Environmental Studies
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The importance of maintaining aquifers

This Factsheet:
- Summarises key terms on this topic
- Explains the key features of aquifers
- Explains the consequences of over-abstraction (taking too much out of the aquifer) using Mexico City as an example
- Reviews recent exam questions on aquifers

Key Points You Must Be Able To Produce In The Exam

Aquifer: An underground layer of porous and permeable rock through which it can flow and be stored. Aquifers supply 66% of our drinking water.
Porosity: a measure of the proportion of the volume of a rock that is space and therefore may hold fluids
Permeability: a measure of the ease with which fluids may flow through a rock because of the interconnections between the spaces and their size.

So, aquifers must be **both** porous and permeable. Most igneous and metamorphic rocks have extremely low porosite. Most aquifers consist of sedimentary rocks. The porosity of sedimentary rocks is influenced by:
- The way in which bigger (coarse) grains fit together with the finer (smaller) grains
- The amount of compaction and cementation the rock has undergone
- The shape of the grains – round-grained rocks have a greater porosity than ones with angular grains that fit together
- The amount of joints and faults in the rock

EXAMPLES: **sandstone (highly porous) and limestone (well jointed)**

The rock below the aquifer must be **impermeable** to prevent the water escaping e.g. ***granite/clay***

Some of the rock above the aquifer must be **permeable** to allow **recharge** of the aquifer with water from above

- **Water table:** the upper surface of the zone of groundwater saturation. Above the water table lies unsaturated rock containing some water and air; below the water table lies saturated rock containing no air

- **Aquifer recharge:** the replacement of water that we have extracted by infiltration of rainfall / melting snow or river water. In order for this to happen precipitation must exceed evapotranspiration so the net effect is that water percolates downwards to the aquifer

- **Unconfined aquifer:** an aquifer that is open to the atmosphere i.e. is not overlain by impermeable rock

- **Confined aquifer:** an aquifer that is trapped, both above and below, between impermeable rocks

Where do aquifers come from?

Water infiltrates at the surface and then percolated under gravity through pores, joints and bedding planes to reach an area where all pores, joints, etc are full of water i.e. saturated. This is an aquifer and the surface of the aquifer is the water table. Aquifers may be seasonal or permanent depending upon the nature of the rock and the volume of water received via rainfall etc. The water table generally follows the surface topography and may emerge at the surface via springs, rivers and lakes or we may abstract it via wells and bore holes.

There are big potential advantages of obtaining our drinking water from aquifers rather than surface sources such as rivers and reservoirs:
- The water requires less treatment / chlorination because the rocks through which it seeps down act as natural filters / purify the water
- It is less expensive as there is no need for a dam / reservoir
- There is no loss of water through evaporation / less seasonal variation in supply
- Dissolved minerals in the aquifer water may provide health benefits
- There is less aesthetic impact / less impact on the landscape
- Aquifers are less environmentally destructive / there is less damage to habitats e.g. to fish in rivers / flooded valleys

However, taking too much water from an aquifer (over-abstraction) can cause serious problems:
- The hydrostatic pressure and the level of the water table will fall
- The well will dry up / a cone of depression will form
- The loss of water may cause the pores to collapse from the weight of material above, resulting in subsidence
- If the aquifer is near the coast, saltwater may be drawn into the aquifer to replace that water extracted (saltwater incursion)

Case study of over-abstraction: Mexico City

Constant migration and urbanisation has resulted in huge loss of natural features such as forests, rural land and lakes in and around the former lake bed upon which Mexico City is situated. Urbanisation has simultaneously increased demand and reduced infiltration.

Q. Why does urbanisation:
(i) increase demand for water
(ii) reduce infiltration?

Huge and increasing abstraction from the aquifer below it has resulted in common and widespread water shortages with water having to be transported in from rivers and reservoirs in other regions, at huge expense.

Whilst most of the city's water still comes from the aquifer, a significant volume is pumped 1200m up along a pipeline running to the Cutzamala River 80 miles to the west.

As the water in the pores within the aquifer has been removed, the weight of overlying sediments, buildings and infrastructure such as roads has compacted the sediments resulting in subsidence estimated at between 15cm and 40cm annually!

