EnviroVigyan

TOXICITY IN WATER

THE

ENVIRONMENTAL TIMES

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BY – KHYATI SHARMA &
ANCHAL GARG

About The EnviroVigyan

EnviroVigyan is a registered not-for- profit, non-government organization (NGO), founded by Dr. Anchal Garg in the year 2021. The scientific activities of this organization are supported by a dedicated team of experts drawn from academia and research institutions. The self-motivated dynamic group of experts works in multi-disciplinary areas of societal importance covering different issues of environmental concern. The research, training, and awareness programme focus on the thematic areas ranging from air pollution, waste management, water and sanitation, to climate change, ecosystem restoration, and associated public health.

About The Environmental Times

The Environmental Times is a monthly report prepared by EnviroVigyan. The aim of The Environmental Times is to highlight the significance, major contribution, and way forward to solve the major environmental issue. It also focuses on changing our pathways from unsustainable to sustainable practices.

About The Authors

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Anchal is the Founder at EnviroVigyan since 2021. She is a researcher, consultant, activist, and educator in the field of Environment Management.

WATER POLLUTION

Water pollution is basically defined as the contamination of water bodies i.e. oceans, lakes reservoirs, groundwater, etc. causing widespread diseases in humans and threatening the lives of aquatic plants and animals.

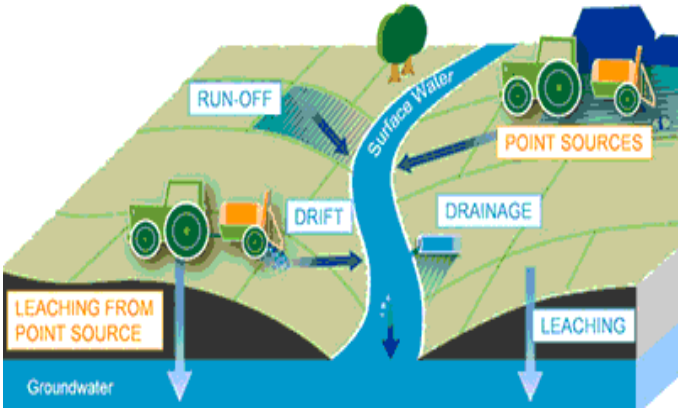
Pollution in New River (Mexico to California)

Source: Wikipedia

Wastewater that comes from the domestic sector, industrial sector, agricultural sectors many other sources consist of many pollutants like dissolved solids, nutrients, heavy metals, etc. The wastewater that reaches the water bodies ends up polluting it and threatening the lives of aquatic plants and animals. If that water is used by humans, it ends up causing many water-borne diseases and disabilities in human beings. This toxic surface water can also reach up to the groundwater by processes such as leaching.

Out of all the pollutants found in wastewater, heavy metals are found to pose a serious threat as they are generally non-biodegradable, toxic, and have bioaccumulation and biomagnification properties.

The four major heavy metals that are included in the present study are: Mercury, Cadmium, Arsenic, and Chromium



Surface and Groundwater pollution

Source: Water air pollution. org

MERCURY (Hg)

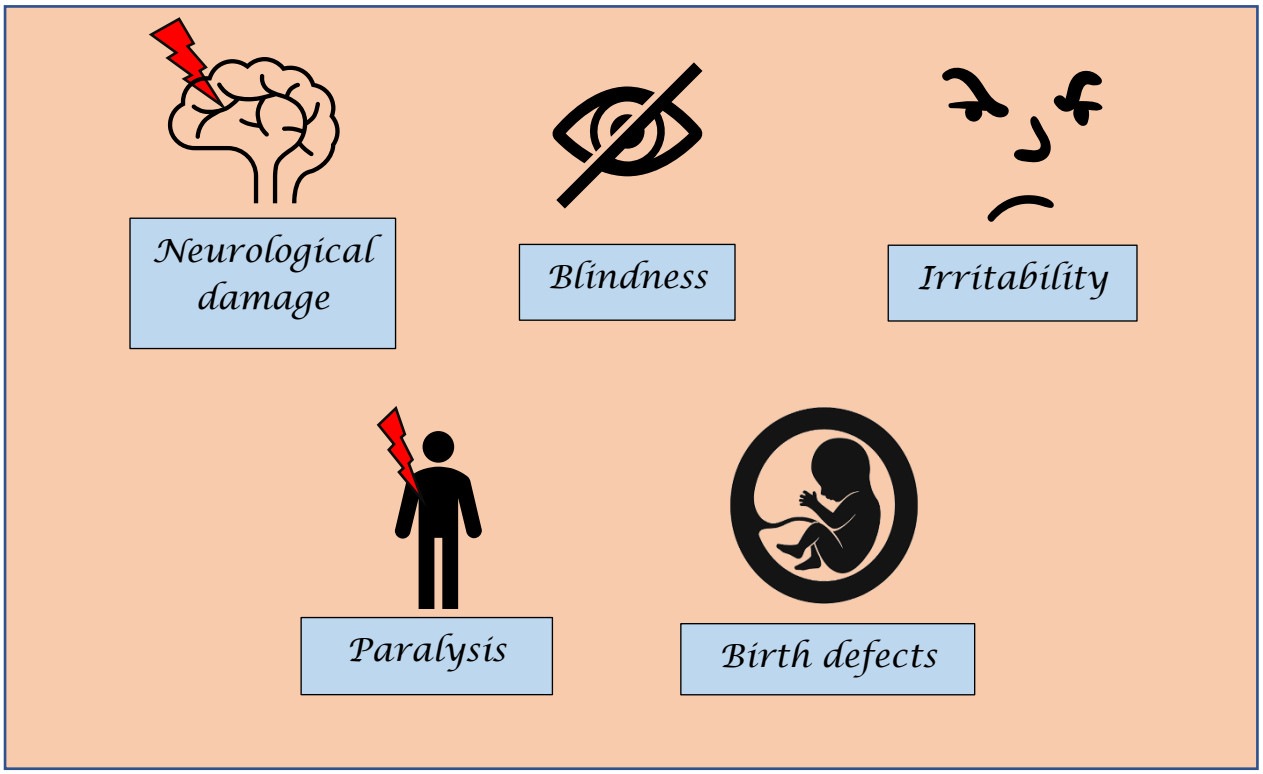
Mercury exists in organic and inorganic forms.

