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Agrochemicals as a potential cause of ground water pollution: A review

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Abstract
The increasing food demand to feed the continuously increasing world population has put a lot of pressure on our already over burdened agricultural system. The urge to grow more food has made us dependent on more use of agrochemicals like pesticides and fertilizers. Indiscriminate use of agrochemicals has increased the production of crops but it has also posed severe hazards to environment because it has contaminated the natural resources, like groundwater. Agriculture is both a cause as well as victim of ground water pollution. Various agriculture practices leads to discharge of pollutants and sediments into ground water system. When this contaminated and polluted water is used as source of irrigation, it contaminated the crop and transmits its ill effects in the ecosystem.

Keywords: Agrochemicals, ground water, nitrates, pesticides

Introduction

Groundwater is the water that is located below the surface of earth or it is any water that lies in aquifers beneath the land surface. Further over the period of time, water present in rivers and water received as rainfall migrates into the ground and gets it stored in porous soils and rocks, which also contribute to ground water reserves. Groundwater is one of the most important natural resources of a country. The ground water availability of any place depends on rainfall and recharge condition. Till now groundwater is considered as the most reliable source of uncontaminated water. It plays an important role in maintaining the hydrological cycle as; ground water is intimately linked to surface water within the hydrological cycle. The importance of groundwater for existence of human society cannot be neglected as it is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for agricultural and industrial sector. The demand for water is continuously increasing, more amount of water is needed to meet the demand of over-populated country, erratic rainfall patterns are forcing agriculture to become more irrigation dependent and rapid industrialization is also consuming water to a greater extent. This situation of water crisis is further enlarged by problem of pollution or contamination of fresh water resources that are present below ground or above ground. Faulty agricultural practices play a major role in contaminating and polluting the ground water. Since, chemicals like fertilizers and pesticides are becoming an integral part of modern agriculture system, their indiscriminate use to satisfy the food demand is playing a major role in polluting the ground water (Keeney, 1989 [1]). Agriculture is both a cause as well as victim of ground water pollution. Various agriculture practices leads to discharge of pollutants and sediments into ground water system. When this contaminated and polluted water is used as source of irrigation, it contaminates the crops and transmits its ill effects in the ecosystem. The pollution due to use of agrochemicals on ground water is mainly caused by use of fertilizers and pesticides.

Ground water Pollution by Nitrogen fertilizers

Nitrogen is a very important nutrient element in agriculture. It occurs in both organic and inorganic forms in the soil system. Inorganic N is primarily found in the form of nitrates in arable soils. Nitrate is formed by the biochemical activities of microorganisms or it is added in the chemically synthesized forms to lithosphere and biosphere, from where it enters into hydrosphere very easily, because all these components of environment are closely interlinked. Nitrate is subjected to various processes like plant uptake and leaching etc. Leaching of nitrates from soil is considered to be a global phenomenon. Nitrate is becoming a major component of ground water due to high solubility in water and less retention by soil particles.

