



Review Article

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The Impact of Sea Level Rise and Urban Flooding on Ground Water Quality in Municipal Areas of the Niger Delta, Nigeria

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To Cite This article: Aroloye O Numbere*, Keayiabarido Jude, Sobomate B Chuku, Miracle C Uzoma, Emmanuel B Bakpo, Peace Ohia, Emoyoma Udi¹, Princess Wome, The Impact of Sea Level Rise and Urban Flooding on Ground Water Quality in Municipal Areas of the Niger Delta, Nigeria. *Am J Biomed Sci & Res.* 2026 32(3) AJBSR.MS.ID.004151, DOI: [10.34297/AJBSR.2026.32.004151](https://doi.org/10.34297/AJBSR.2026.32.004151)

Received: 📅 September 12, 2026 **Published:** 📅 September 22, 2026

Abstract

Groundwater plays a crucial role in water resources and serves as a source of water supply in many rural and urban communities. There is an increase in urban flooding in the Niger Delta region of Nigeria as a result of coastal surges and increased precipitation leading to land subsidence. Multiple factors, including hydrogeological and climatic factors, facilitate coastal surge. For instance, anthropogenic factors such as increased sea level rise, dredging, blocking of waterways for developmental projects, and over-exploitation impact groundwater. In the Niger Delta, 60% of the river has been dredged for the establishment of roads and other projects. Coastal projects lead to the narrowing of the waterway, resulting in negative feedback by tidal surges resulting in the inflow of river water, which erodes the river bank and continuously wear away the bank and push saltwater upland. The combined activities of natural and human factors have worsened flooding, leading to groundwater contamination from polluted coastal and upland waters. Groundwater contamination impacts drinking water sources and can lead to public health problems. Many wells and boreholes in urban areas have been contaminated, leading to poor water quality. This study is thus conducted to provide information on groundwater contamination and proffer solutions to resolve the problem. It also involves recommendations and policy changes to help resolve the groundwater contamination issue.

Keywords: Chemical composition, Firewood, Mangrove, Multivariate analysis, Plastic

Introduction

The environment has a way of maintaining equilibrium in the midst of challenging conditions caused by humans and nature [34]. Anthropogenic activities such as pollution has pushed the earth to its limit by causing disasters such as climate change and global warming. The impact of climate change, which cuts

across international boundaries is the major cause of sea level rise. Sea level rise is caused by the melting of the polar caps at the arctic region as a result of increase in global temperatures [9].

Increase in water volume lead to increase in oceanic water globally. Global warming has effect on all parts of the earth that is

why global effort is needed in the fight to stop activities that results to global warming. Parts of Africa is surrounded by the Atlantic Ocean and increase in the volume of the ocean will have a negative effect on the continental shorelines. Increase in sea level will also impact the mangrove wetland in the Niger Delta by causing soil erosion and land accretion. Thus, if the coastal land loss continue to encroach on the land while increase in annual precipitation lead to flooding in the landward area of the city limits leading to the submergence of farmlands and houses. High volume of flooding stagnated by the lack of proper drainage impact the groundwater quality [32]. Urban flooding is facilitated by poor drainage system or no drainage. Thus, when rain falls it flows into people's home to cause colossal property damage.

Sea Level Rise and Urban Flooding

Sea level rise is an outcome of ozone layer depletion, which lead to increased temperature and the heating of the earth surface resulting to the melting of the polar caps. The melting of the arctic snow, which has been frozen for thousands of years increase the sea level, which over flows and has the potential of flooding coastal areas [13]. The addition of water to the ocean by few inches can raise the height of the sea leading to over flow and flooding. Many coastal communities are already being flooded by increase in water from upland areas as a result of increased precipitation. An additional tidal increase will further increase oceanic altitude resulting to urban flooding. The Niger Delta region is at the interface with the Atlantic Ocean at the southern part of Africa, thus global climate changes can have far reaching consequences on the landform, which host many aquatic and terrestrial organisms [7]. For instance, mangrove wetland will be first victims of increased flooding in Africa [16]. Increase in sea level from 64-126 cm per year will lead to the flooding condition that will affect millions of people and lead to loss of property in the range of billions of dollars [16]. The socioeconomic life of people living at the Atlantic corridors of Central and West Africa is affected. Most cities in West Africa are situated close to the Ocean or right at the tip of the ocean causing increased vulnerability [37].

