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Assessment Of the Impact of Industrial Effluent on Groundwater Quality: A Review

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***Abstract* - Groundwater demand in India has significantly increased as a result of the country's fast population development, industrialization, and urbanization. Due to anthropogenic activities including overexploitation and improper waste dumping (industrial, domestic, and agricultural) into groundwater reservoirs, the availability and quality of groundwater are being negatively impacted at an alarming rate. While the development of industries produces useful products, it also produces detrimental byproducts in the form of solid, liquid, or gas that result in risks, pollution, and energy waste. In the end, the majority of solid wastes and wastewaters constitute a substantial threat to people and ecosystems since they are released into the soil and water bodies. Intensity of pollution can be determined by computing water quality parameters TDS, Chlorides, Alkalinity, DO, Temperature, COD, BOD, pH, Magnesium, Hardness, Total Coliform, calcium etc. It has been found that groundwater could be contaminated by different pollutants which causes adverse effect on the environment. Therefore, it must be remediated to fit human, agricultural and industrial needs. To monitor and assess the quality, water quality index has to be taken into consideration. Forecasting the pollution trend using regression models are widely used to plan remedial measures appropriately. Comprehensive study on different types of industrial pollution is helpful to estimate the major problems of contamination in different areas intending to improve the quality of water.**

Keywords—Groundwater, water quality index, pollutants,

Contamination, industries.

1. INTRODUCTION

Water is essential to all life on Earth. The two main sources of water are groundwater and surface water. Due to its increased use for drinking purpose, water supply, agriculture, industrial purposes, etc., groundwater has become an essential resource over the past few decades. Large-scale industrial development has raised severe concerns about the potential for groundwater contamination from waste products. The quality of the ground water is decreased when factory effluents and other waste products react with percolating rainwater and reach the aquifer system. Population growth and urbanization necessitate growth in the agricultural and industrial sectors, both of which require more fresh water.

2. GROUNDWATER POLLUTION FROM INDUSTRIES

Groundwater pollution (also called groundwater contamination) occurs when pollutants are released to the ground and make their way into groundwater. This kind of water pollution can also happen naturally due to the existence of a tiny and undesired element, contaminant, or impurity in the groundwater. Groundwater contamination can be brought on by onsite sewage systems, landfill leachate, wastewater treatment plant effluent, leaking sewers, gas stations, hydraulic fracturing (fracking), or excessive fertilizer use in agriculture. Natural pollutants like arsenic or fluoride can also cause pollution (or contamination). Using polluted groundwater endangers public health and causes the spread of diseases.

2.1 SOURCES OF POLLUTANTS

2.1.1 Construction Industry: Water pollution is a problem that cannot be tolerated even by a construction sector. The pollutants and toxic chemicals generated at the construction sites should be managed well, before discharged into the water bodies [1]. Construction site contaminants such as cement, paint, glues, sand, heavy metals, oil, and toxic chemicals reach water bodies via runoff. Pollutants from building sites can also enter groundwater, which is more difficult to remediate than surface water. Grading and demolition activities during construction generate pollutants that can leave the site and pollute our waterways. Sediment is one of the most serious pollutants. Chemical contaminants, particularly hazardous compounds, arsenic, and lead, entering water bodies can have major human health consequences, including cancer. Wastewater from building sites is hazardous to the environment since it may harm or disturb the entire ecosystem. Sewer leakage is also a contributing factor to ground water contamination. The most important element influencing sewer leakage is age; ground conditions and usage are other crucial factors linked to the possibility of groundwater pollution from leaking sewers[2]. Water quality index (WQI) is a very useful and efficient method for assessing the quality of water. WQI is also a very useful tool for communicating the information on overall quality of water.

2.1.2 Food Industry: Agriculture has been a key practice in sustaining human civilization's life-support systems since earlier period. Modern agriculture has incorporated various novel concepts to improve crop output, such as the use of chemical fertilizers and pesticides in farming. Chemical fertilizers and pesticides have become an essential part of today's agricultural systems in order to meet the world's massive demand for food grains. Yet, excessive agrochemical application degrades soil and groundwater quality due to the addition of nitrogen, phosphorus, and persistent pesticides. Groundwater contamination creates various human health hazards as it is the main source of safe drinking water. Using sustainable agriculture practices and mitigation strategies can avoid groundwater contamination from these agrochemicals while also increasing crop output and protecting environmental habitats [3]. Another type of food industry waste is abattoir or meat processing waste. The main issue with abattoir waste is the high amount of suspended solid and liquid waste, as well as contamination of ground water and the environment with odour [4].

