Chapter 11

Status of Soil Pollution in India

Abstract Industrial sector in India is witnessing rapid growth since the last decade of twentieth century with reforms in economic laws and with establishment of special economic zones (SEZ). Such rapid industrial growth has also increased threat to the environment. In spite of great difficulty in its remediation in comparison with polluted air and water, soil pollution as a threat to human life is by and large ignored at national level in India due to lack of comprehensive information on the subject. Though coordinated effort on assessment of soil pollution is absent at national level, sporadic information has been generated by several researchers on various aspects of pollution affecting soil quality. This chapter analyses these information and attempts to assess the quantum of threat being faced by agroecosystem in the country. It indicates that soil resources are facing threats from deliberate use of contaminated organics, amendment materials and irrigation water or from atmospheric depositions, spillage of effluents etc. Nature pollutants varies from salts, toxic metals, metalloids, persistent organics with varying degree of toxicity and may be of both industrial and geogenic origins.

Keywords Soil • Pollution • India • Heavy metals • Groundwater • Organic pollutants • Salinity

Over the years agriculture has been the major source of livelihood of the Indian population. During the period from 1940–1970, there was restrictive growth of private sector and Gross Domestic Product (GDP) grew at a rate of 1.4% per annum. In 1994–1995 the industrial sector registered remarkable 8.4% growth and its contribution in GDP increased thereafter. However, rapid industrial growth was also associated with surge in release of toxic effluents in the environment, including land and water bodies. Entry of pollutants directly (release of effluents on land) or indirectly (use of polluted water as irrigation to crops) has been reported to contaminate vast area of soil resources and groundwater bodies, affecting crop production as well as human and animal health through food contamination. As per the latest available estimate, about 33,900 million litres per day (MLD) urban waste water and 23,500 MLD industrial waste water was generated in our country during 2009, polluting water and soil resources of India. Small scale industries with less or no effluent treatment plants are considered bigger polluter than big industries. In another category of soil pollution, pollutant chemicals enter into the soil body

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through processes uncontrollable by land owners. For example, air borne pollutants enter the soil body from the emissions from several industries, power plants, vehicles, radioactive and toxic chemical fallouts during disasters. Gas-dust releases into the atmosphere under high temperature technological processes (e.g. power plants, metal smelting, the burning of raw materials for cement, etc.), waste incineration, vehicular activities and fuel combustion; and get deposited on land surface far away from source of generation. All these pollutant activities call for a need to develop a database on pollutant element contamination in soil and water so that remedial measures can be undertaken to protect our soil resources.

11.1 Land Use Pattern in India

India has a total land area of approximately 328 million hectares. Land utilization statistics are available for almost 93% of the entire area that is around 306 million hectares. The land use pattern of India is as below:

Agricultural land : 43.6%
Permanent pastures and meadows : 4.6%
Cultural wastelands : 12.2%
Forests : 10.7%
Barren and uncultivable land : 8.4%
Urban land : 5.3%
No information available : 5.2%

The mounting population and advanced standards of living have resulted in an ever increasing demand for residential land, both in villages and towns. Land is also needed to develop industry, commerce, transport and recreational facilities. Area under non-agricultural use includes all lands occupied by buildings, roads, railways, industrial establishments or that under water, e.g. rivers and canals etc. The increasing area under non-agriculture use driven by population growth is of major concern. Land under non-agricultural uses increased by 11.73 million hectares during 1950–2000. The increasing population and change in life style would further aggravate the pressure on agricultural land in the future.

11.2 Soil Degradation in India

Soil degradation is the decline in quantity and quality of soil. It includes: (a) Erosion by wind and water; (b) Biological degradation (the loss of humus and plant/animal life); (c) Physical degradation (loss of structure, changes in permeability); and (d) Chemical degradation (acidification, declining fertility, changes in pH, salinisation and chemical toxicity). Soil degradation encompasses several issues at various spatial time scale. The major types and underlying causes of soil degradation is presented Table 1.2 in Chap. 1. This indicates that soil degradation estimates in India is almost entirely focused on loss of soil and its productivity due to either natural processes or accelerated natural processes of erosion and ionic movements through faulty soil and water management. There is no denying fact that arresting soil loss and its productivity through above degrading forces are extremely important for ensuring food security in the country. Quality of human health is often linked with soil quality (Parr et al. 2009). Therefore, soils around cities and industrial areas having high population density play an important role on human health, as considerable fraction of the food requirement are met from the agricultural activities surrounding the area. An estimate of area under soil degradation (erosion, inundation, salinity build up, acidity) has been made mostly using satellite images and remote sensing data as well as through extensive network of organizations & Institutes like Soil and Land Use Survey of India and ICAR-National Bureau of Soil Survey and Land Use Planning. However such quantitative assessment of area under pollution by industrial, urban and mining activities is only possible through information on geographical locations of such activities as well as through direct estimation of pollutants accumulation in soil and their transfer to food and organisms around the intense activity zones. Information generated on the pollutants accumulation in environmental samples related to agriculture and foods are described in the following sections.

11.3 Soil Pollution Due to Anthropogenic Activities

Although surge in India's economic growth aided by higher levels of industrialization has remained a subject of pride, there is also a huge concern for the environmental degradation that slowly but loudly being voiced out. CPCB identified critically polluted industrial areas and clusters or potential impact zone based on its Comprehensive Environmental Pollution Index (CEPI) rating. Forty three critically polluted zones were reported in the 16 states which have CEPI rating more than 70 (Table 11.1). Among the 43 sites, 21 sites exist in only four states namely Gujarat, Uttar Pradesh, Maharashtra and Tamil Nadu.

Information on soil pollution has been generated by research organizations in several of these critically polluted areas and such information is unevenly distributed. In some areas having very high CEPI rating like Haldia, Bhiwadi, Chandrapur, Singrauli, Bhiwadi, published information on the soil pollution in nearby agricultural areas is practically absent (Table 11.1). Information on type of pollutants and location of sites covered were highly skewed towards nearness (to the polluted area), facilities available and mandate of the organizations responsible for the study.

Table 11.1 Critically polluted industrial areas in India

State	Critically polluted industrial area	CEPI rating	Information available on soil pollution[a]
Andhra Pradesh	Vishakhapatnam	70.82	*
	Patancheru – Bollaram	70.07	***
Chhattisgarh	Kobra	83.00	***
Delhi	Nazafgarh drain basin	79.54	**
Gujarat	Ankleshwar	88.50	*
	Vapi	88.09	*
	Ahmedabad	75.28	–
	Vatva	74.77	*
	Bhavnagar	70.99	–
	Junagarh	70.82	–
Haryana	Faridabad	77.07	–
	Panipat	71.91	–
Jharkhand	Dhanbad	78.63	**
Karnataka	Mangalore	73.68	–
	Bhadravati	72.33	–
Kerala	Greater Cochin	75.08	–
Madhya Pradesh	Indore	71.26	–
Maharashtra	Chandrapur	83.38	–
	Dombivalli	78.41	–
	Aurangabad	77.44	–
	Navi Mumbai	73.77	–
	Tarapur	72.01	–
Orissa	Angul Talcer	82.09	***
	Ib Valley	74.00	–
	Jharsuguda	73.34	*
Punjab	Ludhiana	81.66	**
	Mandi Gobind Garh	75.08	–
Rajasthan	Bhiwadi	82.91	–
	Jodhpur	75.19	–
	Pali	73.73	**
Tamil Nadu	Vellore (North Arcot)	81.79	***
	Cuddalore	77.45	*
	Manali	76.32	*
	Coimbatore	72.38	***
Uttar Pradesh	Ghaziabad	87.37	**
	Singrauli	81.73	–
	Noida	78.90	–
	Kanpur	78.09	***
	Agra	76.48	*
	Varansi-Mirzapur	73.79	***

(continued)

Table 11.1 (continued)

State	Critically polluted industrial area	CEPI rating	Information available on soil pollution[a]
West Bengal	Haldia	75.43	–
	Howrah	74.84	*
	Asansol	70.20	–

CPCB (2009)

[a] '–': no information; '*': very few information; '**': few information; '***': moderate information

11.3.1 Entry of Sodium into Ecosystem and Increase in Soil Salinity and Sodicity

Industries, particularly those associated with chlor-alkali, textiles, glass, rubber production, animal hide processing and leather tanning, metal processing, pharmaceuticals, oil and gas drilling, pigment manufacture, ceramic manufacture, soap & detergent production are the major consumers of salts (mainly NaCl) produced in the world today. When released into the environment, salt ions present in the industrial effluents percolate through the soil profile and contaminate the groundwater due to their high mobility in the matrix. Most of the effluent treatment plants don't remove salts from the effluent water. As a result of this, salinity of groundwater has been found elevated in and around many industrial clusters of India; deteriorating drinking and irrigation water quality (Table 11.2). As crop production in most of the countries rely considerably on groundwater and surface water, salinity build-up in soil is inevitable around areas of high industrial activity through 'industry → effluent → soil →groundwater → soil' route (Fig. 11.1).

Soils of agricultural land surrounding industrial areas of several cities recorded high electrical conductivity (EC) and exchangeable Na indicating considerable accumulation of salts due to irrigation with contaminated surface and groundwater (Saha 2005, Panwar et al. 2010).

11.3.2 Entry of Heavy Metals in Soil

Soil health assessment surveys in India have been carried out discretely by several researchers. These indicate clearly that contamination of soils with heavy metal in the impact zone is quite prevalent nearby industrial areas. However, such surveys are highly inadequate keeping in view of the extent of polluting activities going on in the country and many of the studies had in the past been carried out using less sensitive instrumental techniques. Inadequate numbers of competent laboratories with limited organizational strengths have generated some indicative information only on extent of soil contamination with heavy metals. A study conducted by ICAR-Indian Institute of Soil Science, Bhopal has indicated built-up of heavy

Table 11.2 Impact of industries on electrical conductivity (dS m^{-1}) of groundwater

Location	Nature of industries	Polluted area			Unpolluted area		
		Range	Mean	Reference	Range	Mean	Reference
Gajraula (district: Jyotiba Phule Nagar, UP)	Distillery	0.71–0.88	0.79	Jain et al. (2005)	0.46–0.48	0.47	Jain et al. (2005)
Kancheepuram (district: Kancheepuram, TN)	Textile dyeing	1.76–4.21	3.34	Balakrishnan et al. (2008)	0.23–3.42	1.28	CGWB[a]
Mettupalayam (district: Coimbatore, TN)	Textiles, paper and pulp	0.14–10.38	3.91	Mukherjee and Nelliyat (2007)	0.76–4.15	1.87	Mukherjee and Nelliyat (2007)
Dindigul (district: Dindigul, TN)	Tannery industry	0.52–21.2	3.72	Mondal et al. (2005)	0.125–6.52	1.9	CGWB[a]
Chennai (district: Chennai, TN)	Tannery, textile	0.48–3.76	2.02	Somasundaram et al. (1993)	1.17–1.93	1.75	CGWB[a]
Tiruppur (district: Tirupur, TN)	Textile, dye	0.41–15.95	4.02	Sellamuthu et al. (2011)	0.66–4.08	1.93	CGWB[a]
		5.9–8.4	6.78	Panwar et al. (2010)	2.4–2.9	2.62	Panwar et al. (2010)
Patancheru (district: Medak, AP)	Miscellaneous	0.70–10.2	2.6	Panwar et al. (2010)	0.18–4.85	1.78	CGWB[a]
Ratlam (district: Ratlam, MP)	Chemicals, dye, pharmaceuticals, distillery	1.49–4.50	2.84	Saha and Sharma (2006)	0.28–3.08	1.03	CGWB[a]
Udaipur (district: Udaipur, Rajasthan)	Zn smelter	3.14–6.79	5.43	Panwar et al. (2010)	0.36–6.44	1.33	CGWB[a]
Pali (district: Pali, Rajasthan)	Textile	5.91–9.54	7.36	Panwar et al. (2010)	0.35–7.95	2.73	CGWB[a]

[a] Range and mean values have been compiled for the district in which the study areas belong (Source: CWGB 2013), assuming most of the information belonged to unpolluted area.

