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# Risk Assessment process of ground water pollution

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**Abstract**
Ground water is the most valuable and scarce resource, and it can contaminate or pollute easily, due to which, the freshwater quality becomes expensive and difficult to restore. Therefore, many scientific tools are developed by the Environmental Protection regulatory agencies to protect the water quality in theearth's ground water segment. Water gets collected underneath the surface of Earth. Groundwater stems from melting snow, ice and from rain. It percolates into the ground, to fill the empty spaces in porous rocks, sediment, and soil. Springs, Aquifers, and wells remain the main supply source and the groundwater flow.
The water flows perennially is subject to heavy stress, due to its constant use for recreation, industry, water supplies, agriculture, and hence, it can easily get contaminated. Natural groundwater sources are contaminated because of mining like anthropogenic activities and also due to open dumping of domestic and industrial wastes leading to deprive groundwater quality.
The pollution prevention and manipulation of groundwater is provided prior to evade expensive remediation because groundwater pollution is complex, invisible, and generates a long-lasting impact. This review paper assesses the groundwater pollution risks due to several pollutants.

**Keywords:** Groundwater pollution, Risk Assessment, Environmental Microbiology, Viruses, Bacteria, pathogens

## Introduction
Groundwater contamination or pollution occurs when a variety of pollutants move unrestricted on the ground, to make the way towards and into the groundwater**.** Also, by natural means, it can rally with minor unwanted contaminants, constituents, and impurities join the groundwater**,** and they are dangerous to human health of consumed.
Groundwater, the most vital water resource, is constantly impacted by agriculture, industry, human activities and mining. The risk assessment of Groundwater is a prime issue because contained groundwater and aquifer are intrinsically susceptible to contamination from anthropogenic influence and land use (Zhang, *et al.*, 2013) [41].
The NRC, National Research Council, 1993 has recognized four categories for the analysis of groundwater vulnerability, and they are: program management, policy development and analysis for land use assessment, and also to improve the awareness of hydrology region resources (Tartakovsky, 2007) [31].

## Relevance
Groundwater contamination occurs specifically when the pollutants from the air and ground surface joins the groundwater. These pollutants generate a contaminant plume within the aquifer, while water pollutant dispersion and movement within the aquifer stretch and multiply over a wider area. The advancing boundary level, called a plume edge, intersects with groundwater through springs and seeps making the water unsafe for wildlife and humans. The plume movement or a plume front, can be analyzed by a groundwater or hydrology transport model. The groundwater pollution analysis can be conducted to obtain the soil characteristics, site Hydrology, Hydrogeology, Geology to identify the nature of the pollutants and contaminants (Stigter, Ribeiro & Carvalho, 2006) [30].
Also, water contamination can happen due to wrong landfills, sanitation systems, from wastewater treatment plant effluent, petrol filling stations, leaking sewers, by agricultural fertilizers, from naturally created contaminants, like fluoride or arsenic. They are hazardous to human health, can produce poisoning and the spread of diseases. There are various

Mechanisms to influence pollutant transportation like precipitation, decay, adsorption, diffusion in the groundwater. Further, any groundwater contaminant interaction with surface water can be analyzed by the use of transport model hydrology (Huan, Wang, Zhai, *et al.* 2016) [17].

## Analysis, Synthesis, Interpretation

### Ground water balance equation

The ground water stability and balance equation can be considered with several different components of inflow and outflow, and it can be specified as:

$Ri + Rc + Rr + Rt + Si + Ig = Et + Tp + Se + Og + \Delta S$

Where, Ri = Rainfall Recharge; Rc = Canal Seepage Recharge; Rr = Field Irrigation Recharge; Rt = Recharge through tanks; Si = River Influent seepage;Ig = Basin water inflow; Et = Evapotranspiration; Tp = ground water draft; Se = effluent seepages in the River; Og = outflow to many basins; and ΔS = groundwater storage changes (Chandra, Satish, 1979; Walker & Fitzsimmons, 2019) [5, 34].

This equation is valid for one aquifer process and does not Include inter flow between various aquifer system.

