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Impact of Climate Variability on Ground Water Pollution and Recent Development in Remediation Approach

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Abstract

Groundwater is the cleanest natural resource; however, in the past decades several anthropogenic problems have threatened the natural quality. In coming decades, the population growth in global scenario may further lead pressure on it, while the ecology and chemistry of ground water quality may be amplified due to consequences of climate change. Eventually, it would be risk to use in human, agricultural, and recreational practices, particularly in developed and underdeveloped countries. Because of the numerous human activities contaminating drinking water and its assurance to continue to be used safely, water quality is be restored through the contemporary remediation processes. The importance of ascertaining processed water quality cannot be overstated in this context. Comprehending groundwater quality can greatly assist policymakers when it comes to effective water resource management in polluted areas. This report is outlined with an effort to explore the fundamental causes and impacts of groundwater contamination, as well as to address the current controlling concerns and contemporary challenges.

Keywords: Groundwater; Pollution; Remediation; Phyto-management

Introduction

At the global, continental, as well as sub-continental levels, some of the observed climate changes include an increase in temperature and a water-rise in sea level, a decrease in the extent of snow and ice levels, irregular precipitations, shifts in terrestrial and marine living biodiversity, and ocean acidification, as well. However, increases in grain output and food-animals and cattle in industrialized countries followed the so-called 'green revolution' during the second half of the last century has made the greater use of both synthetic and organic fertilizers. Consequently, there is a widespread nutrient pollution in surface and groundwater's; nevertheless, there was harmony between demand and supply of quality food everywhere. The deposition of nitrogenous salts in land and in seas resulting from the on-going freshwater and coastal ecosystem services, which has impacted water quality, fisheries, and amenity values negatively [1]. The serious threat to man and biodiversity from several environmental issues relating to human survival and progress, such as climate change, decreased quality of natural resources, scarcity of freshwater, and groundwater with increased water pollution has been bolder than that imagined [2].

Several factors contribute to the deteriorating water quality in Indian rivers, such as natural flood pulses and industrial effluents, household wastewater, municipal sewage, and non-point agricultural drainage. Agricultural runoff through fields, domestic and industrial sewage drainage, and the combination of these are major contributors to river pollution, nonetheless each is a grave factor of water pollution. Water quality deterioration is especially worrisome because of the rising health concerns associated with many water bodies due to human activity and the climate change. A rise in the world's population to almost 10 billion people is predicted for 2050. This will result in the stresses on aquatic ecosystems being worse. Additionally, the negative effects on the chemical and ecological quality of water may be amplified by global climate change. However, most scientific studies on climate change concentrate on how glacier melting, rising sea levels and water supply are affected. Although complex, the relationship among climate and water condition is still not fully understood. It is well-known that changes in things like rains, temperature, forest cover, and, eventually, climate change can significantly impact the ability of any region to restore the cleanliness of surface water; subsequently, natural, and anthropogenic processes affect it. Temperature and precipitation affect the water quality of a river, which changes seasonally [3].

As it is, the entry or migration of faecal wastes into the subsurface cause's groundwater contamination with harmful microbes. Enteric viruses, multidrug resistant pathogenic bacteria, and protozoa might all be the principal pathogenic microorganisms of concern. Numerous microbial infections have been found to pollute groundwater [4]. These pathogens comprise more than 100 viruses and several bacteria. Protozoa like Giardia and Cryptosporidium are included on this list, albeit their presence in groundwater typically suggests surface-water influence [5, 6]. Most of these microorganisms have faecal origins and are spread through the oral contact with faecal matters. The potential microbial illnesses brought on by infection vary significantly in severity and with each pathogenic organism. Generalized acute gastrointestinal disease, which causes fever, nausea, diarrhoea, and/or vomiting, is the most common ailment. Unlike human diseases, which are mostly caused by human-specific pathogens, reovirus, Cattle, other mammals, and some birds as carriers can have harmful germs for humans, such as Giardia, Cryptosporidium, and others. Concentrated point sources, such as cesspools, leaking sewage lines, and malfunctioning septic systems, are of particular concern. Dairy farms, industrial animal husbandry enterprises, and animal feedlots would be substantial

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contributors in particular contexts but are far less frequent. The hydrogeological context and weather are the main determinants of transport to groundwater.

