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Research Article

GROUNDWATER CONTAMINATION AND EFFECTIVE WAYS OF RECTIFICATION

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ABSTRACT

Groundwater contamination is a common occurrence the world over. When it occurs, it is very difficult and expensive to overcome. Since groundwater is a major source of potable water and the most widespread, it is very necessary to explore all avenues to avert its contamination. The impact that contamination has on groundwater, its environment and consumers were discussed. These include health hazard, imbalance in the ecosystem, water scarcity, negative economy and inflation. The various steps to prevent groundwater contamination such as efficient waste disposal method, safe storage and handling of hazardous materials and protection of chemicals or waste from floods and rainfall percolating underground were briefly discussed. Also discussed under prevention are good management of waste products, monitoring of storage tanks and pipelines, well monitoring as well as formulation of an effective Water Policy. The solution to contamination are broadly grouped into two; namely ex-situ and in-situ technologies. Some case studies were analyzed for future references.

INTRODUCTION

Water is very important for human existence. Without water there is no life. Man therefore goes to all extent to find water because he has to survive. Water could be got from rain, oceans, lakes, streams, glacier or underground. The water from underground is groundwater. It is very important because it is the most uniformly distributed. It could be got from sedimentary, igneous and metamorphic rocks environment. The basic requirement for the availability of water in rocks is the availability of porosity and permeability. Other sources of water are mostly restricted to some areas while some areas are partially or totally lacking in water. Some water from these sources still percolate into the soil and become groundwater. These, in some cases, join fossil water which has been trapped over geologic time. In addition to its uniform distribution, it is relatively cheap to access because the cost of digging a well is comparatively low. It makes up about 97% of the world's accessible freshwater reserve.Another factor that favors groundwater is that its potability is higher than other sources, except rain water. It has high potability because it has gone through filtration through the rocks which must have removed most of the impurities. However, the rocks through which it has passed and its host rock usually have impact on its chemical composition. (Offodile, 2002).

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This does not pose great problems. The problem usually encountered by consumers through groundwater is pollution which, in most cases, makes the water loose quality or render it totally unusable. When this situation occurs, consumers are forced to either abandon the water or embark on purification which consumes resources and time. Scientists predicted that in the next few decades more contaminated aquifers will be discovered, new contaminants will be identified and more contaminated groundwater will be discharged into wetlands, streams and lakes. The need to avoid such situations or take the right steps at the lowest possible cost necessitated this study.

AIM

This paper aims at detecting sources of pollution, its effects, indicators, solutions and the methods of preventing it.

SCOPE

The paper will discuss the following;

- Causes and Sources of Pollution.
- Indicators of Contamination.
- Impact of Contamination.
- Solutions to Contamination.
- Prevention of Contamination.
- Case Histories.
- Facts about Contamination.
- Recommendation to Stakeholders.

CAUSES AND SOURCES OF POLLUTION

What is Pollution?

Pollution is the act or process of making land, water or air dirty and not safe or unsuitable for use especially when caused by environmental contamination with man-made waste. This leads to uncleanness, poisoning, presence of impurities or harm to the consumers. This article will focus only on pollution of groundwater.Pollution of groundwater may be caused by natural or human activities, that means they may be geogenic or anthropogenic. Those caused by human activities may be further described as point source pollution. Point source refers to contamination originating from a single tank, pipeline, truck, livestock waste, road salt storage and industrial chemical spill. Other point sources are graveyards, coal tar, mining areas, asphalt production site, chemical at wood preservative sites, sludge disposal, waste dump disposal sites or any other facility. Non-point source is the pollution caused through infiltration spread over a large area. They include fertilizers on agricultural land, pesticides on agricultural lands and contaminantsin rain, snow and dry atmospheric fallout. Because they are used or applied over a large area, they can have more serious impact on the quality of the water than the point sources.

