



# Remediation of industrial brownfield sites Part 1

Maggie Williams

# What is a brownfield site?

In the UK, a brownfield site is defined as a piece of "previously developed" land that has the potential for being redeveloped.

A brownfield site is often (but not always) land that:

- has been used for industrial and commercial purposes
- is now derelict
- is possibly contaminated due to hazardous waste
- may contain contaminants that cause harm to the environment &/or humans.





## Why are brownfield sites important in the UK?

- Approximately 3 million new homes will be required by 2030.
- Building options - use brownfield sites or greenfield sites?
- Lack of available green spaces for development, but over 66,000 hectares of brownfield sites in England. *(N.B. 33% of these brownfield sites in the North & the Midlands, but most housing demand is in the S.E.)*

# Why are brownfield sites important in the UK?

## Policies/statements

- 1998: UK Government set a national target for 60% of all new developments to be built on brownfield sites.
- 2014: UK Government plans giving pre-planning approval for housing on brownfield sites
- 2016: £1.2bn fund announced to prepare brownfield sites for starter homes in the next 5 years
- 2017: brownfield registers compulsory for local authorities
- 2018: major overhaul to the National Planning Policy Framework.

*'Although significant progress has been made, we must do more to deliver 300,000 homes a year by the mid-2020s.'*

Brownfield sites	Greenfield sites
Often on disused or derelict land	Include the greenbelt land around cities
More sites available in the North and Midlands	Sites which have not previously been built on
Sites already developed so reduces urban sprawl	Are not favoured by environmentalists, as it encourages urban sprawl
Unsightly areas developed for building, so this improves the urban environment.	Mean that countryside is built on and this damages the rural environment
Existing buildings can be altered to create more homes on sites.	People travel into urban areas so pollution and traffic congestion increase
More expensive to build on because the land needs to be cleared first and the land may be contaminated.	Are cheaper to build on

**n.b. Brownfield sites are considered for redevelopment of:**

- **housing and commercial buildings**
- **open spaces for recreation, conservation, woodland and other community areas.**

# Main problems of industrial brownfield sites

- Toxic chemical materials
- Groundwater pollution
- Ground instability
- Subsidence



Credit: By Dumelow - Own work, CC BY-SA 4.0,  
<https://commons.wikimedia.org/w/index.php?curid=3664752>



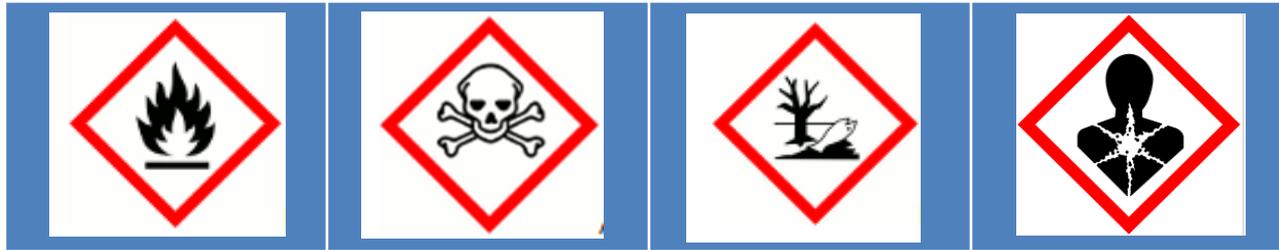
# What is a contaminant?

- A contaminant is a minor substance, material or agent that is unwanted in the environment and may or may not be harmful.
- Contaminants can affect water, air and soil.
- Contaminants are not necessarily pollutants.
- A pollutant is a contaminant which, due to its properties or amount or concentration, causes harm to the environment &/or humans.