SOURCES:

- Combustion of fossil fuel, lignite, and coal
- Thermal and coal-based power plants
- Industries (Chlor Alkali Industry) Chlor = Chlorine gas and Sodium hydroxide
- Agricultural Industry (Fungicide), Calomel is used as a fungicide (to kill fungus)

The organic form of mercury is more toxic than the inorganic form.

TOXICOLOGICAL EFFECTS OF MERCURY:



Mercury (Hg) Vapours

These are the inorganic substances that are toxic and known to cause damage to Central Nervous System (CNS) by diffusing into the bloodstream and reaching the lungs and then the brain.

DO YOU KNOW

Haemotoxin:

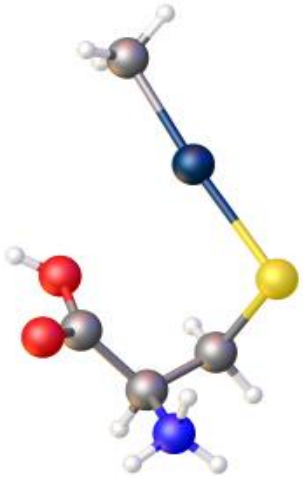
Compounds causing toxicity by mixing with the blood.

Methyl Mercury (CH_3Hg):

Methyl mercury *or* ***methyl mercury cations*** *are the organic mercury that is responsible to cause one of the major diseases found in the water body which is* ***Minamata disease*** *due to processes such as bioaccumulation (concentrates in the tissues of aquatic organisms) and biomagnification (the concentration keeps on increasing with the food chain).*

Methyl mercury is also soluble in the liquid fraction of the plasma membrane and disrupts the sugar and potassium transport hence resulting in energy deficiency.

Methyl mercury is also a known teratogen, known to cause irreversible damage to the CNS of newborn babies.



Methyl mercury

Source: Wikipedia

DO YOU KNOW?

Teratogens: *The substances that cause developmental problems (like mental and limb development) in the fetus or newborn babies are called teratogens. Apart from Methyl Mercury, there are various other known teratogens like Lead, benzene (also a carcinogen), endosulfan, Polychlorinated diphenyl, and thalidomide (a famous pain reliever drug earlier given to pregnant women in the U.S).*

MINAMATA DISEASE:

Source: Wikipedia

Toxicity due to Hg was first observed in Minamata bay in Japan during the period 1953 to 1960.

MINAMATA DISEASE

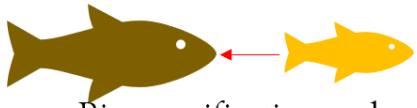
Methyl Mercury (CH_3Hg^+) is majorly responsible for causing Minamata disease.

Industries, Agricultural sector, thermal power plants

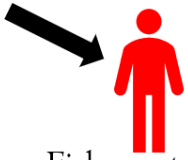
→ $HgCl_2$ Introduced in water → Anaerobic bacteria synthesis **Methylcobalamine**

Methylcobalamine reacts with $HgCl_2$

Formation of CH_3Hg^+



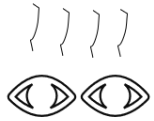
Biomagnification and bioaccumulation in fishes



Fishes eaten by humans

SYMPTOMS

Headache



Blurred vision

Numbness

Loss of muscle control

Death

- **Minamata Bay area of Japan observed the toxicity of Hg during the period 1953 to 1960.**
- **Methylcobalamine is a Vitamin B12 analog.**

CADMIUM (Cd)

Cadmium is generally found in a +2 oxidation state hence it is a divalent cation.

It may arise from mining waste (leaching of sulfide ores of Zn, Cu, and Pb generally results in impurities such as Zn^{2+}, $Hg^{2+,}$ and Cd^{2+} respectively) and industrial discharges, especially from metal plating.

APPLICATIONS OF CADMIUM

- *Cadmium and Nickel batteries*
- *Alloys*
- *Electroplating of steel*
- *Used in ink along with Ni^{2+} for color pigment production (magazines, books, and newspapers)*

CHARGE BALANCE:

A charge can only be replaced by a similar charge. For eg; the $^{+2}$ charge can only be replaced by the +2 charge. Cd^{+2} is chemically similar to Zn^{+2} and Ca^{+2} in our body; hence, it can replace them. When Ca^{+2} is taken in excess, it replaces Zn^{+2} from major enzymatic sites, disrupting metabolism. Replacing the Ca^{+2} causes the fragility of the bones, this condition is called as Itai-Itai disease or Ouch-Ouch disease.

CADMIUM POISONING

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Divalent cation of Cadmium (Cd^{+2}) can replace Zinc (Zn^{+2}) and Calcium (Ca^{+2}) in the human body.

Source: people.ucsc.edu

Cd^{+2}

IN HUMAN BODY

Ca^{+2}

Affects the bones and teeth

Causing fragility of bones

Itai-Itai disease

Zn^{+2}

Replaces Zn at enzymatic sites

Disrupt enzymatic activities and metabolism

ITAI-ITAI DISEASE:

This disease was observed in Toyoma, Japan around 1912.