2.1.3 Agricultural Industry: Agriculture consumes 70% of total water use worldwide and is the single greatest source of non-point-source contamination to surface and groundwater. Water quality is significantly impacted by agricultural pollutants, which are present in lakes, rivers, wetlands, estuaries, and groundwater. Sediments, fertilizers, pesticides, metals, and salts are all examples of agricultural pollutants. Nitrate is one of the most prevalent groundwater pollutants in rural regions. The main sources of nitrate in groundwater are fertilizers, septic tanks, and manure storage or spreading operations. The health of people and the ecosystems of the earth are seriously at danger due to water contamination caused by unsustainable farming practices. Agricultural pollution also has an influence on aquatic ecosystems; for instance, eutrophication brought on by the build up of nutrients in lakes and coastal waterways affects biodiversity and fisheries. A study by [5] describes the quantitative influence of pesticides on groundwater quality owing to farming in Jenin and Tulkarem, northern section of the West Bank. In comparison to Tulkarem, where the majority of the samples collected had amounts of 10 g/L, Jenin was found to have greater pesticide concentrations. Because the majority of the samples were free of pathogenic signs, it was concluded that the pollution of the studied wells was caused by pesticides rather than wastewater discharge. According to the findings, drinking from these wells may constitute serious health risk .This is mainly due to the uncontrolled industrial and agricultural activity as well as the lack of monitoring. Concentrations of heavy metals including cadmium (Cd), lead (Pb), iron (Fe), zinc (Zn), chromium (Cr) and copper (Cu) were also quantitatively determined . Concentrations of Pb and Cr in most of the tested wells in Tulkarem complied with the WHO guideline; while nitrate (NO3) and potassium (K) concentrations exceeded the permissible concentrations.

2.1.4 Health Care Industry: The term "Health Care Waste" or "Bio-Medical Waste" includes all the wastes from any medical procedure in healthcare facilities, research centres and laboratories . Poor biomedical waste segregation and disposal has the potential to pollute groundwater sources, which might then infect humans and animals. Substantial efforts have been made to ensure that landfills are constructed in such a way that they safeguard the environment surrounding them. The majority of them are constructed with a unique liner to prevent contamination of the soil and groundwater in the area. Mishandled biohazard waste, on the other hand, can destroy even the greatest landfill design. Syringes and other sharp things can easily shred the lining. As rain falls, toxins in landfills can seep into the surrounding soil, contaminating groundwater. Physicochemical and microbiological characterisation studies performed on hospital effluents in several industrialised countries have highlighted the presence of pathogenic microorganisms, some of which are multi-resistant to antibiotics, heavy metal, radioisotopes organohalogens, stemming in particular from the use of bleach on organic compounds present in effluents . In some of these countries, the wastewater produced by hospitals is usually discharged into septic tanks equipped with diffusion wells. This type of discharge can lead to the pollution of groundwater resources used intensively for drinking water by the population. The impact of septic tanks on groundwater resources has been reported in the literature [6].

2.1.5 Petroleum Industry: Petroleum is vast and rapidly growing industry. Every year more than 3.5 billion metric tons of crude oil and 2.5 trillion m3 of natural gas are produced from about 885,000 wells around the world and about 7 million tons/day of crude is traded by trucks, tankers and pipelines. Petroleum industry involves many process such as exploration, extraction, refining, transportation and marketing of petroleum products. During surface operations such as storage and pipeline transportation, accidental oil spills always poses risks for the environment, contamination of soil, lakes, rivers, fresh water springs and underground aquifers affect the biological environment as well as human life. A study conducted by [7] on groundwater contamination due to petroleum product spillage in Ijegun area of Lagos, Nigeria in May 2008 reveals the aftereffects of oil leakage on groundwater. The study shows that total hydrocarbon concentration (THC) in groundwater as high as 757.97 mg/l was obtained which were much above the WHO permissible limit of 0.1 mg/l. The level of lead in groundwater sampled in all the buffer zones was higher than the WHO limit of 0.01 mg/l in 2009. Studies have shown that lead emitted to the environment is mainly associated with lead-rich petrol in Nigeria. The high concentration of hydrocarbons were found in low elevation areas compared to high elevation areas. Thus pollutants are more likely to migrate faster to the groundwater system where the elevation is lower.