However, the growing human population, urban and industrial growth, and agricultural development contribute to the intensification of human activities, which contribute in raising the risk of groundwater pollution with subsequent demand for clean groundwater. Thus, groundwater pollution has emerged as one of the most significant issues affecting human life since the twenty-first century has in pipeline its due to high population density, escalation of human activities, rising clean-water demand, in a fragile environment. This paper focuses on various routes of groundwater pollution and recent initiatives to enhance emerging remediation opportunities that would shape clean water in the environment.

Sources of Groundwater pollution

One of the causes of groundwater pollution naturally is the mineral environment with trace elements mainly, along with toxic ions, at times. Before being utilized for drinking and other domestic purposes, groundwater needs to be protected, regularly monitored, and treated whenever necessary. There are two types of sources of ground water: point and non-point. Industrial facilities, communities, agricultural installations, manure storage facilities, and landfills are a few examples of significant point sources. The leaching of nitrates and pesticides into surface and groundwater because of precipitation, soil infiltration, and surface runoff from agricultural land are examples of diffuse, non-point sources that are more difficult to identify and control. Over time, these sources significantly alter the number of contaminants in water (Figure 1) [7]. Additionally, these are differences between two categories of water contamination: (1) Emergency contamination (single), which frequently has an immediate catastrophic effect through chemical/biochemical toxicities including depletion of dissolved oxygen from oxidation of organic substances with eventual death of fish and other aquatic life as well; and (2) Long-term contamination, which is characterized by persistent rather non-degradable organic pollutants. It completely degrades the milieu of the water, resulting at disturbance of the structure of the aquatic food chain, which leads to the loss of biodiversity in the impacted zones.

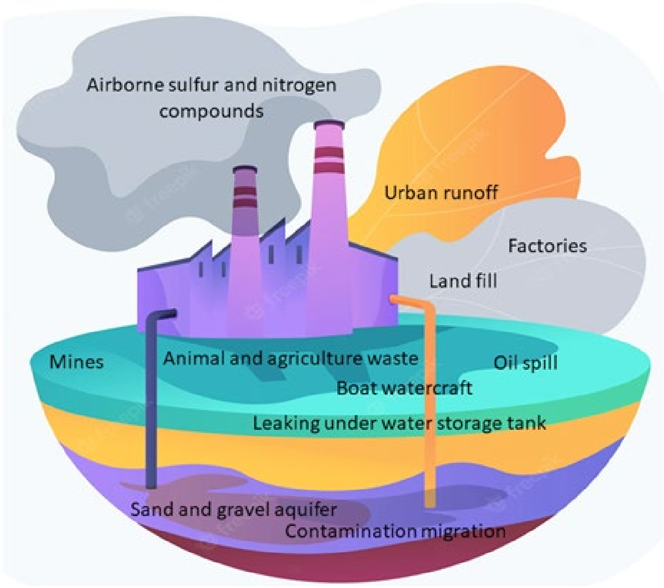

Figure 1: Schematic illustration of groundwater contamination by various factors.

Effects of biomedical wastes

The inappropriate disposal of biomedical wastes should have a negative effect on the water quality because of the contained chemicals may seep into the groundwater from waste disposal sites. A high concentration of metal ions and a high likelihood of migration from an open dumping site were indicated by the presence of trace and toxic ions, Mn, Pb, Cu, and Cd. Burning biomedical wastes produce continually unfavourable levels of hazardous elements, which can contaminate surface and ground waters [8]. A high concentration of heavy metals and polycyclic aromatic hydrocarbons might occur. The analysis of biomedical waste-ash revealed an increased hardness of 1,320 mg/L and chloride content of 8,500 mg/L in leachates. Because harmful compounds, such as detergent residues from municipal solid waste percolate into the groundwater. The presence of heavy metals in landfill leachate from biomedical wastes, poses a concern to the environment, particularly in unlined landfills where leachate dissipate into groundwater [9].