# Possible sources of contamination

Type of industrial brownfield site	Possible source	Contaminant/ pollutant
Petrol station	Petrol	Hydrocarbons, benzene, toluene, xylene (BTX)
Commercial buildings, schools and houses	Heating oil	Hydrocarbons, benzene, toluene, xylene (BTX)
Dry cleaners	Cleaning solvents	Tetrachloroethylene, trichloroethane trichloroethylene (TCE),
Machine shops	Cleaning solvents, metal debris	Solvents e.g. Tetrachloroethylene, trichloroethylene, trichloroethane, Metals e.g. copper, nickel, iron, zinc, cadmium
Metal finishing/ plating shops	Plating solutions, cleaning solvents, acids & bases	Metals e.g. chromium, cadmium, tin, zinc, nickel, copper, lead Acids & bases e.g. sulphuric acid, nitric acid, hydrochloric acid, sodium hydroxide Solvents e.g. TCE
Landfills & dumps	Solvents, paints, batteries, metal parts	Almost anything

# Benzene and benzene derivatives



## Benzene

- Increases the risk of cancer and other illnesses
- Affects liver, kidney, lung, heart and the brain
- A cause of bone marrow failure and abnormalities

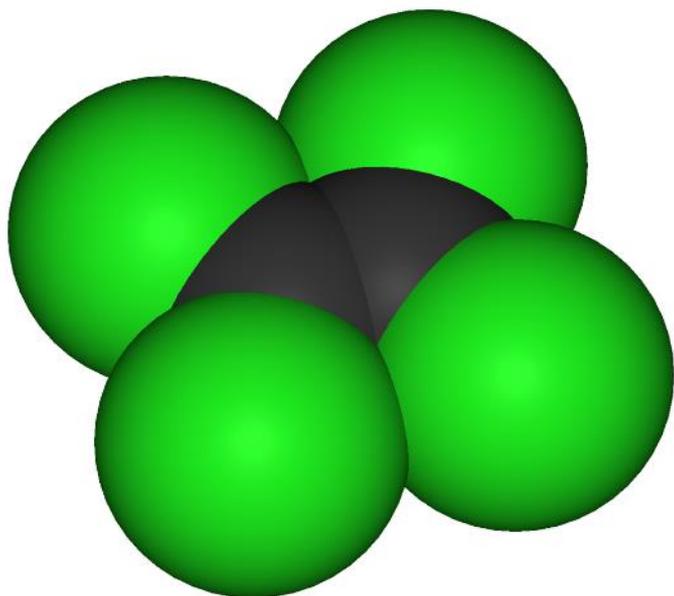
## Xylene

- Causes loss of balance
- Reduces coordination and reaction times
- Irritates the skin & strips the skin of its oils

## BTX (mixtures of benzene & toluene)

- Toluene is much less toxic than benzene

# Trichloroethylene & tetrachloroethylene



Tetrachloroethylene

Credit: This file is licensed by under the  
[Creative Commons Attribution-Share Alike 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

## Trichloroethylene (TCE)

- Carcinogenic (risk of kidney cancer and liver cancer)
- Toxic to the:
  - central nervous system
  - kidney & liver
  - immune system
  - male reproductive system
  - developing foetus

## Tetrachloroethylene (PCE)

- Possibly carcinogenic
- Affects nervous system and respiratory organs

# Arsenic

- Classified as "toxic" and "dangerous for the environment" in the European Union
- Carcinogenic (bladder & kidney cancer)
- Causes arsenic poisoning
- Bioaccumulative in many organisms (marine species in particular)



Credit: This file is licensed by under the [Creative Commons Attribution-Share Alike 3.0](https://creativecommons.org/licenses/by-sa/3.0/)



Credit: This file is licensed by Tomihahndorf under the [Creative Commons Attribution-Share Alike 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

# Copper

- Neurotoxicity
- Causes poisoning vomiting, hematemesis, low blood pressure, coma
- Chronic exposure damages the liver & kidneys

Native copper



Credit: This file is licensed by Jonathan Zander under the [Creative Commons Attribution-Share Alike 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

# Cadmium

- Risk factor associated with kidney disease, early atherosclerosis, hypertension and cardiovascular diseases

Cadmium metal



Credit: USGS



Fibrous tremolite asbestos on muscovite

Credit: This work has been released into the public domain by its author, Aramgutang at English Wikipedia

