Chapter 15
An Overview of Agricultural Pollutants and Organic Contaminants in Groundwater of India

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Abstract Major part of Indian population depends on groundwater for drinking purpose. Recent reports of detection of trace quantities of agricultural pollutants and organic contaminants in groundwater have raised serious public health concern. Organic contaminants can enter into groundwater system both through infiltration and through interaction of surface water and groundwater. In addition, problems also arise from the disposal of large amounts of manure and slurries from the increasing numbers of animal rearing units. A series of problems emerge gradually with the utilization of contaminated groundwater. Groundwater wells in Ganges basin which occasionally has very high level of organic contaminants require careful monitoring. The detection of a number of pesticides in groundwater in recent years has been made possible due to development of analytical methods capable of measuring concentrations in parts per billion (ppb) or even lower. It has been found that mostly two herbicides, Alachlor and Atrazine, and one insecticide, Malathion, are found in significant levels in groundwater of India. In lower Ganges basin, Malathion concentration is much higher than the permissible limit. Significant amount of nitrate and phosphate fertilizers has also been detected in

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groundwater systems of India. Research on pesticide and fertilizer contamination and their dissemination in groundwater system is being studied. Adverse effect of these contaminants on human health in India is yet to be established, but research on such fields is been undertaken by different scientific communities.

Keywords Groundwater · Organic pollution · Pesticides · Chemical fertilizers Malathion

15.1 Introduction

Groundwater sources comprise of seepage from the surface water mainly from river water, rainwater, lakes, and streams. Entire human population depends on 6% of the aggregate water on Earth which is freshwater of which majority is in the form of ice caps and ice masses. If these sources are deducted from the total freshwater content, only 0.3% of the water on Earth is accessible for drinking purposes of which majority is groundwater (USEPA 1992). Since significant part of the population in the developing countries relies entirely on groundwater for drinking purpose, groundwater pollution may cause serious health concerns (APHA 1995). Groundwater pollution can be broadly categorized into two types: natural geogenic pollution and anthropogenic pollution. Anthropogenic pollution has more impact than geogenic pollution in the shallow dug which is mainly used by people for drinking purpose. Anthropogenic pollution in groundwater can be broadly clustered into four groups: municipal, industrial, agricultural, and individual domestic sources. Contamination of municipal sources includes open dumpsites, inadequately constructed latrines, and other waste places. Each of these can contain a huge number of pathogens and also high metal concentration that can infiltrate to the groundwater aquifers. Mining activities effect groundwater contamination through draining of mine tailing piles. Another major source of groundwater pollution is agricultural contamination which essentially comes from use of pesticides and fertilizers which can later infiltrate to the groundwater system. Contamination in India's groundwater has long been a natural concern and focus of global environmental concern. Since there are very few studies on the agricultural contaminants in groundwater, this chapter deals with the general assessments of agricultural contaminants with special reference to pesticides and fertilizers present in Indian groundwater.

Groundwater contamination differs from surface water contamination in several points of views. During late nineteen, the quality of groundwater has been degraded and presence of hazardous waste in groundwater was reported. Later, a considerable effort was applied to protect and clean the surface water where pollution was readily visible. During 80s, widespread reports on presence organic pollutants in trace quantity in groundwater shifted the focus from surface water to groundwater protection, resulting in the change of drinking water regulation. Groundwater contamination has been called the problem of the 1980s. Arsenic pollution in groundwater was first reported during this time.

This chapter is intended to provide an overview of the organic pollution in Indian groundwater and health effects of contaminated groundwater (Chap. 1, Fig. 1.4). Organic pollutants from surface water can seep into groundwater from any place (Winter 1983). Quality of groundwater also degrades due to contact with sediments. In recent studies, it has been observed that excessive use of agricultural fertilizers increases the nitrate and phosphate contents in groundwater.

Punjab and Haryana are one of the most agriculturally productive lands in India. These two places are rich in natural resources which include nutrient-rich soil and a satisfactory amount of water supply and favorable climate conditions for agriculture. As a result, two or more types of crop in a year have been obtained from this land. During the 1970s and 1980s, green revolution was held to expand the irrigated areas by the development of surface water and groundwater resources. Increased use of fertilizers and pesticides improved the quality of the crop and food (Avtar et al. 2013). Subsequently, groundwater of these places becomes vulnerable to organic pollution, and drinking water supply was threatened. A series of difficulties developed eventually with the application of pesticides and organic fertilizers which seeped into groundwater.