Adopted from Saha et al. (2013b)

Fig. 11.1 Salinity build-up due to irrigation with polluted river water at Nagda

metals in soils due to industrial activities and nature of contamination varied with type of industries operating (Table 11.3). The study had also indicated contamination of groundwater with heavy metals at different locations of India due to industrial activities (Table 11.4).

11.4 Instances of Pollution from Industrial Effluents

Significant part of the pollutant loaded effluents, generated particularly from small scale industries are released untreated into land and water bodies. In most of cases, metals are present in dilute and small quantities in polluted water bodies and may not cause any harm to plant growth immediately when used for irrigation. However, their immobility and consequent persistence imply that concentrations may become elevated in the long run to such an extent that they begin exhibiting toxic effect on plant, soil microorganisms and food chain. Long-term exposure to heavy metals has been reported to affect human and animal health adversely (ATSDR 2005). Among the heavy metals, Ni, Co, Cr and Cu are relatively more toxic to plants and As, Cd, Pb and Hg are relatively more toxic to higher animals (McBride 1994). Build up of different pollutants in Indian soils and their impact on soil quality, agricultural productivity and food quality as well as impact on organisms were investigated by researchers which are described below.

Table 11.3 Heavy metals accumulated in soils around different industrial areas

Location	Nature of industries	Heavy metals accumulated
Pithampur (Dhar), Madhya Pradesh	Automobile manufacturing, food processing, chemical processing, distilleries, textile industries and other manufacturing industries	Cr, Zn, Co
Debari (Udaipur), Rajasthan	Zinc smelter	Zn, Cd, Pb
Korba, Chhattisgarh	Thermal power plant, Metallurgical (Al), Textiles, Engineering workshops, Tyre retreading, and others	Cd, Cr
Coimbatore, Tamil Nadu	Electroplating, Textile, Dye	Ni, Pb, Cd, Cr
Kanpur-Unnao (UP)	Textile, leather tanning, fertilizer, miscellaneous small scale chemical factories	Ni, Zn, Cr, Sn

Panwar et al. (2010)

Table 11.4 Impact of industrial activities on soil and groundwater bodies

Industrial area	Soil quality parameters affected	Surface water quality parameters affected	Groundwater quality parameters affected
Ratlam industrial Area, Madhya Pradesh	EC, ESP	–	TDS, SAR, Coloration, Pb, Cd
Nagda industrial area, Madhya Pradesh	EC, ESP	TDS, high Na, Cl, SO_4^{-2}	
Pithampur (Dhar) industrial area, Madhya Pradesh	EC, SAR, Co, Cr		EC, SAR, Cr
Patancheru industrial area, Medak district, Andhra Pradesh	–	EC, As	High pH, EC, Ni, As
Zinc smelting area in Udaipur, Rajasthan	Zn, Cd	Zn, Cd, F	Zn, Cd
Textile industries in Pali, Rajasthan	EC		EC, Na, Cu, Pb, Cr, As
Korba industrial area (Chhattisgarh)	Acidic pH, EC, Cr, Cu		Cd, Co, Cr, Ni, Zn
Tiruppur Industrial Area	EC, ESP	EC	Pb, Cr
Coimbatore industrial area, Coimbatore	Ni, Pb, Cd, Cr		EC, Na, Cl, SO_4^{-2}

Adopted from Panwar et al. (2010) and Saha and Sharma (2006)

11.4.1 Ratlam Industrial Area, Madhya Pradesh

In Ratlam, about 2000 m^3 effluent per day generated from industrial area was used to pour through Dosinala which runs through the city southwards, finally draining into river Mahi. Majority of the industries were shut down by 1996 due to Supreme Court order on the Public Interest Litigation (PIL) filed on pollution related issue.

Polluted groundwater at Ratlam Polluted river water at Nagda

Fig. 11.2 Pollution of groundwater at Ratlam and river water at Nagda due to industrial activity

As a result of industrial activities, groundwater of nearby villages has turned red and the impact is still visible even after 20 years (Fig. 11.2).

The groundwater at about 60–80 m depth in several villages had been polluted with salts due to contamination with percolating industrial effluent and was being used for irrigation to winter crops (Saha 2005). While mean EC values of ground water of unaffected villages were in the range of 0.85–0.92 dS m^{-1}, the same in affected villages ranged from 1.49 to 4.50 dS m^{-1} with an overall mean of 2.84 dS m^{-1}. Contents of sodium, sulphate and chloride in groundwater of affected villages were, respectively, in the range of 14.5–30.9 m*M* (mean 22.61 m*M*), 0.92–3.55 m*M* (mean 2.02 m*M*) and 6.16–35.88 m*M* (mean 2.83 m*M*). These values were, respectively, 348%, 288% and 364% more than the similar values obtained in groundwater samples of surrounding unaffected villages. The values of sodium absorption ratio (SAR), a measure of Na hazard, were considerably higher (range 3.36–12.29; mean 8.52) in ground water of affected villages as compared to the values (range 2.57–6.19; mean 3.88) obtained for unaffected villages. About 40% of the water samples in the polluted area were categorized as having very high salinity ($>$2.25 dS m^{-1}) and sodium hazard (SAR > 9) and about 71% of the samples had potential for severe Cl^- hazard ($>$10 meq Cl^- L^{-1}) permitting their use as irrigation only to tolerant crops. Use of such bad quality irrigation water caused considerable decline in area under vegetable cultivation in the groundwater pollution area. Groundwater samples of polluted area contained, on an average, 9.1 μg Pb L^{-1}, 4.1 μg Cd L^{-1} and 18.5 μg Cu L^{-1}; which were more by about 162, 26 and 83%, respectively over those in groundwater samples of unpolluted area. Considering World Health Organization (WHO) limits for groundwater, samples from Bhajankheda, Jadwasa khurd and Dosigaon villages of polluted area contained unsafe levels of Pb and Cd.

There were significant increases in salinity as well as exchangeable sodium percentage (ESP) levels in soils due to irrigation with polluted water in the affected villages. Soil samples collected from groundwater polluted villages in the month of

Table 11.5 Mean chemical properties of soils of polluted and unpolluted area in Ratlam

Parameter	Polluted area			Unpolluted area		
	Mean	Range	Standard deviation	Mean	Range	Standard deviation
pH (1:2 in water)	7.70	7.11–8.27	0.28	7.83	7.28–8.01	0.14
EC (dS m^{-1})	1.83	0.49–5.01	1.00	0.41	0.25–0.76	0.21
SAR	3.98	0.69–27.12	4.72	0.86	0.69–2.65	0.86
OC (%)	0.70	0.44 0–0.98	0.15	0.45	0.15–0.89	0.19
Available P (mg kg^{-1})	18.70	16.0–22.4	1.65	26.64	11.5–43.7	7.95
Available K (mg kg^{-1})	230.38	171.5–332.5	49.30	188.58	128.0–293.5	43.76

Saha (2005)

February had, on an average, higher EC (4.5 times), SAR (4.6 times), organic C (1.5 times) and available K (22% more) as compared to the soils from unpolluted area (Table 11.5). Significant increases in concentrations of Na^+, Cl^-, SO_4^{-2} and HCO_3^- and decreases in the concentrations of K^+ and NO_3^- in the soil solution were observed in the polluted soils of Ratlam, which indicates that salt loaded polluted groundwater/river water had direct impact on the crop yields as well as soil parameters in the polluted area. Monsoon rainfall decreased EC as well as concentrations of Na^+, Cl^- and SO_4^{-2} indicating reduction in soil salinity. However, a significant increase in the soil pH was observed after rainy season, due to washing out of Cl^- and SO_4^{-2} from surface soil layer and their replacement with CO_3^{-2} and HCO_3^- in the soil matrix.

Groundwater pollution had adversely affected the economic condition through changes in cropping pattern, reduction in crop yield, as well as reduced longevity of irrigation infrastructure (Saha and Sharma 2006). Area under vegetable and pulse cultivation was severely reduced and the same under fallow had increased during rabi season as many farmers preferred to keep their land fallow instead of using polluted groundwater as irrigation. The yields of the traditional crops such as soybean, gram wheat, methi and garlic were less on the fields irrigated with polluted ground water (Table 11.6). Onion grown using polluted groundwater had a short keeping quality and started rotting within 10–15 days after harvest; thus inflicting heavy economic losses to the farmers. Poppy (*Papaver somniferum*) cultivation, previously grown widely in the area, was abandoned because of drastic reduction in yield and consequently the government denotified the area for its cultivation. The iron pipes of the tubewell got rusted within 5 years; and therefore, the farmers incurred losses on account of repair and maintenance of their irrigation infrastructure. The drinking water source of the eight villages became unfit for human use. People were either forced to consume polluted drinking water or to spend much effort and time in fetching potable water from a distance up to 3–4 kms.

Table 11.6 Estimation of losses due to reduction of crops yields

Crop	Average yield (q ha^{-1})		Yield reduction (q ha^{-1})	Price (Rs q $^{-1}$)	Loss (ha $^{-1}$)
	Normal conditions	Polluted conditions			
Wheat	36	29	7	650	4550
Gram	12.5	9[a]	3.5	1400	4900
Soybean	15	11.5	3.5	1200	4200
Methi	18	12	6	1500	9000
Garlic	60	45	15	2000	30,000

Saha and Sharma (2006)
[a]When irrigation is given at later stages

Approximately 300 man-days were used each day for bringing potable water from distant sources.

11.4.2 Nagda Industrial Area, Madhya Pradesh

In Nagda, a textile industry complex located on the North-West of town manufactures a variety of products including viscous rayon, caustic soda, liquid chlorine, carbon disulfide, etc. A few other ancillary industrial units have also been established to make various chlorinated products utilizing the chlorine produced by the textile industry complex. All these industrial activities result in a high volume of wastewater generation, which is carried away by a natural surface drain, leading to river Chambal.