2.1.6 Clothing Industry: The rising demand for textile products, textile mills and their wastewater have been increasing proportionally, causing a major problem of pollution in the world. Many chemicals used in the textile industry cause environmental and health problems. Textile dyeing is the second-largest polluter of water worldwide and the fashion industry produces 20 percent of the world's wastewater. Water is an important aspect of textile industry, it is used for scrolling, bleaching and dyeing processes. If the contaminated water released from the industry is not treated before discharging into the reservoir, then this wastewater can reduce the concentration of oxygen, which can be harmful to both aquatic life and human life. Contaminated water in the textile industry may contain formaldehyde, chlorine and heavy metallic chemicals and when this contaminated water is used for drinking and other purposes, people get infected with various water-borne diseases such as cholera, also it affects the livelihood of fishermen as species of fishes become extinct or reduce due to contamination. Textile industries have been placed in the category of most polluting industries by the Ministry of Environment and Forests, Government of India. Dyes are the most important chemical constituents used in the textile industry, which impart color to yarn or cloth. Several adverse health effects are caused by dyes. Heavy metals have often been used in dye fixatives and also in dyes. Apart from this, several dyes and their decomposition derivatives have proved toxic to aquatic life (aquatic plants, microorganisms, fish, and mammals). They are also carcinogenic in nature and can cause intestinal cancer and cerebral abnormalities in the fetus[8]. Hence textile wastewater has to be properly treated before releasing into the environment.

2.1.7 Mining Industry: Mining is one of the major anthropogenic activities that is responsible for degrading the quality of water, soil, and the environmental ecosystem not only in the immediate vicinity but also far away via rivers and streams. Anthropogenic activities can have a negative impact on water quality by introducing contaminants like metals and metalloids and by enhancing natural processes like acid drainage generation. Four main types of mining impacts on water quality are Acid Mine Drainage, Heavy Metal Contamination & Leaching, Processing Chemicals Pollution, Erosion and Sedimentation. For mining related activities field investigations are done to find the water quality index which provides a comprehensive picture of the quality of surface and ground water for most domestic uses [9]. WQI is defined as a rating that reflects the composite influence of different water quality parameters. It is calculated with the assumption that a lower value indicates less departure from the recommended values of parameters and more good quality water for human consumption, or vice versa. For that different physiochemical parameters are considered. If the pollution rate is high immediate attention towards proper management and conservation for water resources is needed by the all concerned stakeholders, particularly the mine owners In order to check further deterioration, an effective plan for protection of water sources and water conservation strategy must be developed and implemented as soon as possible in the area [10]

2.1.8 Manufacturing Industry: Raw resources are transformed into useable products during the manufacturing process. Yet, some production byproducts, such as leftover waste or compounds created during the manufacturing process, may be hazardous to the environment. A growing proportion of confronts poor water quality as population, urbanization, and industrialization expand. Expanding manufacturing will distress world's environment by consuming water, releasing waste and wastewater, and escalating pollution-prone industries. Direct discharges of BOD ad TSS can be determined [11] . BOD is widely used to measure water quality and is the most appropriate measure to express the relationship between upstream water quality and its impact on downstream. Suspended solid is an important water quality parameter; its higher level of occurrence deteriorates the esthetic value of water, increases the costs of water treatment, and has a significant impact on aquatic environments.

3. CAUSES OF GROUNDWATER POLLUTION

Landfills, effluents discharged from industry or wastewater treatment facilities, sewage leaks, gas stations, and fertilizers/pesticides used in agriculture are some of the causes of groundwater pollution.

3.1 Naturally Occurring Chemicals

The main causes of natural groundwater pollution are compounds of arsenic and fluorine that occur in the aquifers under specific conditions. Arsenic is a metal that occurs naturally in the earth's crust. It is dangerous and highly fatal in nature when it is in its biological form. Due to the anaerobic conditions created by the organic matter present in the aquifers, it dissolves in groundwater. The microbial breakdown of the organic waste causes the oxides of iron to be released into the groundwater aquifers. Subsequently, these iron oxides combine with the arsenic to create the hazardous arsenic compounds arsenite and arsenate, the former of which is more toxic than the latter.

The presence of fluoride compounds in groundwater is the second major cause of groundwater contamination. These are located in aquifers with low calcium levels. According to

WHO Guidelines, the maximum amount of fluoride that can be present in groundwater is 1.5 mg/l

3.2 Improper Sewage Disposal

Poorly treated sewage water disposed either on the ground surface or in local water bodies is another source of groundwater pollution. This problem occurs in locations with inadequate sewage treatment facilities or poorly managed sewage systems. Additionally, even conventional treatment plants may be unable to eliminate certain impurities if there are micro-pathogens present in the sewage, such as hormones, pharmaceutical residues, and other micro-contaminants found in urine or faeces.