The unseen microorganisms prevail in their single-cell, or in a colony cell format in the environment is ubiquitous and diverse in origin. These microorganisms are always present in the environment, are fundamentally diverse from clinical isolates and laboratory-maintained microbes, because they are accustomed to widely fluctuating and often harsh environments. In their smallest form, these organisms are known as viruses, and do not carry any metabolic reactions and hence require a host space for self-replication. They are unique, consisting mainly of proteins and nucleic acids, technically not viable, the surviving organisms. All the biological entities have nucleic acids as RNA or DNA. In the study of environmental microbiology, they are categorized as microbes, prokaryotes, eukaryotes, and clearly have an effect on human health, but they are very essential to maintain life. The below table explains these details. Prokaryotic form Bacteria and Actinomycetes, while the bigger and complex organisms involve protozoa, algae, and eukaryotic fungi (Pepper, 2019) [25].

**Table 1:** Environmental Microbiology (Ian Pepper, Gerba &Gentry, 2015) [19].

| Activities | Environment and Matrix | The Impacts they make | Microorganism involved |
|---|---|---|---|
| Municipal wastewater treatment | Wastewater | Waterborne disease reduction | Escherichia Coli- E Coli & Salmonella |
| Water treatment | Water | Waterborne disease reduction | Noro-virus &Legionella |
| Food consumption | Food | Foodborne disease | Clostridium botulinum & E Coli O157:H7 |
| Indoor activities | Fomites | Respiratory diseases | Rhino-virus |
| Breathing | Air | Legionellosis (Legionella Pneumonia) | Legionella –pneumophila |
| Enhanced microbial antibiotic resistance | Hospitals | Antibiotic-resistant microbial infections | Methicillin Resistant &Staphylococcus aureus |
| Nutrient cycling | Soil | Maintaining cycling of Bio-Geochemical | Soil heterotrophic bacteria |
| Rhizo-sphere & Plant interaction | Soil | Enhanced growth of plant | Rhizobia& Mycorrhizal fungi |
| Bio-remediation | Soil | Degradation of toxic organics | Pseudomonas |

These Viruses create significant effects and have the capability to infect several other living organisms to cause diseases. Some Bacteria also can cause infection, but they have the capacity to convert inorganic and organic compounds. Also, Fungi can involve biochemical transformations, whereas, Algae affect sand pollutes surface water to develop microbial toxins. However, the overall pollution impact is not significant due to the existence of fungi and bacteria to oppose their harmful actions. Moreover, the protozoa make a significant pathogen sources that affect human health directly. For instance, the Cryptosporidium contamination of potable water resulted in more than 100 deaths in the year 1993 in Wisconsin (Pepper, 2019) [25]. Protozoa are very important grazers of bacteria in surface environment to help control and monitor bacterial populations. Fungi, bacteria, viruses, carry certain importance and significant applications to environmental issues. Some of them help ferment our favorite foods like miso, bread, soy sauce, tempeh, and wine.

However, certain fungi, protozoa, algae genera are naturally macroscopic, resulting from viruses and bacteria become entirely microscopic.

When minerals like iron sulfide are left open to the atmosphere, due to moisture absorption, the water turns acidic, enriched in iron, eventually leaving reddish-yellow deposit in its wake. Sulfide like metal reacts with atmospheric water to discharge toxic metals like cobalt, nickel, arsenic, copper, cadmium, and zinc.

Microorganisms are pervasive and vital ecosystem elements. They exist in every Autotrophic microorganisms, in the form of algae and bacteria (Cyanobacteria) to supply oxygen to aquatic ecosystem and produce the photosynthesis process. They absorb inorganic substances taking the help of the sun rays to transform into organic elements for nourishment. Therefore, Autotrophs are the main producers to initiate the food chain. Bacteria and Fungi like Heterotrophic microorganisms carry an aquatic ecosystem irreplaceable role to decompose complex organic matter into simple ones that will be later used by Autotrophs in the production of organic matters (Gribaldo, & Brochier-Armanet, 2006) [15].