Water of Chambal river became severely polluted with effluents from textile industry containing salts namely, Na^+, Cl^- and SO_4^{-2} and was being used for irrigation to winter crops in nearby areas of several villages (Saha 2005). Irrigation water (from Chambal river) near affected villages had EC ranging from 2.38 to 4.11 (mean 3.56 dS m^{-1}) and contained 31.6–57.5 m*M* Na, 0.44 to 1.66 m*M* K, 3.54–4.32 m*M* Ca, 1.07–2.72 m*M* Mg, 2.93–6.76 m*M* SO_4^{-2} and 25.6–25.8 m*M* Cl^-, which were on an average, 4.7, 9.9, 7.7, 5.8, 1.8, 9.0, and 6.9 times more than the corresponding mean values obtained in irrigation water (groundwater) in unaffected villages. The mean SAR value in Chambal river water was 5.1 times higher than the similar value obtained in groundwater of unaffected villages. Long-term application of these polluted water to soil resulted significant accumulation of salts in the root zone layer (Table 11.7). There were significant increases in salinity as well as ESP levels in soils due to irrigation with polluted water. Magnitude of salinity development in soil was much more in the soils irrigated with polluted river water at Nagda as compared to polluted groundwater irrigated lands in Ratlam. Polluted soils of Nagda recorded much higher concentrations of major cations and anions (except NO_3^-) in soil solution. Monsoon rainfall decreased EC, SAR, ESP as well

Table 11.7 Mean chemical properties of soils of polluted and unpolluted area in Nagda

Parameters	Polluted area			Unpolluted area		
	Mean	Maximum	Standard deviation	Mean	Maximum	Standard deviation
pH (1:2 in water)	7.69	7.10–8.50	0.30	7.96	7.83–8.32	0.20
EC (dS m^{-1})	4.03	0.35–12.90	3.10	0.44	0.25–1.32	0.52
SAR	19.31	0.45–75.97	20.70	1.57	0.53–2.43	0.69
OC (%)	0.67	0.29–0.99	0.20	0.53	0.33–0.75	0.11
Available P (mg kg^{-1})	18.48	14.9–23.0	2.16	11.35	5.9–22.3	4.24
Available K (mg kg^{-1})	270.00	145.5–454.0	88.03	177.10	110.0–300.5	45.95

Saha (2005)

as concentrations of Na^+, Cl^- and SO_4^{-2} in solution of soils irrigated with polluted water. However, the impact on the soil properties lessened considerably during rainy season, probably due to the presence of appreciable amount of divalent cations, Ca^{+2} and Mg^{+2} in polluted irrigation water. Available Cu contents in soils of polluted area were higher as compared to the soils of unpolluted area. Concentrations of Zn and Cu were also considerably more in the in the wheat plant tissue of polluted area as compared to those of unpolluted area.

11.4.3 Pithampur (Dhar) Industrial Area, Madhya Pradesh

Pithampur is the second largest industrial area in Asia having both large and small scale industries. Majority of the automobile companies of India have their factories in Pithampur. Also, this area is housing food processing, chemical processing, distilleries, manufacturing, and textile industries.

Water of open wells and tube wells in Cheerkhani and Silotia villages near the industrial area tested high salinity (EC 1.91–4.07 dS m^{-1}) and sodium hazard ($SAR > 10$) and about 82% of the samples had potential for severe Cl^- (>10 me L^{-1}) hazard permitting their use as irrigation only in tolerant crops. The EC of some of the tube well water samples from polluted villages had gone up by more than 2.5 mS cm^{-1} indicating that effluents contaminated the ground water. The ground water samples of polluted area contained, on an average, 84.2 μg Cr L^{-1}, 3.7 μg Pb L^{-1} and 1.2 μg Cd L^{-1}. Several groundwater samples of polluted area had Cr concentrations more than the WHO permitted level for drinking water. Surface soil samples of Cheerkhani and Silotia villages had, on an average, higher EC (3.4 times) and SAR (3.1 times) due to considerable accumulation of Na^+ and Cl^-. The soils receiving polluted ground water was higher in Co (7.5 times) and Cr (1.5 times) contents as compared to soils of unpolluted area (Table 11.8).

Table 11.8 Impact of industrial activity in Pithampur on total heavy metal contents in soil

	Unpolluted area			Polluted area		
Heavy metal (mg kg^{-1})	Range	Mean	Median	Range	Mean	Median
Cd	0.05–0.1	0.1	0.1	0.05–0.1	0.1	0.1
Co	5.2–6.7	5.9	5.9	26.8–63.9	49.9	51.5
Cr	18.4–47.1	34.6	35.5	68.1–252.0	87.3	96.9
Cu	382.4–445.3	417.5	424.9	82.4–252.4	179.4	170.3
Ni	32.1–38.1	35.3	34.5	21.4–39.2	37.8	37.1
Pb	5.2–6.1	5.7	5.7	1.1–21.0	7.6	6.2
Zn	27.2–29.4	28.5	28.9	76.6–763.0	145.2	96.3

Panwar et al. (2010)

11.4.4 Patancheru Industrial Area, Medak District, Andhra Pradesh

Pattancheru-Bollaram cluster is an agglomeration of different industrial areas. Production in these areas is dominated by bulk drug manufacturing. It is located at the north-western outskirts of Hyderabad. Starting with the first pharmaceutical production facilities in the mid 1970s, it is now one of the biggest pharmaceutical industrial areas of India, with more than 90 manufacturers (Beijer et al. 2013). Since 1989, wastewater generated from these facilities is being treated in a common effluent treatment plant (CETP). Until 2009, most of the CETP pretreated effluents were being drained into rivers and lakes in the Patancheru area (Larsson 2007). Patancheru-Bollaram cluster was banned for further projects in 2013 by Ministry of Forests and Environment (MoEF) due to investigations conducted by the Central Pollution Control Board (CPCB).

Arsenic levels were found to be high in effluent water from the industrial area. In effluent water, Ni concentration varied from 4.7 to 57.4 μg L^{-1} (average of 23.4 μg L^{-1}), Pb varied from 0.3 to 14.2 μg L^{-1} (average of 2.0 μg L^{-1}) and Zn varied from 32.9 to 293.9 μg L^{-1} (average of 81 μg L^{-1}) (Panwar et al. 2010). Some samples showed high values of Fe, Ni, Pb and Zn, which are near the vicinity of industrial areas. The groundwater in some places near the study area has also been found contaminated with salts (high pH and EC) and some metals like As, Ni, Cr and Zn (Table 11.9).

11.4.5 Zinc Smelting Area in Udaipur, Rajasthan

The zinc smelter plant near Udaipur has smelting capacity of about 49,000 tonne per annum (TPA). With the expansion of the smelter plant, a number of other production units was commissioned which includes production units for sulphuric acid (87,000 TPA), cadmium metal (190 TPA), phosphoric acid (26,000 TPA), single superphosphate (72,000 TPA) and zinc dust (36,000 TPA). Since its

Table 11.9 Descriptive data on groundwater analysis (μg L^{-1}) from Pattancheru industrial area, Medak district

Parameter	Mean	Median	Minimum	Maximum
pH	8.1	8.0	6.9	9.4
EC (dS m^{-1})	2.6	1.7	0.7	10.2
Cr (μg L^{-1})	13.3	6.9	2.0	69.7
Mn (μg L^{-1})	75.8	75.6	2.4	11,384
Fe (μg L^{-1})	106.7	87.3	34.6	497.2
Ni (μg L^{-1})	69.0	43.0	3.9	264.8
Zn (μg L^{-1})	89.4	57.8	21.4	310.8
As (μg L^{-1})	129.4	119.3	4.2	1139.0
Pb (μg L^{-1})	2.10	0.95	0.30	7.20
Sr (μg L^{-1})	1079	875	134	2681

Panwar et al. (2010)

Fig. 11.3 Accumulation of pollutants on soil surface receiving Zn-smelter industrial effluent from Udaipur industrial area

inception the effluent from the plant was being discharged into a stream which flowed through 3 kms to the east and merged into Berach river. The effluent of zinc smelter was being discharged in a stream, employed for irrigating the crops in the vicinity of the smelter plant (Fig. 11.3).

The concentrations of zinc and fluoride in the groundwater were higher than permissible limit of 5 and 2 mg L^{-1}, respectively (BIS 2012). Well water samples had high concentrations of Zn (2.2–9.7 mg L^{-1}) and Cd (0.004–0.081 mg L^{-1}) which indicates contamination of groundwater due to industrial activity. The concentrations of these (Zn and Cd) heavy metals were high in effluent irrigated soils nearer to the discharge point (Gorla and Bichhari village) and decreased with the distance from the effluent discharge point. A large variation in the content of total zinc (65–1860 mg kg^{-1}), total cadmium (0.07–10.4 mg kg^{-1}) and total lead

Table 11.10 Chemical parameters and total heavy metals content (mg kg^{-1}) in soil of agricultural land irrigated with effluent water from smelter industries in Udaipur

Parameter	Range	Mean	Median
pH	7.2–10.4	8.2	8.3
EC (dS m^{-1})	0.2–6.5	1.0	0.6
Zn	65–1860	619	590
Pb	27.5–180.0	51.4	38.0
Cu	21.2–70.0	36.0	34.9
Cd	0.07–10.37	1.56	0.86
Co	7.6–18.5	11.9	11.8
Ni	19.8–50.2	34.9	34.3

Panwar et al. (2010)

(27.5–180 mg kg^{-1}) was recorded in the soils of the area (Table 11.10). While comparing with the safe concentration limits determined for soils (Saha et al. 2010b; Saha et al. 2013a), most of the soils nearby Zn smelting area accumulated toxic levels of Zn and Cd. With few exceptions, total Zn, Cd and available Zn content of the soil decreases with an increase in the lateral distance from the stream and river.

11.4.6 Soil and Water Pollution by Textile Industries in Pali, Rajasthan

Industrial area at Pali is having more than 800 textile units and is indicated as one of the critically polluted area by Central Pollution Control Board (CPCB). The textile printing and dyeing industries were discharging industrial effluents into the river Bandi, a non-perennial river with no flow in the lean season, thus severely contaminating both the river as well as the groundwater. The industries discharged a variety of chemicals, dyes, acids and alkalis besides heavy metals and other toxic compounds. The effluents were multi-colored and highly acidic and/or alkaline. Groundwater from downstream villages was highly saline with salts of Na as compared to upstream villages. Copper concentration was more than drinking water standards in all the wells in downstream villages; while Pb was high in Kerla, Sukarlai and Nehada; Cr level is high in Kerla, Sukarlai, Gadhwara and Phikaria; As is high in Jewadiya, Kerla and Phikaria (Table 11.11).

The well water was not suitable for irrigation due to high salinity (>4 dS m^{-1}). The Nahada dam built for storing water, has become a industrial storage tank and thus led to groundwater contamination. The soils under cultivation using contaminated well waters also showed high salinity due to high salt content of irrigation water (Fig. 11.4).