# Asbestos

- Asbestosis
- Carcinogenic - causes malignant mesothelioma in humans

# Zinc

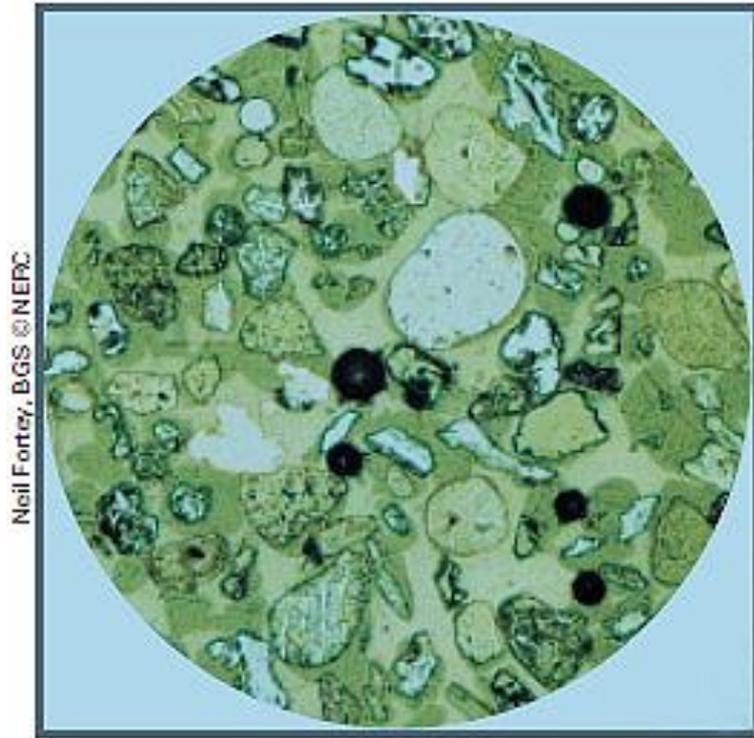


Credit:

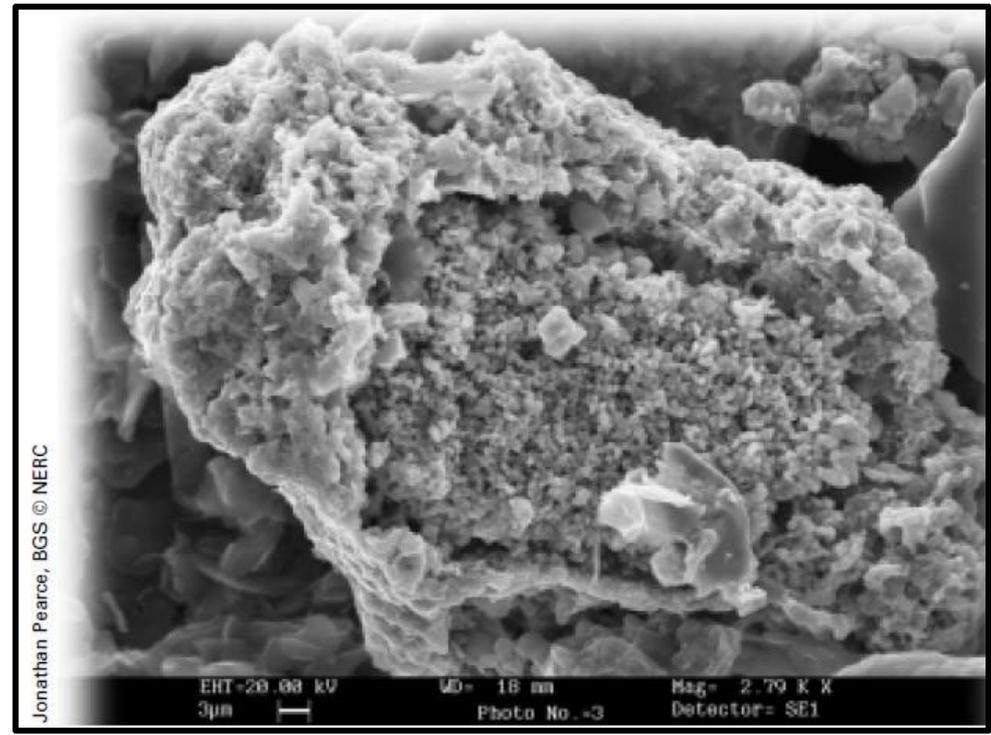
<https://nutrawiki.org/zinc/>

- Excessive intake of zinc reduces copper & iron absorption
- Causes damage to nerve receptors in the nose
- Risk of zinc poisoning (can be fatal)
- > 500 ppm zinc in soil affects plant absorption of other essential metals e.g. iron and manganese
- Free zinc ion in solution - highly toxic to plants, fish and invertebrates

# Heavy metals as residues



e.g. Metal shards in brownfield soil fragments  
(Optical image of polished section.  
Field of view approximately 0.5mm  
across.)



e.g. Metallic slag particle from contaminated  
brownfield soil  
(SEM image, approximately 85 microns across)

Ref: *Heavy metals - contaminants under the microscope* by Neil Fortey *et al.*

This Earthwise Magazine article (Earthwise Issue 17: Geology and health) maybe downloaded from:

<https://www.bgs.ac.uk/discoveringGeology/newsAndEvents/earthwise/downloadSearch.cfc?method=viewArticles>

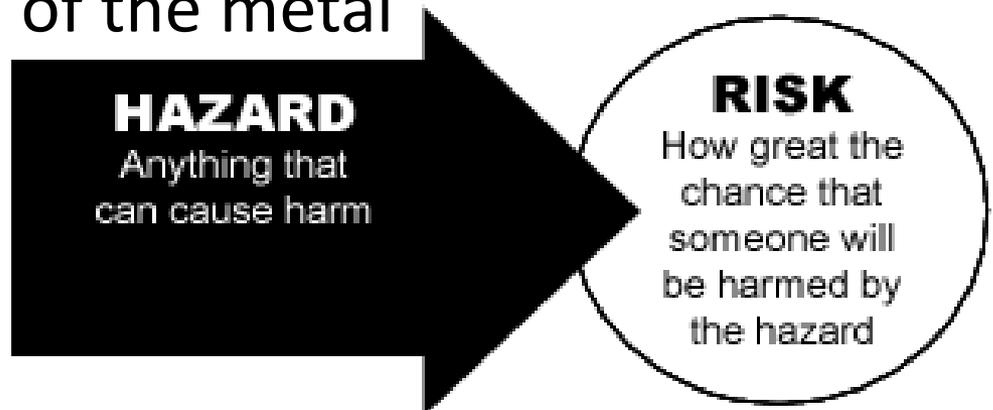
# Hazards of heavy metals

Heavy metals may :

- migrate into water supplies
- be adsorbed from soil by being eaten
- be absorbed from soil by being inhaled

Hazard is related to:

- how metal-rich particles react in the human body
- solubility of the metal
- the way in which they occur
- overall concentration of the metal