Impact of Salt Intrusion in Plants

Increased concentration of salt in soil is facilitated by irrigation [38]. Irrigation is the artificial application of water to a dry land to aid crop production. Over-irrigation increased the water table, thus leading to water logging. Stagnant water percolate into the parent rocks to dissolve the sodium and calcium and chloride content releasing them into the soil [31]. The liquid chemicals migrate into the soil surface from the bed rock. It is reported that 20-30 million hectare of land is severely affected by salinity [36]. Among countries that practice irrigation United States (28%) and China (23%) have the highest percentage of area impacted by salinity [36]. Salinization is a major problem that destroys agricultural land. On a flip side irrigation is beneficial because it leads to poverty alleviation, provides employment, reduces hunger and prevents

environmental degradation. Land drainage is a way of reducing water logging and thus, salinization [14].

Water logging occurs when the water table rises and eventually approaches the soil surface rendering the root zone unsuitable for crop growth. Excessive wetting and water logging are generally accountable by oxygen (O_2) deficiency [23] because most pores are filled with water. This deficiency leads to increased resistance to transport of water and nutrients through the plant roots, reduction in root respiration, and formation of toxic compounds in soils and plants [21]. Except aquatic species (macrophytes), all plants will suffocate from excessive watering and waterlogging. Inadequate aeration in the root zone occurs when the effective air content falls below 5-10% by volume [6]. Plant sensitivity to wet conditions depends on temperature. Crops suffer more from waterlogging under warm weather because oxygen consumption is higher than in cold weather [35]. Moreover, evaporation rate in a warm climate is higher and hence the danger of salinity is greater in warm than cold weather. Waterlogging also has an adverse effect on soil biological life and on its structure. This impairs mineralization and nitrification by microbes resulting in nitrogen deficiency in crops. This deficiency can be reduced by using NPK fertilizer.

In tropical region with high precipitation excessive waterlogging occur from increased rainfall for a long period of time. In arid region over irrigation is the cause of waterlogging. Waterlogging may also occur as a result of seepage from high-laying lands into neighboring valleys. In the estuaries and wetland region of the Niger Delta, waterlogging is caused by high water table, which overflows onto land surface after a heavy downpour. Poor drainage system as well as blocked drainages also lead to overflow of drained water into land surface causing the water logging of the land.

The purpose of drainage in humid areas is not only to evacuate the surface runoff after a rain storm but also to lower the moisture content of the upper layer of soil to allow air to enter more easily to the roots. This will provide the needed oxygen to enter the root zone and facilitate the transport of carbon dioxide (CO_2) produced by roots. Microorganisms and chemical reactions in well-drained soils have higher temperatures which helps crop growth during rainy season.

Soil salinity refers to the soluble-salt content of the soil. When soil salinity increases to harmful levels, plants are subject to reduced osmotic potential of the soil solution and to toxicity of boron, chloride and sodium [3]. The original source of soluble salts are the primary minerals in soils and exposed rocks of the earth's crust [15]. Chemical decomposition and physical weathering release these minerals, which are usually transported by wind or water; water from natural surfaces or underground sources contains dissolved salts.

In tropical humid climate like the Niger Delta region of Nigeria where there is heavy rainfall, water pushed the salts deep down into

the groundwater aquifer and ultimately transported to the ocean by streams. In arid and semi-arid regions irrigation is the main cause of salts. The salts applied to the soil with irrigation water remains in the soil unless it is flushed out in drainage water or removed by harvested crops. The content of totally dissolved solids in irrigation water or the soil solution is usually expressed as a concentration

or as corresponding electrical conductivity. Mangrove have unique advantage by surviving saline environment because of their ability to eject salt from their leaves through defoliation (Figure 1).



Figure 1: Salt intrusion into mangrove trees via the roots is deposited in the leaves, which later falls off.

Characteristics of Salt-Affected Soils

The characteristics of saline and alkali soils was first introduced by the salinity laboratory of Riverside California [20]. Saline soils are defined as those soils for which the saturation extract is more than 4ds/m and exchangeable sodium percentage is less than 15. The pH of these soils is normally less than 8.5. The dominant anions are chlorides and sulfates. Few plants can survive in a waterlogged or salt-affected soil. Plant species differ widely in their tolerance to a high-water table or a high salt concentration. The groundwater table depth determines the state of moisture conditions during the entire growing season and therefore, influences water supply, aeration conditions and heat properties in soil. Crop yields decrease as depth of groundwater table decreases at shallow depths because the crops suffer from a lack of aeration. Salinity mostly impact germination and seedling growth in plants.