River water has been over-exploited and polluted in many parts of the world, so have groundwater. During 1978, the presence of dioxins in Love Canal is one of the exemplars which cause carcinogenic effects and an alarming number of neonatal deformities. Similar event persists in the present world. Well, documentation of nature and pollution mechanism of the organic contaminants in the groundwater has been done after years of researches. The present study focuses on the types of organic contaminants in groundwater, sources of it along with the present scenario of contaminants in groundwater system in India. More related information regarding groundwater of South Asia is available in (Mukherjee 2018).

15.2 Present Scenario of Agricultural Pollution in Groundwater in India

Water passing through an aquifer is naturally filtered, either by the natural degradation of contaminants or through surface adsorption. Groundwater often serves safe and clear drinking water. Water from shallow aquifer is safer than deep aquifer in respect of natural geogenic pollution such as arsenic. But anthropogenic activities are the major cause of pollution in shallow groundwater. As of 2011, India is the second largest country in the agricultural sector. About 40% of the total land use is covered by agricultural field. Since India is the largest user of groundwater, groundwater pollution is a major concern in India. Sometimes organic compounds are stable and also soluble in water. Surface adsorption also depends on the soil properties and residence time. During 1948–49, use of organic pesticides started with DDT (Dichlorodiphenyltrichloroethane) and BHC (benzene hexachloride). During the 1970s, the green revolution had been aimed to increase the crop productivity, and organic pesticides and agricultural fertilizers have been applied in the agricultural field. Indian pesticide market comprises more than 550 pesticides (Gupta 2004).

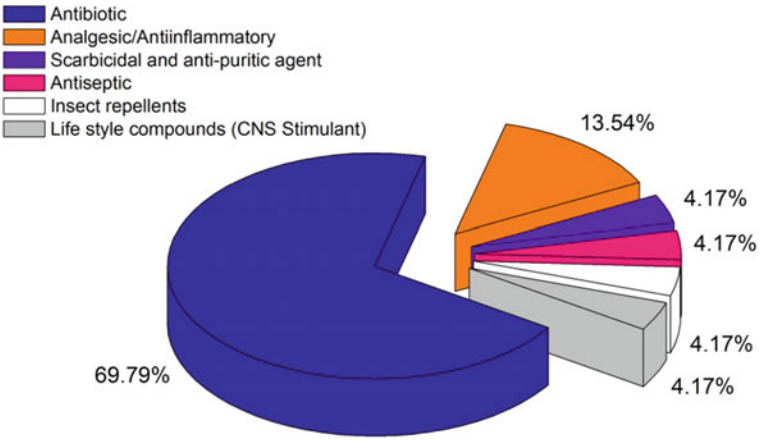

Fig. 15.1 Occurrence (%) of organic compounds detected in groundwater in Asiatic countries. *Data source* Ministry of chemicals and petrochemicals; number of compound identified = 24

Twenty-four pharmaceutical compounds are present in the groundwater of Asian countries, among them 23 are pharmaceuticals antibiotics and another one is Caffeine (Hu et al. 2010; Zhou et al. 2013; Yao et al. 2014). There is very few literature which reports occurrence of pesticides and other agricultural pollutants in groundwater. Antibiotics, analgesic/anti-inflammatory, anticonvulsant, herbicidal, and anti-puritic agents, antiseptics, insect repellents, and lifestyle compounds (Central Nervous System Stimulant) are mostly reported and identified compounds in groundwater of Asian countries (Fig. 15.1). Two most common identified compounds include two antibiotics, namely sulfamethoxazole and tetracycline (Hu et al. 2010).

Most of the countries in Southeast Asia are trying to find their gateway in the global market as a supplier of varieties of fresh fruits and vegetables. The recent agricultural practice involves a use of pesticides and fertilizers which gradually infiltrates into groundwater resulting drinking water pollution. Report from a study in Hanoi, in the Red River Delta, showed that proper guideline was followed by only 25% farmers and 58% followed their own experience and 17% were unskilled (Jaeken et al. 2005). In developing countries, after applying the pesticides on the fields, farmers dispose of the remaining spray in the surface water and the spraying equipment is cleaned in canal and ditches. Unaware about the proper disposal procedure, remaining part is sprayed on other plants (Castillo et al. 2007). Due to this kind of agricultural practices, infiltration of contaminants in groundwater pollution increases.