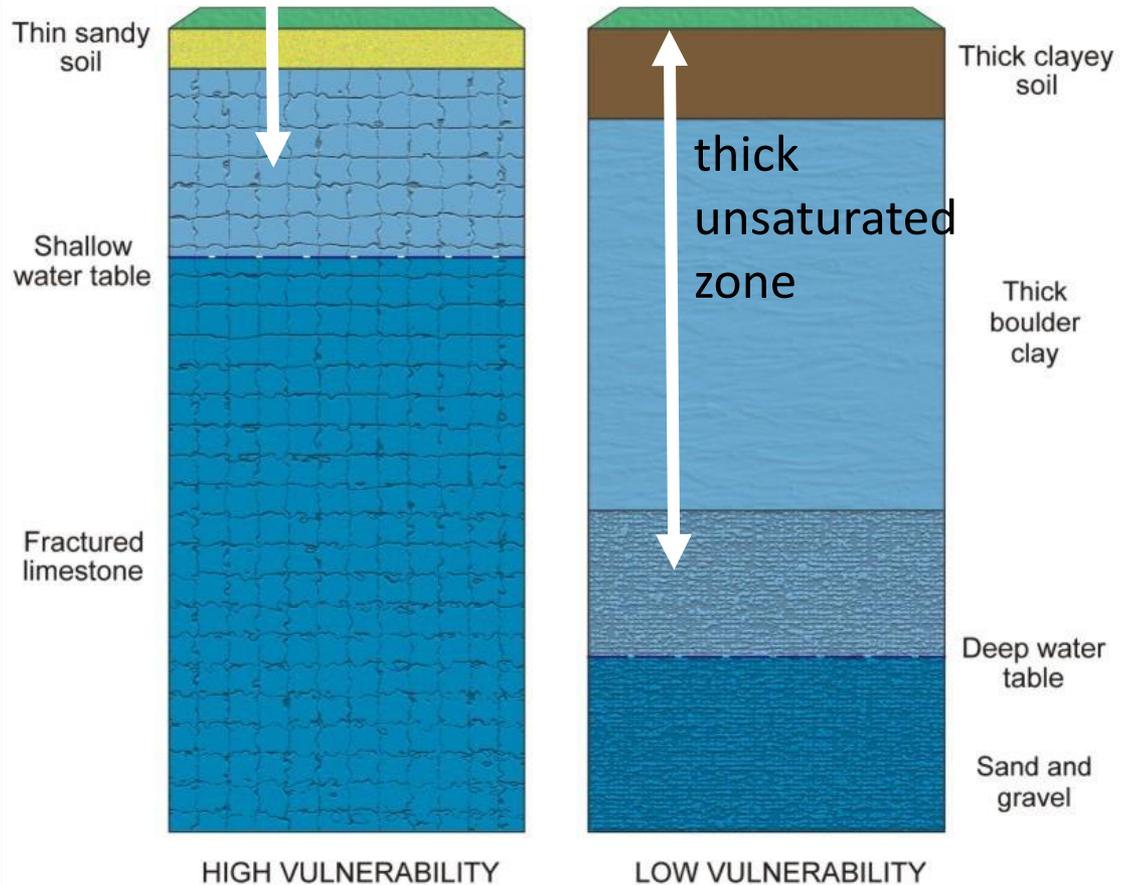
# Hazards posing threats to quality of groundwater