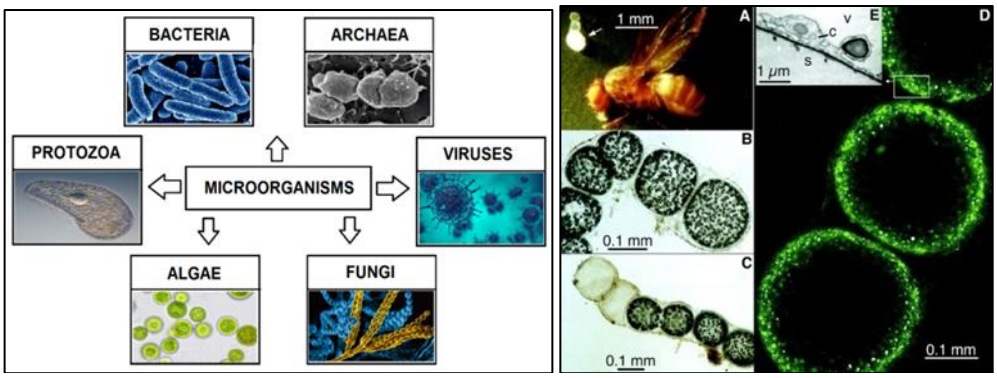


**Fig 1:** Microorganisms, the unseen and mysterious (Gribaldo, & Brochier-Armanet, 2006) [15].

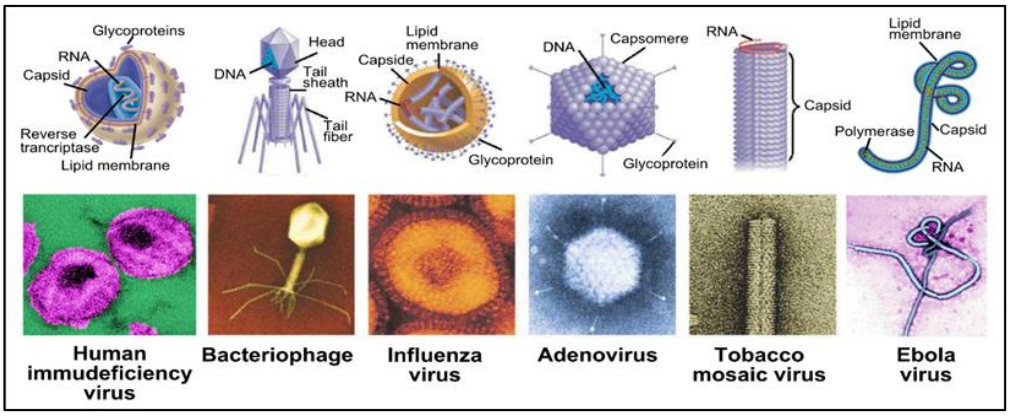


**Fig 2:** Aquatic microorganism Role in the recycling of matter (Leliaert, *et al.*, 2012) [23]

Contamination of drinking groundwater can generate severe health problems. The initiation of diseases like dysentery and hepatitis is mainly caused due to septic tank water contamination from waste. Also, poisoning is the result of toxins leached into sources of well water. Several long lasting effects like cancer can result from polluted ground water exposure, including the harm done to wildlife (Bai & Wang, 2009) [2].

## Objectives

**To identify and explore the reasons and risks due to ground water pollution.**

## Learning experience from the Present and Past

The science and society have shown their inability to assess the ground water contamination risk entirely in a timely manner and demonstrated by assessing how industrialized field and societies have so far dealt with the situation related to pollution of groundwater. For instance, since the commencement of the 20th century, in the western countries, various instances of ground water pollution due to unregulated compounds and unrestricted use of chemicals were reported (Walker & Fitzsimmons, 2019) [34]. Similarly, there was a scene of unregulated use of weed killer, 2, 4-D, observed to have polluted many wells in several places in groundwater (Huan, Zhang & Kong, *et al.* 2018) [18].

Environmental Protection Agency EPA is an independent executive branch agency to control and abate environmental pollution. The agency deals with independent programs related to toxic substances, pesticides, solid waste, water, radiation and air. There are separate programs to manage, monitor and protect groundwater quality (Fan, 2007) [9]. Their risk management depends on regulating specified chemicals, overlapping environmental management and complicated control programs that are put in place. Every program is linked to the water quality standard concept, as a result the risk assessment process was assigned to find the hazard level of specific chemicals in ground water as per the standards. The risk assessment of the traditional process is included for food additives and toxicology testing (Firouz Darroudi & Volker Mersch-Sundermann, 2010) [13].