Table 11.11 Average heavy metal (μg mL^{-1}) contents in groundwater in selected villages towards upstream and downstream side of effluent discharge point in Bandi river of Pali

	Village	Cu	Zn	Pb	Ni	Cr	As
Downstream	Jewadiya	0.17	0.07	0.03	0.25	0.04	0.28
	Kerla	0.52	0.12	0.56	1.42	0.11	0.49
	Sukarlai	0.05	12.16	0.08	0.78	0.27	0.03
	Nehada	0.07	0.06	0.08	0.16	0.05	0.02
	Phikaria	0.13	0.03	0.02	0.22	0.05	0.13
	Gadhwara	0.16	0.09	0.04	0.26	0.06	0.07
Upstream	Iycea	0.03	0.04	0.03	0.08	0.03	0.01
	Hemavas	0.02	0.03	0.01	0.11	0.01	ND[a]

[a] *ND* not detected

Panwar et al. (2010)

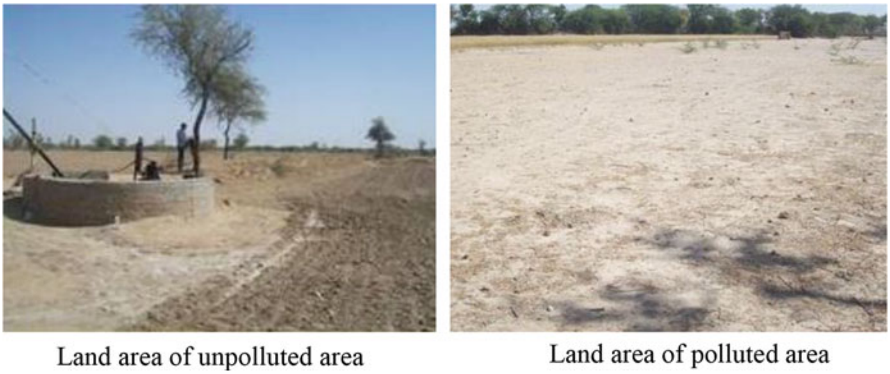

Fig. 11.4 Soils of land receiving unpolluted groundwater and polluted industrial effluent

11.4.7 Korba (Chhattisgarh) Industrial Area

Korba city is the power capital of central India with the National Thermal Power Corporation Limited's (NTPC) super thermal power plant working at 90% plant load factor. Korba is also having aluminium industry Bharat Aluminum Company Limited (BALCO), textiles, engineering workshops, hardware (aluminum & iron), detergents, plastic toys, PVC cable pipes, cement products, electricity transformer, bakelite, distemper, clay insulator manufacturing units and other small industries, generating large quantity of acidic effluents which contaminated surrounding land areas (Fig. 11.5).

Groundwater samples collected from villages nearby industrial area contained high levels of heavy metals Cd, Co, Cr, Ni, and Zn; mean values of which were considerably higher (Cd: 19 times, Co: 67 times, Cr: 6 times, Ni: 5 times, and Zn: 10 times) as compared to those collected from far away villages. Majority of the groundwater samples from polluted area had heavy metals more than the levels

2008

2010

Fig. 11.5 Same agricultural land near Korba industrial area before (year 2008) and after (year 2010) contamination with industrial effluent

permitted for drinking purpose. Soil irrigated with industrial effluent turned highly acidic (Table 11.12). Contents of soluble salts, soil organic carbon, DTPA extractable heavy metals and total heavy metals contents increased due to use of industrial waste/effluent or contaminated water as compared to the non-polluted soils. The total as well as DTPA extractable heavy metals particularly, Cr and Cd were in toxic range in most of the polluted soils (Table 11.12).

11.4.8 Tiruppur Industrial Area, Tamil Nadu

Tiruppur has been identified as one of the critically polluted area by CPCB. Industrial area discharges more than 90 MLD into Noyyal river (tributary of Cauvery river). Industrial effluent passes through Tiruppur and is stored up in the Orathapalayam Dam to be used in agriculture and drinking purposes for the downstream villages in the Tiruppur and Erode district. The Industrial area is having 729 bleaching and dyeing units. Due to pollution, drinking water, fisheries and the agriculture in Tiruppur area and downstream villages of Noyyal river has been affected.

The river water was injurious (EC >3 dS m^{-1}) to agriculture in an area of about 146.3 km^{-2} and critical (EC 1.1 to 3 dS m^{-1}) in about 218.3 km^{-2}. The groundwater in some villages was having high values of Pb and Cr which may be attributed to the industrial activities (Panwar et al. 2010). Majority of the samples were not suitable for domestic purposes and were far from drinking water standards. Irrigation of cropping land with polluted water transformed the productive soils into saline soil (>4 dS m^{-1}); the dominant cations and anions being Na^+ and Cl^- and SO_4^{-2}, respectively. Irrigation with polluted Noyyal river water resulted build-up of salinity (EC > 4 dS m^{-1}) in soils of agricultural land (Table 11.13).

Table 11.12 Soil physico-chemical properties and heavy metal status of soils irrigated with industrial effluent in Korba

Parameter	Mean	STDEV
pH	4.61	±0.093
EC (dS m^{-1})	2.21	±0.196
OC (%)	0.46	±0.062
DTPA extractable heavy metals (mg kg^{-1})		
Cd	0.056	±0.009
Co	1.726	±0.029
Cr	0.096	±0.006
Cu	2.356	±0.038
Ni	1.828	±0.028
Pb	5.944	±0.042
Zn	1.350	±0.062
Total heavy metals (mg kg^{-1})		
Cd	8.10	±0.031
Co	25.1	±0.42
Cr	172.3	±6.41
Cu	40.5	±3.86
Ni	14.1	±0.86
Pb	15.3	±2.16
Zn	29.4	±2.31

Panwar et al. (2010)

Table 11.13 Soil properties in selected villages around Noyyal river in Tiruppur district

	Downstream villages			Upstream villages		
Parameters	pH	EC (dS m^{-1})	OC (%)	pH	EC (dS m^{-1})	OC (%)
Minimum	7.24	4.29	0.19	7.27	1.86	0.21
Maximum	8.37	8.31	0.57	8.34	3.62	0.69
Mean	8.07	6.59	0.39	7.52	2.39	0.34
Median	7.92	6.47	0.36	7.63	2.53	0.47

Panwar et al. (2010)

11.4.9 Coimbatore Industrial Area, Tamil Nadu

Coimbatore industrial area is the 2nd largest industrial area in Tamil Nadu. The industrial area is having about 500 textile industry, 200 electroplating industry, 100 foundries and 300 dyeing industries. All the industrial effluent/sewage finds its way to Ukkadam river, which is source of irrigation in nearby area. Heavy metal contents in the city sewage water were quite high and varied widely with season. ICAR-Indian Institute of Soil Science, Bhopal investigated changes in soil properties in agricultural land nearby different industrial clusters; namely electroplating industry, textile industry, dye industry and city sewage irrigated areas (Panwar et al. 2010). Groundwater near industrial area has developed salinity due to contamination mainly with salts of Na^+ and Cl^-; magnitude of contamination was more near textile and dye industries. Sulphate contamination was the highest in the groundwater near electroplating industries.

Soils of agricultural land near textile and dye industries have developed severe salinity (EC > 6 dS m^{-1}) and slight alkalinity (pH >8.0). Soils of agricultural land near industrial areas contained 47–178 mg Ni kg^{-1}, 47–214 mg Pb kg^{-1}, 0.5–4.2 mg Cd kg^{-1} and 43–241 mg Cr kg^{-1} (Table 11.14).

Most of the soils had all the heavy metals more than the safe concentration limits determined by Saha et al. (2013a), which indicate that these soils may pose threat to the environment. Nickel and Pb concentrations were high in soils near the electroplating and sewage from industrial area; Cd concentration was higher in soils irrigated with mixed effluents, and sewage; Cr concentration was higher in soils irrigated with textile, dye and sewage effluent. DTPA extractable heavy metal contents were also very high as compared to those normally observed in unpolluted soils, which indicates soils of agricultural land near industrial area of Coimbatore are likely to impart considerable threat to living organisms (Table 11.15).

11.4.10 Katedan Industrial Development Area in South of Hyderabad, Andhra Pradesh

Katedan industrial area of Hyderabad is hosting more than 300 industries which are involved in dyeing, edible oil production, battery manufacturing, metal plating, chemicals production etc. Dumping of the waste materials around this area is commonly observed and is a major cause of soil pollution which occurs due to spreading hazardous material through rainwater and wind. Govil et al. (2008) reported the prevalence of very high concentrations of Pb, Cr, Ni, Zn, As and Cd throughout the industrial area. Hazardous metals like As and Cr, Cu, Pb and Zn had also been observed in some of the residential area nearby industrial complex.

The wastes and effluents generated from different industrial activities in and around this area are discharged into the ponds without adequate treatment. It resulted in contamination of groundwater in and around Katedan area with salts and several heavy metals (Cd, Cr, Ni and Cu). All these heavy metals exceeded the permissible limits in the groundwater, except Pb. Continuous use of the contaminated groundwater for agricultural production increased the contents of Pb, Ni and Cr in the soil (Bhupal Raj et al. 2009).

11.4.11 Industrial Area at Thane Region of Maharashtra

There are about 5449 industries in Thane region, which includes textile industries, dye manufacturing industries, match box factories, canning factories of various food stuff, pharmaceutical and chemical industries, paper mill, paint industry,

Table 11.14 Total heavy metal contents (mg kg^{-1}) in soils of agricultural land nearby different industrial clusters at Coimbatore

	Ni		Pb		Cd		Cr	
Source of contamination	Range	Median	Range	Median	Range	Median	Range	Median
Sewage	78–140	107	116–214	158	1.2–4.2	2.17	75–176	124
Electroplating	84–178	122	74–167	136	1.1–2.7	1.63	48–152	109
Textile	47–126	72	52–159	114	0.6–3.1	1.28	86–241	168
Dye	62–111	89	58–147	82	0.5–2.4	1.34	79–187	127
Mixed effluents	58–132	96	47–171	92	1.3–3.8	2.39	43–158	96

Table 11.15 DTPA-extractable heavy metal contents (mg kg^{-1}) in soils of agricultural land nearby different industrial clusters at Coimbatore

	Ni		Pb		Cd		Cr	
Source of contamination	Range	Median	Range	Median	Range	Median	Range	Median
Sewage	0.9–9.7	5.34	1.6–9.6	5.26	0.5–1.7	0.79	0.2–4.6	2.69
Electroplating	1.0–8.8	4.71	0.8–3.4	2.81	0.1–0.8	0.34	1.2–4.7	3.92
Textile	0.3–1.2	0.79	1.3–2.6	2.31	0.1–0.4	0.18	2.4–6.8	4.61
Dyeing	0.5–3.6	2.26	1.4–2.3	1.79	0.05–0.3	0.09	1.9–4.2	2.87
Mixed effluents	1.5–4.9	2.14	1.8–4.3	2.74	0.1–0.5	0.19	0.6–4.3	1.81

insecticide industries, etc. Waste effluents from the industrial area contaminated surface water and groundwater bodies. The random dumping of hazardous waste was the cause of contamination (Bhagure and Mirgane 2011). Ground water in this region contained very high concentration of total dissolved solids, total hardness, total alkalinity, chemical oxygen demand, chloride, as well as heavy metals like As (12–500 μg L^{-1}), Cd (4–21 μg L^{-1}), Hg (1–12 μg L^{-1}), and Ni (5–38 μg L^{-1}), most of which were more than WHO limits for drinking water (10, 3, 1 and 20 μg L^{-1} respectively). Similarly, the soils samples collected from residential, commercial and industrial areas were heavily contaminated by As, Cd, Hg, and Ni (as per the Swedish soil guideline values for polluted soil), mainly because of local dumping of hazardous wastes.