According to Pakistan Council of Research in Water Resources, by-products of various industries such as textile, metal, dyes, fertilizers, pesticides, cement, and petrochemical industries are the primary contributors of the organic pollution in groundwater (PCRWR 2010). Between July and December 2002, the Pollution Monitoring Laboratory of the New Delhi-based Center for Science and Environment (CSE) examined 17 brands of bottled water. Among them, six bottled

water plants showed the frequent presence of beta-Hexachlorocyclohexane (HCH), Dichlorodiphenyltrichloroethane (DDT), Malathion, and Chlorpyrifos. Some raw water samples also showed the presence of Endosulfan, Dieldrin, Dimethoate, and Methyl parathion which was more than the permissible limit.

In 2008, a study was directed to scrutinize the ecological exposure of natural water pollution distant mountainous areas of northern Vietnam. The study observed the fate of four groups of pesticides, namely imidacloprid, fenitrothion, fenobucarb, and dichlorvos, from paddy field to a stream on the watershed scale and computed groundwater pollution. Maximum measured concentration was 0.47, 0.22, 0.17, and 0.07 ppb for fenitrothion, imidacloprid, fenobucarb, and dichlorvos, respectively. The report suggests that present agricultural use of pesticide in the paddy field causes a serious ecological concern in the region (Lamers et al. 2011).

Pesticide includes a wide variety of compounds which contain insecticides, fungicides, herbicides, and plant growth regulators. Approximately, in India, 76.3% of the pesticide used is insecticide, and use of herbicides and fungicides is comparatively less. This chapter contains the yearly variation of use of pesticides in India since 2000 (Fig. 15.2). The pesticide consumption in India during 1954 to 2000 has been increased from 434 to 46,195.16 Metric Tonne. The increase in use of pesticides supports the increase in residual pesticide concentration in groundwater and surface water by percolation and surface runoff, respectively.

The discovery of a numerous number of pesticides in groundwater in past few decades has been made feasible by the improvement of new cutting-edge technologies which are capable of determining concentrations in the parts per billion (ppb) ranges or even less than that. Distribution of different classes of pesticides applied on agricultural fields in India has been shown in Fig. 15.3.

Central Pollution Control Board (CPCB) has detected the pesticides in groundwater. It has found that mostly two herbicides such as Alachlor and Atrazine and two pesticides such as Lindane and Chlorpyrifos are found in groundwater in India. Pesticide concentrations in groundwater in recent years have been monitored

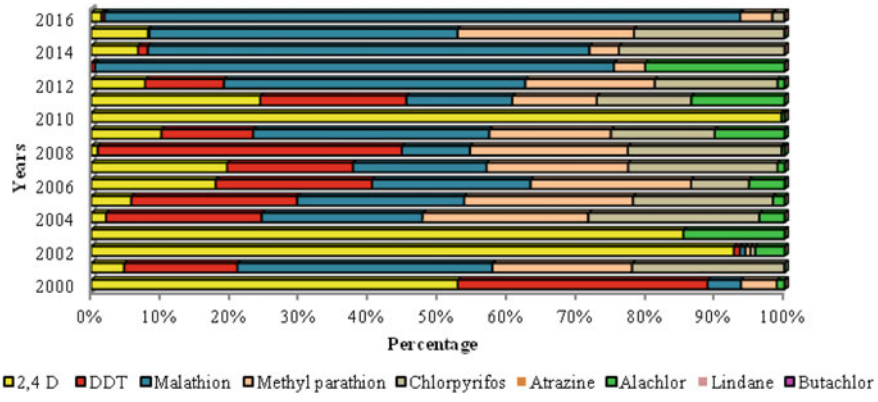

Fig. 15.2 Use of pesticides during 2000–2016 in India. *Data source* Central Pollution Control Board