Natural Pollution

Natural pollution is the unsuitability of groundwater caused by the effect of nature. Natural pollution can be caused by microorganisms in the soil, nitrates or nitrite compounds found in the soil and also radionuclides, radioactive or nucleotides found in underlying rocks. It could be from the host rock or soils that the groundwater has passed through. The geological formation can be a source of contamination if it contains minerals such as calcium, magnesium, iron, arsenic and various radioactive elements. Potable water has an upper limit that each of these minerals must not exceed. Anything above this will lead to contamination. Some of these minerals are carcinogens e.g. arsenic and the radioactive elements. Arsenic is tasteless, colorless and odorless and therefore not easy to detect. It can only be detected through test.

The movement of groundwater along its course from recharge to discharge area enable it to undergo some chemical and physical charges. This is because the water reacts with some minerals within the source or rock. This is even more pronounced in soils where the temperature is above normal. The most commonly dissolved mineral substances are calcium, magnesium, sodium, potassium, chloride, sulfate and bicarbonate. When the concentration of one or more of these minerals is very high to a point that they cannot be tolerated by human beings, diseases may set in. The deeper the ground water is, the more likelihood of having enough concentration.
Coliform contamination can also be a natural form of contamination. When its concentration is high in the ground, it may pollute groundwater and this may lead todiseases. This is different from the coliform introduced through human or animal waste. Another natural source of pollution is high concentration of legionella which multiplies in heating system. This can cause legionnaire's disease which is a type of pneumonia. Heterotrophic plate count (hpc) is a type of bacteria that are naturally present in the environment.

When conditions permit, its concentration in groundwater may increase to a level that will make the water undesirable. When groundwater passes through a very clayey soil, the turbidity may increase to an abnormal level making the water undesirable. The turbidity level of water is not expected to rise beyond 5 nephelometric turbidity units (NTV). Salt water intrusion is another source of groundwater pollution into groundwater thereby polluting the water. This increase the hardening of the groundwater leading to higher consumption of soap when washing. Several manmade chemicals are referred to as groundwater contamination because they are being used extensively. While being used, they spill accidentally and leak into the aquifers and are often mismanaged or dumped illegally.

Some of the popular contaminantsinclude:

- DNAPL-Dense non aqueous phase liquids.
- LNAPL- light non aqueous phase liquids.
- Inorganic chemicals- Ammonia, cyanide, fluoride.
- Metals.
- Bacteria and viruses.

DNAPL are organic compounds heavier than water but less soluble. They include chlorinated solvent and halogenated aromatics. They migrate very fast through the soil formation and reach water table because of their high density and low viscosity. They sink fast to the bottom of the aquifer tillthey reach the impermeable bedrock. Pollution caused by DNAPLS can be treated with in-situ thermal treatment, in- situ chemical oxidation,surfactant flushing or in- situ bio remediation. Other methods of treatment are groundwater extraction, excavation and containment with engineered caps and slurry walls. LNAPL are organic compounds lighter than water but with low solubility. These liquids include gasoline, fuel oil and other petroleum products. Their remediation may require the use of more than one technology. Combination of one or more methods may be required.

Artificial Pollution

Artificial pollution is a contamination resulting from human induced activities. This includes industrial discharges, urban activities, mining, agriculture, groundwater pumping and waste disposal. Another important source of pollution is the release of explosive chemicals through bombs during military hostilities.

Industrial Discharges

Industrial pollution is the waste produced by industrial activity which includes any material rendered useless during a manufacturing process. It includes wastes from factories, mills and mining operations. Examples are chemicals solvents, paints, sand paper, paper production, industrial bye-products and metals. The rapid technological development has been associated with industrial pollution. Any form of pollution that can trace its immediate source to industrial practices is known as industrial pollution. They contaminate air, surface water, the soil and groundwater. Most industries require large amount of water in their production. The water comes in contact with heavy metals, harmful chemicals, radioactive waste and organic sludge. Such waters percolate the soils and mix up with groundwater.

Urban Activities

Urban areas are always associated with overblown population. Such large population are not always supported with increased amenities and utilities. Such deficiencies include poor sanitation which includes development of pit latrines. Such latrinesintroduce nitrates into groundwater. Other urban wastes may also be introduced into the soil such as waste water which, when in high concentration, will greatly affect groundwater. Runoff from streets carries oil, rubber, heavy metals and other contaminants from auto mobiles. These, in addition to garbage dumps, leaking fuel tanks and storage tanks, can lead to pollution of groundwater.