11.4.12 Manali Industrial Area in Chennai, Tamil Nadu

The Central Pollution Control Board (CPCB) has identified Manali industrial area as one of the critically polluted areas in the country. The industrial town is situated to the north of Chennai near the Buckingham canal. It encompasses all types of processing industries, including chemical, plastic, petrochemicals, refineries, and fertilizers industries. The industrial area houses about 300 industries generating hazardous wastes. Soils in the industrial area of Manali had very high concentrations of Cr (149.8–418.0 mg kg^{-1}), Cu (22.4–372.0 mg kg^{-1}), Ni (11.8–78.8 mg kg^{-1}), Zn (63.5–213.6 mg kg^{-1}) and Mo (2.3–15.3 mg kg^{-1}) (Krishna and Govil (2008). The enrichment factors for Cr in soils ranged between 5.88 and 51.85, which categorized these under the class of extremely high enrichment. The source of Cr appears to be anthropogenic from some industries producing steel, textiles in the area. The assessment of the overall contamination of soil was based on the degree of contamination (C_{deg}). On the basis of the contamination factor (C_f^i), the soils were classified as slightly contaminated with As and Ba, moderately contaminated with Co, V and Zn, considerably contaminated with Ni, Mo and Pb and highly contaminated with Cr and Cu. Chromium contributed most (22.38%) to the degree of contamination index (C_{deg}). Copper accounted for 21.6%, Ni-8.57%, Mo and Pb- 7.31%, Zn- 6.33% and Co- 5.9% (Krishna and Govil 2008).

11.4.13 Kanpur-Unnao Industrial Area of Ganga Plain, Uttar Pradesh

Kanpur-Unnao region is an industrial hub for leather processing and manufacturing of leather goods and includes several multinational leather industries. The industrial hub is situated on the bank of Ganges and is considered to be the hot spot region of pollution in the Gangetic Plain. The outskirts land of both the cities is mainly utilized for agricultural purposes. These land area are flooded with wastewater either by over flooding of city drains or by sheet flow during heavy monsoon rainfall. Additionally, farmers utilize the wastewater of the city drains for irrigation, as they do not have any other option. The studies conducted by Ansari et al. (1999) registered the elevated contents of Cd, Co, Cr, Cu, Hg, Ni, Pb, Sn, Zn and organic carbon in sediments and soils of this region. Very high contents of OC (upto 5.9%), Cr (upto 2.16%), Sn (upto 1.21%), Zn (upto 975 mg kg^{-1}) and Ni (upto 482 mg kg^{-1}) were found in top 20 cm soils during the pre-monsoon period in 1994. In relation to the natural background values, the contribution of anthropogenic inputs of the toxic metals in soils were about 90% of Cr and Sn; about 75% of Cd; and 25% of OC, Cu, Ni and Zn. The Enrichment Factors were 10.7 for Cr, 9.0 for Sn, 3.6 for Cd, 1.8 for Ni and 1.5 for Cu and Zn in soils, respectively. The considerable Cr accumulation in soils and other environmental samples were also reported by other workers from this area. Concentration of this metal in soils was found quite high (1323 mg kg^{-1}) in the area having large number of tanneries (Rawat et al. 2009). Analysis of surface soil samples from Jajmau and Unnao industrial areas using X-ray fluorescence spectrometer indicated that these were significantly contaminated with heavy metals such as Cr (161.8–6227.8, average 2652.3 mg/kg) (Gowd et al. 2010). The plant available Cr in soil (extracted by 0.01 M $CaCl_2$) was not detected at control (unpolluted) site while its level at wastewater irrigated soils was quite high (33.26 to114.26 μg g^{-1} dw) (Sinha et al. 2006).

11.4.14 Chromium Pollution in Soils Around Vellore Tannery Industries, Tamil Nadu

Leather industry is among the major sources of pollution in the state of Tamil Nadu. It has been estimated that more than 50,000 ha of productive agricultural lands in Vellore district have been contaminated with Cr alone due to the disposal of tannery wastes, where more than 60% of Indian tanneries are located (Rangasamy et al. 2015). Effluent generated from the tanneries had highly variable characteristics and had pH 6.17–8.17 and contained very high soluble salts (EC 10.4–23.0 dS m^{-1}; sodium 2.04–9.0 g L^{-1}) and Cr (0.62–26.2 mg L^{-1}) (Mahimairajah et al. 2000). Soils surrounding tannery industries were severely contaminated with Cr (16731–79,865 mg kg^{-1}). More than 90% of the soil samples from agricultural land in 65 locations of *six Taluks* (Walajapet, Arcot, Vellore, Thirupattur, Vaniyambadi, and Gudiyatham) had high concentration of Cr (>200 mg kg^{-1} and upto 1646 mg kg^{-1}) due to use of tannery wastes (Rangasamy et al. 2015). Since $Cr_2(SO_4)_3$ is predominantly used in tanning process, the tannery effluent and sludge are rich in Cr III. As a result, contaminated soil contained mostly trivalent Cr (Mahimairajah et al. 2000). Chromium and salts had also leached through soil profile and contaminated ground water. The Cr concentration in groundwater ranged from trace to 36.7 mg L^{-1}. About 28% of the samples had relatively higher concentration of Cr, exceeding the safer limit of drinking water (0.05 mg L^{-1}) and irrigation water (2 mg L^{-1}), prescribed by the WHO and FAO, respectively.

11.4.15 Mercury Pollution in the Vicinity of Chlor-Alkali Plant at Ganjam, Orissa

Chlor-alkali plants are major consumer of mercury for its operation; and considerable concentration of this extremely toxic metal is found in liquid effluent and in solid wastes generated from there. Sediments of effluent carrying channel and low lying area and solid waste deposits had been found to contain high concentration of Hg (41–2550 mg kg^{-1}) (Lenka et al. 1992). Aquatic plants growing in effluent carrying channel and low lying area as well as vegetables grown in soils nearby solid waste dumping site accumulated high levels of Hg. However such impact (Hg contamination) due to chlor-alkali plant was highly localized as rice crops in the surrounding agricultural land did not show any Hg accumulation.

11.4.16 Fluoride Contamination in Soil and Plant in the Vicinity of Aluminium Smelter Plant at Angul, Orissa

The Angul Talcher area in Angul district of Orissa has been declared by CPCB as one of the hot spot of pollution in Orissa with CEPI rating index of 82.09. The industrial area houses about 184 industries which includes thermal power plant, aluminium smelters, steel plants as well as coal mines. The activity of aluminum industry is one of the major environmental concerns in this area. The most highlighted pollutant from the smelter plant is fluoride. During smelter process, F is volatilized from molten cryolite at 1000 °C as gaseous fluoride such as HF, SiF_4 and flurosilicic acid (H_2SiF_6). Tiny particles in the form of different compounds such as various aluminum fluoride, apetite, CaF_2 and NaF are mechanically blown out through the stacks. Such particles ultimately settle down on the natural vegetation and water bodies. In the effluent treatment plant, most of the fluoride is caught as sodium fluoro-silicate, cryolite, AIF_3 etc., which are again recycled. But due to poor effluent treatment facilities and lack of efficient techniques to catch the whole fluoride, it escapes into the environment and create nuisance. Although fluoride is beneficial for dental health in low dosage, its chronic exposure in large amounts causes gastro-intestinal problems and interferes with bone formation. A study was conducted around smelter plant to determine the fluoride content of water, soil and plant samples (Jena et al. 2003). The fluoride content of soil, water and leaf samples varied from 0.52 to 5.52 (water soluble fluoride), 0.2 to 3.24 and 25 to 390 mg kg^{-1}, respectively. Similar samples collected from places around

Bhubaneshwar (180 km away from Angul) showed fluoride content in the range of 0.36–0.44 mg L^{-1} (water soluble fluoride), 0.10–0.19 mg L^{-1} and 10–30 mg L^{-1}, respectively. The fluoride content of soil, water and soil samples decreased with increasing distance except in Santiri and Purukia village, which might have contaminated due to the inflow of effluent water from aluminum industry.

11.4.17 Lead Pollution in Some Industrial Cities of Chhattisgarh

Lead pollution has become global health issue due to its toxicity to human and widespread use and leakage into the environment. In industrial areas, Pb enters the environment through particles generated by coal burning in power plants and roasting of minerals in smelters. The elevated levels of Pb in blood of children and dogs of Indian mega cities have been reported (Kaul et al. 2002; Balagangatharathilagar et al. 2006). Lead levels in various environmental compartments (air, rain water, runoff water, surface soil, sludge and plant) of different industrial cities of Chhatisgarh states (viz., Raipur, Bhilai and Korba) was investigated (Patel et al. 2010a). Different medium and large industries are located in Raipur (cement, steel and ferro-alloy), Bhilai (steel and others) and Korba (thermal power plants and others). These industrial areas recorded considerably higher levels of Pb in air as compared to far away small residential cities. Soils of these cities, particularly from coal burning area of Korba city contained very high amount of this metal.

11.4.18 Heavy Metal Contamination in Agricultural Soils and Plants in Peri Urban Areas of Some Cities in Gujarat

Ankleshwar, Vatva, Nandesari in Gujarat have high industrial activity and is considered to have significant impact on environment. Patel et al. (2010b) conducted study to assess impact of the industrial activities on environment. Soil and sewage effluent samples from peri-urban areas of Ankleshwar (Bharuch), Vatva (Ahmedabad) and Nandesari (Vadodara) cities were analyzed for different quality parameters. The effluents were generally alkaline and contained high salts with EC ranging from 1.90 dS m^{-1} in Koyali (Vadodara) to 12.0 dS m^{-1} in Kasbativad (Ankleshwar). The concentrations of different micronutrients in the effluents samples from major industrial areas of Gujarat were generally high while that of pollutant elements were quite low, except for Cd and Co. Among the pollutant elements, only Co and Cr were above the threshold level in several areas and contaminations of other heavy metals viz. Cd, Ni and Pb was low in soil samples from these areas.

11.4.19 Impact of Industrial Effluent Form Visakhapatnam City on Soil and Plants

Industrial effluent from Visakhapatnam industrial area (having chemical, petrochemical, metallurgical industries) contained high soluble salts and heavy metals (Cu, Pb, Mi, Cr, Zn) (Bhupal Raj et al. 2009). Soils of agricultural land receiving effluents from different industries developed salinity. All the soil samples collected from surrounding areas contained high levels of Pb, Zn, Cu, Cd, Ni and Co. About 100%, 96%, 91%, 70%, 65% and 44% of the plant samples from the polluted area contained high levels of Cr, Zn, Pb, Ni, Co and Cu, respectively.

11.4.20 Effect of Cement Kiln Dust Pollution of Heavy Metal Accumulation in Soils

Cement industry is one of the 17 most polluting industries listed by the CPCB. Cement dust contains heavy metals like chromium, nickel, cobalt, lead and mercury, which are having impact on vegetation, human health, animal health and ecosystem. Effect of dust pollution from cement plant in Dindigul district (Tamil Nadu) on soil with reference to EC, pH, total Pb, Ni and available Zn, Cu, Fe and Mn content was seen up to 1 km distance and the effect was more pronounced in soil samples collected at 0.5 km distance. The soil reaction tended towards alkalinity while no effect was seen on salt concentration. An increase in total Pb and Ni content was also seen in the samples collected from 0.5 km (Stalin et al. 2010).