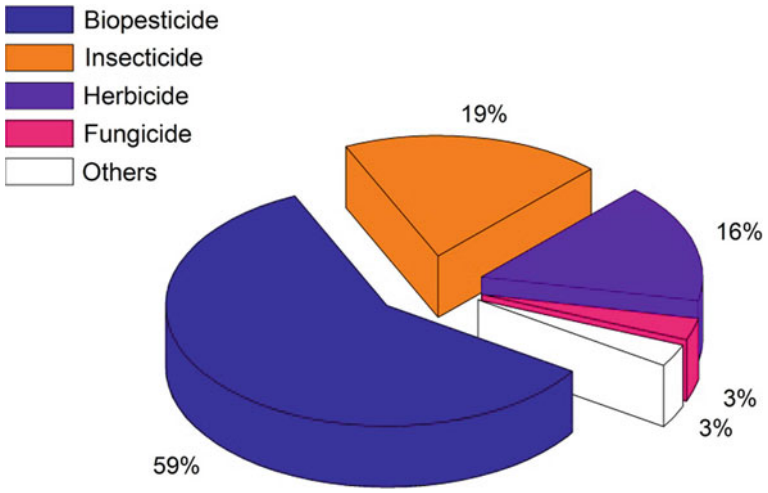

Fig. 15.3 Distribution of different classes of pesticides used in India. *Data source* State Pollution Control Board

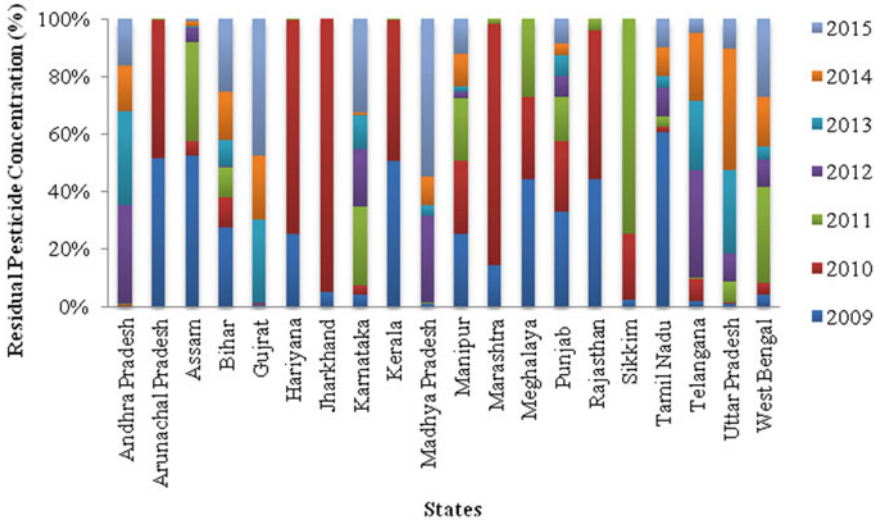

Fig. 15.4 Overall pesticide concentration in groundwater for different states in recent years

by state pollution control board (Fig. 15.4). Three states Haryana, Punjab, and West Bengal found to be most susceptible area to pesticide pollution in groundwater (Fig. 15.5). This figure depicts locations having the high amount of residual pesticide concentration in groundwater. These areas are agricultural dependent land, and people are also dependent on groundwater from private wells those are situated

