



## Review Paper

# Impact of water pollution on human health and environment: a review

O.P. Bansal

Chemistry Department, D.S. College, Aligarh-202001, India  
drop1955@gmail.com

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## Abstract

About 70% of the earth is covered by water but only 2.5% of it is freshwater and less than 13% is available to our increasing population. Globally groundwater is the main source of water for domestic, agricultural, industrial purposes in rural and urban areas. Due to increase in population, rapid industrialization, mismanaged agricultural practices, household sewage water, and sewage, landfills, medicines the groundwater is becoming contaminated by potentially toxic metals, pesticides, nitrate, fluoride, volatile organic compounds and pharmaceuticals by leaching process. Groundwater contamination causes a range of effects to animals and human beings. In developing countries, about 80% of diseases are waterborne diseases. Typhoid, Cholera, bacillary dysentery, hepatitis, amoebic dysentery, skin irritation, schistosomiasis, respiratory problems, gastrointestinal disorder, diarrhoea, stomatitis, tremor, hemoglobinuria, ataxia, pneumonia, depression, liver cirrhosis, hair loss, renal failure, Parkinson's disease, Alzheimer, and neural disorder dental or skeletal fluorosis, methemoglobinemia, neurological disorder, cardiovascular disease, cancer, muscle paralysis, pneumonia, fetal malnutrition, leukemia, urticaria, anaphylaxis, bronchospasm, hemolytic anemia, thrombocytopenia, acute interstitial nephritis, serum sickness, Stevens-Johnson syndrome, toxic epidermal necrolysis, optic neuropathy, retinal detachment and brain abscess are some diseases caused by contaminated groundwater.

**Keywords:** Environment, water pollution, human, pesticides, potentially toxic metals, antibiotics, nitrate, fluoride.

## Introduction

Globally groundwater is 13% of total consumable water available on the earth which is about 2.5% of total earth water<sup>1</sup>. Groundwater or subsurface water is that water which occurs below the surface of Earth occupying void spaces in soils or geological strata. As per the estimation of Scientists about 5.97 quintillion gallons (22.6 million cubic km) of groundwater resides in the upper 2km of Earth's surface. The geological formations which bear water is called aquifers. Aquifers can be divided into two series, i. Confined aquifers: which lie below a layer of rock or less permeable clay and are recharged by water-bearing zone having no confined layer, ii. Unconfined aquifers: which have no confining layer, and water level depends on rainfall, atmospheric pressure, etc. Groundwater is the main source of domestic drinking water in rural and urban areas globally. The groundwater fulfils approximately 80% need of drinking water in the rural areas and 50% of urban water need. As surface water infiltrates to unconfined aquifers easily these aquifers are contaminated very easily. Pollution of groundwater causes significant alteration in the environment. The main source of lakes, rivers, ponds, streams is the groundwater when contaminated groundwater is supplied to these sources the surface water is also contaminated which causes harm to birds, animals, and plants<sup>2, 3</sup>. Due to population growth over the last 50 years, the abstraction of groundwater has increased resulting in reduced natural discharge flows, and groundwater quality.

Groundwater quality is also affected by recharge rate, and recharge quality. This review gives causes of groundwater pollution and its impact on the environment and consequences for humans.

## Groundwater contaminants

Potential groundwater contaminants are: i. Pesticides and Chemical fertilizers, ii. Sewage and wastewater, iii. Nutrients (iv) Synthetic organics including pharmaceuticals.

The geogenic contaminants are Arsenic, fluoride, nitrate, and iron. Contamination of groundwater by bacteria, heavy metals and phosphates are due to anthropogenic activities viz; domestic and industrial effluents, agricultural practices, overuse of fertilizers, and pesticides and overuse of pharmaceuticals.

**Causes of groundwater contamination:** Major causes of groundwater contamination are:

**Natural:** Drifting or leaching of the saltwater to aquifers, moving of groundwater through sedimentary rocks containing arsenic, boron selenium, etc.

**Agricultural:** Chemical fertilizers (nitrogen, phosphate), pesticides and animal wastes used by farmers are the agricultural sources of groundwater contamination.