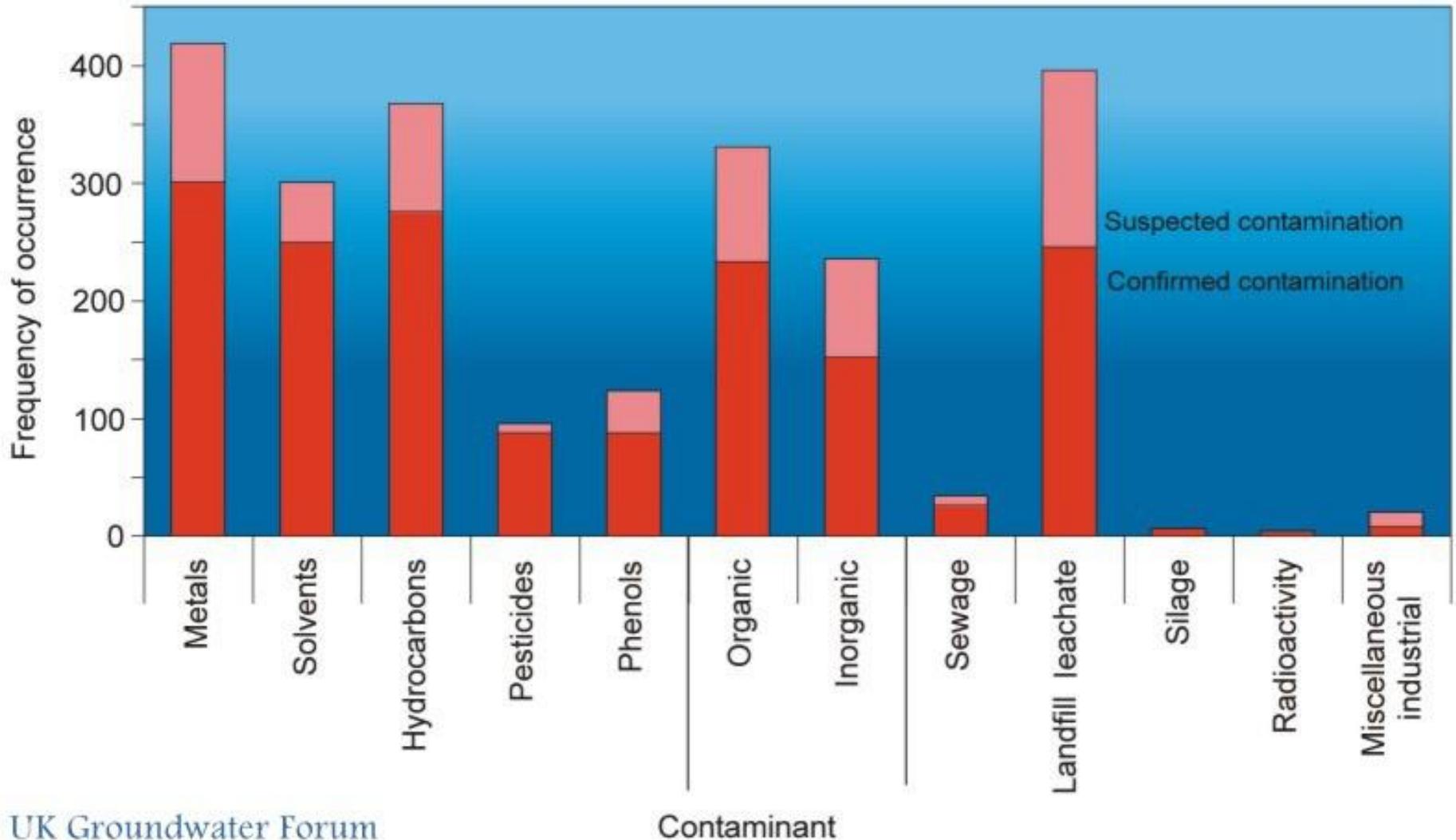
N.B. Main sources of pollution are from industry, agriculture, domestic waste & urban areas