To reclaim salt-affected soil topographic survey maps and aerial photographs are needed [22]. The soil survey should be carried out in the project area to define the soil physical and chemical characteristics and dominant ions. Poor drainage is a common

feature of salt-affected soils. The first measure for reclamation is to install a drainage system to control the water table. The drainage system s. Some requirement for reclamation includes: soil texture and structure, soil pore geometry, cracking phenomena, initial salt content and the chemical composition of the soluble salts in the soil.

The Impact of Flooding on Wildlife

Over flow of water from drainages and river bank cause flooding in coastal and terrestrial environments [5]. Flooding occurs when the ground has been saturated by water as a result of continuous recharge by rainfall or groundwater. The addition of water down the soil profile pushes up the water table to the ground surface level making it impossible for the seepage of water into the soil. Further, addition of water results in the overflow of water along the earth surface resulting in flooding. The Niger Delta region is prone to flooding because it is surrounded by water bodies and has high precipitation and temperature levels. During the dry season the water table drops and no flooding occurs except there is an addition through irrigation. But during the wet season the groundwater gets recharged by external source of water e.g. rainfall, and river flow

and eventually become saturated with increased additions of water resulting in flooding in many coastal and upland communities.

The sloping relief and landform of the area cause water flow from upland to lowlands during flooding. Lowland areas are the coastal and wetland areas. Similarly, coastal flooding does occur seasonally in riverine communities as a result of the release of excess water from dams from neighboring countries (e.g., Cameroun). The surplus water volume often overwhelm many communities where forest, farmland, residential areas and the entire landscape is flooded. The flooding submerges animals and plants in their natural environment. Animals that are mostly impacted by floods are the walking and ground-dwelling ones but arboreal or flying organisms (e.g., birds, bats and insects) often evade the impact of flooding, but are still susceptible to impact when their breeding sites and egg-laying holes on the ground is washed away by the floods. Similarly, fishes too are impacted when flood water carry pollutants and waste products into the water body that is detrimental to their health. In addition, some fishes are flushed ashore by tidal surge and die on land. The list of organisms directly or indirectly impacted by floods are endless, but to mention a few are: antelope, bush rat, monkey, crocodile and turkey. Others organisms are crabs, ground-dwelling insects, lizard and snake. Although, birds fly away during floods, but those that lay their eggs in the soil have it damaged or washed away by floods. Monkeys climb to the tree top to evade the flooded water but can't come down to feed on the forest floor during flood. Burrowing organism are also impacted because their burrows are destroyed and their food stock in their burrows are washed away including their young ones.

Plants withstand flooding better than animals, but continuous flooding and the presence of standing water can lead to nutrient leaching down the soil profile out of the reach of the plant roots.

Impact of Flooding on Mangrove

Mangrove are hydrophilic plant, so they thrive in saline coastal environments. Thus, increase in sea level during flooding do not affect them much. However, flooded water dilutes the saline water and make them more like a freshwater habitat. Nevertheless, mangroves can withstand a watery environment since they evolve from the sea [19].

Drainage Blocking and Solid Waste Management Problem

Drainage is an outlet constructed to convey water from homes and streets into the main water course mostly a river or a central water collection channel. In the Niger Delta concrete drainage are built along the sides of the road to help evacuate water from residential quarters and streets. They are connected to drains from homes and industries, most drainages are old and are not properly maintained through the evacuation of their content. Over the years these drainages accumulate waste and sand resulting to blocking of the drainage, which prevents the free flow of water into the river, thus leading to quick over flow during a heavy rainfall resulting

to urban flooding. The flood enters homes and business premises causing nuisance and distribution of sewage which causes public health problem. A practice of pouring waste into public drainages during rainfall is a trending habit in many parts of the Niger Delta [11]. This waste disposed clog up the drains and cause blockage. The effect of dumping of waste in public drainage is evident at the end of a rainfall when the whole streets in a city is littered with waste flushed out from the drains by flooded water. Thus, to prevent the blocking of drainages, sand and waste materials are often removed by paid agents of government of private citizens but the problem of this evacuation is that the waste is usually dumped by the side of the drainages for so long that the sand is washed back into the drains.