***Sources:** Pb, Zn, Cu, and Cd mines were observed to be the major sources of cadmium poisoning.*

The drainage of these mines contaminated the Jinzu river water. Unaware of the effects of the Cadmium, locals used that water for irrigation purposes in their paddy fields, resulting in cadmium poisoning in them. The disease was named Itai- Itai (locally called Ouch- Ouch disease) due to the extreme pain suffered by the patients in the bones. The bones become so fragile that they can even brake on sneezing. The poisoning mainly affects the kidneys in our body leading to cancer of the kidneys.

Jinzu river

Source: Wikipedia

ARSENIC (As)

Arsenic is found in two forms: As^{+5} (Arsenate) and As^{+3} (Arsenite).

Arsenate is a highly toxic form of Arsenic while Arsenite is non-toxic.

ARSENIC PROBLEMS:

Arsenic toxicity in India is majorly found in West Bengal, Uttar Pradesh, and Bihar. While West Bengal and Bangladesh have the highest toxicity in the world. In Bangladesh, mass arsenic poisoning took place due to the excessive digging of wells for irrigation pumping. According to WHO, it was estimated that approximately 19 million and 39 million people in Bangladesh were exposed to Arsenic poisoning above the national standard of 50 µg/l and WHO guidelines of 10 µg/l.

Source: The wire

Although the exact mechanism is not known, but it is thought that it is the result of reductive dissolution of Arsenate (non-toxic) to Arsenite (toxic).

SYMPTOMS OF ARSENIC POLLUTION

Muscle spasms

Nausea

Vomiting

Diarrhoea

Dehydration

Abdominal pain

Garlic odour to breath

Hypertension

Cardiovascular collapse

Death

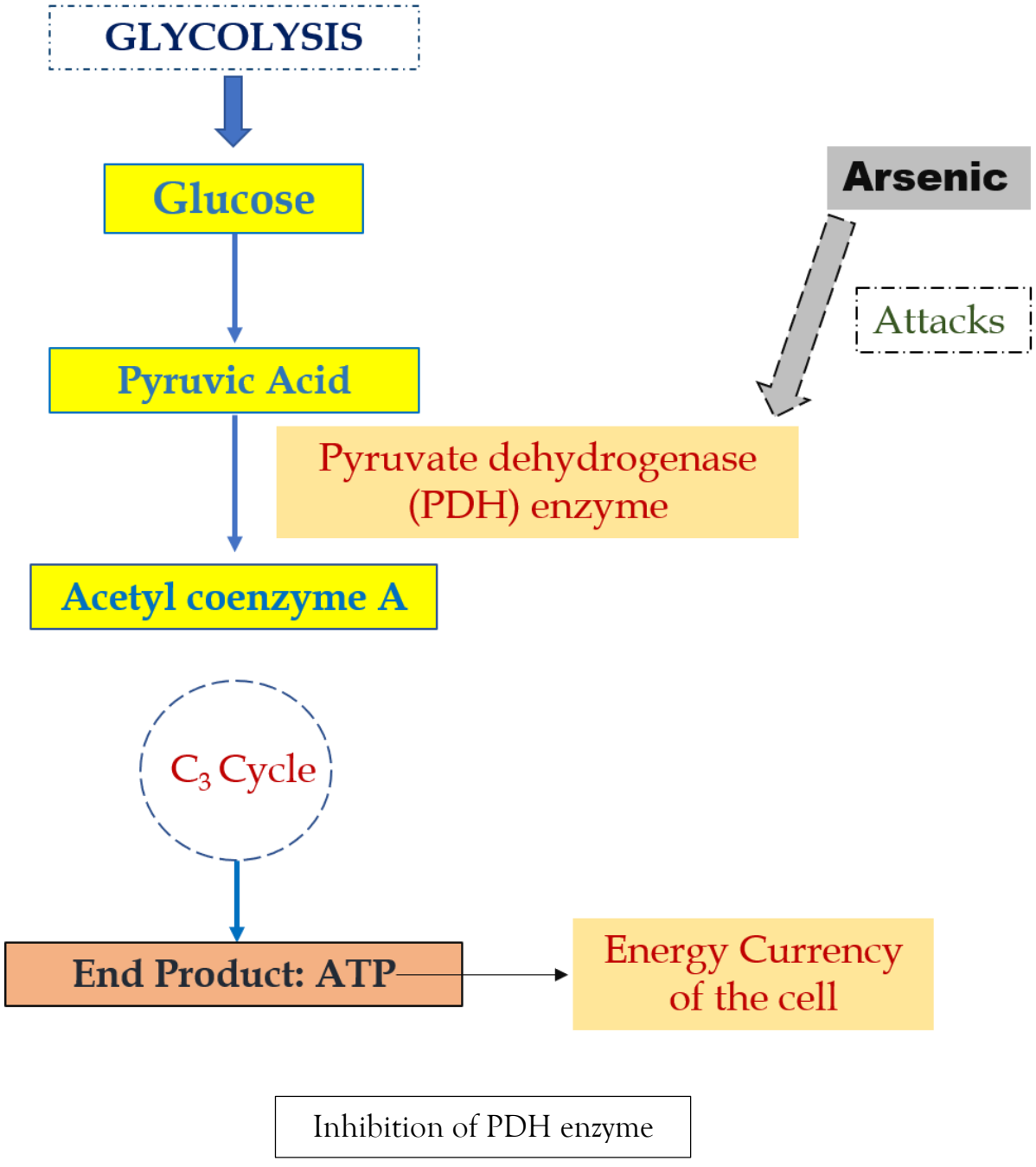
EFFECTS

Arsenic pollution causes Black foot disease. It is a form of peripheral vascular disease in which the lower limbs are severely damaged resulting in gangrene.

