be living with less than 100 L of fresh water?
   c By 2050 how many people may be living without basic sanitation?
   d What are the statistics on access to drinking water and health?
   e How effective are graphics such as these in informing people about water issues?
2 Refer to 4.11.2.
   a What is Peepoo?
   b Explain how Peepoo improves water quality, soil quality, food security and health of people living in developing countries
3 Creativity: Design a graphic entitled '21st century solutions to water scarcity'. Publish your work on the school website.

Peepoo: self-sanitation

Peepoo is a personal, single-use, self-sanitising, fully biodegradable toilet that prevents faeces from contaminating the immediate area as well as the surrounding water bodies. After use, Peepoo turns into valuable fertiliser that can improve livelihoods and increase food security for people living in developing countries in places such as the slums in Kenya.

Peepoo contains urea—a non-hazardous chemical that is the most common artificial fertiliser in the world. When the urea in Peepoo comes into contact with faeces or urine, a breakdown into ammonia and carbonate takes place. As the urea is broken down, the pH value of the material increases and sanitisation begins.

Disease-causing pathogens, which may be found in faeces, can be rendered inactive within as few as two to four weeks, depending on the surrounding environment and temperature. This process is the most simple and efficient possible. When Peepoo disintegrates in the soil, plants take up the ammonia along with nutrients from the human excreta.

Peepoo in schools

Peepoo ensures a healthy, safe and clean sanitation solution in schools and daycare centres by providing a personal toilet supplemented by hygiene promotion and health education for teachers and students. Peepoo is designed so that no water is used while using it and very little water is used for anal cleansing in communities where that is a hygiene practice. This ensures that diseases are unlikely to be spread from one host to the other. This also helps save precious water supplies.

In schools, Peepoos are distributed for free to the children, and are initially financed by the parents of the schools or the teachers themselves. In the long run, the value of the increased yield from the school gardens can potentially finance the Peepoo sanitation solution. As a result, the system may become self-sustainable and the schools less dependent on donors.

4.11.2 Less 'poo' in water: Peepoo improves water quality

Source: www.peepoople.com

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