Surface and Ground Water Quality Monitoring

Surface water such as river, seas and oceans are impacted by flooding. Flooding increases the turbidity of water, which is caused by the mixing of bottom sediments of a water body [28]. The increase in circulating sediments is caused by the excitation of the river bed by flooded water. Groundwater is a water stored beneath the earth surface in pockets of holes between consolidated (e.g., rocks) and unconsolidated (sand) materials called aquifer. The groundwater is surrounded by rocks, which help to improve their mineral content and quality.

Flushing solids and liquid waste into the ground through dug boreholes weaken the soil layer and contaminates the water [26]. There is a need for the establishment of a monitoring station in a centrally located place to help monitor ground and surface water activities in the area. The monitoring team should monitor and prevent waste disposal in public drainage and also conduct water test for quality control.

Groundwater has always been considered to be readily available source of water for domestic, agricultural and industrial use [18]. Water has contributed in the improvement of the social and economic life of people. However, great global demand has resulted to over exploitation, which has resulted to environmental consequences such as land subsidence and water quality deterioration. Increase industrial, agricultural and domestic activities have resulted in the emission of effluents into the hydrologic cycle leading to surface and sub-surface pollution. The study of groundwater is multidisciplinary and includes science, engineering and economics.

Flow System Characterization

Groundwater is an integral part of hydrologic cycle. Waters enter the groundwater system by infiltration to the saturated zone of the aquifer [2]. Surface area is unsaturated because it has little or no water but the sub-surface area has water and is called the saturated zone. Thus, a groundwater flow system consists of aquifers, which are water yielding strata of confining beds which are geologic units restricting flow of water. Water enters the recharge areas and moves through the aquifer according to their hydrologic

properties and gradients to discharge areas. Climate, topography and geology determine the nature and location of areas of recharge and discharge.

Aquifers in humid environments are replenished from infiltration of rainfall through downward percolation of soil water past the plant root zone. Seepage from streams, rivers and lakes also contributes to groundwater recharge [25]. Hydrologic framework such as voids, fissures and fractures are openings that allow water passage.

Hydrogeology Framework

Groundwater occurs in many different geologic formations. Nearly all rocks in the upper part of the earth's crust possess openings called pores or voids [12]. The level of openings of these voids determines the quantity of water it contains, which is referred to as the porosity of the underground formation. The Niger Delta region of Nigeria is made up of unconsolidated formations, which are alluvial, glacial, lacustrine, marine or aeoline deposition. Thus, aquifers of alluvial origin are important sources of water supply. These deposits are composed of gravel, sand, silt or clay size laid down by physical processes in river channel or on floodplain. Twenty five percent (25%) of sedimentary rock is made of sandstone. Sandstone has its origin from various depositional environments including floodplain, marine shoreline and deltaic, aeoline and turbidity-current.

Data important to the prediction of groundwater flow include the following physical framework such as (1) hydrogeologic map, showing aquifer boundaries, (2) topographic map showing surface water bodies, (3) water table, bedrock configuration and saturates, (4) hydraulic conductivity and storage maps, (5) maps showing variation in storage coefficient of aquifer (hydraulic connection) and (6) relation of stream and aquifer. Other factors include surface water diversion, stream flow, precipitation and evapotranspiration, water levels and environmental factors. Similarly, in terms of physical properties of groundwater, the movement of water is dependent on the hydraulic properties of the formation and hydraulic energy gradients across the flow domain. Groundwater flow is generally very slow and are usually measured in meters per year. Thus, residence time for a groundwater system may range from months to hundreds of years. Hydraulic conductivity and storage coefficient determine the rate of flow and water release capability in aquifer. The hydraulic conductivity is a function of direction of measurement, and for sedimentary system like in the Niger Delta, horizontal hydraulic conductivity is greater than the vertical hydraulic conductivity.