As^{+3} also inhibits Pyruvate dehydrogenase (PDH), resulting in no production of Adenosine triphosphate (ATP) in the human body.

Blackfoot disease

Source: Community Health Rehabilitation Program



Inhibition of PDH enzyme

CHROMIUM (Cr)

Chromium has various oxidation states (+1, +2, +3, +4, +5, +6, +7) but as per the environment perspective, Cr^{+3} and Cr^{+6} are important forms that are required to be decided.

SOURCES:

- Paint Industry
- Tannery Industry (leather coloring industry)
- Stream Plants and boilers
- Electroplating Industry

Out of the two forms, Cr^{+3} is a non-toxic form while Cr^{+6} is a toxic form.

Cr^{+3} is an essential nutrient that helps in lowering blood sugar levels in our body by improving the efficiency of Insulin (which helps in the digestion of sugar). The deficiency of Cr^{+3} in our body can lower the effectiveness of insulin, ultimately leading to high sugar levels.

The toxic form of Chromium (Cr^{+6}) causes gastrointestinal tract (GIT) cancer, hence injurious to health.

DO YOU KNOW?

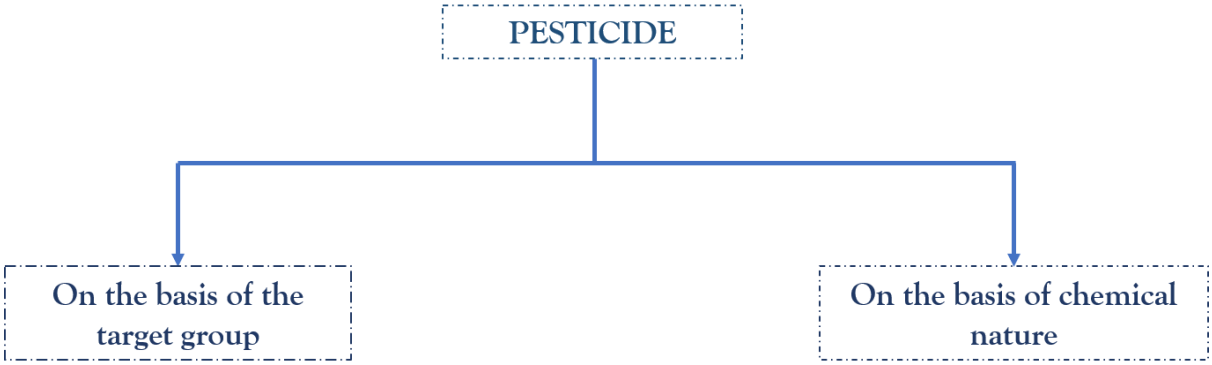
Soil act as a detoxifying agent by reducing the toxic and soluble form of Chromium (Cr^{+6}) and converting it into the non-toxic and insoluble form of Chromium (Cr^{+3}).

PESTICIDE

Pesticide is a general term used for insecticide, herbicide, fungicide, rodenticide, etc.

DO YOU KNOW

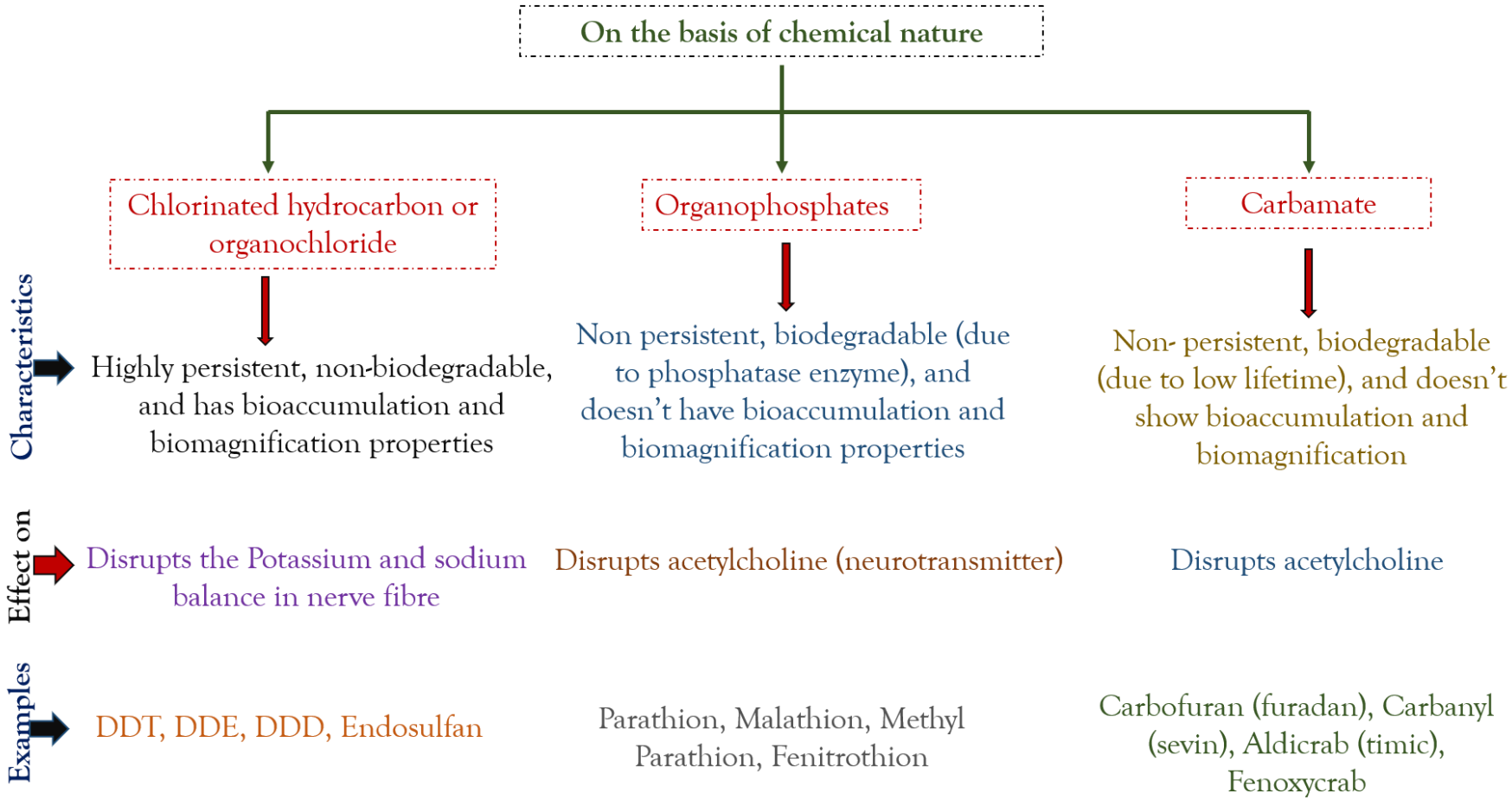
Pesticide can be broken down into two words i.e., cide = to kill and pests.