With the increasing use of nitrogenous fertilizers in Indian agriculture and huge amount of organic wastes generated by massive Indian population, the nitrate pollution in ground water is reaching to alarming values in many parts of the country (Majumdar and Gupta, 2000 [2]). The problem of Nitrate-N contamination in agriculture is becoming an issue of global concern. (Spadling and Exner, 1993 [3]). The fear of ground water pollution due to excess use of nitrogen fertilizers has increased in the past few years. Intensive agricultural practices are leading to accumulation of nitrate fertilizers in the ground water systems (Singh and Sekhon, 1979 [4]). The extent of nitrate contamination depends on various factors like amount of excess nitrogen fertilizers applied (Pustaji, 1989 [5]), the pattern and distribution of rainfall (Hall *et al*, 1989 [6]), type of soil texture, as it affects the binding ability (Jorgensen *et al*, 1989 [7]), bacterial population that oxidizes ammonium ions into nitrate ions (Barnes *et al* 1992 [8]) etc. The ground water is most likely to get contaminated by nitrate ions as compared to ammonium ions (whose contamination is more in surface water), because nitrate ions being negatively charged are more easily lost to deeper layers of soil than ammonium ions which are positively charged (Matukhno, 1988 [9]). The contamination of ground water by nitrates has a series of side effects and out of which contamination of drinking water is one of the major issues, because groundwater is a reliable source of drinking water to most of the population. The similar problem was also reported by a number of researchers including Moody, 1990 [10] from USA and Barnes *et al*., 1992 [8] from Australia. In intensive cropland areas, the concentration of nitrate N in ground water commonly exceeds the natural safe levels which may pose potential hazards to human health such as birth defects, digestive cancers and immune system impairment (Fan and Steinberg, 1996 [11], Gelberg *et al*., 1999 [12], Guli *et al*., 2002 [13] and Johnson *et al*., 2010 [14]). Excess use of fertilizer in agriculture has resulted in more concentration of residual nitrate in soil, which causes higher nitrate leaching to ground water (Kanwar *et al*., 1995 [15], Karlen *et al*., 2004 [16] and Bakhsh *et al*., 2005 [17]). Higher nitrate concentrations in intensive agricultural systems are generally believed to be because of agricultural activities (Fabro *et al*., 2015 [18]). Hu *et al*., 2005 [19] reported that due to use of waste water for irrigation and excessive application of fertilizers, the ground water was found to be contaminated with nitrate fertilizers. Liu *et al*, 2017 [20] also concluded from their study that high level of nitrate- N in ground water is a serious problem particularly in areas that are agriculturally more active. In Shandong Province of China, about 29.5% of ground water samples had excess nitrate concentration which was above the safe limits.

In India the maximum values of nitrate concentration was reported from water of dug wells where the principal land use was agriculture (Pawar and Sheikh, 1995 [21]). Mehta *et al*., 2006 [22] reported that in 11 states of India, the nitrate contamination in groundwater has exceeded the permissible levels provided by GOI (> 45 mg/L). The groundwater of several agricultural areas in Southern Ontario, Canada has reported that the nitrate concentrations has exceeded 10 mg/L nitrate- N (Gillham, 1991 [23]). In Israel, NO_3^- contamination of shallow ground water beneath sewage irrigated land was attributed to application of excess amounts of fertilizer and sewage effluent (Ronnen and Magaritz, 1985 [24]). Mascher and Marth, 1991 [25] reported that 21% of underground water samples tested in Australia contained more than 30 ppm of nitrates and 10% of water samples were reported to have more than 50 ppm of nitrates. Barnes *et al*., 1992 [8] also reported that 1/4 to 1/3 of drinking water wells in the rural areas of Australia have nitrate levels above the recommended safe limits. Agarwal *et al*., 1999 [26] had studied the correlation between amounts of nitrogenous fertilizers applied to the average