Agricultural Pollution

Agriculture is a dominant component of the global economy and the pressure to produce enough food has led to worldwide impact on agricultural practices, such as expansion of irrigation, increased dependence on fertilizer and pesticides, to achieve higher yield. A large proportion of water being used in agriculture isrecycled back to groundwater. The agricultural agents of groundwater pollution include fertilizers, pesticides, weed killers, animal feedlots and liquid waste disposal. Most of the chemicals they carry react with the soil through which groundwater will pass to produce toxic substances. Concentration of such chemicals in high level, on making contact with groundwater, leads to pollution which could have disastrous effects on humans.

Mining

Groundwater pollution can occur both directly or indirectly as a result of surface mining. Direct degradation canoccur in groundwater situated downhill from a surface mine or by flow of contaminated drainage from the mine. Indirect degradation of groundwater could result from blasting which causes a temporary shaking of the rock and result in new rock fracture within the working areas of the mines. It may also cause existing rock fracture to further break and be more exposed to weathering and other chemical changes. The rock fragments or rock itself may become more permeable therefore allowing water to travel freely downwards leading to further weathering and chemical reactions. Rauch stated that groundwater contaminated by mine drainage is often different in chemistry from normal groundwater. They usually have higher pH, higher total hardness, lower acidity, higher total iron, manganese, aluminium and suspended solids. It usually have dissolved sulfate which does not precipitate as it remains in solution following natural or artificial acid treatment. For this reason, it serves a useful purpose of indicating present and past mine drainage pollution. Generally, shallow groundwater is usually more affected by deep groundwater. In areas of coal mines, carbonic acid is usually present in light concentration, while in gold mines, arsenic acid is usually high in concentration. Other problems that may be associated with mine pollution of groundwater include water pollution from mine waste rock and tailings whichmay need to be managed for decades, even after closing of the mine. There are four main types of water pollution from mining and these include acid mine drainage, heavy metal contamination with leaching, processing chemical pollution as well as erosion andsedimentation.

Over Pumping of Groundwater

The demand for water has caused human to look for it, at times, without thinking of its implication. Consequently, when extracting water from wells or borehole, one hardly knows when he is overdrawing the water. This may lead to deterioration of water quality and land subsidence. The water quality may reduce when the water table is lower and air moves lower to occupy the void left by the water. The air reacts with the rock surface in the presence of the thin layer of water left behind. This promotes weathering and some other chemical reaction. When the aquifer is recharged, this dissolves in the water leading to higher concentration of the product of weathering and the chemical reaction. In addition, when the groundwater is lowered, in areas not far from salt water environment, the salt water may migrate to the void left behind resulting in salt water contamination of the groundwater.

Waste Dump

The increasing production of municipal solid waste worldwide is an important source of groundwater contamination. Increase in solid waste has been exponential in most cities. Contamination of groundwater surrounding municipal solid waste is threatening the health of the people. Contamination from solid waste in an open area leads to leachates which percolate down to the aquifer. Generally, wells around solid waste show higher values for most of the parameters involved in determining water quality. These higher values are resultant from percolation of waste products and the reaction of some of them with the ground water. Wagh, G. (2008) in his study of the waste dump in Pune City, discovered that the amount of pollution in the West decreases with the increasing distance from the West where waste dumps are located. Even during rainy season pollution is observed in the West around waste dump.

Direct Human Activities

It is natural for human beings and animals to defeacate.Whenever they are under pressure where there are no facilities, they enter the bush and defeacate, leaving the feaces on the surface of theground. When rain falls, the feaces may be carried by flood and eventually dissolve in the water from which it percolates into the ground, causing contamination of groundwater. Urine too, may contain some infection and in a very porous soil, this easily contaminates the groundwater. Other ways that individuals contribute to groundwater pollution include leaking of motor oil, detergents and cleaners into water source. These ones are not easily filtrated by sand or soil, therefore, find their ways easily into groundwater.