Shallow aquifers are usually the most important sources of groundwater for water-supply purposes, but the upper portions of these aquifers are also most susceptible to pollution. The entry of contamination to shallow aquifers occurs directly through wells

by downward percolation through the zones of aeration, by induced recharge from surface water bodies, by inter aquifer flow and by upwelling of deeper saline water carried downward over pumping of wells. The extent of groundwater contamination due to waste percolation from the land surface depends strongly on the rate and volume of recharge water. In a humid environment, contamination may be rapidly carried downward from the land surface to water table. Contaminants can be transported in groundwater in two ways:

1. Adsorption or desorption: These processes involve the mass transfer of contaminants. Adsorption is the transfer of contaminants from the groundwater to the soil; desorption is the transfer of contaminants from the soil to the groundwater.
2. Chemical reactions: These processes involve mass transfer of contaminants caused by various chemical reactions (e.g., precipitation and dissolution, oxidation and reduction). For some contaminants, degradation is also an important process that may need to be characterized.

In many countries of the world groundwater is the major source of water and is used for drinking, municipal, industrial and agricultural water supply.

Lastly, the reduction in the potentiometric level or water table can result in environmental consequences for groundwater such as land subsidence, water quality degradation and saltwater encroachment. Land subsidence is the accumulated effect of compression of different strata at different depth below the ground surface due to increase in intra-granular pressure. Changes in groundwater quality is caused by groundwater overdraft resulting from geochemical evolution and induced anthropogenic pollution. In coastal aquifers fresh and saltwater are in dynamic equilibrium. Under natural conditions of flow freshwater discharges into the sea. Thus, pumping groundwater in coastal aquifers will disturb this dynamic equilibrium, and over pumping a well will cause the encroachment of seawater into aquifers contaminating the freshwater resource in the production areas.

Groundwater Contamination

The quality of groundwater in aquifers can be affected by natural and anthropogenic activities [17]. Aquifers not affected by human activities can be impacted by geochemical reactions between the water and the rock matrix as the water flow between the areas of recharge to areas of discharge. Contaminants may reach groundwater from different sources as shown in Table 1. Waste may be discharged into groundwater intentionally or unintentionally [26]. Intentional discharges are septic system, spray irrigation and land disposal sludge, while example of unintentional discharge into groundwater include waste from impoundments, landfills, animal feedlots, and leaking sewer lines.

Table 1: Distribution of contaminants from waste and non-

waste sources into groundwater.

S/No	Waste		Non-wastes
	Intentional	Unintentional	
1	Spray irrigation	Surface impoundments	Buried product storage tank
2	Septic tanks	Landfills	Crude oil pipelines
3	Infiltration or percolation basin	Animal feedlots	Accidental spills
4	Waste disposal wells	Acid mine drainage	Product storage ponds
5	Brine injection wells	Mine spoil and tailings	Agricultural activities

Pollution can be characterized into four groups namely:

1. Physical: heat, suspended solids, etc.
2. Chemical: inorganic chemical contaminants e.g., brine, acid, nitrates, sulfates, chlorine; organic chemical contaminants e.g., gasoline, hydrocarbons, phenol, etc.
3. Biological: derived mainly from sewage and decomposable by microorganisms such as bacteria, virus and protozoa.
4. Nuclear: uranium, radioactive elements derived from nuclear power plants, chemical reprocessing plants, etc.

Climate Change Impact on Precipitation

Climate change is a global phenomenon that is caused by anthropogenic activities such as emissions into the earth's atmosphere. Increased emissions increase global temperature resulting in global warming [33]. Global warming increases the earth's temperature leading to the melting of the polar ice caps and causing sea level rise. Emissions of greenhouse gases such as methane, water vapor, nitrogen oxide, Chlorofluorocarbon (CFC), and carbon dioxide deplete the ozone layer, which is found in the stratospheric layer [10]. Among the gases CFC cause the most damage to the ozone layer by inverting triatomic oxygen into the products diatomic and monoatomic oxygen. Chlorofluorocarbon is dangerous to the environment because it has no natural sink and remains in the atmosphere for thousands of years compared to the carbon dioxide that has trees and oceans as the natural sink. However, the problem of the proliferation of carbon dioxide is that it traps heat from the solar radiation and sends it back to earth to cause further warming. Increased CO₂ from emissions from car exhaust, burning and natural tectonic processes like volcano forms a cloud above the troposphere, which prevents reflected solar radiation from going into space [24]. Thus, reflected, refracted or direct rays from solar radiation (thermosphere) are trapped and sent back to earth to increase the global temperature.