nitrate content in different states of India. The results inferred that, in Orissa with application of 8.5 kg N fertilizer/ha/year, they reported a NO_3^- level of 14.8 mg NO_3^-/ L in ground water. Whereas, in Haryana, 99.5 mg NO_3^- /L was reported with application of 91 kg N fertilizer/ha/year. They had also classified the country on the basis of risk associated with ground water pollution. The states having high risk of nitrate pollution included Punjab and Haryana; states with moderate nitrate pollution were U.P, Bihar, West Bengal, Andhra Pradesh, Gujarat, Karnataka and Tamil Nadu and the states with low risk of nitrate pollution were Himachal Pradesh, Madhya Pradesh, Orissa and Maharashtra. Handa *et al*., 1975 [27] conducted a study to find out the extent of nitrate contamination in ground water of different parts of India. By extensively studying 2500 samples, they found that high nitrate content in the samples was attributed to animal and human activities and irrigation return flow from agricultural fields that were heavily supplied with fertilizers. Deep ground water reported only a concentration 1-2 mg/L, whereas shallow ground water reported up to 100 mg/L of nitrates in humid areas and 1000 mg/L in arid and semi-arid regions. In Uttar Pradesh (India) the data collected from 276 ground water samples, revealed that number of wells with nitrate concentration below 10, 20, 50 and 100 mg/L were 53.6%, 71.7%, 89.5% and 95.3%, respectively (Pathak, 1980 [28]). Handa, 1986 [29] reported the presence of exceptionally high concentration of nitrate nitrogen in Hisar (1800 mg/L) and Mahendragarh (1620 mg/L) districts of Haryana. Rao and Prakash, 1991 [30] studied the distribution of nitrate in ground water of different districts of Karnataka and found that in Hassan district 46.27% of total area is affected by very high nitrate content in the ground water i.e. greater than 45 mg/L. Further, 41.58% of total area of Raichur, 36.22% of Mandya, 38.08% of Tumkur and 34.28% of Bijapur is affected by high nitrate concentration in the ground water. Mukharjee and Pandey, 1944 [31] reported a nitrate concentration in the range of 65-1250 mg/L in the Jaunpur district of Uttar Pradesh which was probably attributed to combined effect of agricultural activities, improper management of sewage and inappropriate disposal of waste products. Ground water were collected from dug wells and borewells of Thanjavur city of Tamil Nadu, India and out of which 13% of the samples had elevated nitrate content (>45 mg/L) and these elevated concentration are mainly attributed to manmade activities (Nagarjuna *et al*, 2010 [32]). In Rajasthan, the ground water of 22% of the villages has nitrate concentration above the safe limits (Gupta and Gupta, 2010 [33]). Gupta *et al*, 2011 [34], reported that out of the ground water collected from 1407 locations in Maharashtra, the ground water of 544 locations had reported nitrate concentration above 45 mg/L and about 227 locations has exceeded nitrate levels beyond 100 mg/L. Dar *et al*, 2010 [35] also confirmed nitrate pollution in the ground water of sapore town and its environs in Kashmir. About 85% of samples during summer and 67% of the samples during winter season were found to have high concentration of nitrate that was exceeding the permissible limit of WHO (50 mg/L) and this high nitrate concentration in the ground water was attributed to the excess use of N-fertilizers in that area. Adhikary *et al*, 2012 [36] reported alarming levels of nitrate pollution in the ground water of peri- urban area of Delhi, India. Mondal *et al*, 2008 [38], measured the nitrate concentrations in the ground water samples of Krishna delta, India and the results indicated that out of 79 ground water samples, about 39% had recorded higher nitrate contents (> 50mg/L). In North Krishna delta, 49% and in south Krishna delta 26% of water samples were found to exceed the permissible nitrate limits in drinking water. Kumar *et al*, 2009 [39] reported that, major pollutants of ground water in Manimuktha river basin, Tamil Nadu, India are nitrate and phosphate and these pollutants were contributed by sewage effluents and fertilizer applications.