Septic Tank

Septic tanks are constructed to store human wastes. They are mostly buried underground. With time, such tanks deteriorate and develop cracks or the concrete walls get weakened leading to the leakage of the waste therein.Such waste pass through the soil and may eventually find its way into an aquifer from where wells and boreholes derive their water. Such contaminated water causes disease for the consumers of the water. Most septic tanks are designed for some of the sewage to be degraded in the tank while some are degraded and absorbed by the surrounding sand and sub soil.

Through the latter, contaminant such as bacteria, virus, detergent, household cleaners and chemicals may enter groundwater.

Storage Tanks

Storage tanks are constructed to store petroleum, lubricants and other fluids. They are mostly made of steel which normally gets corroded over time. Corrosion of such fluids lead to leakage. This is moreso because most people or establishments do not lay emphasis on corrosion prevention. Therefore, after installation, it is difficult to inspect such tank for corrosion. Groundwater dissolves many different compounds most of which could contaminate large quantity of water. A little quantity of gasoline, petrol or kerosene could contaminate millions of liters of groundwater. This renders such waters useless and impose danger or diseases on those depending on the water for their daily use.

Dense Non-Aqueous Phase Liquids (DNAPLs)

DNAPLs are chemicals used in dry cleaning, wood preservation, asphalt operations, machining as well as automobile repair and production. They are also used in production of aviation equipment, munitions and electrical equipment. They are denser than water and sink quickly into the ground. Their spills are therefore more difficult to rectify than that of petroleum products. Apart from detection through taste and odor, drinking water is rarely tested for these contaminant.

Petroleum and Related Products Pipeline

A network of pipelines have been laid across countries to reduce transportation costs. Such pipelines convey petroleum, gasoline, kerosene, natural gas and other related products. Such pipelines could be broken through means such as excavation, vandalization and flooding. The products that are leaked into the sub soil subsequently percolate the surrounding soil and eventually contaminate the groundwater within the aquifer. The contamination render the water undesirable and in the absence of an alternative, may be consumed, leading to diseases.

Petrol Oil Lubricant Trailer Tankers

Trailers and trucks convey petroleum, diesel, kerosene and lubricants across countries. Such trailers may be involved in accident and the contents get spilled on the ground. Such products percolate into the ground and may affect a very large area rendering groundwater in such areas useless. The community people are therefore subjected to difficulty of getting water.

Hazardous Wastes

Hazardous wastes are wastes that are dangerously harmful to handling and consumption. They could be from by-products of mining such as arsenic in the mining of gold and heavy metals. Others are radioactive elements such as uranium, lead, etc. They are very dangerous to health and can lead to deformation or death if consumed. In case of spillage, they may percolate the subsoil and contaminate the groundwater in the aquifer.

INDICATORS OF CONTAMINATION

Groundwater could be contaminated without the consumers knowing. This could be very dangerous because a lot of harm might have occurred before it is realized. It is therefore of very great importance to know all possible indicators of contamination. The likely indicators of contamination include, but are not limited to, the following;

- Change in color:Anytime a change is noticed in the color of groundwater, a test should be carried out to determine the potability.
- Emergence of an unusual sickness among consumers: When an unusual sickness emerges among consumers of groundwater, or when skin diseases are noticed, the water should be tested for contaminants.
- Unusual change in level of water:An unusual rise in water level that is not caused by excess rainfall could be as a result of pollution. The source should be investigated.
- Film coatings: Appearance of film coating on water surface is a sign of pollution which should be traced. This could come from a point source caused by human activities.
- Unusual change in appearance of groundwater. Such change could be in form of touch, color, turbidity or presence of impurities.
- Unusual casualty of water animals. When animals in the water start exhibiting sluggish behaviour or death is noticed among them, tests should be carried out.
- Poor growth or death of plants around the water: When the animals in or around the water starts displaying stunted growth, yellowness or death, there is need for caution.
- Higher concentration of chemical concentration: Any unusual increase in chemical concentration should be investigated.
- Change in taste: A pronounced change in the taste of the water calls for caution which implies that the water should be tested for contaminants.
- Emergence of an unusual odor: An unusual change in the odor of the water could be caused by chemical or biological contamination.
- Presence of bacteria, E. coli. When biological tests are carried out on groundwater and bacteria such as E. coli is detected, it is an indication of seepage from a septic tank.