Effects of agriculture

In certain advanced nations, agriculture is now the primary cause of groundwater pollution with chemical fertilizers, nitrates, pesticide residues and salts, leading to eutrophication of inland and coastal waters, with contamination from settlements and industry [10]. In many developing nations, it is a growing concern for both the environment and health, with pesticide contaminations of vegetables/crops serving as example [11]. These have brought a number of adjustments in agricultural production, including intensification, growth of irrigated and agricultural land, and increased use of agricultural inputs. Since the 1980s, aquaculture has increased more than 20-fold, while land, water, and other agricultural inputs are exploited more intensively than before [12].

Effects of pesticides and fertilizers

Although pesticides and fertilizers are primarily used to grow crops, they are also utilized in homes, businesses, and local governments for pest control and gardening. Pesticides may behave differently and end up in different places after being introduced into the environment. While some of them may deteriorate or break down through biotic and abiotic processes, others will stay in the environment for a very long time without changing. The latter was noticed for pesticides known as organ chlorines, which are currently mostly prohibited in many industrialized nations. Groundwater contamination from pesticides like atrazine, lindane, and endosulfan was regularly found in nations where their usage. The physical-chemical characteristics of pesticides, such as their solubility, ionization constant, and octanol-water partition coefficient, as well as their movement across the vadose zone where few degradation processes occur, result in their presence in groundwater. Furthermore, improper use of agrochemicals in terms of quantity and frequency increases the likelihood that these substances will leak into groundwater. Because nitrate is a highly soluble anion and often behaves conservatively in most aquifers, nitrate pollution of groundwater is a big concern when it comes to fertilizers [13].

Effects of mining activities

Water resources both in terms of quantity and quality are significantly impacted by mining activities. Mines that are open or closed pose a risk to groundwater. Acid mine drainages, which are leachates containing metals and minerals produced from mine wastes for hundreds of years, can flow across the unsaturated zone and into the saturated zone after precipitations. The mobilization of heavy metals from the rocks is facilitated by the low leachate pH. Additionally, the chemicals required to extract the desired mineral compound from the ore, such as cyanide or sulfuric acid, might spill or leak and contaminate groundwater [14].

Effects of microbiological pollution

Numerous pathogens, including bacteria, viruses, protozoa, and helminths, would contaminate the water [15]. According to the WHO, polluted water is the cause of 80% of infections in developing nations. The primary sources of infectious agents are, (1) untreated or desperately treated sewage, (2) animal waste in fields and feedlots near waterways, (3) meat packing and tanning facilities that discharge untreated animal waste into water, and (4) some wildlife species that spread waterborne diseases.

Effects of organic pollution

The organic material produced by a variety of human activities is the source of organic pollution. This includes sewage from homes and industries, animal and agricultural waste, food processing plants, and other sources. Acidification of inland waters by sulfur and nitrogen-based acidifying chemicals lowers water quality and harms aquatic ecosystems, notably fish [16].

Eutrophication of freshwater is another issue on a global scale. The enrichment of water with nitrogen and phosphate leads to eutrophication, which is the excessive development of phytoplankton and filamentous algae that results in increased turbidity, the creation of toxins, and diurnal fluctuations in dissolved oxygen [17]. Although home and industrial effluents account for the majority of phosphorus emissions, agriculture also plays a role. In addition to receiving rainwater from pertinent catchment areas, rivers also get treated and untreated effluent.