Based on the Target group, Pesticides can be divided as follows:

S.no	Pesticide	Target Group
1.	Fungicide	Fungus
2.	Insecticide	Insects
3.	Rodenticide	Rodents
4.	Weedicide	Weeds
5.	Bactericide	Bacteria
6.	Herbicide	Herbs, plants
7.	Avicides	Birds
8.	Algicides	Algae
9.	Lampricide	Lampreys
10.	Miticide	Mites
11.	Molluscides	Molluscs
12.	Nematocide	Nematotodes
13.	Simicide	Slime molds, alage, bacteria
14.	Virucide	Virus

Based on the chemical nature:

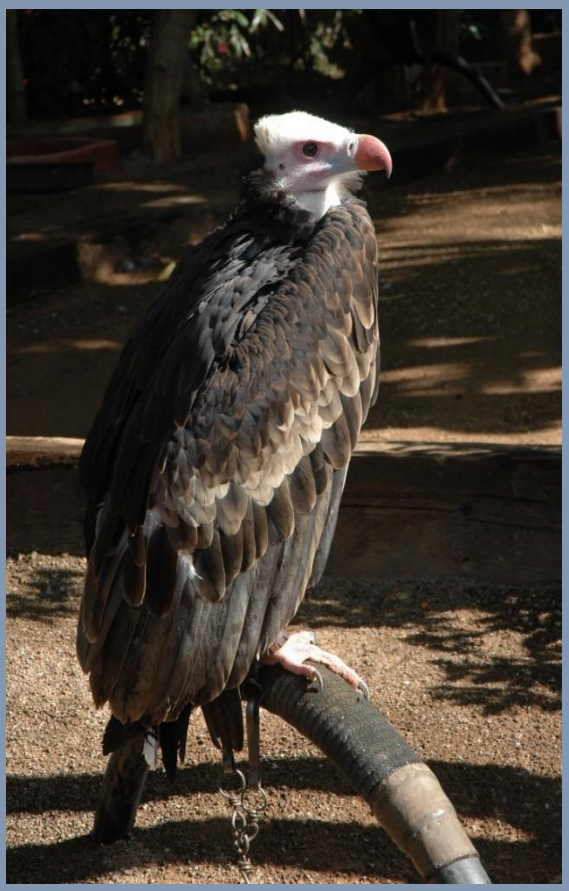


TESTING KNOWLEDGE

Can you name one pesticide derived from natural materials like animals, plants, and certain bacteria.

HAVE YOU HEARD ABOUT THE DECLINING POPULATION OF WHITE BALD-HEADED VULTURE??

Sodium diclofenac was given as medicine to animals such as cows and buffalos, and after their death, the vulture that eats the carcasses of such animals was not able to form eggshells. This is because the Sodium ion interferes with the calcium ion (from calcium carbonate) and vultures cannot properly form their eggshells.



White bald- headed vulture

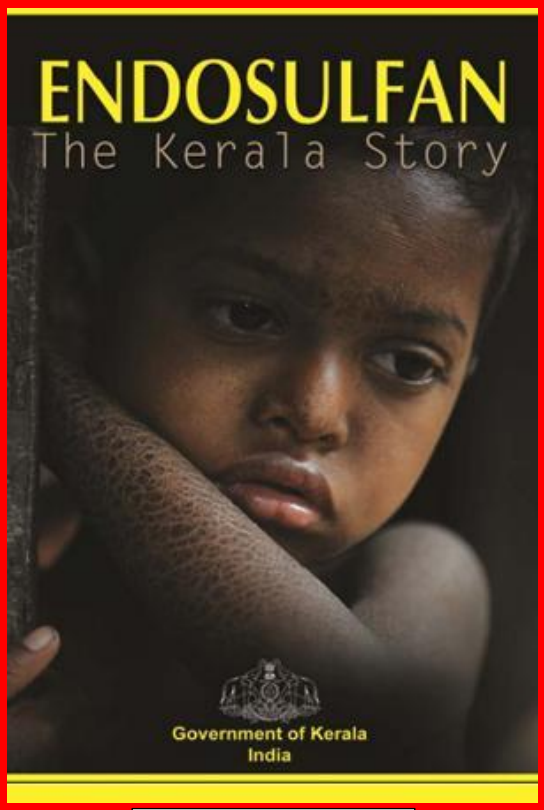
Source: Wikipedia

REVISION TIME

Which process was responsible by which the animals (cows and buffaloes) were not able to excrete out sodium diclofenac from their body?