IMPACTS OF GROUNDWATER CONTAMINATION

Contamination of groundwater can lead to serious impacts on the health, the environment and on all living things. Its impact on the ecosystem cannot be overemphasized. Some of its impacts are as follows:

Health Hazard

The effect of groundwater pollution on human health can be devastating. It could cause severe sickness which may lead to death in some cases. Such diseases include nausea, vomiting, diarrhea, headache, respiratory diseases, eye irritation and nose irritation. Chronic diseases that could be caused by groundwater pollution include cancer, liver damage, kidney damage, anemia, nervous system problems, circulatory system problems, bone diseases, hair loss and reproductive difficulties. An annual average of 7 million people are sickened in the USA from drinking polluted water. Boulding, J.R(1995).

Disruption or Imbalance in the Ecosystem

Nature has designed the ecosystem to be balanced with one group of organisms depending on the other while over population of a group is controlled by their predators. Any reduction or increase in the population of a group could lead to an imbalance in the ecosystem. Such imbalance may have ripple effect on the whole ecosystem. For example, crocodiles feed on fishes, if all the fishes in a riverine environment die as a result of pollution, this will affect the crocodiles which may lead to them being starved to death or migration.

Water Scarcity

Pollution of groundwater can lead to scarcity of water. A very large percentage of the world's population depends on groundwater for their daily use. When pollution occurs on a large scale, the entire consumers in a community are forced to abandon the consumption of the affected water. Alternative water supply has to be sought. This is always a problem as it is not usually easy to find alternative water supply for a large population.

Economy

Groundwater pollution affects a population group. Such group becomes redundant especially if they have consumed a large volume of the water. They may not be strong enough to go to work. They spend money in treatment of their health which consumes money that would have been used for other productive ventures. When not consumed before the pollution is discovered, time that would have been used for their daily routine would now be used to source for water. All these have pronounced cumulative effect on the economy.

Inflation

Pollution wastes time and prevents some workers from coming to work. This reduces the production capacity of the affected organization or individual. Because of the time being wasted, companies may not be able to meet demand, especially if demand does not reduce. When demand exceeds supply, prices are raised. Such situation may occur in cases of companies or individuals affected by pollution. Inflation therefore, becomes imminent.

PREVENTION OF GROUNDWATER POLLUTION

Investing in safe drinking water is not only good for personal health and hygiene as well as the environment. It also promotes economic growth. It is therefore necessary to have effective means of remediating groundwater pollution. The cheapest and most effective solution is prevention. Groundwater pollution can last for years without being detected and by the time it is detected, it must have caused a lot of havoc. Prevention, therefore saves tremendous cost. An effective prevention plan should take the following points into consideration.

Waste Disposal

Wastes should be properly disposed. The disposal plan must ensure proper waste water discharge connections and if possible, floor drains should be eliminated. The plan must provide for proper use and maintenance of on-site septic systems. Plug and cover waste dumpsters must be provided.

Hazardous Materials

Chemicals and fuels must be safely stored and handled, underground fuels and chemical tanks should be well monitored. Preference should be given to surface tanks which can be monitored more easily. Storage and loading areas are to be controlled while use of chemicals could be reduced or substituted.

Storm Water

Efforts need to be made to protect chemicals and waste from rain and flood. Drains could be isolated from storage and loading areas while deicing salt and particles should be sparingly used.

Management Practices

It is important to conduct environmental audit periodically. This would lead to the development of pollution prevention plan. High risk areas must be regularly inspected while an emergency response plan is developed. Land use plans would need to protect important aquifers and well fields. Residents and businesses must be educated and well informed. Hazardous waste collection must be conducted in all households.

Storage Tanks and Pipelines

All pipelines and storage tanks must be monitored. The right quality of these materials should be procured. Their life span must be noted and they must be replaced at the appropriate time. Those that contain corrosive chemicals should receive special attention. Unused water wells should be properly disposed of.

Small and Medium Scale Businesses

Special attention must be paid to individual, small and medium scale ventures that their activities produce chemical wastes. The level of their financial capability may not enable them to provide adequate preventive measures. The government should come to their aid. Use of insecticides and pesticides should be eliminated or reduced to the barest minimum. This could be done by relying more on waste from livestock.