11.5 Soil Pollution in Mining Areas

Most of the country's mining activities (about 92%) are concentrated in the states of Gujarat, Andhra Pradesh, Jharkhand, Madhya Pradesh, Rajasthan, Karnataka, Odisha, Tamil Nadu, Maharashtra, Chhattisgarh and West Bengal. Geological Survey of India (2007–2008) estimated an affected area of 1394 km^2 through large-scale mapping (Ministry of Mines 2008). A number of studies have been carried out around mining areas in India to evaluate the extent of soil pollution (Goswami et al. 2008, 2010a, b; Swain et al. 2011). The changes in soil quality were found to be drastic and continuously deteriorating in and around mining areas.

11.5.1 Coal Mines Impact in Eastern India

India is rich in coal mines and excavation processes have devastating impact on terrestrial ecosystem including nearby agricultural land area. Coal fires are common in coal mine areas which may start by natural cause like forest fire or by human activity. In Jharia (Jharkhand), coal in the mines is burning for more than 100 years. Hazardous effects from coal fires include the emission of noxious gases and particulate matter into the atmosphere, and their condensation on the land and water surfaces leading to water and soil pollution (Stracher and Taylor 2004). Soil samples analyzed from an opencast coal mine (OCM) and a coal fire affected area (CFA) in Jharia coalfield revealed that Cr and Ni contents were elevated in soils nearby both CFA and OCM; V and Zn were enriched in soils nearby CFA. However, the levels of Cr, Ni, and Zn in these soils are below the USEPA soil screening limits (Masto et al. 2011). Using statistical tools (principal component analysis combined with multiple linear regression analysis), Pandey et al. (2016) identified coal mining activities (including mine fires) as major factor for build-up of Ni, Cu and Cr in soils of the area; while wind-blown dust was the major contributor Pb and Cd. Chemicals released from the coal mines; overburden and tailings contained high concentration of metals such as Cu, Cd, Fe, Hg and Zn; which also affected the organisms adversely.

A core committee (along with its sub-committees) was constituted by National Green Tribunal (NGT) to quantify industrial pollution and impact assessment of water, air, soil and health in and around Singrauli. The committee observed that groundwater in the villages was contaminated with high fluoride and mercury. The mercury concentration in groundwater was found exceeding the limit of 0.001 mg L^{-1} in the samples collected from Kirwani, Parasi, Harrahwa, Naktu, Sirsoti, Chilkadand, Parsavar-raja, Govindpur, Kusmaha, Khairahi, Jayant Colony, Jaitpur, MPCC colony, and Dibulganj villages around thermal power plants and mines in Singrauli and Sonebhadra area (Business Standard 2015).

A study was conducted to investigate changes on soil fertility near open cast coal mining area Godda district of Jharkhand (Ghose 2004). Soils around the area had lower soil fertility (in terms of available major plant nutrients) and microbial population as compared to unmined soils. Similarly other workers also reported that organic matter content and available nutrients like N, P, K in soils were much lower while heavy metals content were higher in mining areas as compared to normal soils (Maharia et al. 2010; Yellishetty et al. 2009; Juwarkar et al. 2003).

11.5.2 Copper Mines Impact

Soil samples collected from Khetri copper mine area were found to contain abnormally high Cu concentration (763 mg kg^{-1}), which was 30-folds higher (phytotoxic level) than that of uncontaminated soil (26.4 mg kg^{-1}). Also concentrations of Cr, Fe, Zn and Pb in soil were elevated as compared to unpolluted soils (Maharia et al. 2010). The abandoned copper mines in Mosaboni (Jharkhand, India) left huge amount of untreated tailings containing high concentration of toxic, environmentally available (equal to total metal except silicate matrix bound metal) Cu (154 mg kg^{-1}), Ni (136 mg kg^{-1}) and Pb (9.9 mg kg^{-1}) which became a source of metal pollutants. About 12.5%, 0.8% and 8% of environmentally available fractions of Cu, Ni and Pb were in bio-available forms (DTPA extractable), respectively (Shyamsundar et al. 2014). In all the samples, concentration of total Cu and Ni were found exceeding the toxicity threshold limit as indicated by Kabata-Pendias and Pendias (1984).

11.5.3 Chromite Mining Impact

About 95% of India's chromite minerals are deposited in the state of Orissa with approximately 183 million tons of deposits located in the region's Sukinda and Baula-Nuasahi mining belts (Ministry of Mines 2010). Sukinda chromite valley in the district of Jajpur, Orissa has one of the largest chromite deposits of the country and produces 8% of total chromite, mainly through opencast mining method. High Cr(VI) concentration in ground and surface water, mine effluents and seepage water samples in the area was reported (Tiwary et al. 2005). Chromium (VI) concentration was found to be varying between 0.02 and 0.12 mg L^{-1} in mine effluents and 0.03–0.8 mg L^{-1} in shallow hand pump waters and 0.05–1.22 mg L^{-1} in quarry seepage. The concentration of Cr(VI) in the surface water source (Damsal creek) was in the range of 0.03–0.14 mg L^{-1}, which increased in the downstream due to mining activities.

Dhal et al. (2010) also assessed the environmental impact of chromite mining belts in Baula-Nuasahi area and they reported hostile conditions for organisms in the surrounding environment. This study also revealed that most of the water quality parameters exceeded national/international permissible standards. The soils in and around the overburden region had low nutrient (N, P and K) and the microbial population. Also hazardous metals were found to be leached and accumulated in nearby agriculture lands and caused them less fertile for crop production. The main source of Cr pollution in this region was found to be overburden dumps and seepage water.

A case study at South Kaliapani, Chromite Mine Area, Orissa on mine waste water irrigated rice grown soil indicated that Cr(VI) concentration (0.65 mg L^{-1}) in the mine wastewater used for irrigation was beyond the toxic limit i.e., > 0.008 mg L^{-1} and total Cr content in soil irrigated with mine waste water was very high (11,170 mg kg^{-1}) compared to normal soil (Mohanty et al. 2011). Soils of agricultural land near abandoned chromite-asbestos mine area of Chaibasa (Jharkhand state) had accumulated high Cr and Ni as indicated by values of contamination factor and geoaccumulation index (Kumar and Maiti 2015). Concentrations of Zn, Mn, Co, Cu, Pb, and Cd were found low and within toxicity limit. Metal grouping and site grouping cluster analysis also revealed that Cr and Ni were closely linked with each other and chromite-asbestos mine waste was the major source of contamination.

11.5.4 Arsenic Toxicity Near Gold Mining Area of Karnataka

Prevalence of arsenicosis and As related cancers among human population had been reported from several villages of Raichur, Yadgir and Gulbarga districts in north-eastern Karnataka and a study conducted jointly by Govt. of Karnataka and UNICEF indicated a unsafe levels (>10 µg L^{-1} As) of As in drinking water samples (groundwater) of 69 villages in these districts. A comprehensive study to investigate the cause of As like symptoms among villagers of the area was conducted in Kiradalli Tanda village of Yadgir district (Chakraborti et al. 2013). The village is only 4 km away from a gold mine which had been closed for mining operations since 1994. Arsenical skin lesions (as confirmed through histopathological analysis) were observed among 58.6% of a total 181 screened individuals. Analysis of hair and nail samples from all of these As affected individuals had elevated As contents. About 79% of the tube-well water samples had As above 10 µg L^{-1}. Top soil samples from the residential area contained As in the range 99–9136 mg kg^{-1}, which were very high considering the its commonly reported range of 2.2–25 mg kg^{-1} for unpolluted soils (McBride 1994). This indicate that inhalation of soil dust might be another route of As entry into human being. Arsenic concentrations in the food grains were however, found considerably low in the area.

11.6 Aerial Deposition of Heavy Metals on Land

The rapid industrialization and urbanization have resulted atmospheric deposition of heavy metals. Several case studies have indicated that industrial, mining and urban activities generate considerable dust in the atmosphere and these dust particles are normally enriched with heavy metals (Patel et al. 2010a; Mishra et al. 2013; Pal et al. 2014). A study conducted by CPCB (2011) indicated that suspended particulate matter (SPM) was more in air near industrial areas as compared to that in city residential areas of both Raipur and Raigarh in Chhatisgarh. SPM of these areas are loaded with heavy metals (0.43–0.89% in Raigarh and 1.17–1.87% in Raipur). Moradabad in UP is known as brass city due to large number of brassware industries. Pal et al. (2014) found that SPM (PM_{10}) was highest in industrial area followed by commercial area and least in residential area. Metal (Cd, Cr, Cu, Fe, Ni, Pb and Zn) concentrations in the air due to suspended particles were also considerably higher near industrial area as compared to commercial and residential areas. Coal mining areas in Jharia also contained high SPM (PM_{10}) in air (20.8 μg m^{-3}) (Mishra et al. 2013). Mean concentrations of all SPM were around 2 times higher than that of non-mining area. Level of these pollutants for coal mining areas was found higher than that of most of the cities nearby.

Tiwari et al. (2008) investigated atmospheric deposition of heavy metals in urban and sub-urban area of Varanasi city. Atmospheric deposition was maximum for Mn (387.3 g ha^{-1} $year^{-1}$) followed by Zn (336.7 g ha^{-1} $year^{-1}$), Cr (124.4 g ha^{-1} $year^{-1}$), Pb (71.0 g ha^{-1} $year^{-1}$), Ni (51.2 g ha^{-1} $year^{-1}$), Cu (39.8 g ha^{-1} $year^{-1}$) and Cd (6.9 g ha^{-1} $year^{-1}$). Their deposition was the maximum in heavy traffic zone followed by commercial, residential and sub-urban areas in the decreasing order. Another study (Sharma et al. 2008) in Varanasi indicated deposition rate of Cd as 13.8 g ha^{-1} $year^{-1}$, Zn as 525 g ha^{-1} $year^{-1}$, Cu as 66.8 g ha^{-1} $year^{-1}$ and Pb as 9.8 g ha^{-1} $year^{-1}$. An earlier study (Tripathi et al. 1993) in Mumbai showed deposition rate for Cd, Zn, Cu, and Pb as 0.4, 371.6, 94.3 and 32.4 g ha^{-1} $year^{-1}$, respectively.

11.6.1 Risk to the Peri-Urban Agriculture with Atmospheric Deposition

Most the atmospheric emissions of heavy metals from the centers of anthropogenic activities are likely to end up as their depositions over nearby agricultural land directly or through washing-off of the vegetations. If the mean metal concentration in biomass of rice and wheat grown in uncontaminated soils (Kabata-Pendias and Pendias 1992) are considered, annual uptake of heavy metals by rice-wheat cropping system should not be more than 1.3 g Cd ha^{-1}, 2 g Cr ha^{-1}, 65 g Cu ha^{-1}, 6 g Ni ha^{-1}, 5 g Pb ha^{-1} and 440 g Zn ha^{-1} under Indian condition (assuming wheat and rice grain yield of 5 and 4 t ha^{-1}). On the other hand, if means of the annual heavy metal deposition rates, as found out by different workers above are assumed (7 g Cd ha^{-1}, 124 g Cr ha^{-1}, 67 g Cu ha^{-1}, 51 g Ni ha^{-1}, 38 g Pb ha^{-1} and 410 g Zn ha^{-1}), the annual deposition of Cd, Cr, Pb and Ni can be several times higher than their uptake by above ground biomass (Table 11.16). However, even at this rate of soil contamination due to atmospheric deposition, heavy metal build-up in the soil would be very slow. For example, it will take 200 years for Cd, 460 years for Cr, 2900 years for Ni and 1050 years for Pb to get their total contents become double than the present level in plough layer at Bhopal city as an example.