HAVE YOU HEARD ABOUT THE TOXICITY IN KASARGOD, KERALA???

Endosulfan was majorly used to increase the productivity of cashews in the Kasargod village of Kerala. This poisonous pesticide spread in the whole environment and almost thousands of people were killed and poisoned. The pesticide had a detrimental effect on children. Many were born with congenital disabilities, physical and mental disabilities, cerebral palsy, and disease of the nervous system to name a few.



Source: CSE India

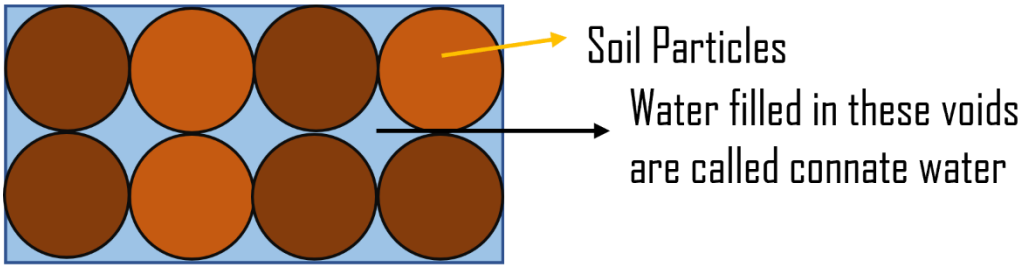
DIFFERENCES BETWEEN

BIOACCUMULATION	BIOMAGNIFICATION
Accumulation of toxic substances in the body of an individual organism/ plant/ animal.	Accumulation of toxic substances across the food chain and food web and concentration increases with each trophic level.
Associated with a particular trophic level	Associated with a food chain or food web.

Groundwater pollution

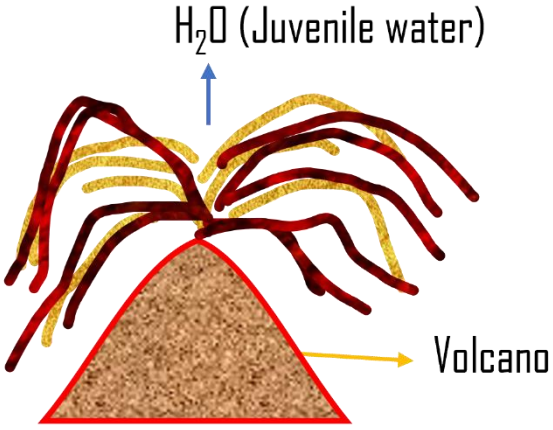
To know about groundwater pollution, it is important to know about the different types of groundwater. Basically, it is of four types:

1. Connate water



CONNATE WATER

2. Juvenile water/ New water



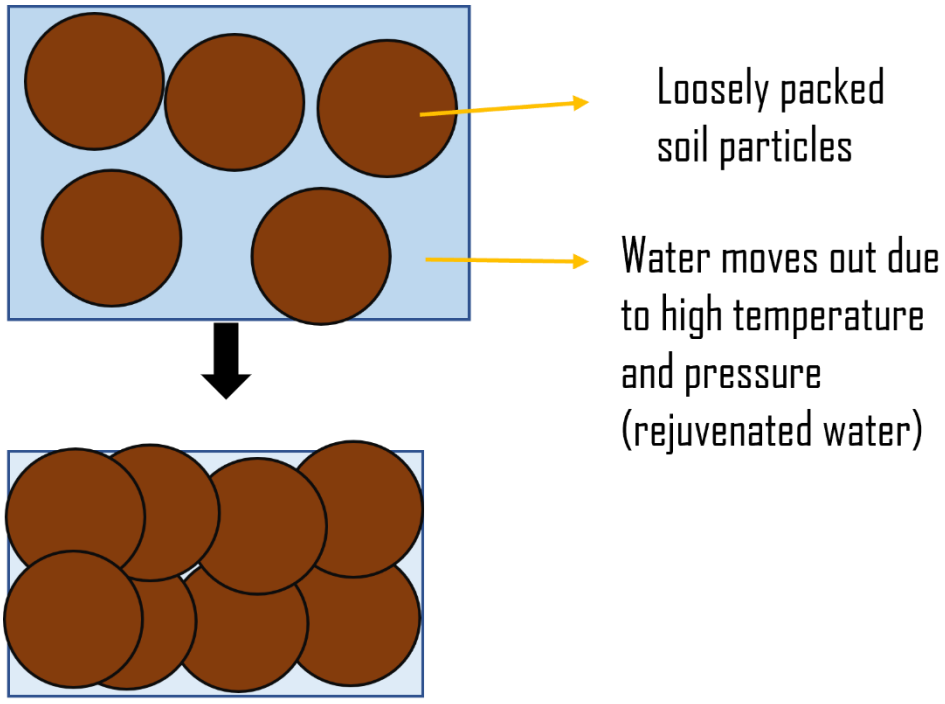
JUVENILE WATER

3. Meteoritic water

METEORITIC WATER

Water that comes from rainfall, is called Meteoritic water.