Monitoring Wells

Monitoring wells should be installed at intervals on pipeline network and the vicinity of storage tanks. These would be inspected periodically to ensure early detection of leakages. This will ensure lead detection, lead control and emergency response.

Water Policy Formulation

The Water Policy formulation should clearly spell out all prevention plans and a body must be tasked to implement the Policy. Awareness measures and penalty should be spelt out and the citizenry should be well informed.

SOLUTION TO GROUNDWATER POLLUTION

Groundwater remediation is the process that can be used to remove pollution from groundwater.

There are many ways to remove pollution. These methods can be broadly divided into two groups. There are ex-situ and in-situ technologies. Whatever method is employed, groundwater clean-up is a very expensive venture. The cost however depends on extent, potential health effects and the alternatives available. The aquifer may be capped to prevent more pollution.

Dewatering the polluted aquifer (pumping out). The water is then treated on the surface by physical, chemical or biological technology. It is then finally re-injected back into the aquifer. In-situ technology involves treatment of groundwater within the aquifer by using thermal, chemical or biological treatment technology.

Ex-situ technology may involve the use of the following methods;

- Steam Stripping. The water is treated by introducing steam which extracts the contaminants from the pumped out groundwater. The extracted steam can be recovered from the condensate or treated further by incineration.
- Oxygen Sparging. This involves the introduction of oxidizing and reducing agents. Example include O_3, H_2O_2 and hypochlorite. These will chemically convert the toxic contaminants to less toxic compounds.
- Bio Remediation. This is achieved through treating pumped up groundwater by air with careful control of moisture, heat nutrients, oxygen and pH.
- Carbon Adsorption. It involves the passing of contaminated pumped up groundwater through activated carbon column in which contaminants get adsorbed.

In-Situ technology involves treatment of groundwater in place without extracting the water from the aquifer. These may come in any of the following methods:

- Air Sparging. This is the injection of contaminant free air into the sub-surface saturated zone which enables a phase transfer of hydrocarbons from a dissolved state to a vapor phase.
- Bio Remediation. This is the injection of oxygen to enhance biodegradation. It also combines the injection of degrading bacteria and nutrients into the aquifer to stimulate biodegradation.
- In-Well Air Stripping. It is the injection of air into a double screened well, lifting the water up the well and forcing it out in upper screen. VOCs in the contaminated water are transferred from dissolved phase to vapor phase in air bubbles and drawn off and then treated.
- Chemical Oxidation. Chemical oxidation involves reduction oxidation reactions that chemically converts hazardous contaminants to less toxic compounds. Typical examples of this are cyanide oxidation and dechlorination.
- Thermal Treatment. Thermal treatment involves increase in temperature of the source zone to increase the mobility of the pollutants. This mobility facilitates removal of pollutants and can also result in In-Situ destruction of contaminants.
- Phyto Remediation. This involves the use of macroscopic plants to destroy, remove, immobilize and treat contaminants. This process does not use microorganisms.

Selection of Remedial Technology

The method to be employed in remediating pollution depends on the following factors:

Contaminant Profile

Types of compounds causing the pollution: DNAPL, LNAPL, Ammonia, Virus,

Bacteria Quantity and Solubility: What is the quantity and how soluble are they in water.

Toxicity and Volatility: VOCs, SVOCs, Metals etc. Biodegradability: Is it readily biodegradable?

Aquifer Profile

Soil type of the aquifer: What is its permeability, homogeneity and chemistry? Is it confined orunconfined?

Find out the groundwater flow direction.

Determine the water table level.

Where is it recharged from?

Is rainfall in the area seasonal?

Feasibility Profile

What is the cost of the method being employed?

How long will it take to complete?