**Industrial:** Groundwater can be polluted by industries in the following ways: i. Manufacturing and service industries used water for cooling, processing, and cleaning when this used water is returned to the hydrological cycle causes groundwater pollution. ii. Improper disposal of industrial waste containing organic and inorganic chemicals using cesspools or dry holes is another source of groundwater contamination, iii. Wastewater disposal into the ground by automobile service stations, dry cleaners, photo processors containing toxic chemicals also pollute groundwater, iv. another industrial way of groundwater contamination is the leakage of petroleum products, solvents, and chemicals from underground storage tanks/ pipes and fittings due to corrosion v. Mining of fuel, and other minerals also pollute the groundwater.

**Residential:** Residential waste water which contains harmful bacteria, viruses, nitrates, and other organic compounds is discharged into groundwater recharge wells pollutes the groundwater. Improper disposal of household chemicals such as detergents, paints, disinfectants, pesticides, medicines, etc. also contaminates the groundwater. When it rains the variety of contaminants is leached from soil to the groundwater from the waste dumped /buried grounds.

The groundwater is also polluted by pathogens, bacteria, protozoa, virus, and helminths. The major sources are – i. untreated sewage ii. animal wastes in groundwater via leaching from fields, iii. due to the release of untreated animal waste into the water by meat packing and tanning units.

### Impact of pesticides and other organic wastes on Human and other animals

Pesticides are used not, only in the agriculture sector but also used for pest control in homes, restaurants, hospitals, etc. To prevent food damage by pests' worldwide more than 1000 pesticides, having different properties, toxicological effects are used. Excessive use of the pesticides, the water solubility of pesticides, improper irrigation and rainfall are the main reasons for the leaching of pesticides in the groundwater<sup>4</sup>. A number of studies<sup>5-8</sup> have found an association between pesticide exposure and asthma. Pesticide exposure causes irritation, inflammation, endocrine disruption causing an exacerbation of asthma. A number of studies have shown that worldwide more than 50% of samples of groundwater have more than one pesticide beyond their permissible limits. Commonly found pesticides besides DDT and DDE are 2, 4-D, dicamba, HCH, MCPA, diazinon, imazethapyr and imazaquin, acetochlor, bromoxynil, etc.

A number of studies<sup>9,10</sup> have shown the presence of Pesticides in groundwater. Ghose et al<sup>11</sup> found organochlorine pesticides Lindane, DDT in the groundwater samples of greater Kolkata. The groundwater of Gurgaon and Ambala is contaminated with the isomers of HCH, endosulfan and metabolites of DDT were the findings of Kaushik et al<sup>12</sup>. Delhi's groundwater also contains atrazine and simazine was the report of Aslam et al<sup>13</sup>.

In Chennai, 20% of samples contain aldrin beyond the permissible limit (the maximum concentration was 13.33ug/L; the WHO permissible limit is 0.03ug/L). The concentration of pesticides aldrin,  $\beta$ -BHC exceeds beyond permissible limit in 4% groundwater samples of Madurai city and Vijaywada city while  $\alpha$ -BHC,  $\gamma$ -BHC and  $\delta$ -BHC in 8% groundwater samples of both the cities were beyond permissible limit. Long-term studies (11 years) made by Bansal<sup>14</sup> revealed that pesticides 2, 4-D, HCH, DDT, parathion are present in the groundwater of Aligarh city. The concentration of pesticides DDT and BHC were more in domestic well water than in irrigating well water while the concentration of 2,4- D in the irrigated well water was 2-3 times than that of domestic well water. The concentration of these pesticides became beyond permissible limit after the year 2002.

Groundwater contamination by pesticides poses significant risks to insects, plants, fish and birds besides the human. The risk of human health hazards by pesticides depends on the active ingredient and exposure level. Pesticides are related to various diseases such as cancer, asthma, leukemia, nausea, damage to the nervous system, birth defects, etc. Organophosphates and carbamate pesticides affect the nervous system<sup>15,16</sup>. The hormonal/ endocrine system of the body is also affected by some pesticides. Muscle paralysis, pneumonia, fetal malnutrition, and respiratory failure are caused by pesticide Chlorpyrifos.