4. Rejuvenated water



REJUVENATED WATER

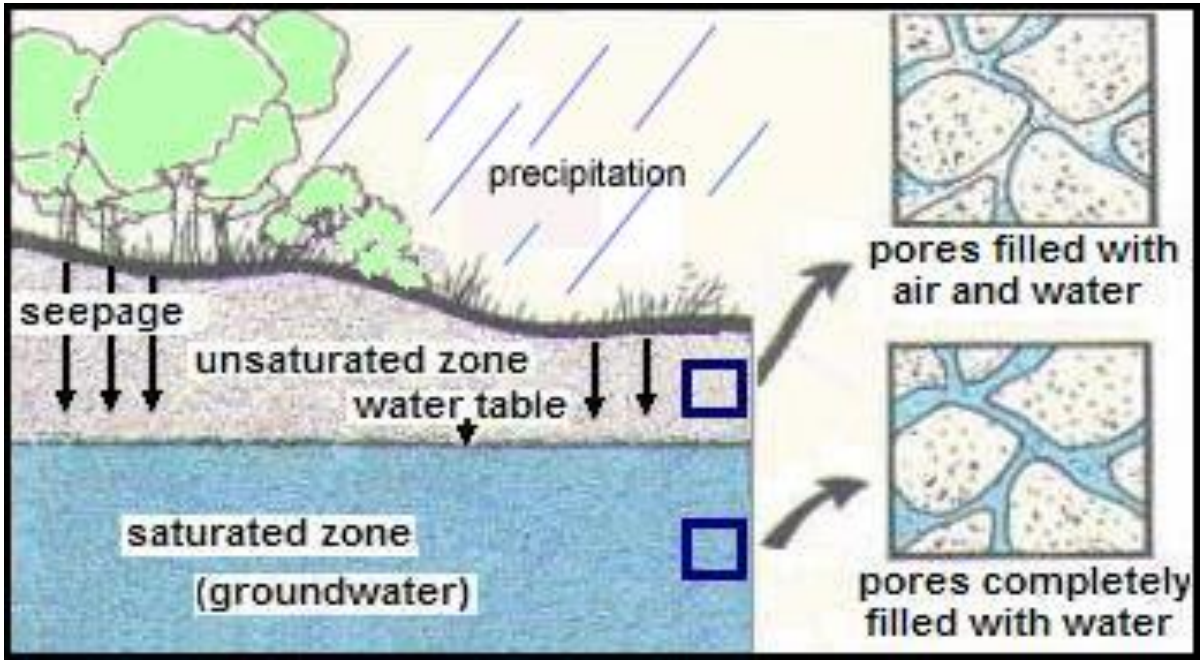
GROUNDWATER ZONES

UNSATURATED ZONE/ ZONE OF VADOSE WATER/ZONE OF AERATION:

The zone where all the soil pores are filled with water and air.

It further classified in 3 categories:

- *Soil water zone*
- *Immediate Vadose Zone*
- *Capillary Zone*



Source: New York State Department of Environment Conservation

Soil water zone is available to plants and hence it is subjected to transpiration and evaporation.

ZONE OF SATURATION:

Soil pores are filled with water only and not air.

DO YOU KNOW

The water below the water table is called groundwater.

DIFFERENCE BETWEEN POROSITY AND PERMEABILITY

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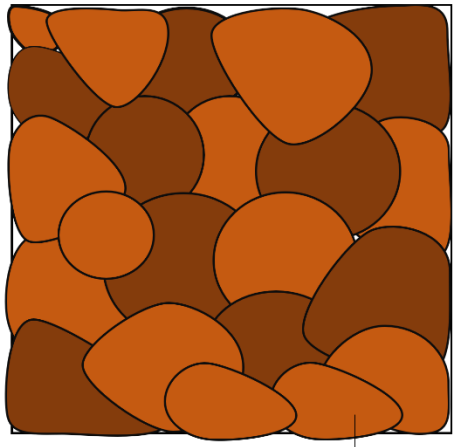
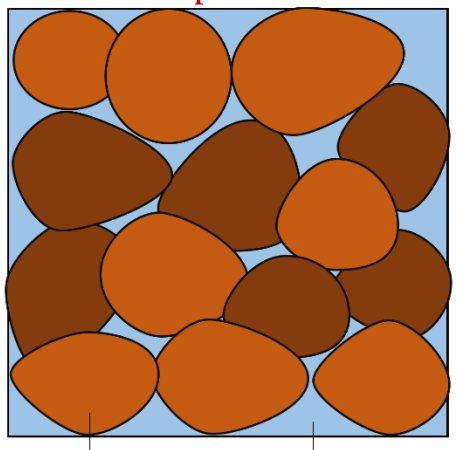
Porosity: water holding capacity of materials

Permeability: how well the materials allow the flow of water

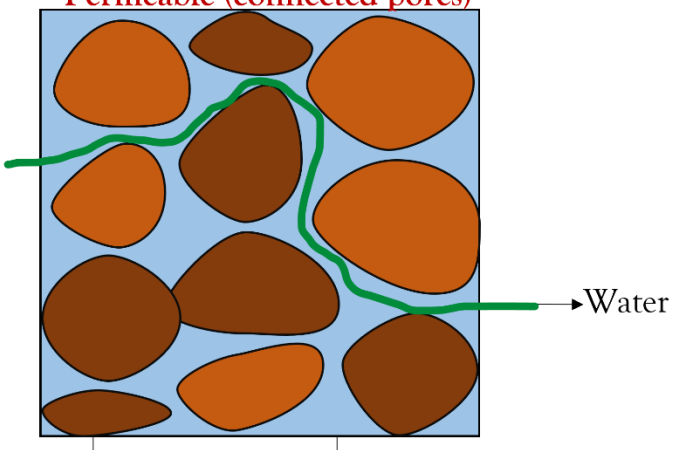
Non-porous
Non-permeable



Porous
Non- permeable



Porous
Permeable (connected pores)