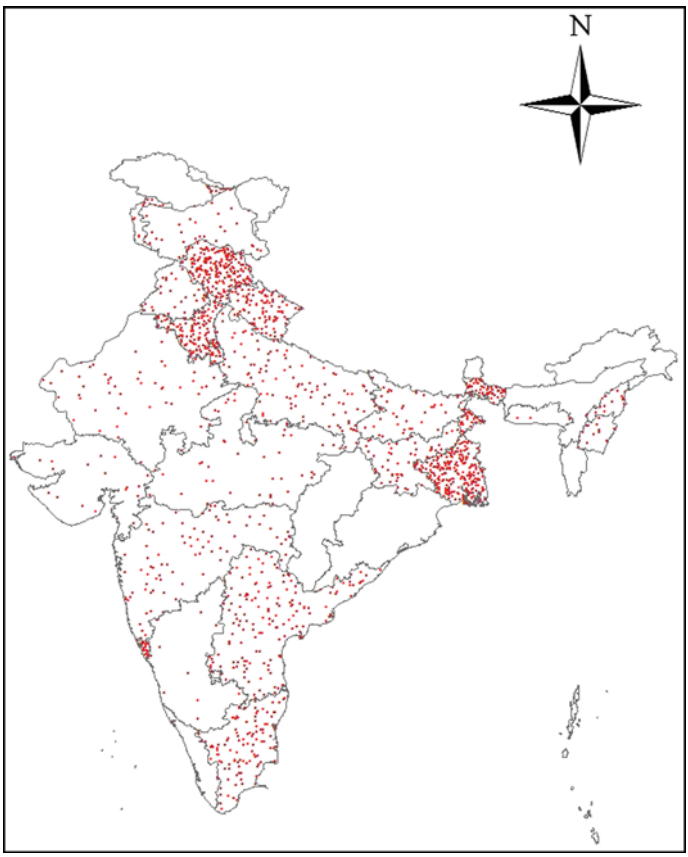

Fig. 15.5 Distribution of residual pesticide in different locations of each state in Indian groundwater

just beside the pesticide-applied agricultural field. Pesticides have been detected in private wells and even in public shallow wells adjacent to the pesticide-treated field. Twelve pesticides have been detected which showed higher than permissible limit as per Environment Protection Agency (EPA) in drinking water wells under specific conditions from the limited monitoring sites.

Most of the pesticides listed are applied to the surface of the soil or are fused with the soil, as opposed to being sprayed onto growing crops. Discontinuation of use of pesticide in affected area may be obtained if the concentration of pesticide in groundwater reaches the permissible limit. The higher amount of aldrine has been found in groundwater in rural areas of Uttar Pradesh. Approximately 62% of the total area of West Bengal has cultivated the land. According to West Bengal pollution control board, lower Ganges basin showed the higher amount of Malathion concentration which is three times more than the permissible limit. Ecological cautions on pesticide concentrations should always be noticed. Activated carbon filter is an

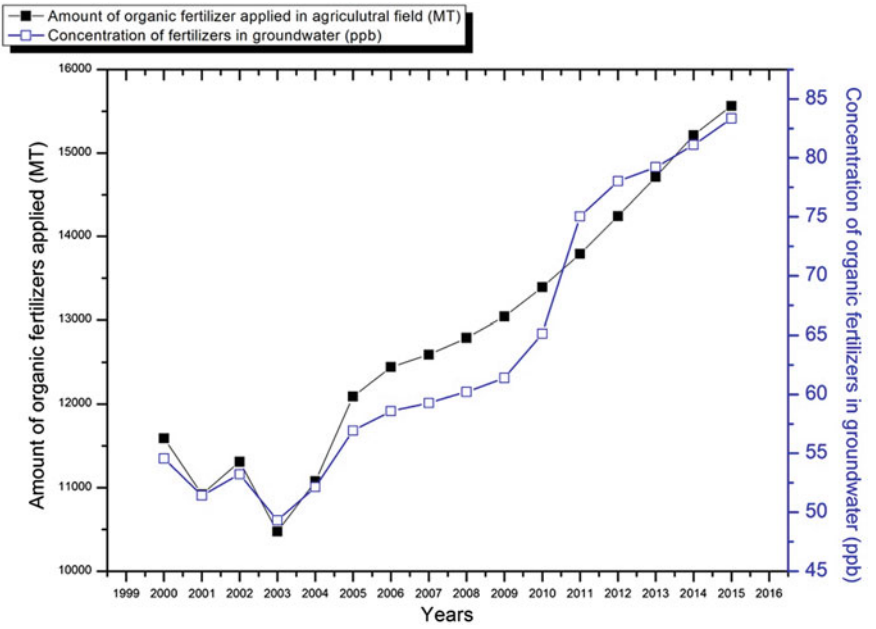

Fig. 15.6 Use of organic fertilizer in agricultural field and concentration of organic fertilizer in groundwater. *Data source* Department of Fertilizer and Public Health Engineering Department, Govt. of India

effective remediation technology to reduce the concentration of pesticides in drinking water. Use of ultraviolet light to decompose the pesticide residues can be an alternative way to get rid of pesticide pollution. Regular monitoring of groundwater must be observed at monthly intervals to regulate the concentration. Research on organic pollution is continuing for many organic compounds.