Koutros et al<sup>17</sup> during their studies found that pesticides imazethapyr and imazaquin are associated with bladder cancer and colon cancer. Amr et al<sup>18</sup> also found that agriculture workers who exposed to pesticides in Egypt are on high risk of bladder cancer. Brain tumors are significantly associated with the exposure of pesticides was the findings of Provost et al<sup>19</sup>. Pesticide chlorpyrifos adversely affects the antioxidant defense system of breast cancer cell was the inference of the studies of Ventura et al<sup>20</sup>. Arrebola et al<sup>21</sup> found that in Tunisia in female population breast cancer risk was positively linked with serum concentrations of organochlorine pesticides. As per studies of Lerro et al<sup>22,23</sup> in the USA acetochlor pesticide users were more susceptible to lung cancer than nonusers. There is a strong association between pesticide exposure and lung cancer was the findings of Luqman et al<sup>24</sup>.

Jaacks and Stainez<sup>25</sup> during their research studies found a positive correlation between diabetes and serum concentration of organochlorine pesticides (DDT, DDE, HCH, etc), dibenzofurans, PCBs.

Moisen et al<sup>26</sup> during their studies on vineyards found that Parkinson's disease is associated with pesticide exposure. During the studies in the Netherlands did by James and Hall<sup>27</sup>; Brouwer et al<sup>28</sup> it was observed that chronic exposure to metals and pesticides enhances the development of Parkinson's disease at a younger age. Similar inferences were also reported by other workers<sup>29,30</sup>.

Risk of developing acute leukemia was more in occupational farmers than in other jobs in Iran was the findings of Maryam et al<sup>31</sup>. Exposure of pregnant women to residential pesticides enhances childhood leukemia<sup>32</sup>. Lee et al<sup>33</sup> during their studies in Sweden found that individuals with high levels of organochlorine, organophosphate exposure has three times more risks of cognitive impairment than those who are exposed with low levels. Prolonged exposure to organophosphates affects the male reproductive system by reduction of sperm activities, by damaging sperm DNA<sup>34</sup>. Hypospadias is also induced by exposure to organophosphates and organochlorine<sup>35</sup>.

The groundwater is also contaminated with volatile organic compounds which are widely used in refrigerants, paints, deodorizers, adhesive and fumigants, as these compounds have high vapor pressure, low molecular weight and medium water solubility can persist for a long period and can be transported for a long distance in the groundwater. For animals and human these volatile organic compounds act as carcinogenic, mutagenic and teratogenic.

### **Nitrate, fluoride, arsenic in water and their impact**

Typhoid, Cholera, bacillary dysentery, Hepatitis, amoebic dysentery, skin irritation, and respiratory problems are some common waterborne diseases caused by contaminated water<sup>36, 37</sup> (as pathogens are present in the contaminated water). Ullahet al<sup>38</sup> reported that polluted groundwater causes neurological disorder, respiratory disease, cardiovascular disease, cancer in human. As per World Health Organization report<sup>39</sup>, worldwide water-related diseases are responsible for the death of more than 1.5 million people annually and 260 million people are infected with schistosomiasis. WHO has estimated that globally by 2020 contaminated water-related diseases will kill 135 million people. World Health Organization has recognized arsenic a metalloid and fluoride as a most harmful contaminant of groundwater and potable water. Nitrate is the other chemical contaminant found globally in groundwater. Arsenic in the groundwater is mainly due to the microbial dissolution of arsenic bound iron oxides present in the aquifer sediments. Fluoride is due to abundance and solubility of fluorite (CaF<sub>2</sub>). Excessive use of nitrogen fertilizers and manure spreading is the main reasons for groundwater contamination of nitrate.

Major sources of nitrate in groundwater is the nitrogen fertilizers, potassium nitrate used for glassmaking, sodium nitrite used as a food preservative. Sharma et al<sup>40</sup> studied the concentration of fluoride and nitrate in the groundwater of Ferozpur, Faridkot and Bathinda districts of Punjab and found that 59% samples contain fluoride beyond the permissible limit the highest concentration was 10.6mg/L (permissible limit is 1.5 mg/L); and 95% of water samples contain nitrate beyond limit maximum was 90 mg/L. Narsimha and Sudarshan<sup>41</sup> found that in Medak district of Telangana state the concentration of fluoride in 22% of groundwater samples exceeds the limit the

maximum concentration was 2.2mg/L. The maximum concentration of nitrate was 361mg/L.