Method of Attack

Contaminant main source should be directly attacked with the following methods;

- Pump and treat trichloroethylene extract for oil and waxes, fumigants, paints and adhesives.
- Thermal and biological MTBE can be released to groundwater by air sparging leaking underground storage tanks, in-situ oxidation, MTBE piping and atmospheric deposition or spills. This can be treated with in-situ oxidation bioremediation, pump and treat by air stripping and activated carbon adsorption.
- Bioremediation and bioaugmentation can be used to rectify leaks and refineries.
- In-situ bioremediation for pipelines, gasoline and other petroleum fuel tanks.
- In-situ bioremediation for gasoline, petrol stations, storage tanks and pipelines.
- Vapor extraction for ammonia storage tanks and land fill leaks.
- Pump and treat method for ammonia waste stockpile.
- Combination of air stripping, nitrification and ion exchange may be employed in some situations.
- Bacteria and other organic pollution can be treated after tests have been carried out to determine the right chemical to employ.

CASE STUDIES OF GROUNDWATER POLLUTION

In Nigeria, oil spill incidents have occurred in various parts of the Niger Delta area. These include the GOCON's Escravos spill of 1978 in which about 300,000 barrels of crude oil were involved. Another one is the Shell Petroleum Development Company (SPDC). Forcados Terminal tank failure also in 1978 in which about 580,000 barrels were involved as well as Texaco Funiwa–5 blow-out in 1980 involving about 400,000 barrels. Others are Abudu pipeline in 1982 involving about 18,818 barrels, Idoho oil spill of about 40,000 in 1998 and the most publicized oil spill in Nigeria at Funiwa-5 oil station involving about 37 million liters of crude oil in January 17, 1980. This spill occurred as a result of a blow out at Funiwa-5 offshore station.

Another Nigeria's major spill was an offshore well blow out in January 1980 when an estimated 200,000 barrels of oil (8.4 million US gallons) spilled into the Atlantic ocean from an oil industry facility. This damaged about 340 hectares of mangrove. The Department of Petroleum Resources reported that a total of 4647 incidents of oil spills of about 2,369,470 barrels occurred between 1976 and 1996. All these spillage were caused by one or more of lack of regular maintenance of the pipelines, lack of maintenance of storage tanks, sabotage, oil bunkering errors and illegal fuel siphoning. Other causes are faults in engineering drills, inability to effectively control the oil wells, failure of machines and inadequate care in loading and unloading (Peter and Olusegun 2006). In all these cases, contracts were awarded for the clearance of these pollution by either the Federal Government or the oil companies involved. The successful completion of these clearance could not be determined. However, there are still cases of uncleared pollution from various communities in the Niger Delta.

Koko Waste Dump

Sometime in 1988, it was revealed that a large amount of toxic waste was dumped at Koko Port, Delta State of Nigeria. The source could not be traced but it was brought in from outside the shores of Nigeria. There were pointers to the fact that it was dumped by some Italians with connivance of some hungry villagers. This revealed the inadequacy of environmental protection institutional framework and regulations. Immediately after this incidence, two major legislations on environmental protection were enacted. They are Federal Environmental Protection Agency (Decree No58 of 1988 and Harmful Waste Decree No 42 of 1988). The effect of this toxic waste could not be overemphasized since it must have percolated into the soil. This affected the plants and animals, especially amphibians, thereby destabilizing the ecosystem.

Urban Groundwater Pollution: Coventry, United Kingdom

Regional groundwater survey from 28 wells in the Coventry area identified widespread groundwater pollution. Trichloroethane was found to be up to 547 µg/l at the industrial "Site A" during this study. Also inorganic and trace elements were elevated relative to assumed base line only in some industrial wells unlike the trichloroethane which was widespread. The limited extent of inorganic contamination may be due to retention of pollutants within the unsaturated zones, groundwater mixing in wells, ferric hydroxide precipitation resulting in heavy metal precipitation and sorption of some grains coated with ferric hydroxide.

Regionally, concentration of trichloroethane and inorganic determinants did not reveal any significant correlation with depth. The solutions recommended are identification of past and present contamination sources in relation to storage, handling and disposal of hazardous substances as wells as implementation of corrective action measures to prevent on-going or future groundwater contamination.