Effects of septic tanks

In developed nations, septic tank systems are utilized to treat home wastewater in locations without access to municipal sewers [18]. This is the most extensive approach used to enhance sanitary conditions in poor nations. However, if those are improperly positioned, designed, built, or maintained, those can contaminate groundwater with biological and chemical substances like, nitrates, detergents, medications, personal care items, and oils. Untreated wastewater leaks at the surface or seeps into the soil when a septic system fails. Because these systems are notoriously inefficient at removing nutrients like, nitrates and phosphates, nutrient migration into source waters is directly correlated with the ability of soil to hold nutrients in place around the septic system's leaching area. In addition, some organic substances are resistant to the anaerobic treatment that takes place in the septic tank and could potentially are released into the ground. The cleaning agents utilized in these systems have the potential to produce extra pollutants that could eventually find their way into the groundwater. The risks associated with a garbage disposal to public health and safety is reduced in part by landfills [19].

However, the leachates it produces pose a serious risk to the quality of groundwater. Leachates are created when solid trash decomposes and liquid waste is placed in a landfill. Toxic and hazardous chemicals will therefore be more prevalent in the leachates as a result of incorrect disposal of untreated industrial and hazardous chemicals into municipal trash dumps. Heavy metals and other kinds of organic compounds are the most frequent hazardous chemicals identified in landfill leachates and associated plumes since most of them are environmentally hazardous and persistent substances, contamination issues might become comparatively more serious.

Effects of chemical storage tanks

Storage of chemicals, fuels, and wastes used oil, and industrial hazardous wastes in underground and aboveground storage tanks are a prevalent practice all over the world. When these tanks are overfilled, spills may occur. Additionally, corrosion causes leaks to emerge in tanks made of bare steel over time. Thus, the tank-contents have the potential to leak out, migrate into the subsoil, and eventually contaminate groundwater. Groundwater pollution is caused by improper handling and the use of low-quality containers, which increases the dangers related to storage tanks [20]. Trucks and railroads can also emit during transport chemicals using storage tanks. An important source of hazardous chemicals entering groundwater is the accidental leaks that happen during transport and transfer operations.

Effects of pipelines

Pipelines are used to transfer any chemically stable material, including oil brines and industrial chemicals. They are also built up for trash transportation e.g., sewer pipelines. All of the type of pipe used, pipeline systems inevitably develop leaks that put groundwater pollution in danger. If the substances being conveyed via the pipes are corrosive, this phenomenon is considerably more important than imagined. The material that the pipes carry is directly related to the pollutants that seep out of them. Sewer pipelines provide a significant risk of biological and chemical pollution in the concerned area [21].

Effects of improperly constructed wells

Groundwater flow is modified by vigorous pumping. As a result, shallow groundwater or surface water may be mixed with old groundwater. As a result, the quality of the former may be negatively impacted by the mixing of clean, old groundwater with dirty water. This result could also occur if pumping wells are improperly built e.g., with poor inadequate cover. Because they collect storm water runoff or may be utilized for waste disposal, abandoned and dry wells are another source of groundwater pollution [22].

Effects of application of chemicals

In most cases, chemical substances such as, alcohols and glycols, in addition to inorganic salts such as NaCl, $MgCl2$, $CaCl2$, and KCl are utilised. Additionally include benzotriazole and methyl-substituted benzotriazoles in de-icing formulas helps prevent corrosion and reduces the likelihood of a fire starting. The brines that are formed as the salt dissolves and after the application of the de-icing formulation can be carried into the subsurface and impact the quality of groundwater if there is precipitation [23].