The EPA procedure of risk assessment depends on the assumption that, as executed, the ground water or drinking water should not pose a problem, threat or risk to the public health. The statistical model is used by them to justify and ensure that the standards selected to control and release certain specified chemical pollutant level into the water resources, to regulate pollution should be "protective of the environment and human health" (Miklas Scholz, 2016) [24].

There seems to be unregulated pesticides observed in the resources of drinking water. When humans consume a chemical pollutant mixture of water and food suggests that the overall chemical exposures should be considered while evaluating their probable impact on human health (Sónia Rodrigues, & Römkens, 2018) [27].

## The current position of knowledge

The groundwater contaminants include a large variety of radioactive physical, organic chemical, inorganic chemical, and bacteriological parameters. Predominantly, several similar pollutants play the role to influence the groundwater pollution even though their respective value may differ (WHO, 2006) [12, 35].

## Fluoride and Arsenic

Fluoride and Arsenic are known by the WHO- World Health Organization as serious contaminants of inorganic chemicals

existing in drinking-water on a global basis (WHO, 2006) [12, 35].

In groundwater, the Metalloid Arsenic is produced naturally as observed very frequently in the entire Asian countries (Ravenscroft, 2007). In the Plain of Ganges severe naturally occurred groundwater contamination was identified by arsenic affecting 25% in the water wells in all the two shallow regional aquifers.

When there is mine waste dumping or mining operations going on, the Arsenic in groundwater can be observed because the water will leach arsenic.

In groundwater, natural fluoride remains a growing concern because the deeper levels of groundwater areutilized, and hence, above 200 million people in the surrounding regions are at elevated risk when they consume the drinking water with such large concentrations (Smith, Cross, Paden, & Laben, 2016) [28]. Basically, Fluoride comes from volcanoes, acidic rocks and there on the volcanic ash is dispersed when the hardness of wateris low. High contents of fluoride remaining in the groundwater can pose serious problems to Mexico, the Argentinean Pampas, the East African RiftChile, Pakistan, India, and other volcanic islands (Custodio, 2013) [5].

Skeletal and dental fluorosis are prevalent and have severe effects in areas and regions where the groundwater have the contents of naturally occurring large fluoride levels used for drinking water (Fawell, Bailey, Chilton, & Dahi, 2006) [12, 35].

**Pathogens**

In the absence of proper and effective sanitation measures, and improper location of wells, they can lead to contamination of drinking water due to the presence of pathogens, which carry feces with urine. They develop and transmit fecal and oral diseases that include diarrhea and cholera (Wolf, Nick, & Cronin, 2015) [36]. Out of the four types of pathogen present in the form of feces are viruses, bacteria, helminths, protozoa, and helminth eggs. They are mostly observed in polluted and contaminated groundwater, while comparatively large eggs of helminth get filtered, and removed from the soil matrix (Wolf, Prüss-Ustün, Cumming, *et al.* 2014) [37].

Living organisms can be classified into three types of features, like Eukarya, Archaea and Bacteria domains and they are shown in the below figure (Creative Diagnostics, 2019) [6].