Chemical fertilizers are widely used in the agricultural sector of India. It has been observed that nitrate and phosphate concentration has been increased during last few decades. Since potassium having limited mobility and phosphorus being virtually immobile, neither is leached out very easily and does not appear to have any adverse effects on the natural water. On the contrary, nitrogen fertilizers are readily converted to nitrates which are soluble, thus posing more serious problems. Studies show, however, that a proportion of the nitrate is contributed by nitrogen-fixing bacteria found in all fertile soils. Reports also suggest that nitrate is also contributed by rainwater and sewage effluents. Groundwater wells associated with Ganges basin which occasionally have very high levels of fertilizers do require careful monitoring. In current years, there has been alarm about environmental pollution and it has been frequently stated that chemical fertilizer usage has added to this pollution by increasing the fertilizer concentration in groundwater. The tonnages of manufactured fertilizer nutrients such as nitrate used in India in recent years are given in Fig. 15.6.

These data, which are readily obtainable from Department of Fertilizer, Govt. of India, shows that the use of nitrate fertilizer has been increased in last 16 years. The concentration of nitrate in groundwater showed the same result over the last 16 years. Although the fertilizer loss is important economically to the farmer, the more important concern is its effect on the environment. Two major problems contributed by high nutrient levels are algal blooms which have been attributed to soluble nitrates and phosphates in water and adverse effect on young babies up to the age of about three months, which is due to the presence of excessive levels of nitrate in drinking water. Algal growths which have been known for centuries are incompletely understood, but the levels of nutrients which it is claimed to limit algal growth are below 0.3 ppm nitrate and 0.01 ppm phosphates, respectively. It is thought that factors such as water temperature, carbon dioxide concentrations, and the presence of organic matter are important, and in general, it seems unlikely that marginal increase in nitrate levels would initiate algal growth.

References

APHA (American Public Health Association) (1995) American Water Works Association and Water Pollution Control Federation, Standard methods of examination of water and waste water, 19th edn, New York, USA

Avtar R, Kumar P, Singh CK, Sahu N, Verma RL, Thakur JK, Mukherjee S (2013) Hydrogeochemical assessment of groundwater quality of Bundelkhand, India using statistical approach. Expos Health 5(3):t05–I15

Castillo MDP, Torstensson L (2007) Effect of biobed composition moisture, and temperature on the degradation of pesticides. J Agric Food Chem 55:5725–5733

Gupta PK (2004) Pesticide exposure—Indian scene. Toxicol 198:83–90

Hu G, Dai J, Mai B, Luo X, Cao H, Wang J, Li F, Xu M (2010) Concentrations and accumulation features of organochlorine pesticides in the Baiyangdian Lake freshwater food web of North China. Arch Environ Contam Toxicol 58

Jaeken P, Debaer C (2005) Risk of water contamination by plant protection products (PPP) during pre- and post-treatment operations. Annu Rev Agric Eng 4(1):93–114

Lamers M, Anyusheva M, La N, Nguyen VV, Streck T (2011) Pesticide pollution in surface-and groundwater by paddy rice cultivation: a case study from Northern Vietnam. Clean Soil Air Water 39(4):356–361

Mukherjee A (2018) Groundwater of South Asia. Springer Nature, Singapore (ISBN 978-981-10-3888-4)

PCRWR (2010) Water quality status in rural areas of Pakistan, Pakistan Council of Research in Water Resources, Islamabad, Pakistan

United States Environmental Protect ion Agency (1992) Pesticide industry sales and usage, 1990 and 1991 market estimates. United States Environmental Protection Agency Publishing, Washington, D.C.

Winter TC (1983) The interaction of lakes with variably saturated porous media. Water Resour Res 19(5):1203–1218

Yao LQ, Huo ZL, Feng SY, Mao XM, Kang SZ, Chen J, Xu JJ, Steenhuis TS (2014) Evaluation of spatial interpolation methods for groundwater level in an arid inland oasis, northwest China. Environ Earth Sci 71(4):1911–1924

Zhou F, Guo HC, Liu Y, Jiang YM (2013) Chemometrics data analysis of marine water quality and source identification of Southern Hong Kong. Mar Pollut Bull 54(6):745–756