Besides dental and skeletal fluorosis<sup>42</sup> fluorine beyond permissible limit also causes muscle fiber degeneration, excessive thirst, headache, skin nervousness, low hemoglobin level, urinary tract malfunction nausea, reduced immunity, etc<sup>43</sup>. Excess of fluorine also affects functional mechanisms of liver, kidney, digestive system, central nervous system<sup>44,45</sup>. Milk production of lactating cows decreases by drinking the groundwater containing nitrate -N more than 100ppm.

Methemoglobinemia or blue -baby syndrome is caused in the infants of less than six months due to excess of nitrate in groundwater<sup>46</sup>. Nitrate converts the iron (II) present in hemoglobin into iron (III) methemoglobin which decreases the oxygen carrying capacity of blood causing suffocation<sup>47</sup>. Nitrate also act as procarcinogen, high concentration of nitrate in drinking water is associated with tumors in bladder, stomach, kidney, liver, lung, and pancreas<sup>48</sup>. Consumption of groundwater with a high concentration of nitrate may cause abortion<sup>49</sup>. Drinking of high nitrate water may also causes diabetes (type -I), thyroid and cardiovascular system disorder.

Excessive nitrogen in water causes eutrophication in which there is abnormal growth of aquatic plants and algae causing water column anoxia, fish mortality which in term has a negative effect on humans. The uptake of groundwater containing a higher concentration of nitrate reduces the iodine assimilation in the human body causing goiter. The drinking of such water may also cause the malformed child in the pregnant woman<sup>50</sup>.

### **Adverse effect of antibiotics present in groundwater**

As per EPA estimation, about 50% of the population worldwide uses groundwater for drinking. Releasing of hospital wastes, fertilizers, pesticides, potentially toxic metals, industrial waste and other organic pollutants in the water bodies without proper treatments causes hypoxia, eutrophication, bioaccumulation, and dissemination of pathogens in the aquatic system<sup>51</sup>. A number of researchers<sup>52,53</sup> have reported that water used for drinking and agricultural purposes has numerous antibiotics resistant bacteria use of such water causes serious health risks in the humans. The main source of antibiotics in the environment is wastewater. There are three different routes by which antibiotics can reach the water bodies: (i) improper disposal of unused antibiotics, (ii) agricultural runoff and (iii) inadequate treatment of wastewater. During the studies on the groundwater contamination of Aligarh author himself<sup>54</sup> found that Aligarh potable water contains antibiotics and antibiotic-resistant bacteria. It was also reported by the author that the concentration of antibiotics in the sewage effluent used for irrigation of crops was 2-4 times than that of groundwater. The concentration of antibiotics in the sewage irrigated soils was 5-8 times than that of groundwater irrigated

soils. Bansal<sup>55</sup> during their studies also found that antibiotics are taken up by tomato and cucumber plants when introduced to plants via irrigation with sewage effluent. They also reported that introduction of antibiotics through the food chain pathway is within the same magnitude or even higher than via drinking water.

The wastewater microbiome harbors the antibiotic resistant genes by bringing together bacteria of the environment, animal and human origin. The antibiotics used in agriculture are one of the factors which cause the clinical problem in human medicine<sup>51,56</sup>. Gastrointestinal problems as salmonellosis, campylobacteriosis in the millions of humans globally are caused by the use of antibiotic-resistant pathogens infected meat<sup>57</sup>. Anderson and Hughes<sup>58</sup> studied the effects of fluoroquinolones in cattle and reported 12 such cases after one year of an application. To feed non-vegetarian population globally production of animal meat has to be increased. Use of antibiotics in the livestock industry is increasing to growing meat demands. The antibiotics residues in animal products such as milk, eggs, milk products, meat cause harmful effect on consumer's health. The harmful effects in human may be carcinogenic, mutagens, drug allergy, teratogenic, etc<sup>59</sup>. The presence of antibiotics residues in milk is the major concern for scientist globally as the intestinal microflora became drug resistant. Consumption of milk or meat containing  $\beta$ -lactam residues causes food allergic reactions like urticarial, anaphylaxis, bronchospasm, hemolytic anemia, thrombocytopenia, acute interstitial nephritis, serum sickness, Stevens-Johnson syndrome; toxic epidermal necrolysis are reported in human beings<sup>60,61</sup>. Wong et al<sup>62</sup> found that optic neuropathy is associated with long exposure to chloramphenicol, Weist et al<sup>63</sup> found that chloramphenicol also causes brain abscess. Retinal detachment and exposure to fluoroquinolones are correlated with each other is the findings of Etminan et al<sup>64</sup>.