Remediation approaches

As it is, people want to be sure their drinking water comes from clean, safe sources everywhere. Obviously, high-quality groundwater is essential for sustaining healthy soil and maximising crop yields. Therefore, effective tools for natural resource sustainable management include both adequate monitoring and novel measurement methodologies. Remediation methods in this field can be roughly divided into two categories: in situ as well as ex situ. Groundwater can be treated in the aquifer using a variety of in-situ thermal, biological, and chemical processes. When using an ex situ technique, contaminated groundwater is first extracted from the aquifer before being treated. The second and third approaches are usually very costly. Thus, the average citizen and the government of a developing nation would benefit more from a cost-effective and efficient remediation [24]. Now days, there are several methods to remediate the waste water which is explained in the (Figure 2).

One of these promising technologies is the remediation, and it has the potential to restore an area that has been contaminated to its original, pristine form. Techniques that are economically viable and successful in protecting the environment are utilised in contaminated areas in order to mitigate the impact of chemical contaminants. A combined strategy of phytoremediation and microbial remediation is the most successful way to clean up polluted areas, according to some estimates (Figure 3). There are several plants reported for remediate of water contaminants namely, *Allium fistulosum*, *Acorus calamus*, *Brassica campestris*, *Cucumis sativus*, *Helianthus sp*, *Jatropha curcas* and a few more [25].

In addition, it is essential to point out that few researchers really put their antimicrobial extracts or fractions to use in direct application in water treatment. While the antibacterial potential of their plant of study is the end goal for many research groups, some take it a step further and use plant extracts to the process of water purification. One study used *Ocimum sp*. (Tulsi, Or.) and *Azadirachta sp*. (neem) extracts in vitro against the pathogenic bacterium Salmonella sp. using ethanolic, aqueous, and fresh juice applications. The alcoholic extract offered the best outcome for water, whereas aqueous extract was excellent for lake water. Similarly, another researcher was motivated to compare the efficacy of *Ocimum sp*, neem, as well as *Phyllanthus Emblica* (amla) in water filtration by the fact that they are used to cure microbial illness without any negative effect. When herbs are used in the production of nanoparticles, those particles are then used to filter out harmful substances in water, bringing about water purification in an assortment of ways. The specific characteristics of the nanoparticles are determined by the effect of extracts on the surface of nanoparticles. More study into natural ingredients for water purification is required because of the clear benefits of natural disinfection [26].

Developing a level of structured hierarchy would be the comprehensive goal of quantifying the feasibility of groundwater resources, while level two involved an assessment of water quality

Figure 2: Systematic flow chart of pollution remediation methods by several approaches.

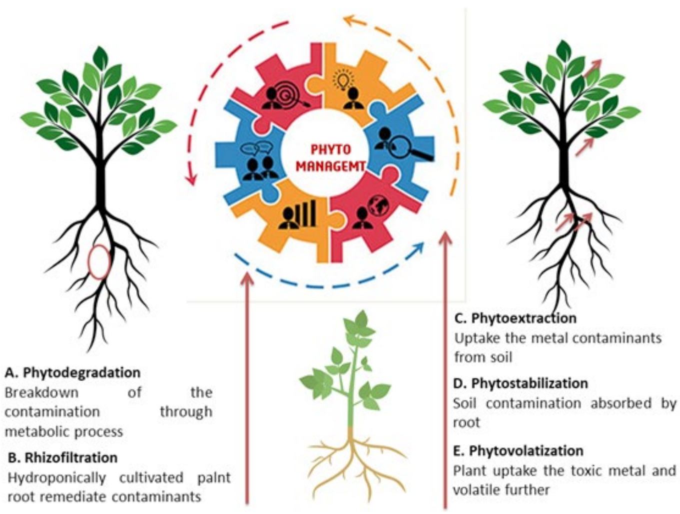

Figure 3: Recent advancement of remediation of water pollution by plant.