- **All permeable materials are porous.**
- **Porous materials may or may not be permeable.**

DIFFERENCES BETWEEN AQUIFER, AQUICLUDE, AQUITARD AND AQUIFUDGE

AQUIFER	AQUICLUDE	AQUITARD	AQUIFUDGE
The material that can hold as well as transmit water.	The material which can hold but can't transmit water.	The material that can hold and transmit water, but its permeability is not sufficient for making wells.	The material that can neither transmit or hold water
Unconsolidated gravel, sandstone	Clay	Sandy clay	Solid granite, igneous rock

Aquifers can be classified in two categories:

- *CONFINED AQUIFER*
- *UNCONFINED AQUIFER*

CONFINED AQUIFER:

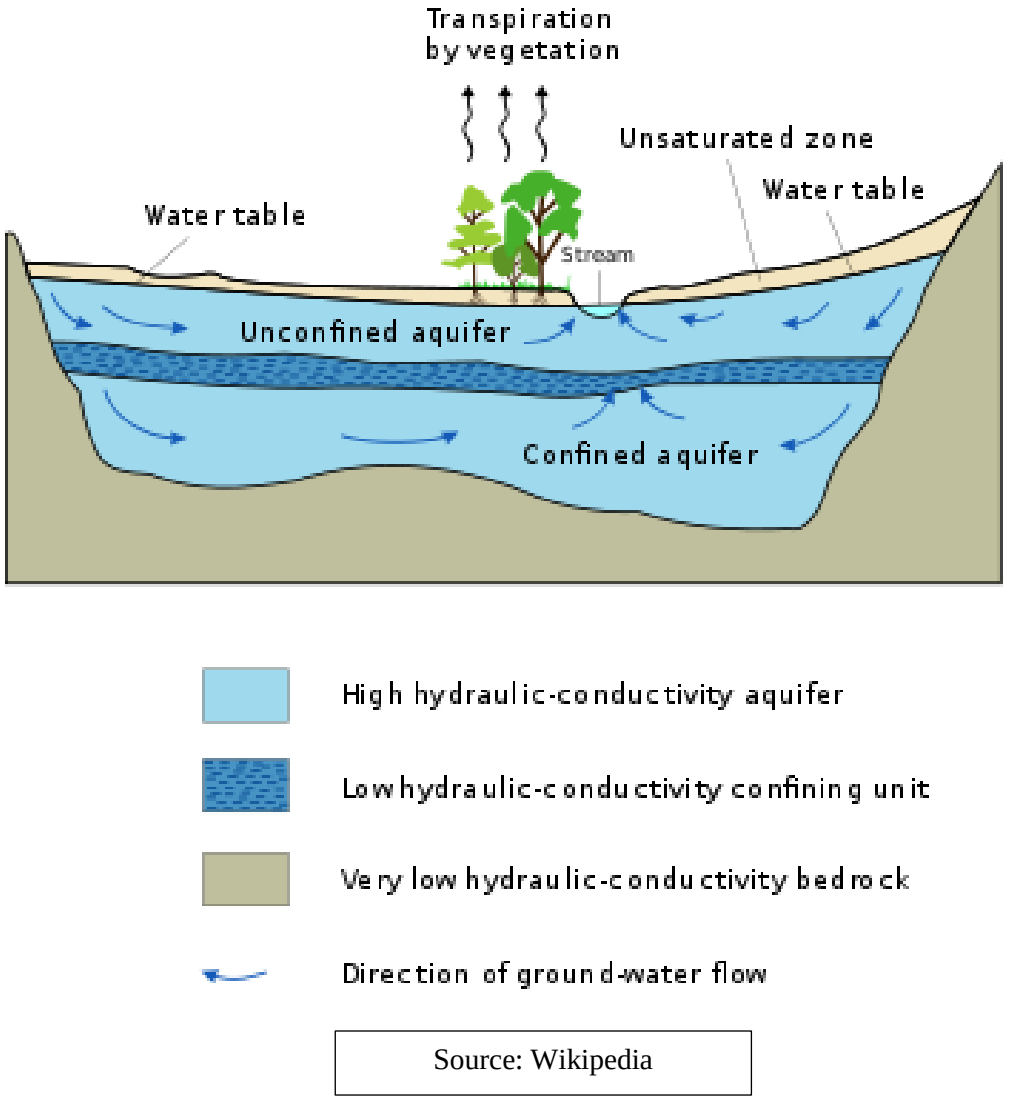
Many permeable aquifers are bounded by low permeability bed from above and below and water can't flow through them, this is called a confined aquifer.

Direct recharge is not possible in confined aquifer.

UNCONFINED AQUIFER:

Water table is not bounded by any impermeable layer above it.

Direct recharge is possible in an unconfined aquifer.



Source: Wikipedia

ARTESIAN WELL:

If a well is built in a confined aquifer, it has more pressure and water will naturally rise above the surface of confined aquifer.

GROUNDWATER POLLUTANTS

Fluoride Pollution

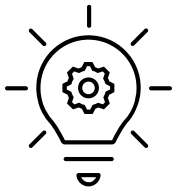
In small doses, it causes adverse effects on dental systems and can lead to dental caries. At high doses, it can cause dental fluorosis.

Arsenic Pollution

Causes black foot disease.

Nitrate Pollution

Causes blue baby syndrome/ methemoglobinemia in babies.



TESTING KNOWLEDGE

Can you tell why blue baby syndrome happens only in babies?