Rahmati *et al*, 2015 [40] reported that in Western Iran ground water of 12.9% of total wells under study had nitrate concentration above the threshold set by WHO. The detailed analysis of spatial distribution of polluted wells, made it clear that wells were located within the area where irrigated agriculture was practiced. In Luzon, Phillipines, in irrigated double rice cropping system areas, the mean nitrate content in the season was in the range of 0-2 mg/L, whereas in wet season, rainfed rice and dry season irrigated sweet pepper, the mean monthly nitrate concentration was in the range of 5-12 mg/L (Bouman *et al*. 2002 [41]). Apart from humans the aquatic life is also affected by nitrate pollution. Fleischer and Stibe, 1989 [42] reported severe loss to fishes and marine population in Sweden due to coastal eutrophication caused by excessive use of nitrogen fertilizers in agriculture.

Ground water Pollution by Pesticides

Agriculture development is closely related to use of pesticides. The use of pesticides has helped in preventing the losses caused by pest attack and has improved the production potential of crops, but these excess quantities are leaching down to ground water and causing its pollution (Zhao and Pei, 2012 [43]). Pesticide contamination in ground water is very closely related to persistence of pesticides in soil. The ability of a pesticide to get absorb decides whether it will leach down to ground water or not. The pesticides with poor adsorption or absorption on soil surface will leach down to ground water and will lead to its contamination. A number of reports are recorded about the ground water contamination from residues of pesticides. Pesticides causes serious health hazards to living systems as they are rapidly soluble in fat and they can accumulate in target organisms (Agrawal *et al*, 2010 [44]).