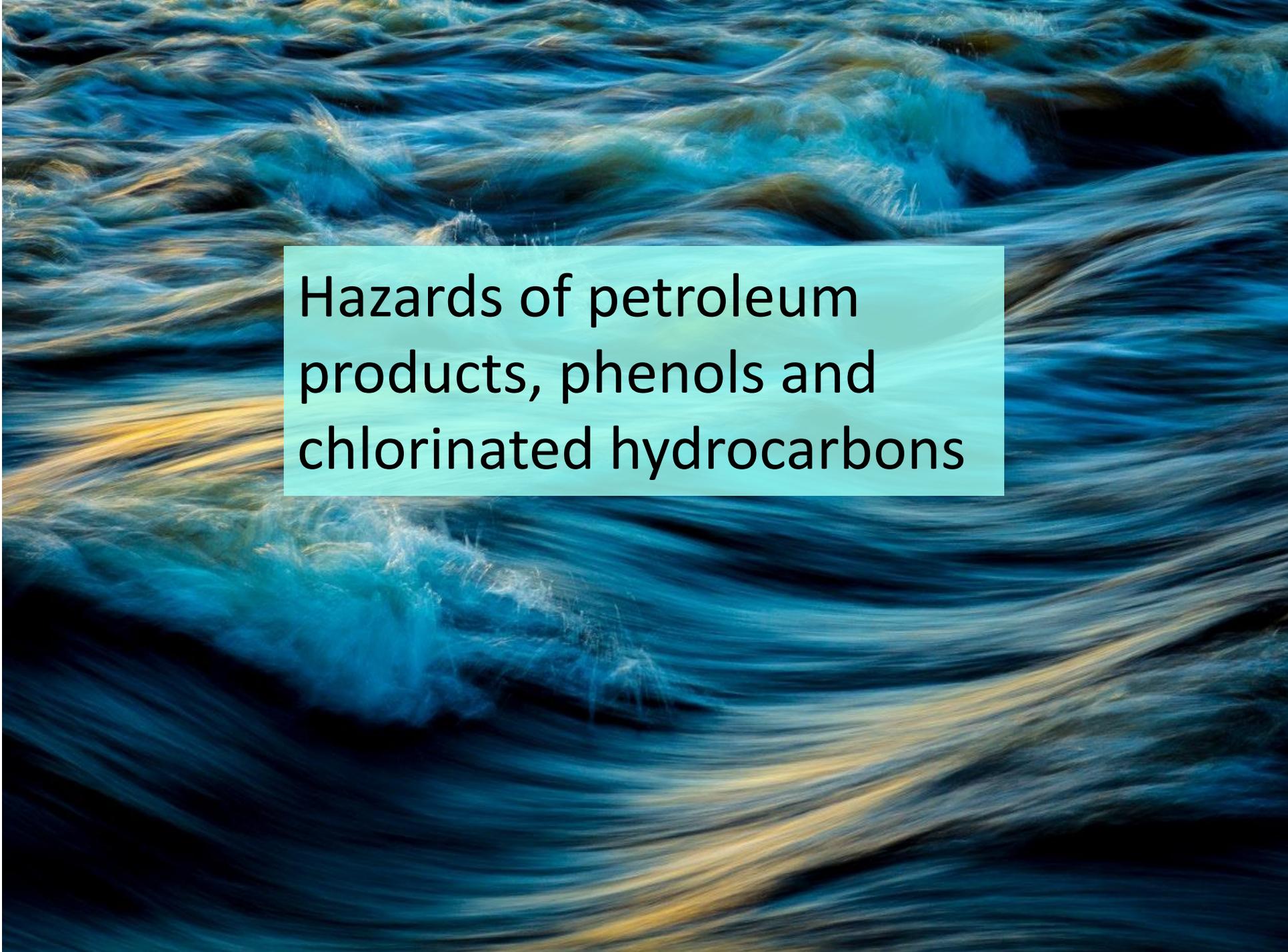
# Why some aquifers are more vulnerable to contamination

- Fractured limestones with a thin soil cover and a shallow water table are very vulnerable
- Aquifers are least vulnerable where there is:
  - a thick cover of clay
  - a thick unsaturated zone