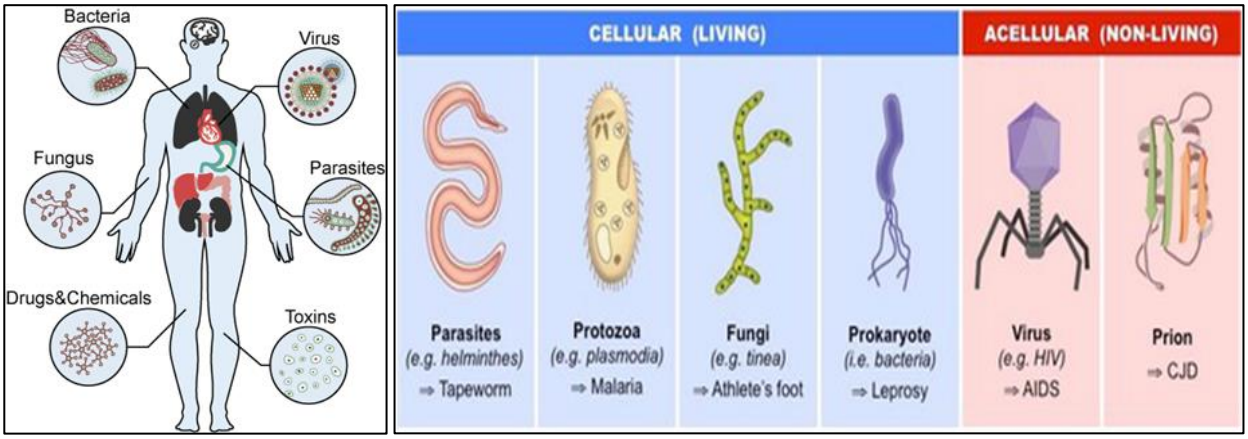


**Fig 3:** The multiplication and invasion of microorganisms like viruses, bacteria, parasites and fungi lead to illness and tissue injury by a variety of toxic and cellular mechanisms (Creative Diagnostics, 2019) [6].

Confined and deep aquifers are normally considered to be the safest and secure drinking water source in connection with all types of pathogens. When Pathogens out of wastewater, treated or untreated, can easily contaminate shallow, aquifers (Bacteria and Their Effects on Ground-Water Quality, 2017).

**Environmental Contaminants and Management System**

**Nitrate**

Nitrate remains as the highly widespread chemical contaminant in the groundwater globally in all aquifers (Ross, 2010) [26]. In certain underdeveloped and low-income nation the level of nitrate in groundwater is enormously high, and they cause exceeding health problems. The nitrate condition remains stable, does not degrade, even under excessive oxygen conditions (WHO, 2006) [12, 35].

Above 10 PPM, (10 mg/L) Nitrates in groundwater can initiate the acquired Methemoglobinemia disease called "blue baby syndrome" (Knobeloch, *et al.*, 2000) [22]. The quality of drinking water in the European Countries specifies below 50 mg/L nitrate contents in drinking water (Fewtrell, 2004) [11]. This syndrome outbreak occurs mainly due to the elevated nitrate concentration in drinking water, which mainly caused due to sewage sludge contents of disposal, sanitation condition on-site and other agricultural activities in the nearby regions. Therefore, the excessive nitrate contents in the groundwater have basically an agricultural origin in the urban regions (Custodio, 2013) [5].

**Major Organism Groups in ground water**

Groundwater is located underground in soil spaces, sand, rock and cracks, stored in these places and moves gradually through rocks, soil, sand, aquifers as the geologic formation.

- Groundwater is provided as drinking water for 98% of the rural population;
- Groundwater also provided for agricultural use to grow food. In such conditions, 68% of groundwater is utilized to grow crops and for irrigation;
- Groundwater is a vital component in several industrial activities;
- Groundwater is a recharge source for rivers, lakes, and wetlands.

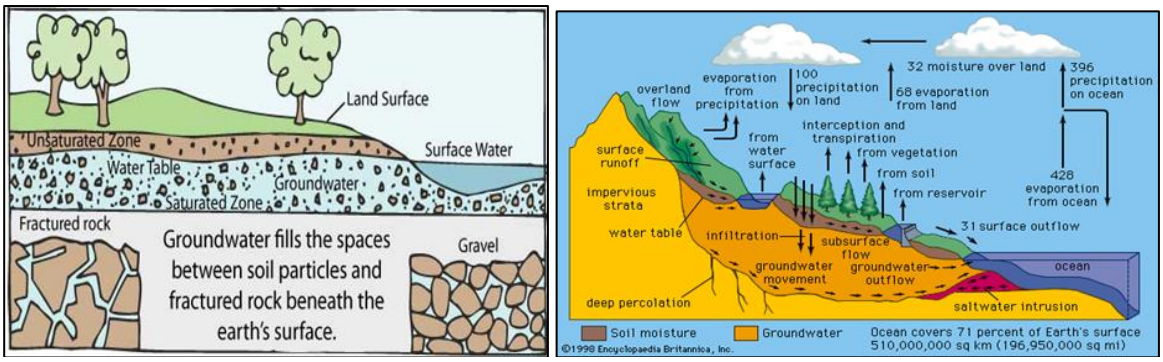


**Fig 4:** Major Groups of Organisms in ground water and Groundwater supply system, Hydrologic Cycle (The Groundwater Foundation, 2019)