The 56 shallow ground water samples from agriculture land in Taibu basin of China were collected by Li *et al*, 2013 [45] and they reported the presence 13 types of organo-chlorine pesticides in the ground water. In Hebei and Shandong regions of China, the ground water samples were collected from sweet potato planting area and the analysis of ground water revealed the presence of aldicarb, pharate and terbulos in it (Kong *et al* 2004 [46]). Similarly, Stover and Guitjens, 1990 [47] also reported the presence of extremely toxic insecticide Aldicarb in the ground water. Later, Rothschild *et al*. 1982 [48], also reported the concentration of aldicarb in ground water of Central sand plain of Wisconsin. The results of the study inferred that highest aldicarb concentration was present in shallow wells, which were located immediately above the water table, whereas no aldicarb concentration was detected in deep well that were located 60 feet below the water table. High levels of aldicarb (> 10 mg/L) as well as sulfones and sulfoxides of aldicarb were also recorded in eight states of United States (Moye and Miles, 1988 [49]). In districts of Howrah (West Bengal, India) the ground water was found to be affected by elevated levels of pesticides and thus considered to be unfit for drinking (Chaudhary *et al*, 2002 [50]). The ground water samples collected from Kanpur (India) has also reported the presence of high concentration of both organochlorine and organophosphorus pesticides. The ground water samples collected from various hand pumps located in agricultural and industrial areas, reported the presence of gamma- HCN, malathion and dieldrin in concentration of 0.9000, 29.835 and 16.227 µg/L, respectively (Sankaramakrishnan *et al*, 2004 [51]). Bouman *et al*, 2002 [41] reported that, the mean pesticide content in the ground water of agriculture land of Luzon, Phillipines were one to two orders of magnitude below the WHO single (0.1µg/L) and multiple pesticides(0.5 µg/L) limits, although temporary peak concentrations of 1.14 - 4.17 µg/L were recorded. In Portugal Gonclaves *et al*, 2007 [52] studied the impact of intensive horticultural practices on ground water contamination. The most frequently detected pesticides were lindane (53%), Pendimethaline (49%), endosulfan sulphate (44%) and endosulfan (38%). Kumari *et al* 2008 [53], collected 12 samples of ground water from paddy- wheat, paddy cotton, sugarcane fields and tube wells from areas around Hissar, Haryana and in the ground water samples, HCH, DDT, endosulfan and cypermethrin residues were found frequently. Among organosulphates, only chloropyriphos was detected in 10 samples. On consideration of tube well ground water about 80% of samples were found unsafe for drinking as pesticidal residues were present above the safe prescribed limits. The ground water of Thirvallur district of tamil Nadu, India was found to be highly contaminated with DDT, HCH, endosulfan and their derivatives (Jayashree and Vasudevan, 2007 [54]). Among the derivatives of HCH, the concentration of γ-HCH residues was found to be maximum (9.8 µg/L) in Arumbakkam open wells. pp-DDT & op-DDT were reported to have a concentration of 14.3 µg/L & 0.8 µg/L, respectively. The ground water of Kandigai village borewell recorded the maximum residues of endosulfan sulphate (15.9 µg/L). Croll, 1991 [55] reported the presence of atrazine in ground water in a low concentration upto 0.1 mg/L in Anglian water region of UK. In hawai islands, the ground water was found to be contaminated with DBCP & EDB (Oki and Giambelluca, 1989 [56]). Ground water of rural areas near Farrukhabad (U.P) of India was analyzed to observe the pesticide contamination and it was reported that almost all the samples were contaminated with residues of HCH and DDT. The residues of Aldrin, endosulfan and heptachlor were also present in a large number of samples. The recharge of ground water by contaminated ganga river and downward movement of pesticide residues along with rain water are the important sources of ground water contaminated with pesticides (Mohapatra *et al*, 1995 [57]). Tariq *et al*, 2003 [58], reported that ground water samples collected from cotton growing districts of Bahwalanagar, muzafargarh, D.G.khan and Rajanpur were found to be contaminated with 6 types of pesticides, which were commonly used in that area. The percentage of detection of bifenthrin, λ-cyhalothrin, carbofuran, endosulfan, methyl parathion and monocrotophos, respectively 13.5, 5.4, 59.4 8, 5.4 and 35.1% in july whereas in October their concentration was 16.2%, 13.55, 43.2, 8.0, not detectable and 24.3%, respectively. A study was conducted at Jaipur (Rajasthan, India) to study the pesticide content in wheat flour and drinking water and the experimental results indicated that all the wheat and water samples were found to be contaminated with various organochlorine pesticide residues of DDT and its metabolites, HCH and its isomers, heptachlor and its expoxide and aldrin (Bakare *et al*, 2004 [59]). In North-eastern parts of country, pesticide residues were reported in both surface water and ground water. Alpha HCH, total HCH and aldrin were detected in all the samples. The total DDT was detected in 90.9% ground water samples and 82% surface water samples. Ground water samples collected from that area reported the presence of alpha HCH, beta HCH, gamma HCH, op DDT, pp DDT, pp DDE, pp DDE, endosulfan and aldrin in a higher concentration by 4.6%, 14.06%, 2.4%, 24.2%, 15.6%, 101.2%, 174%, 57.85% and 24.73%, respectively as compared to surface water (Kumar *et al*, 1995 [60]). Ghosh *et al*, 2009 [61] also reported the presence of residues of organochlorine pesticides in ground water of greater Kolkata. Lindane (0.01 – 0.43 µg/L) and DDT (0.03-0.65 µg/L) were detected in most of the samples. Kaushik *et al*, 2012 [62] reported that the ground water of Ambala and Gurgaon districts of Haryana, india were found to be contaminated with isomers of HCH, endosulfan and metabolites of DDT. The ground water of Kasargod district of Kerala, (India) has also reported the contamination of organochlorine pesticides in the open wells. The maximum concentration of organochlorine pesticides was observed for endosulfan followed by hexachlorobenzene (Akhil and Sujatha, 2012 [63]). Aslam *et al*., 2013 [64] reported the presence of Atrazine and Simazine in ground water of delhi, India. Analysis also revealed that conbcentration of Simazine was higher as compared to atrazine. Highest concentration of atrazine was recorded in the North region of Delhi. Atrazine and its metabolites are becoming the main toxic contaminants in the ground water of USA/ Canada (Belluck *et al*, 1991 [65]). Somashekhar *et al*, 2015 [66] reported the presence of Methylisocynate (MIC) in 5 out of 12 samples of ground and surface water collected at Mysore, India. MIC is an intermitant compound of carbamate pesticide and is harmful to health.