### Impact of Potentially toxic metals

Existence of human on earth without potentially toxic elements are not possible. Potentially toxic metals are essential in a small amount for different biochemical and physiological functions in the plants, animals, and humans. These metals participate in the redox reactions and are an essential part of enzymes<sup>65</sup>. Cobalt is a constituent of Vitamin B<sub>12</sub>, Manganese acts as an activator of the enzymes in the human body<sup>66</sup>. Heavy metals interfere in the normal functioning of structural proteins, enzymes; nucleic acids by binding them. Groundwater containing even a smaller amount of potentially toxic elements became harmful<sup>67</sup>.

When potentially toxic metals exceed their permissible limit in the groundwater causes gastrointestinal disorder, diarrhoea, stomatitis, tremor, haemoglobinuria, ataxia, pneumonia, elevated blood pressure, lung cancer, memory problems, depression, liver cirrhosis, hair loss, renal failure<sup>68, 69</sup> and neuro-behavioural disorders<sup>70</sup>. Presence of excessive trace metals in

groundwater also causes several diseases viz; boron causes low sperm count, nose, throat and eye irritation; cobalt damages lung; manganese affects respiratory, gastrointestinal and reproductive systems. Zinc damages the pancreas enhances the symptoms of Alzheimer's disease enhances the chances to become anemic also causes short term illness "Metal Fume Fever"<sup>71</sup>. Lead toxicity in human affects kidney and liver, decreases hemoglobin synthesis. Cadmium leads to cardiovascular diseases and cancer and chromium damages the liver and causes dermatitis. Presence of aluminum in drinking water is one of the factors of Alzheimer disease in some people.

The major route of the groundwater contamination by potentially toxic metals is the leaching from toxic waste dumps, municipal landfills and leaching of agricultural chemicals from soils into the upper aquifers. As the concentration of potentially toxic metals in the environment is continuously increasing, and the soil retention capacity of these metals is decreasing resultant is the leaching of these metals in the groundwater<sup>72,73</sup>. Fertilizers and pesticides applied in the fields contain these potentially toxic metals as impurities. Another source of groundwater contamination by potentially toxic metals is the urban runoffs which contain Pb, Cu, Zn, Fe, Cd, Cr, and Ni. The intrusion of seawater in aquifers also causes an increase in concentration levels of Na, Mg, Ca and HCO<sub>3</sub><sup>-</sup> and potentially toxic metals in the groundwater. 42% of groundwater samples in the Chennai contain Manganese beyond permissible limit. Bansal<sup>74</sup> studied the concentration of potentially toxic metals in the groundwater samples for 20 years (1986-2005) and found that i. concentration of these metals is increasing with time, ii. concentration of these metals decreased with depth (iii) the concentration became beyond permissible limit after 2000 iv. the crops grown also contain these metals beyond permissible limit.

### Conclusion

Groundwater a unique gift of nature to human and is the major source of drinking water in both urban and rural areas worldwide are being overexploited due to population growth. Due to agricultural activities, anthropogenic activities, urban and industrial waste, improper disposal of unused pharmaceuticals, un-metabolized medicines the groundwater is being contaminated by nitrate, fluoride, arsenic, pesticides, potentially toxic metals, and pharmaceuticals. The contaminated groundwater also affects the beneficial microbes. The uptake of contaminated groundwater causes serious problems to animals and humans. In developing countries, about 80% of diseases are waterborne diseases caused by contaminated water. So, it is very essential to protect and maintain the groundwater.

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