3.3 Leakage from Industrial Pipes

Groundwater pollution is also being caused by leakage from subsurface industrial pipes and oil tanks in industrial zones. Due to improper waste disposal, the mining of ore may release toxic metals like arsenic into the groundwater. The acidic nature of their waste also helps other harmful metals to get easily dissolved into it and seep into the aquifers.

3..4 Improper Landfill application

Leachates generated from the landfills are considered as one of the major sources of groundwater contamination and surrounding environment. The main concern to groundwater is improper or un-engineered landfills. The magnitude of this threat is determined by the concentration and toxicity of contaminants in leachate, the permeability of geologic strata, the depth of the water table, and the direction of groundwater flow

3.5 Excessive use of Pesticides

Nitrogen-based substances, such as pesticides, synthetic fertilisers, organic fertilisers like manure, can contaminate groundwater by introducing nitrates into it. This is primarily due to the fact that only a small percentage of nitrogen is utilised by plants, and the remaining may either be washed into water bodies or seep into the ground and contaminate aquifer

4. IMPACT OF GROUNDWATER POLLUTION

Groundwater pollution causes great impact on health, economy and ecosystem which are discussed below

4.1 On Health

Human health is adversely affected by contaminated groundwater. Contamination from septic tank waste can result in diseases such as hepatitis and diarrhoea. Toxins that have seeped into well water supplies may result in poisoning. Contaminated groundwater can potentially impact wildlife. Exposure to polluted water may potentially have other long-term impacts, such as some types of cancer.

4.2 On Ecosystem

Groundwater pollution can cause catastrophic environmental impact. The aquatic ecosystem may be altered when the pollutants combine with water bodies. Fish and other aquatic species may perish quickly as a result of too many toxins in bodies of water. The effects also extend to plants and animals that consume contaminated water. As toxic materials build up over time in the aquifers, the groundwater may eventually become unfit for consumption by human and animals.

4.3 On Economy

Groundwater contamination renders the area incapable of supporting plant, human, and animal life. Both the local population and the value of the land decline. It reduces the stability of industries that rely on groundwater to create their products

5. METHODS OF IDENTIFICATION OF INDUSTRIAL POLLUTANTS IN GROUNDWATER

5.1 pH

pH indicates the hydrogen ion concentration in water. It is the negative logarithm of hydrogen ion concentration in water. pH determines how much is the liquid solution is acidic or basic. It ranges from 0 to 14. As per IS 10500:2012 Acceptable limit for drinking water is 6.5-8.5.

5.2 Turbidity

It is the measure with which water losses its transparency due to the presence of total suspended particles. It is measured using turbidimeter. Turbidimeter is used to measure the obstructions due to chemical substances present in water. It is measured in NTU. Maximum Acceptable limit of turbidity is 1 NTU for drinking purpose

5.3 Acidity

Acidity of water is the quantitative capacity to neutralize a strong waste to designated pH. Strong minerals acids, weak acids such as carbonic and acetic and hydrolysing salts such as ferric and aluminium sulphates may contribute to the measured acidity. According to the method of determination, acidity is important because acid contributes to corrosiveness and influences certain chemical and biological processes. It is the measure of the amount of base required to neutralize a given sample to the specific pH.

5.4 Alkalinity

The alkalinity of water is a measure of its capacity to neutralize acids. It is primarily due to salts of weak acids, although weak or strong bases may also contribute. Alkalinity is usually imparted by bicarbonate, carbonate and hydroxide. As per IS 10500-2012 Maximum Acceptable limit of total alkalinity for drinking water is 200mg/L.

5.5 Chlorides

If water containing chlorides is titrated with silver nitrate solution, chlorides are precipitated as white silver chloride. Potassium chromate is used as indicator, which supplies chromate ions. As the concentration of chloride ions approaches extinction, silver ion concentration increases to a level at which reddish brown precipitate of silver chromate is formed indicating the end point. The acceptable limit of chloride for drinking purpose is 250 mg/L.

5.6 Sulphates

The Turbidimetric method of measuring sulphates is based upon the fact that Barium sulphate tend to precipitate in a colloidal form and that this tendency is enhanced in the presence of NaCl-HCl solution containing glycerol and other organic compounds. The absorbance of Barium sulphate solution is measured by a Nephelometer or turbidimeter and the sulphate ion concentration determined by comparison of the reading with a standard curve. As per IS 10500-2012 Maximum Acceptable limit for drinking purposes is 200mg/L.

5.7 Hardness

Hardness is the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The principal hardness causing cations are calcium, magnesium, strontium, iron and manganous ions associated with bicarbonates, carbonates, chlorides and sulphates. The determination of hardness of water is important in assessing its suitability for domestic and industrial use. The acceptable limit of hardness for drinking purpose as per IS 10500-2012 is 200 mg/l.