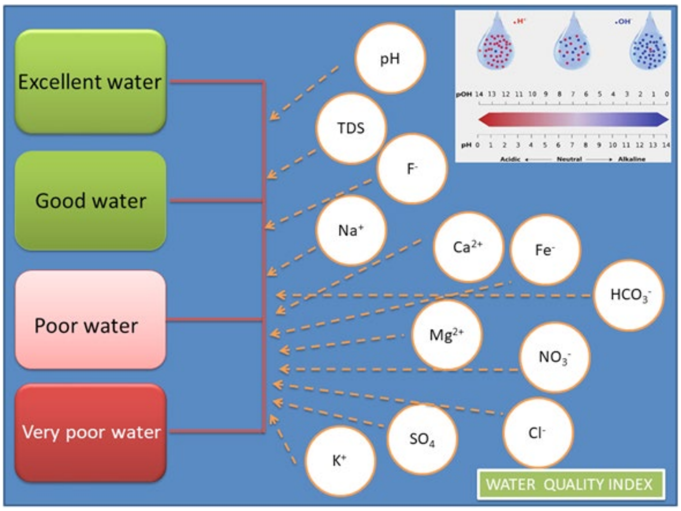

Figure 4: Assessment of ground water quality through various parameters.

metrics. The more the weight given to a parameter, the greater its significance. Classes of the groundwater quality index were used to evaluate groundwater quality (GWQI). The four phases involved in developing the GWQI are parameter selection, in value determination, parameter weighting, and sub-index aggregation to yield an overall water quality score (Figure 4) [27].

Conclusions

The dispersion pattern of groundwater pollution could be traced back to multiple anthropogenic activities; however, the pollution comprises the key factors that are mostly associated with groundwater contamination. These pertinent factors are mining and agriculture, geogenic source, stone-crusher zone and household activities. The general public has to have more awareness concerning water storage, reuse, and ordinary activities that can help minimize water pollution to address the problem of healthy water shortage. To effectively safeguard the groundwater, one of the most important tools that may be utilized is accurate assessment and valuation of the groundwater. It is recommended that the parameters be monitored on a routine basis to maintain the water supplies and keep the water quality good enough for consumption. The high demand or requirement for groundwater indicates the necessity of having the competence to meet that consumption in an equitable and sustainable way. It is quite possible that the insufficiency of water resources would worsen in the not-too-distant future in our country, taking into account the growth rate of the population. There is an immediate need to investigate the interplay between geochemistry, hydrogeology, and climate, as well as anthropogenic inputs, in pollutants that have contaminated groundwater at an alarming rate.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. Martinelli G, Dadomo A, De Luca DA, Mazzola M, Lasagna M, et al. (2018) Nitrate sources, accumulation and reduction in groundwater from Northern Italy: Insights provided by a nitrate and boron isotopic database. Applied Geoche 91: 23-35.
2. Khan R, Saxena A, Shukla S, Sekar S, Goel P (2021) Effect of COVID-19 lockdown on the water quality index of River Gomti, India, with potential hazard of faecal-oral transmission. Environ Sci Pollut Res Int 28: 33021-33029.
3. Das A (2022) Multivariate statistical approach for the assessment of water quality of Mahanadi basin, Odisha. Mater Today: Proceed 65: A1-1.
4. Szekeres E, Chiriac CM, Baricz A, Szőke-Nagy T, Lung I, et al. (2018) Investigating antibiotics, antibiotic resistance genes, and microbial contaminants in groundwater in relation to the proximity of urban areas. Environ Pollut 236: 734-744.
5. Rusin PA, Rose JB, Haas CN, Gerba CP (1997) Risk assessment of opportunistic bacterial pathogens in drinking water. Rev Environ Contam Toxicol 152: 57-83.
6. Hartley WR, Englande Jr AJ, Harrington DJ (1999) Health risk assessment of groundwater contaminated with methyl tertiary butyl ether (MTBE). Water Scie & Tech 39:305-310.
7. Motevalli A, Naghibi SA, Hashemi H, Berndtsson R, Pradhan B, et al. (2019) Inverse method using boosted regression tree and k-nearest neighbour to quantify effects of point and non-point source nitrate pollution in groundwater. J cleaner prod 228: 1248-1263.
8. Manzoor J, Sharma M (2019) Impact of biomedical waste on environment and human health. Environ Claims J 31: 311-334.
9. Olaniyan OT, Dare A, Okoli B, Adetunji CO, Ibitoye BO, et al. (2022) Increase in SARS-CoV-2 infected biomedical waste among low middle-income countries: environmental sustainability and impact with health implications. J Basic Clin Physiol Pharmacol 33: 27-44.
10. Evans AE, Mateo-Sagasta J, Qadir M, Boelee E, Ippolito A (2019) Agricultural water pollution: key knowledge gaps and research needs. Cur opinion environ sustain 36: 20-27.
11. Veeck G, Veeck A, Yu H (2020) Challenges of agriculture and food systems issues in China and the United States. Geogr & Sustain 1:109-117.
12. Hamilton SE (2020) Mangroves and Aquaculture. A five Decades Remote Sensing Analysis of Ecuadors Estuarine Environments. Springer 33: 1-40.
13. Ogrinc N, Tamše S, Zavadlav S, Vrzel J, Jin L (2019) Evaluation of geochemical processes and nitrate pollution sources at the Ljubljansko polje aquifer (Slovenia): A stable isotope perspective. Science total environ 646: 1588-1600.
14. Chattopadhyay S, Chattopadhyay D (2020) Coal and other mining operations: role of sustainability. Fossil energy 1: 333-356.
15. Magana-Arachchi DN, Wanigatunge RP (2020) Ubiquitous waterborne pathogens. Waterborne Patho 2: 15-45.
16. Khosrovyan A, Casillas TA (2022) Advance in studies of CO2 acidification in freshwater ecosystems: sources, impacts, etc. Elsevier 11: 183-198.
17. Wurtsbaugh WA, Paerl HW, Dodds WK (2019) Nutrients, eutrophication and harmful algal blooms along the freshwater to marine continuum. Wiley Interdis Rev 6: e1373.
18. Maxcy-Brown J, Elliott MA, Krometis LA, Brown J, White KD, et al. (2021) Making