Conclusion
Ground water is one of the precious resources of nature, but it is being overexploited. It is getting contaminated and very little effort is paid towards its efficient and wise utilization. The contamination of ground water is a very serious problem as it affects all the living beings, either directly or indirectly. So, it has become essential to manage ground and to protect it. In light of the above evidences it is clear that agricultural activities serves as a potential contaminant of ground water. Therefore, strategies are needed to prevent the flow of excessive agrochemicals from agricultural fields to ground water.

References

1. Keeney DR. Sources of nitrates to groundwater. In N management and ground water protection. Ed. R.F. Follett, 1989, 23-34.
2. Majumdar D, Gupta N. Nitrate pollution of groundwater and associated human health disorders. Indian Journal of Environmental Health. 2000; 42(1):28-39.
3. Spadling RF, Exner ME. Occurrence of nitrate in groundwater- A review. Journal of Environmental Quality, 1993; 33:392-402.
4. Singh B, Sekhon GS. Nitrate pollution of groundwater from farm use of nitrogen fertilizers- A review. Agriculture and Environment. 1979; 4(3):207-225.
5. Pustaji A. Nutrient overloading of soil and protection of water from contamination in Hungary. Vestnikk Sel Skokhozyai Stevannoi, Nauki, Moscow, 1989; 7:143-147.
6. Hall JK, Murray MR, Harturig ML. Herbicide leaching and distribution in untilled and tilled soil. Journal of Environment Quality. 1989; 18(4):439-443.
7. Jorgensen SE, Nielson SC, Marcussen B. Removal of nitrates from groundwater through the use of artificial wetlands. International Journal of Water Research and Development. 1989; 5(3):209-214.
8. Barnes CJ, Jacobson G, Smith GD. The origin of high nitrate groundwater in Australian arid zone. Journal of Hydrology. 1992; 137(1-4):181-197.
9. Matukhno Yu D. Nitrogen and phosphorous in river water. Agrochimia, 1988; 10:82-88.
10. Moody DW. Groundwater contamination in US. Journal of Soil and Water Conservation, 1990; 45(2):170-179.
11. Fan AM, Steinberg VE. Health implications of nitrate and nitrite in drinking water- An update on methemoglobinemia occurrence and reproductive and developmental toxicity. Regulatory Toxicology and Pharmacology, 1996; 23:35-43.
12. Gelberg KH, Church L, Casey G, London M, Roerig DS, Boyd J *et al*. Nitrate levels in drinking water in rural New York State. Environmental Research, Section A, 1999; 80:30-40.
13. Guli G, Czompolyova M, Cerhan JR. An ecologic study of nitrate in municipal drinking water and cancer incidence in Trnava District, Slovakia. Environmental Research, Section. 2002; A88:182-187.
14. Johnson PTJ, Townsend AR, Cleveland CC, Patricia MG, Robert WH Valerie JM *et al*. Linking environmental nutrient enrichment and disease emergence in humans and wildlife. Ecological Applications, 2010; 20:16-29.
15. Kanwar RS, Karlen DL, Cambardella CA, Cruse MR. Swine manure and N management systems: Impact on groundwater quality clean water, clean environment – 21st century. Conference proceedings ASAE (Kansas City, MO, 5-8 March), 1995; 2:91-94.
16. Karlen DL, Cambardella CA, Kanwar RS. Challenges of managing liquid swine manure. Applied Engineering in Agriculture. 2004; 20(5):693-699.
17. Bakhsh A, Kanwar RS, Karlen DL. Effect of liquid swine manure applications on NO3-N leaching losses to subsurface drainage water. Agriculture Ecosystem and Environment. 2005; 109:118-128.
18. Fabro AYR, Avila JGP, Alberich MVE, Sansores SAC, Camargo- Volerop- MA. Spatial distribution of nitrate health risk associated with groundwater use as drinking water in Merida, Mexico. Applied Geography, 2015; 65:49-57.
19. Hu KL, Huang YF, Li H, Li B, Chen D, White RE. Spatial variability of shallow groundwater level, electrical conductivity and nitrate concentration and risk assessment of nitrate contamination in North China Plain. Environment International. 2005; 31(6):896-903.
20. Liu J, Jiang LH, Zhang CJ, Li P, Zhao TK. Nitrate-N contamination in groundwater: Spatiotemporal variation and driving factors under cropland in Shandong Province, China. *In:* 3rrd International Conference on Water Resource and Environment, Earth Environment science. 2017; 82:1-13.
21. Pawar NJ, Sheikh IJ. Nitrate pollution of groundwaters from shallow basaltic aquifers, Deccan Trap Hydrologic Province, India. Environmental Geology. 1995; 25(3):197-204.
22. Mehta M, Sharma BR, Villholth KG, Sharma KD. Status of groundwater and policy issues for its sustainable