**Organic compounds**

VOC is known as Volatile organic compounds, which are very precarious and dangerous groundwater contaminants. They have normally come from the atmosphere by careless industrial activities. Several such compounds and chemicals not known as very harmful. After 1960, frequent groundwater testing identified the chemical substances in all the sources of drinking water near industries.

Most important VOC pollutants were observed in groundwater involved BTEX compounds of aromatic hydrocarbons like xylenes, benzene, ethylbenzene, toluene and certain chlorinated solvents inclusive of Tetrachloroethylene  PCE, Trichloroethylene, PERC, TCE, and VC- vinyl chloride. BTEX is useful gasoline components. They are industrial solvents specifically used in processing of dry cleaning, metal Degreasers, and so on.

There are several organic pollutants prevail in groundwater everywhere and they are mainly arriving from various types of industrial activities of the PAH- Polycyclic aromatic hydrocarbon. Naphthalene is highly soluble due to its molecular weight. There is mobile PAH discovered in groundwater, while Benzo (a) Pyrene  , a Polycyclic Aromatic Hydrocarbon, the most toxic chemical remains in groundwater. PAH is normally generated as byproducts of organic matter due to their incomplete combustion.

In groundwater, organic pollutants are also observed in the form of herbicides and insecticides. Several other organic, synthetic compounds, mainly pesticides generate a complicated molecular structure. The complexity ascertains the solubility of water, pesticide mobility, adsorption capacity in the groundwater structure. Therefore, certain kind of pesticides remain highly mobile, while others can reach the drinking-water source more easily (Ravenscroft, 2007).

**Metals**

Naturally occurred several metal traces in various rock formations can remain in the environment due to natural procedures like weathering process of exposure to the atmosphere. However, many industrial actions like solid waste disposal, mining, paint/enamel work, metallurgy can raise the toxic metal concentration because of cadmium, lead, chromium, as these contaminants have the tendency to locate their route into groundwater (AGW-Net, 2016) [1].

The metal migration in groundwater is affected by many factors, specifically by chemical reactions that determine the contaminant partitioning among various species and phases. Hence, the mobility of metal, basically depends on their pH value and groundwater Redox condition, whose potential is normally reported as Eh (Smith, *et al.*, 2016) [28].

**Pharmaceuticals**

There are traces of pharmaceuticals coming from wastewater treatment infiltrated into the aquifer source and they emerge as the ground-water contaminants. There are well-known pharmaceuticals like antibiotics, antidepressants, anti-inflammation chemicals, tranquilizers, decongestants, and so on, which are generally observed in the wastewater after treatment. This polluted wastewater is sent to the treatment facilities, and mostly makes the road into the water source or aquifer, from where the drinking water is obtained (Vahidnia, Van Der Voet & De Wolf, 2007) [33].

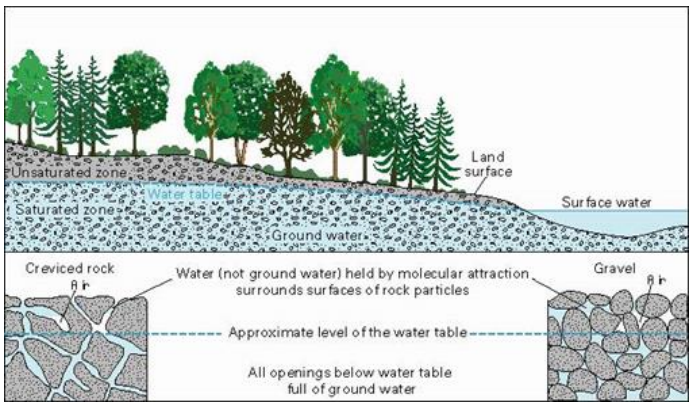


**Fig 5:** Rain water percolates the soil to reach the water table (Gibsons Alliance, 2016). The traces ofpharmaceuticals in a small amounts route through in groundwater far below the dangerous level in many areas, but they can create increasing problems when the population grows and more wastewater is used for the municipal water supply (Chandra, Satish 1979; Custodio, 2013) [5]