# Frequency of contaminants in groundwater in England and Wales





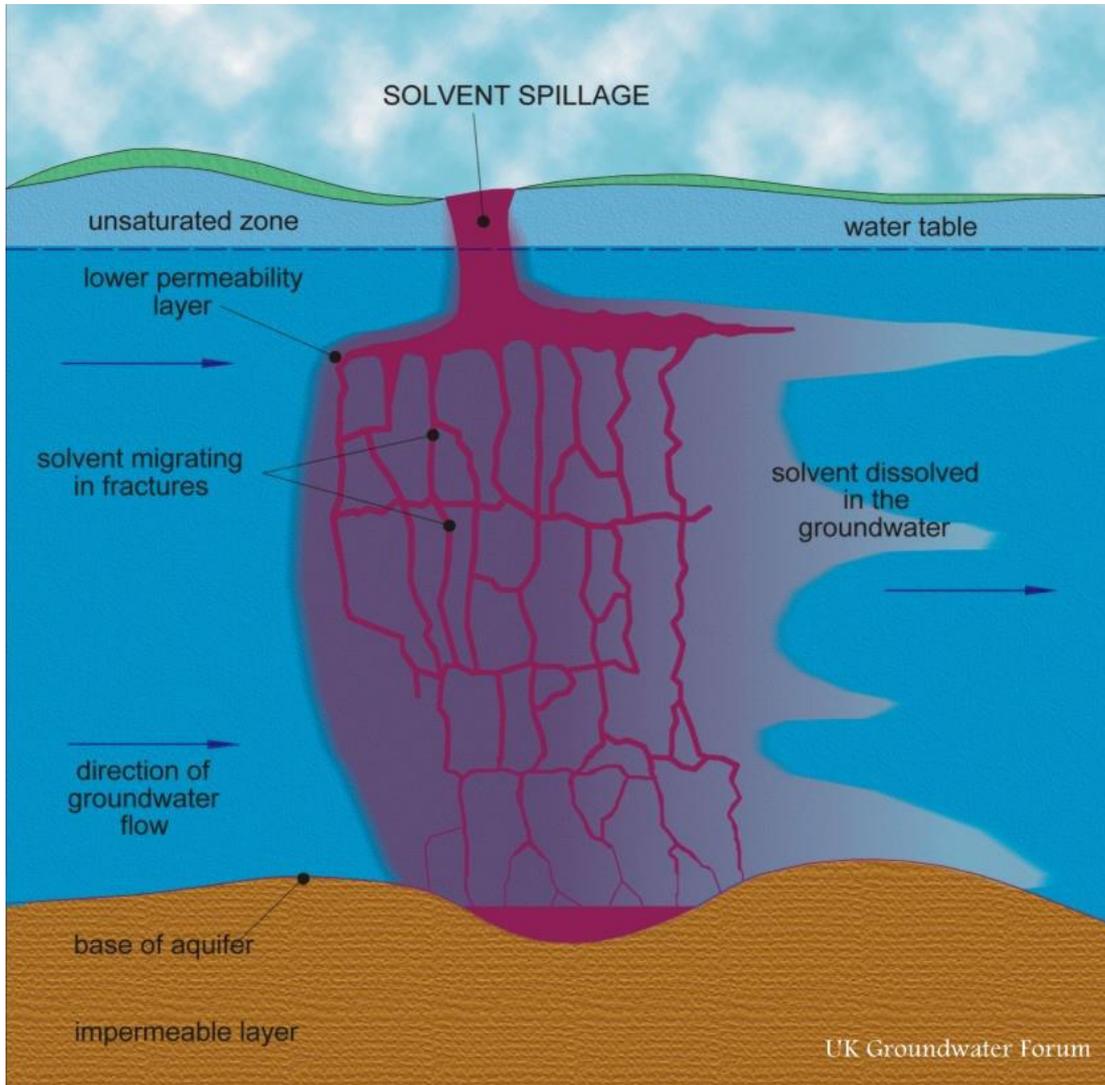
Hazards of petroleum  
products, phenols and  
chlorinated hydrocarbons

- Serious risk to groundwater quality from accidental spills and leaks of these substances from tanks and pipelines. Once an aquifer has been contaminated it is likely to remain so – remediation is very difficult to do.
- WHO drinking water standard for benzene is  $10\mu\text{g/l}$ .
- Some of these substances are soluble in water. Others are only slightly soluble and called non-aqueous phase liquids (NAPLs).

**Light NAPLs (mainly petroleum products) are less dense than water. Light NAPLs are more easily controlled - they float on the water table and occur at relatively shallow depths.**

**Dense NAPLs include the chlorinated hydrocarbons (materials widely used as industrial solvents) and are more dense than water. Dense NAPLs move under the influence of their density, can penetrate to considerable depths and are harder to control.**

# Hazard of spills & leaks from tanks, pipelines & factory sites – the potential scale of the problem



A single spill may contaminate a very large volume of water e.g. a spill of TCE (trichloroethylene) - a dense NAPL from a leather-processing factory in Cambridgeshire polluted the Chalk to a depth of 50m & extended for at least 2km in the direction of groundwater flow.

Pollution of the Chalk by the solvent tetrachloroethylene

# Other sources of information

USGS: Exploring contaminated land

<https://www.usgs.gov/science-explorer-results?es=contaminated+land>

US Environmental Protection Agency

<https://www.epa.gov/environmental-topics>

BGS: Engineering geology

<https://www.bgs.ac.uk/research/engineeringGeology/home.html>

International Information Centre for Geotechnical Engineers

<https://www.geoengineer.org/education>

Wikipedia: Brownfield land

[https://en.wikipedia.org/wiki/Brownfield\\_land](https://en.wikipedia.org/wiki/Brownfield_land)