development in India. In proceedings: Groundwater research and management: Integrating science into management and decisions, International Water Management Institute, Colombo, 2006, 62-74.
23. Ghillam RW. Nitrate contamination of groundwater in southern Ontario and the evidence of denitrification. Ecological Sciences, 1991; 30:181-198.
24. Ronen D, Magaritz M. High concentrations of solutes at the upper part of the saturated zone (water table) of a deep aquifer under sewage irrigated land. Journal of Hydrology. 1985; 80:311-323.
25. Mascher F, Marth E. Influence of nitrate contamination of superficial groundwater through agricultural cultivation in Styria (Australia). Zentralblatt Fur Hygiene and und umweltmedizin. 1991; 192(3):220-229.
26. Agrawal GD, Lunkad SK, Malkhed T. Diffuse agricultural nitrate pollution of groundwaters in India. Water Science and Technology. 1999; 39(3):67-75.
27. Handa BK. High nitrate and potassium ion concentrations as indicators of groundwater pollution in India. Abs. International Symposium on the Geochemistry of Natural Waters, Burlington, Ontario, Canada, 1975.
28. Pathak BD. Hydrogeological and hydrochemical data of permanent hydrograph network station in Uttar Pradesh. Unpublished report, CGWB, Lucknow, India, 1980.
29. Handa BK. Pollution of groundwater by nitrates in India. Bhu-Jal New, 1986; 1:16-19.
30. Rao A, Prakash VS. Potability of groundwater in Krnataka. Bhu-Jal News, 1991; 6:1-6.
31. Mukherjee S, Pandey DS. Nitrate pollution in groundwater at Jaunpur and its environs. Uttar Pradesh. Bhu-Jal News. 1994; 9:22-25.
32. Nagarajan R, Rajmohan N, Mahendran S, Senthamil kumar S. Evaluation of groundwater quality and its suitability for drinking and agricultural use in Thanjavur city, Tamil Nadu, India. Environmental Monitoring and Assessment. 2010; 171(1-4):289-308.
33. Gupta AB, Gupta SK. Presence of fluoride and nitrates in drinking water and human health- A case study of Rajasthan. International conference on environmental health and technology, 2010; 15-17, IIT Kanpur.
34. Gupta I, Salunkhe AS, Rohra N, Kumar R. Groundwater quality in Maharashtra, India: focus on nitrate pollution. Journal of Environmental Science and Engineering. 2011; 53(4):453-462.
35. Dar IA, Dar MA, Sankar K. Nitrate contamination in groundwater of Sopore town and its environs, Kashmir, India. Arabian Journal of Geosciences. 2010; 3(3):267-272.
36. Adhikary PP, Dash CJ, Chandrasekharan H, Rajput TBS, Dubey SK. Evaluation of groundwater quality for irrigation and drinking using GI and geostatistics in a peri urban area of Delhi, India. Arabian Journal of Geosciences. 2012; 5(6):1423-1434.
37. Mondal NC, Saxena VK, Singh VS. Occurrence of elevated nitrate in ground water of Krishna delta, India. African Journal of Environmental Science and Technology. 2008; 2(9):265-271.
38. Kumar SK, Rammohan V, Sahayam JD, Jeevanandam M. Assessment of groundwater quality and hydrogeochemistry of Manimuktha river basin, Tamil Nadu, India. Environmental Monitoring and Assessment. 2009; 159:1-4.
39. Rahmati O, Samani AN, Mahmoodi N, Mahdavi M. Assessment of the contribution of N- fertilizer to nitrate pollution of groundwater in western Iran (case study: Ghorveh- Dehgelan Aquifer). Water Quality, Exposure and Health. 2015; 7(2):143-151.
40. Bouman BAM, Castaneda AR, Bhuiyan SI. Nitrate and pesticide contamination of groundwater under rice based cropping systems: past and current evidence from the Philippines. Agriculture, Ecosystems and Environment. 2002; 92(2-3):185-199.
41. Fleischer S, Stibe L. Agriculture kills marine fish in 1980s. Who is responsilble for fish kills in 2000s. Ambio, 1989; 18(6):347-350.
42. Zhao YY, Pei YS. Risk evaluation of groundwater pollution by pesticides in China: A short review. Procedia Environmental Sciences. 2012; 13:1739-1747.
43. Agrawal A, Pandey RS, Sharma B. Water pollution with special reference to pesticide contamination in India. Journal of Water Resource and Protection. 2010; 2:432-448.
44. Li YZ, Jia XF, Xu CY, Wang QS, Li QZ. A study on the source tracing of ground water nitrate in Shandong province. Ecology and Environmental Science. 2013; 22(8):1401-1407.
45. Kong DY, Zhu ZL, Shi LL, Shan ZJ, Cai DJ. Effect of pesticides on groundwater under sweet potato based cropping systems in Northern China. Journal of Agro-Environment Science. 2004; 23:1017-1020.
46. Stover JA, Guitjens JC. Aldicarls in vadose zone: review. Journal of Irrigation and Drainage Engineering. 1990; 116(1):36-49.
47. Rothschild ER, Manser RJ, Anderson MP. Investigation of Aldicarb in groundwater in selected areas of the Central Sand Plain of Wisconsin. Groundwater. 1982; 20(4):437-445.
48. Moye HA, Miles CJ. Aldicarb contamination in groundwater. Reviews of Environmental Contamination and Toxicology. 1988; 105:99-140.
49. Chaudhary C, Jacks G, Gustafsson JE. An analysis of groundwater vulnerability and water policy reform in India. Environmental Management and Health, 2002; 13:175-193.
50. Sankararamakrishnan N, Sharma AK, Sanghi R. Organochlorine and organophosphorous pesticide residues in groundwater and surface waters of Kanpur, Uttar Pradesh, India. Environment International. 2005; 31(1):113-120.
51. Goncalves CM, Da Silva JCGE, Alpendurada MF. Contamination of groundwater sampled over two years from a vulnerable zone in Portugal. Journal of Agricultural and Food Chemistry. 2007; 55(15):6227-6235.
52. Kumari B, Madan VK, Kathpal TS. Status of insecticide contamination of soil and water in Haryana, India. Environmental Monitoring and Assessment. 2008; 136(1-3):239-244.
53. Jayashree R, Vasudevan N. Organochlorine pesticide residues in groundwater of Thiruvallur district, India. Environmental Monitoring and Assessment. 2007; 128(1-3):209-215.
54. Croll BJ. Pesticides in surface waters and ground waters. Journal of the Institution of Water and Environmental Management. 1991; 5(4):389-395.
55. Oki DS, Giambellula TW. Groundwater contamination by nematicides. Tokyo Publishers, Tokyo, 1989, 75-125.
56. Mohapatra SP, Kumar M, Gajbhiye VT, Agnihotri NP. Groundwater contamination by organochlorine