waves: Right in our backyard-surface discharge of untreated wastewater from homes in the United States. Water Research 190: 116647.

19. Nanda S, Berruti F (2021) Municipal solid waste management and landfilling technologies: a review. Environmental Chemistry Letters 19: 1433-1456.
20. Trávníček P, Kotek L, Junga P, Koutný T, Novotná J, et al. (2019) Prevention of accidents to storage tanks for liquid products used in agriculture. Process Saf & Enviro Prot 128: 193-202.
21. Al-Sudani HI (2019) A review on groundwater pollution. Int J Recent Engin Science 6: 14-22.
22. Gupta A, Aggarwal R, Kaur S (2019) Performance of abandoned well for groundwater recharge using canal water. J Soil & Water Conse 18: 64-9.
23. Ji Y, McCullouch B, Zhou Z (2020) Evaluation of Anti-Icing/De-Icing Products under Controlled Environmental Conditions. Jtrp 1: 253
24. O'Connor D, Hou D, Ok YS, Song Y, Sarmah AK, et al. (2018) Sustainable in situ remediation of recalcitrant organic pollutants in groundwater with controlled release materials: A review. J Contro Rel 283: 200-13.
25. Rout AK, Dixit S, Dey S, Parida PK, Bhattacharya M, et al. (2022) Role of Modern Biotechnology in the Era of River Water Pollution. Springer 1: 63-79.
26. Inyinbor Adejumoke A, Adebesin Babatunde O, Oluyori Abimbola P, Adelani Akande Tabitha A, Dada Adewumi O, et al. (2018) Water pollution: effects, prevention, and climatic impact. Environ Science 33: 33-47.
27. Mahammad S, Islam A (2021) Evaluating the groundwater quality of Damodar Fan Delta (India) using fuzzy-AHP MCDM technique. Appl Water Science 11: 1-7.