The problem **is** made worse by the fact that much of the overlying sediments are clays with extremely high water contents, low shear strength and large but variable compressibility. The amount of compression is therefore different in different parts of the city and at these boundaries, buildings, water and sewage pipes etc are all at particular risk of being damaged.

Regional subsidence caused by over-abstraction has damaged roads, electricity supplies and thousands of buildings including landmark building such as the Metropolitan Cathedral and the National Palace, both have which have had to be shored up and their foundations reinforced to prevent collapse..

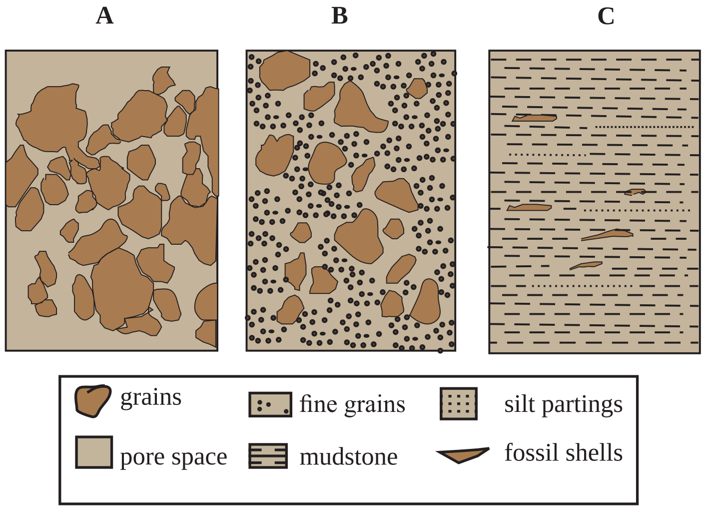
Another problem is that no one knows the precise number of wells that have been dug or the volume of water that is being abstracted because much of it is illegal. The release of sewage into the aquifer from pipes damaged by subsidence has also reduced people's confidence in the safety of the drinking water – in 2009, Mexico was ranked the third largest consumer of bottled water despite the fact that it can be extremely expensive. A recent report indicated that CONAGUA reported that the Valley of Mexico Basin had 50% heavily contaminated, 25% contaminated, 20.8% acceptable, and only 4.2% excellent water quality based on Biochemical Oxygen Demand (BOD) levels. Flooding by sewage is a common occurrence.

Possible solutions

- Increase the importation of water from other regions
- Increase primary and secondary treatment of wastewater – currently only 18% is treated and much is used for irrigation of crops in other regions
- Reduce the volume of wastewater that is exported for irrigation
- Reduce network leakage
- Artificial groundwater recharge using both flood water and treated wastewater
- Improved monitoring of abstractions via metering
- Improved water use by installation of millions of more water-efficient toilets

Practice Questions

1. The diagram below shows three different sediments.



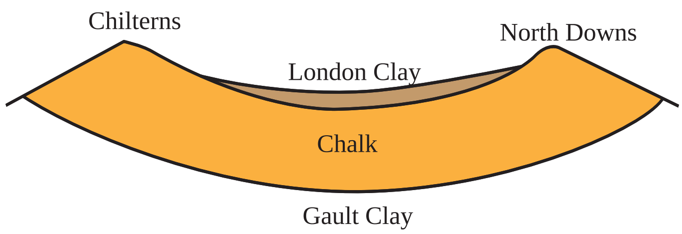
1 **(a) (i)** State **two** properties of a rock that could make it a good aquifer (2)

(ii) **Identify** which sediment is most likely to be exploited as an aquifer. Explain why (3)

(b) In south eastern England, most water supplies are obtained from aquifers. Using the diagram below, identify each of the following:

(i) the aquifer (1)

(ii) an impermeable layer (1)



(c) Describe the geological features shown on the diagram that make it a suitable location as an aquifer supplying this area (2)

Mark scheme

1. (a) (i) porous / able to store water;
permeable / water can flow;
well rounded, well sorted grains;
little / or no cementation / poorly consolidated;
good interconnections between pores / well jointed;
(ii) B;
High porosity;
A cemented;
C is impermeable/contains impermeable clay;

(b) (i) chalk;
(ii) either clay;

(c) impermeable clay above and below;
porous and permeable chalk aquifer;
(wide) basin structure traps large volume of water;
large recharge zones / water percolates into aquifer at edges of basin;

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