Groundwater Pollution in Southern-Friuli

Groundwater from the area of Southern Friuli displayed high level of agricultural pollutants such as nitrates and triazinic herbicides. This was not only in the surficial layers but also in deeper ones, extending below 150m. Some wells of the district of Gonars were monitored and the examined waters were exposed to environmental rise due to both agricultural practices and the presence of many waste disposal sites. Heavy metals, nitrates and triazinic herbicides were measured in samples taken from four wells in three periods having different rain conditions. The groundwater quality is affected mainly by agricultural practices. These two chemicals were present at levels higher than that allowed by Italian laws. Their levels were similar at all sites and no variation between different rainy seasons. However, heavy metal contents were negligible in all waters suggesting that ion-exchange, sorbing and the complex properties of the soil hinder the way of the metal leachates towards underlying groundwater. Zinc is an exception being found at levels near or superior to maximum allowable concentration with the highest contents observed in rainy periods. Zinc concentration differ from site to site indicating different sources. Triazines are specific herbicides for corn growing. Their use has been forbidden by Italian law in recent times, but its presence in groundwater of parent triazines and metabolites is persistent in the area. All efforts to normalize this situation are being taken.

Hinkley Groundwater Contamination

Hinkley California which is located in Mohave dessert had its groundwater contaminated with hexavent chromium from 1952. This resulted in a legal case against Pacific Gas and Electric. The case ended with a multi-million dollar settlement in 1996. The hexavent chromium was serving the purpose of preventing rust in the machinery. This chemical percolates into the groundwater leading to groundwater pollution. The pollution had effect on the soil and well water near the compressor station over a range of 3.2km and 1.6km. This chemical is highly carcinogenic. The California Environmental Protection Agency was tasked to clean it up. They made some progress but also reported that the area of contamination has expanded to about 9.6km by 6.8km.

FACTS ABOUT WATER POLLUTION

Merlin Hearn(2011) listed facts about water pollution as follows:

Pollution of surface water is a problem for over half of this planet's population. Over 250 million cases of water borne diseases are documented annually with about 5 to 10 million deaths. Surface water pollution always percolate to groundwater.

Fifty percent of worldwide groundwater is unsuitable for drinking because of pollution and only about 0.007% of the water on earth is accessible for human use. Most of the world's liquid fresh water is contained in underground aquifers. Water remains in an aquifer an average of 1,400 years and groundwater pollution is extremely difficult to treat because it does not readily wash out. The world water pollution and sanitation crisis claims more lives through diseases than any war can claim through the use of weapon. Every 20 seconds, a child dies from a water related disease. Children in polluted environments often carry about 1,000 parasite worms in their bodies at any time.

At any given time, half of the world's hospital beds are occupied by patients with water borne illnesses. Close to 85% of the total area of Bangladesh has contaminated groundwater: The most dangerous contaminant is arsenic. Thus 1.2 million people in Bangladesh are exposed to the deadly effects of arsenic contaminated water. Asian rivers are considered the most polluted in the world. They have three times as many bacteria from human waste as the global average and 20 times more lead than rivers in industrialized countries. This will impact on the groundwater. In Ireland, about 30% of the rivers are polluted with fertilizers and sewage, which make them too polluted for swimming, fishing or aquatic life.

One of the most polluted rivers in the world is the King River in Australia. Over 1 million sea birds and 100,000 marine mammals and other creatures have died from the toxins and acidity in this river. The UN estimates that by 2025, forty eight nations with combined population of 2.8 billion, will face fresh water scarcity.

Conclusion

Groundwater is the largest and most important source of fresh water. It is also easily available at a reasonable cost. In addition, it has a very high spread almost round the world, even in the desert. Despite its availability at great depth, it is still susceptible to contamination which may be from natural or man-made sources. Its contamination could be in form of taste, color or chemical composition. Its contamination could be very dangerous to health and are usually widespread. The best method of remediation is through prevention. Contamination may be removed through many methods which could be categorized into in-situ and ex-situ methods. Ex-situ methods involve treatment of polluted groundwater by dewatering the polluted aquifer through pumping out and treating it using physical, chemical or biological technology. It is then finally re-injected into the aquifer. In-situ technology involves treatment of groundwater within the aquifer by using thermal, chemical or biological methods. Some case histories were cited while facts relating to groundwater contamination were also highlighted.

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