Increased temperature also facilitates evaporation of surface and ground water leading to increased precipitation. Many parts of the world that has not experienced rainfall like deserts have now recorded rainfall. There is a total turnaround of climate forces leading to unpredictable situation. Increase in precipitation is

advantageous to biodiversity increase. Tropical region of the world like Africa is a biodiversity hotspot because of the constant rainfall recorded and the absorption of CO₂ by trees through the process of carbon sequestration [30]. Tropical region has less impact on global climate change because the role of trees in removing carbon and providing O₂ which helps to cool the earth. Furthermore, increased temperature resulting to increased evaporation will result to increased rainfall and flooding in areas that were not prone to flooding. Climate change has impacted weather and climate conditions in the southern Niger Delta region of Nigeria. There are two seasons in Nigeria, the dry and then wet seasons. Wet season experiences heavy rainfall and occur between March and September, while the dry season experiences little or no rainfall between October to February. This dynamic has changes because of climate change which has resulted to the dry seasons having heavy rainfall in many cases. Rainfall now occurs all throughout the year from January to December.

Impact of Deforestation on River Flow

Eutrophication is nutrient enrichment in aquatic environment. It is the enrichment of nitrogen and phosphorus in river leading to the growth of water plants (macrophyte) on the water surface [8]. Flooding washes away fertilizers from farmland into the water body leading to increase in nutrients and thus, increase in growth of water plants. Eutrophication is a major problem in coastal area because it deprives the fisheries population the much-needed oxygen to survive [33]. Macrophytes deplete the Dissolved Oxygen (DO) and increase the Biological Oxygen Demand (BOD), which results to a toxic environment for aquatic organisms to survive. Widespread growth of macrophyte creates nuisance of rivers by blocking waterway for marine transportation [27]. The organic content deposited from dead plants convert the river to an oxygen-depleted swamps devoid of fishes and other aquatic species. The dead plants block water channel and changes the river course which obstruct migrating organisms leading to their death.

Policy Decision and Management of Flooding in Urban Areas

To stop flooding there are measures that can be implemented to prevent the anthropogenic causes. For instance, blocked drainages

can be freed to allow the free flow of water. Laws preventing refuse disposal and heavy metal discharge in drainages and river should be strengthened and implemented to forestall future occurrence [1]. During town planning flood prevention measures should be implemented from the beginning by constructing underground drainages and channels that will evacuate excess water out of the city into the river. Building of houses on natural drainage should be disallowed. The Niger Delta region is surrounded by rivers and creeks, thus the natural geography and landscape structure should be used to prevent flooding. Artificial or natural slopes can be used to create gravity that will facilitate the flow of surface and underground water out of the city. Similarly, buildings should also be planned and constructed in such a way that they won't block the pathway of natural drainage. A central waste collection facility should be established in the city to help collect and recycle and manage waste so that they won't end up in the drains. During heavy rainfall monitoring teams should go round the city to ensure that waste on road is evacuated and all drainages cleaned up to prevent

the overflow of water into the street due to drainage blockage.

Role of Deforestation in Shoreline Accretion

Mangrove play numerous ecosystem services roles, but one major role is the protection of the shoreline with their adventitious root system. The cutting of the mangrove trees for firewood production has made the forest bare and susceptible to flooding and accretion (Figure 2). The removal of the mangroves reduces the soil strength and stability, leading to their rapid erosion [29]. Many mangrove forest has been disfigured because of deforestation which creates an erosion vortex during high tide. The washing away of the soil sediments deprive the forest of the organic content that enriches the soil [4]. Mangrove is a biodiversity hotspots because it is a habitat for many organisms that depend on it for survival. Thus, the removal of the trees lead to the loss of species. Furthermore, the loss of soil via accretion lead to the loss of ground-dwelling and burrowing organisms.



Figure 2: Coastal accretion caused by tidal flooding at Eagle Island, Niger Delta, Nigeria.

Conclusions

Many household in the Niger Delta depend on water from constructed boreholes and wells. In many areas the quality of water is a cause for concern because of the proliferation of contaminants in the environment. Sea level rise, which is an outcome of global warming causes salt intrusion into the groundwater. Flooded water

also percolates into groundwater after washing up dirt from the city. Anthropogenic pollution is a serious problem, which has resulted in the contamination of surface and groundwater. This study reveal that human-mediated factors intensify natural factors in degrading the groundwater quality. To prevent public health problem there should be constant monitoring of both surface and groundwater points.

Acknowledgement

None.

Conflict of Interest

None.

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