However, Sharma et al. (2008) have reported that atmospheric deposition had substantially contributed towards the heavy metals accumulation in vegetables and consumption of which lead to potential health risks to the consumers. This study revealed that both Cu and Cd posed health risk to human via all the tested vegetables consumption, whereas Pb only through cauliflower. Another study in China revealed that Pb and Cd in the grain grown nearby highway were due to the foliar uptake from atmosphere which, accounted for about 46% of Pb and 41% of

Table 11.16 Estimation of impact of atmospheric deposition on heavy metal contents in soil

Heavy metal	Annual mean atmospheric deposition rate (g ha^{-1})	Annual mean removal by rice-wheat system (g ha^{-1})	Annual increase in total content in soil (mg kg^{-1})
Cd	7	1.3	0.003
Cr	124	2	0.061
Cu	67	65	Nil
Ni	51	6	0.022
Pb	38	5	0.016
Zn	410	440	Nil

Cd of the total uptake and there was no significant contribution of atmosphere to Cr, Zn and Cu in grain. The study concluded that atmospheric Pb and Cd around highway can directly contaminate food (Feng et al. 2011). Smolders (2001) concluded from his research work that in rural areas with low atmospheric Cd deposition, of less than 2 g Cd ha^{-1} y^{-1}, airborne Cd in the plants has only a marginal influence on the crop Cd concentrations. On the other hand, when the atmospheric Cd deposition is well above 10 g Cd ha^{-1} y^{-1} can be a major source of crop Cd and dietary Cd. This kind of conditions may occur in and around the pyrometallurgic smelters with high Cd emissions.

11.7 Pollution Around Municipal and Hazardous Waste Dumpsites

Municipal solid wastes (MSW) are considered to be loaded with hazardous material and have severe environmental consequences if it not properly treated. Unorganized, indiscriminate and unscientific dumping of municipal wastes is very common disposal method in many Indian cities which causes adverse impacts to the environment. Environmental impact of unscientific land-filling/dumping of MSW usually results from the run-off of the toxic compounds into nearby land area, surface water and groundwater which eventually lead to water pollution as a result of percolation of leachate. For example, examination of soils in three municipal waste dumpsites of Allahabad, Uttar Pradesh, showed elevated total metal concentrations of Cr, Cu, Fe, Ni, Pb and Zn (32.46–108.85 mg kg^{-1}) (Tripathi and Misra 2012). Among the sites investigated, Daraganj dumpsite was highly contaminated while Phaphamau dumpsite was least contaminated. The order of metal contamination in dumpsites was Pb > Zn > Fe > Ni > Cu > Cr > Cd. It indicates that the heavy metal contamination at unscientific dumpsites is higher and of great concern for their surrounding environment and organisms. The Thane-Belapur industrial area, in Maharashtra produces 5 tonnes of waste every day, which is co-disposed with municipal waste in municipal waste dumpsites. The water bodies in the vicinity of this dumpsite area are polluted and sediment in the Ulhas river has registered high levels of mercury and arsenic (Vision 2025 of Planning

Commission, Government of India). Considerable leachate migration from municipal dumpsite in Ariyamangalam of Tiruchirappalli district (Tamil Nadu) resulted heavy metals contamination in soils of nearby area (Kanmani and Gandhimathi 2013).

Hazardous waste disposal sites are one of the major sources of elevated levels of metals in the soil environment around industrial area. Parth et al. (2011) studied and reported the degree of contamination of soil in respect of heavy metals accumulation in and around hazardous waste disposal sites located in the north-western part of Hyderabad, India. It was estimated that annual hazardous/industrial waste of approximately 50,000 tonnes was abandoned as landfill over 200 acres of area in the city outskirts. These hazardous wastes were contaminating soil resource. Soils in the vicinity of dumpsite and the downstream were considerably contaminated with metals. The heavy metals such as As, Cr, Pb in the soils was found to exceed the threshold and natural background values. The highest concentrations of Cu, Ni and Zn exceeded the prescribed threshold limit. The soil pH was acidic to alkaline and was one of the major factors affecting mobility/solubility of metals in soil environment. In Kolkata, Adhikari et al. (1993) found significant accumulation of Cr, Pb and Cd in upland surface soils of agricultural land due to long-term application of sewage sludge.

11.8 Soil Contamination Due to Agricultural Activities

Although contribution of agriculture to GDP of India has fallen over time, absolute production has increased almost continuously over the years, mainly due to technological innovations, and intensive use of agricultural inputs. Many a times, safety of environment has been compromised with quality of these inputs due to pressure of enhancing productivity of land. Fertilizers have been considered as an essential input to agriculture as these play an important role in achieving the total food grain production worldwide to feed the ever increasing population and to meet their daily needs of food, fuel and fiber. Consumption of chemical fertilizers and organic manure bear a direct relationship with food grain production. The total nutrient consumption ($N + P_2O_5 + K_2O$) was about 24 million tonnes during 2013–2014, with about 141 kg fertilizer per ha (Annual Report 2014-‘15, Department of Fertilizers, Govt. of India). Excessive use of fertilizers and pesticides, antibiotics and hormones in livestock and irrigating farms with contaminated wastewater are agricultural factors affecting soil pollution. Many of these agricultural inputs have been reported to be contaminated with heavy metals (Table 11.17).

Table 11.17 Agricultural sources of trace element contamination in soils (mg kg^{-1})

Element	Sewage sludge	Phosphate fertilizers	Limestone	Nitrogenous fertilizers	Municipal solid waste compost	Manures	Pesticides
As	2–26	2–1200	0.1–24	2–120	–	3–150	22–60
Cd	2–1500	0.1–170	0.04–0.1	0.05–8.5	Tr.–8.4	0.3–0.8	–
Cr	20–40,600	66–245	10–15	3–19	14–401	5.2–55	–
Cu	50–3300	1–300	2–125	1–15	25–865	2–60	12–50
Hg	0.1–55	0.01–1.2	0.05	0.3–3	–	0.09–26	0.8–42
Mn	60–3900	40–2000	40–1200	–	–	30–550	–
Ni	16–5300	7–38	10–20	7–38	8.6–190	7.8–30	–
Pb	50–3000	7–225	20–1250	2–1450	11–647	6.6–15	60
Zn	700–49,000	50–1450	10–450	1–42	82–946	15–250	1.3–25

Adopted from Kabata-Pendias (2000) and Saha et al. (2010a)

11.8.1 *Impact of Fertilizer Use on Heavy Metal Build-Up in Agricultural Land*

Generally fertilizers are manufactured from the raw materials that are collected from underground through mining like rock phosphate, sulphates etc. Therefore fertilizers contain highly variable amount of heavy metals as impurities (Table 11.17). Among the fertilizers, use of rock phosphates and phosphatic fertilizers in agriculture are considered as environmental concern due to their potential for enhancing heavy metal levels in soil and contaminating food crops (Mortvedt 1996; Gupta et al. 2014). For instance, concentrations heavy metals in phosphate fertilizers were reported as 0.5–20 ppm (mean 11.3) As, 0.1–250 ppm (mean 65 ppm) Cd, 63–896 ppm (mean 173.2 ppm) Cr, 0.2–1170 ppm (56.6 ppm) Cu and 0.5–151 ppm (27.5 ppm) Ni (USEPA 1999). Concerns are raised on accumulation of heavy metals and their contamination to food crops due to continuous application of phosphatic fertilizers in soil. However, long-term experiments in different countries indicated no significant contamination of food due to continuous P fertilizer application (Smilde and van luit 1983; Rothbaum et al. 1986; Mortvedt 1987). On the contrary, uptake of Cd by herbage was found higher where P fertilizer was being applied continuously over several decades under a long-term experiment (Jones and Jonston 1989).

In India, analysis of soils and plant samples from long term (>39 years) fertilizers experiments at Barrackpore, Jabalpur, Bangalore, Ranchi, Palampur, Pantnagar and New Delhi indicated that application of 150% and/or 100% recommended doses of NPK for this period resulted build-up of the heavy metals like Cd, Pb, Co, Cr and Ni. However, contamination level didn't reach the unsafe levels. Also, heavy metals in edible plant parts showed that risk to human health is very little (Adhikari et al. 2012).

11.9 Soil Pollution Through Use of Geogenically Contaminated Groundwater

11.9.1 *Use of Arsenic (As) Contaminated Groundwater for Irrigation*

The prevalence and consistent increase in evidences of As contamination of groundwater has been reported from various countries. In India also, its contamination in water and soil have been recognized a serious clinical problem in several states. In West Bengal, extensive As contamination in groundwater and soil has been reported from nine districts, particularly in intensive cropping areas within the upper delta plain along the Bhagirathi and other rivers (CGWB 1999). About 10% of total human population in the state was exposed to the risk of As toxicity by consuming As contaminated ground water for drinking purpose (Elangovan and Chalakh 2006). Analysis of 140150 water samples from tube wells in all 19 districts of West Bengal for arsenic indicated that 48.1% samples had As >10 μg L^{-1} (WHO guideline value), 23.8% had >50 μg L^{-1} (Bureau of Indian Standard) and 3.3% had >300 μg L^{-1} (concentration predicting overt arsenical skin lesions) (Chakraborti et al. 2009). Arsenic contamination of groundwater, soil and food had also been reported from other regions of India such as Uttar Pradesh, Jharkhand, Bihar, Madhya Pradesh, Chhattisgarh, Assam, Manipur, Tripura, Arunachal Pradesh, Punjab and Andhra Pradesh (Chakraborti et al. 1999, 2003; Chetia et al. 2011; Govil et al. 2001; Mukherjee et al. 2006; Rao et al. 2001; Singh et al. 2011; Sharma et al. 2016). In a study in the state of Punjab, the concentration of As in 200 groundwater and surface soil samples were analyzed (Singh et al. 2011). In southern states of Punjab, As in groundwater varied from 5.33 to 17.27 μg As L^{-1}, and in soil it varied from 1.09 to 2.48 mg As kg^{-1}. About 40% of ground water samples exceed the permissible limit (10 μg As L^{-1}).

Reductive dissolution of Fe-hydroxides (FeOOH) stimulated by microbial activity and organic materials is regarded as the most important mechanism of releasing As into the aquifer (Mukherjee and Bhattacharya 2001; Ravenscroft et al. 2001; Smedley et al. 2003; McArthur et al. 2004). Continuous use of As-contaminated groundwater may elevate the soil arsenic level, thereby increasing the possibility of arsenic entering into the food chain. Arsenic contamination or build-up in fertile alluvial soils of Malda, Dinajpur (North and South), Murshidabad, Nadia, Burdwan, 24 Parganas (North and part of South), Hoogly districts has arisen from use of arsenic loaded ground water as a source of irrigation. Beside underground source of drinking water, As can also enter into human body through consumption of food that is grown using contaminated groundwater for irrigation.

Impact of As contaminated groundwater irrigation in different vegetables and crops (Table 11.18), and their dietary intake was studied (Santra et al. 2013). The results revealed that tubers accumulated higher amount of arsenic than leafy vegetables followed by fruit vegetables. The As accumulation was high in potato, brinjal, arum, amaranthus, radish, lady's finger and cauliflower; and was at moderate level in beans, green chilli, tomato, bitter guard, lemon and turmeric. Its accumulation in mustard was in the range 0.339–0.373 mg kg^{-1}. Among the pulses, pea showed the highest As content (1.30 mg kg^{-1}) and the lowest As concentration was found in moong bean (0.314 mg kg^{-1}).