The traces of pharmaceuticals in a small amounts route through in groundwater far below the dangerous level in many areas, but they can create increasing problems when the population grows and more wastewater is used for the municipal water supply (Chandra, Satish 1979; Custodio, 2013) [5].

**Others**

There are many different organic pollutants including a variety of chemical compounds like organo halides and various petroleum hydrocarbons, observed in cosmetic products, personal hygiene, pollution due to various drugs including pharmaceutical drugs and their respective metabolites. Moreover, Inorganic pollutants include nutrients like ammonia, phosphates, radionuclides like uradon (Rn), uranium (U) and naturally existing in certain geological formations. The intrusion of Saltwater also acts like natural contaminants, but it is further intensified by acute human activities.

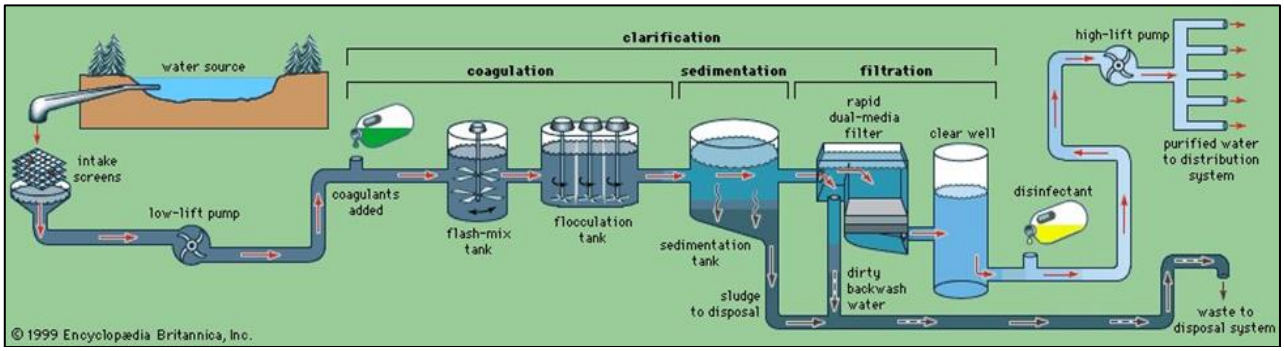


**Fig 6:** Aquifer and groundwater supply route (Salako Adebayo & Adepelumi Abrahim, 2017)

**Conclusion and Discussion**

Water carries a very crucial and critical tendency to dissolve several substances and this is observed rarely in nature in their pure condition. During the rainy season, along with rainwater, a small quantity of gases like carbon dioxide and oxygen gets dissolved in water, while raindrops carry small dust particles along with other substances. As water flows above the ground level, it collects fine particles of soil, organic material, microbes, and minerals. In swamps, bogs, lakes, water obtain different tastes, colors, and various odors from natural organic matters and decaying vegetation. Groundwater normally acquires dissolved minerals more than surface runoff due to its extended direct contact with rock and soil. It further absorbs gases like methane and hydrogen sulfide. In the case of populated regions, the surface water and groundwater quality are directly impacted by human activities and land use. For instance, storm water runoff gets contaminated due to fertilizers, pesticides and agricultural activities, along with motor oil, road deicing fluids and chemicals that flow into lakes and streams. Further, effluents from septic tank malfunctioning and subsurface leaching field activities can percolate into groundwater.

**Groundwater quality monitoring**

There is groundwater quality assessing and monitoring programs implemented frequently in several countries globally. They become a vital component for understanding the Hydro-geological system and standards of water, and also to develop a conceptual model and vulnerability aquifer maps (WHO, 2006) [12, 35].

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