insecticide residues in a rural area in the indo gangetic plain. Environmental Monitoring and Assessment, 1995; 35(2):155-164.
57. Tariq MI, Afzal S, Hussain I. Pesticides in shallow groundwater of Bahawalnagar, Muzafargarh, DG Khan and Rajanpur districts of Punjab, Pakistan. Environment International. 2004; 30(4):471-479.
58. Bakore N, John PJ, Bhatnagar P. Organochlorine pesticide residues in wheat and drinking water samples from Jaipur, Rajasthan, India. Environmental Monitoring and Assessment, 2004; 98(1-3):381-389.
59. Kumar S, Singh KP, Gopal K. Organochlorine residues in rural drinking water sources of Northern and North Eatern India. Journal of Environmental Science and Health Part A. 1995; 30(6):1211-1222.
60. Ghose NC, Dipankar S, Gupta A. Synthetic detergents (surfactants) and organochlorine pesticide signatures in surface water and groundwater of greater Kolkata, India. Journal of Water Resource and Protection. 2009; 1(04):290.
61. Kaushik CP, Sharma HR, Kaushik A. Organochlorine pesticide residues in drinking water in the rural areas of Haryana, India. Environmental Monitoring and Assessment. 2012; 184(1):103-112.
62. Akhil PS, Sujatha CH. Prevalence of organochlorine pesticide residues in ground waters of Kasargod district, India. Toxicological and Environmental Chemistry, 2012; 94(9):1718-1725.
63. Aslam M, Alam M, Rais S. Detection of Atrazine and Simazine in groundwater of Delhi using high performance liquid chromatography with ultraviolet detector. Current World and Environment. 2013; 8(2).
64. Belluck DA, Benjamiu SL, Dawson T. Groundwater contamination by atrazine and its metabolites; risk assessment, policy and legal implications. ACS symposium series, Pub. Minnesota pollution control agency, 1991; 459:254-273.
65. Somashekar KM, Mahima MR, Manjunath KC. Contamination of water resources in Mysore city by pesticide residues and plasticizer- A cause of health concern. Aquatic procedia, 2015; 4:1181-1188.