In Gangetic West Bengal, huge amount of the groundwater is used as irrigation for production of winter (*boro*) and summer (*aush*) rice during winter and summer (November to May). In the affected districts, use of As-contaminated groundwater as irrigation in paddy fields caused accumulation of As in rice irrespective of its varieties (Halder et al. 2014). As a result, As accumulation was found more in *boro* rice than that grown in rainy-season (*aman*, grown predominantly with rain water). Further, high yielding rice varieties accumulated more arsenic than local varieties. Garari et al. (2000) predicted that the left over roots after harvest of crops have contributed substantially to the As accumulation in soils. However, the toxicity due to As to human and crops depends on forms or species of As rather than the total As

Table 11.18 Arsenic levels in soil, crops and vegetables grown in West Bengal, (India) and adjoining countries

Country	Arsenic in soil (mg kg^{-1})	Arsenic in crops and vegetable (mg kg^{-1})		References
		Rice	Vegetables	
Bangladesh	NA	0.358	0.034	Chowdhury et al. (2001)
West Bengal, India	11.35	0.245	<0.0004–0693	Roychowdhury et al. (2002)
Bangladesh	NA	NA	0.306–0.489	Alam et al. (2003)
Bangladesh	NA	NA	0.011–0.103	Farid et al. (2003)
Bangladesh	7.31–27.28	0.04–0.27	0.2–3.99	Das et al. (2004)
West Bengal, India	7.0–38.0	0.30	NA	Norra et al. (2005)
China	6.04	0.117	0.003–0.116	Huang et al. (2006)
Bangladesh	14.5	0.5–0.8	NA	Rahman et al. (2007)
Nepal	6.1–16.7	0.180	<0.010–0.550	Dahal et al. (2008)
West Bengal, India	1.34–14.09	0.16–0.58	NA	Bhattacharya et al. (2009)
West Bengal, India	5.70–9.71	0.334–0.451	0.030–0.654	Bhattacharya et al. (2010)
Bihar, India	0.027	0.019	0.011–0.015	Singh et al. (2011)
West Bengal, India	NA	0.156–0.194	0.069–0.78	Samal et al. (2011)
West Bengal, India	NA	0.01–0.64	0.03–0.35	Halder et al. (2013)

Santra et al. (2013)
NA not available

content. Generally As exists in AsO_4^{3-} and AsO_3^{3-} forms in soil and the later is considered being more toxic to animal and human. Soil properties like texture, mineralogy, redox potential (Eh) and pH control the speciation and mobility of As in soil.

Average daily intakes of As by adult and children through their diet were computed as 560 μg and 393 μg, respectively, on the basis of average dietary habit and concentrations of the toxicant in common food items. Further the people having poor nutrition were found to be more vulnerable to As toxicity than the people having adequate nutrition (Santra et al. 2013). Contamination of food chain and daily intake of As by human through food and drinking water was estimated in Nadia district where unsafe levels of the element in groundwater in widely prevalent (Samal et al. 2011). Average concentrations of As in drinking water and commonly grown food in the area were 16 μg L^{-1} in drinking water, 156–194 μg kg^{-1} in rice, 69–780 μg kg^{-1} in vegetables and 24.7 μg kg^{-1} in pulse (lentil). Total intake of As through foodstuffs was computed as 560 μg day^{-1} by adults and 393 μg day^{-1} by children in the area which were quite alarming. After adjusting the excretion through urine, investigators indicated considerable potential risk of As exposure to local inhabitants through continuous consumption of As-contaminated foodstuffs and drinking water. Such intake rates of As are alarmingly higher keeping in view of maximum tolerable daily intake 2.1 μg kg^{-1} body weight by humans from all sources (WHO 1988). In Ropar district of Punjab, consumption of As contaminated wheat grains was found to pose higher risk of cancer and non-cancer health disorders as compared to intake of As contaminated groundwater by both adults and children (Sharma et al. 2016).

11.9.2 Use of Selenium Contaminated Ground Water for Irrigation

Selenium is an essential element in human and animals; and however, it shows toxicity symptoms when taken in larger amount. Long-term ingestion of excess Se may result in chronic disease, called 'selenosis' with symptoms of nausea, diarrhea, joint pain, loss of nail and teeth and skin rashes appearing according to severity of the disease. Upper intake level of Se is 400 μg d^{-1} for adult and is 45–280 μg d^{-1} (varies according to age) for children (ATSDR 2001). Selenium toxicity is also observed in animals with symptoms of vision loss, random walking, loss of hair, deformed and sloughing hooves, joint erosion, paralysis etc.

Geology of a region affects or influences the distribution of Se in soils. Soils containing >0.5 mg Se kg^{-1} are considered as seleniferous as the forages produced on such soils absorb Se more than the maximum permissible level for animal consumption. Pockets of seleniferous soils have been identified in north-eastern parts (mainly in Hoshiarpur and Nawanshahar districts) of Punjab, India. Dhillon and Dhillon (2003) examined the Se content of soils, irrigation water, plants and animal tissues in the region. These seleniferous soils occupied more than 1000 ha, but toxic sites were reported only in 4–16 ha that were distributed sporadically in the study area. The Se content in surface (2.12 ± 1.13 mg kg^{-1}) and sub surface (1.16 ± 0.51 mg kg^{-1}) soils in the toxic sites was 4–5 times higher than that of non-seleniferous areas. The development of seleniferous pockets was mainly because of the deposition of seleniferous materials transported by seasonal rivulets from higher reaches of the Siwalik hills and use of groundwater for frequently irrigating crops like lowland rice. Some parts of Rajasthan and Southern parts of the Haryana also had soils with selenium levels above normal soil. Selenium in contaminated soil and water exists mainly as highly mobile toxic inorganic species such as selenate (SeO_4^{2-}, Se^{6+}) and selenite (SeO_3^{2-}, Se^{4+}). As a result, these transfer efficiently through the soil-plant-animal- human system. Rice crop grown on a seleniferous soil (2.85 mg kg^{-1} Se) from Nawanshahar, Punjab recorded reduction in growth and delayed flowering. Selenium accumulation increased by about 3 to 20-folds in leaves and grains of rice grown on seleniferous soil as compared to normal soil containing 0.135 mg Se kg^{-1} (Sharma et al. 2014) (Fig. 11.6).

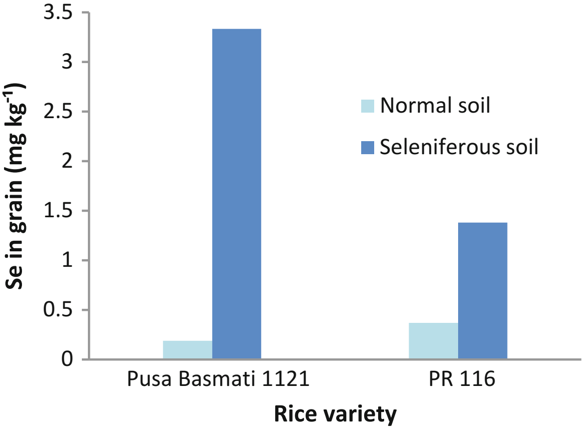

Fig. 11.6 Selenium accumulation in rice grain grown on seleniferous soil (Adopted from Sharma et al. 2014)

11.10 Environmental Risks of Organic Pollutants in Environmental Samples

11.10.1 Indiscriminate Use of Pesticides and Insecticides

In addition to fertilizers, a large amount of pesticides are used in agriculture to ensure a good yield of crops. Most part of the applied pesticide, irrespective of crops, ultimately finds its way into soil. Though a large part of these are degraded by soil microorganisms or inactivated by soil matrix through absorption, these affect adversely the functioning of non-target microbes and other soil organisms before inactivation. Prakash et al. (2004) studied the presence of HCH isomers residues in 45 surface (0–15 cm) and subsurface (15–30 cm) soils samples from agricultural sites of Delhi, Haryana, and Uttar Pradesh and around the HCH manufacturing plant of Indian Pesticide Limited. Thirty nine soil samples contained residues of *b*-HCH (2.5–463 mg kg^{-1}) and the remaining six samples showed the presence of *g*-HCH (0.08–43.00 mg kg^{-1}). And residues of *a*-HCH (0.04–98.00 mg kg^{-1}) and *d*-HCH (0.07–458.00 mg kg^{-1}) were detected less frequently. Random monitoring of pesticides in water had also detected residues of persistent organochlorines in many rivers like Ganga, Yamuna, Cooum, Ulsoor, Mandori, Hoogly inflicting damage to aquatic life and health of fish consuming human population (UNEP 2002).

In India, several cases of residues like parathion, endosulfan, DDT etc. were reported in food samples. The presence of pesticide residues in samples of fruits, vegetables, cereals, pulses, grains, wheat flour, oils, eggs, meat, fish, poultry, bovine milk, butter and cheese in India was reported by several investigators. Analysis of 16,948 samples of vegetable, fruits, spices, cereals, pulses, milk, animal feed, fish/crustacean, tea, honey, meat, egg, soil and ground water by 21 participating laboratories across the country during the period of April 2011 to March 2012, for the possible residues of agrochemicals like organo-chlorine, organophosphorous, synthetic pyrethroids, carbamates, herbicides etc. revealed that about 290 (1.7%) samples were found to contain these chemicals above maximum residue limit (MRL) as prescribed under Prevention of Food Adulteration Act (PFA)/Food Safety Standard Authority of India (FSSAI) (Kulshrestha 2013).

11.10.2 Environmental Risks of Other Organic Pollutants in Environmental Samples

Though persistent organic pollutants (other than pesticides) are less investigated in agricultural soils, concerns are expressed on their entry through several inputs. Devanathan (2012) have studied the contamination status of organo-halogen compounds (OHCs), including polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecanes (HBCDs) in human milk, fish and dust samples collected from different locations in India. Higher levels of OHCs were found in the dust samples near e-waste recycling areas and improper e-waste recycling and dismantling are considered to be the major sources of these contaminants. Farm-raised fishes contain relatively high levels of PCBs and PBDEs than wild fishes. However, the concentration of these contaminants and dietary intake from fish was much lower than the guideline values which indicate less risk. Municipal dumpsites in India have been found to contain dioxins and related compounds like PCDD/DFs high amount (Subramanian and Tanabe 2007, Subramanian et al. 2015). Toxic persistent organic pollutants (PCDD/DFs, PCBs, and PAH) have also been found in significant amount in composts prepared from municipal solid wastes which can be a potential medium for entry of these pollutants in agricultural land (Grossi et al. 1998). Fish and human milk samples particularly from surrounding areas of the municipal waste dumping sites of Kolkata and Chennai in India contain significantly higher levels of PCBs which suggest that there is a greater risk for infants living near these sites (Someya et al. 2010). The hazard quotients (HQs) values were above one for PCBs in the infants and toddlers living near the municipal dumping and e-waste recycling areas and it indicated high risk with toxic organic pollutants among human population living in the city and industrial area. Hence regular monitoring is necessary for having a more real assessment on status of these toxic organic pollutants and taking appropriate measures for reducing the pollutants level in the environment.

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