5.8 Total Dissolved Solids (TDS)

It is the weight of residue obtained after a water sample is evaporated to dry state. It includes calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride and sulphate. As per BIS TDS for potable water should be <500 mg/l.

5.9 Fluoride

Groundwater contains fluoride released from various fluoride bearing minerals mainly as a result of groundwater-host rock interaction. The acceptable limit of fluoride is 1 mg/l and the maximum permissible limit is 1.5 mg/l. Fluoride greater than 1.5 mg/l in drinking water cause decolouration of teeth.

5.10 Iron

The most common sources of iron in groundwater are weathering of iron-bearing minerals and rocks. The iron occurs naturally in the reduced Fe^{2+} state in the aquifer, but its dissolution increases its concentration in groundwater. Acceptable limit of iron in drinking water is 0.3 mg/l and the maximum permissible limit is 1 mg/l.

5.11 Water quality index

Water quality index (WQI) is a very useful and efficient method for assessing the quality of water. WQI is also a very useful tool for communicating the information on overall quality of water. WQI is a single unit less number of 100-point scale that provides a pointer to the quality of water source. According to this water quality index, the maximum permissible value is 100. Values greater than 100 indicate pollution and are unfit for human consumption.

6. MEASURES TO REDUCE INDUSTRIAL POLLUTION

The most effective way of remediation technique is prevention and groundwater remediation is a technique that may be used to clean up contaminated groundwater. An effective plan should have an eye on waste disposal method, handling of hazardous materials, interaction with storm water, proper monitoring of storage tanks and pipelines etc. Besides that monitoring wells should be installed at various intervals so that early detection of leakages in pipelines can be found earlier. As per [12] Groundwater remediation method can be broadly divided into two :– ex-situ and in-situ technologies.

Ex-situ technology involves various methods like: (a)Steam stripping where the water is treated by injecting steam into it, which removes impurities from the pumped-out groundwater. The extracted steam can be recovered from the condensate or incinerated further. (b) Oxygen Sparging: introduction of oxidizing and reducing agents which chemically convert toxic contaminants to less toxic ones. (c) Bio Remediation: Air treatment of pumped-up groundwater with careful management of moisture, heat, nutrients, oxygen, and pH. (d) Carbon Adsorption: It entails sending contaminated pumped-up groundwater through an activated carbon column, where pollutants are absorbed.

In-situ technology includes treating groundwater in place rather than taking it from the aquifer. It involves: (a) Air Sparging: Injection of contaminant-free air into the subsurface saturation zone, allowing hydrocarbons to a transition from a dissolved form to vapour phase.(b) Bio Remediation: Injection of oxygen into the aquifer to stimulate biodegradation. (c) In-Well Air Stripping: Injection of air into a double screened well, volatile organic compounds in the contaminated water are transferred from dissolved phase to vapor phase in air bubbles and drawn off and then treated. (d) Chemical Oxidation: Reduction oxidation reactions that chemically converts hazardous contaminants to less toxic compounds. (e) Thermal Treatment: Thermal treatment involves raising the temperature of the source zone in order to increase the mobility of contaminants. This mobility enhances pollutant removal and may result in in-situ contaminant destruction. (f) Phyto Remediation: Macroscopic plants are used to kill, remove, immobilize, and treat pollutants. This method does not make use of microbes.

The most effective way to reduce energy and raw material consumption as well as waste creation is widely thought to be source reduction of wastes. In the case of hazardous industrial waste, source reduction might relate not only to a reduction in waste volume or weight, but also to a reduction in toxicity. Recycling necessitates extensive physical, chemical, or biological processing. Recycling and re-use limit the amount of garbage that makes its way to the industrial outlet, contributing less to pollution. Consideration of the location of the sites and the potential impact on the surrounding environment can help reduce harmful consequences. The Environmental Protection Agency (EPA) works to correct the damage from industrial pollution. The Water Policy should clearly spell out all prevention plans, and a body should be responsible with implementing the Policy. Awareness measures and penalties should be specified, and citizens should be kept up to date and more significant rewards for companies that operate properly.

7. CONCLUSION

High quantities of pollutants are present in the water and sediment as a result of industrial effluent discharge into receiving water bodies. It has been established that the contaminants are concentrated and may be hazardous to various organisms. The effluents also have a significant detrimental impact on the receiving water bodies' water quality, making them unfit for human consumption. Thus, it is advised that reckless industrial waste dumping without preparation be discouraged. In order to preserve water resources from further deterioration, the regulating body must impose direct levies on industrial effluents and maintain ongoing monitoring and surveillance

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