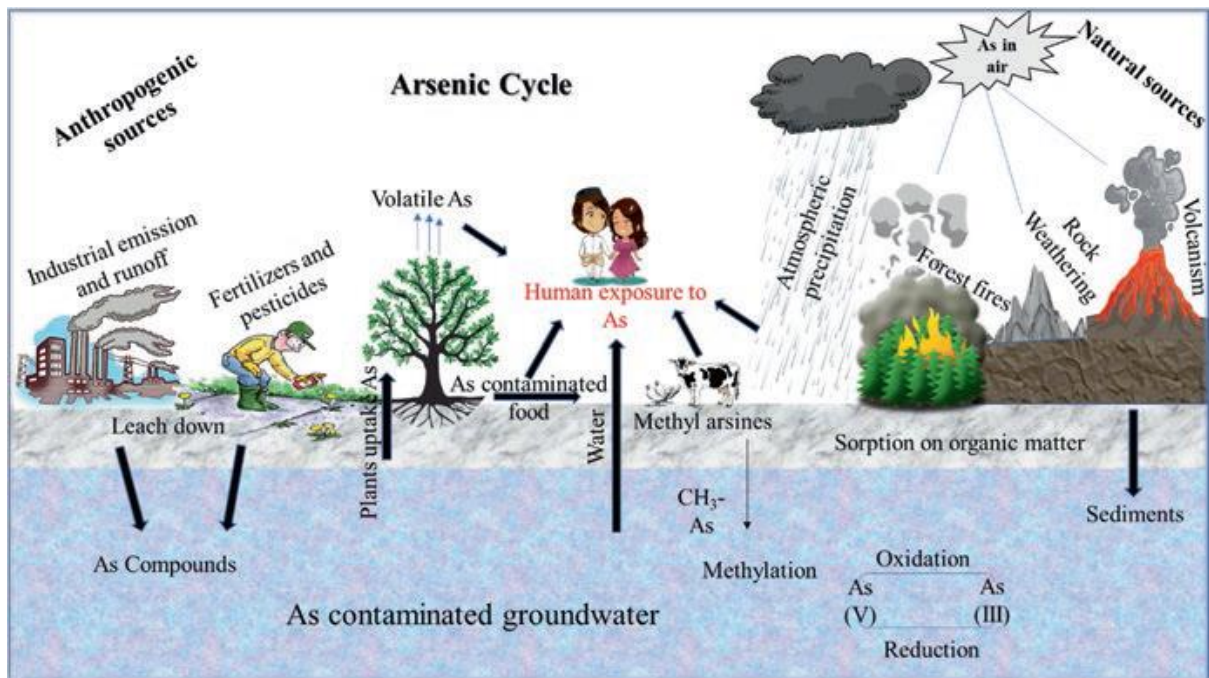
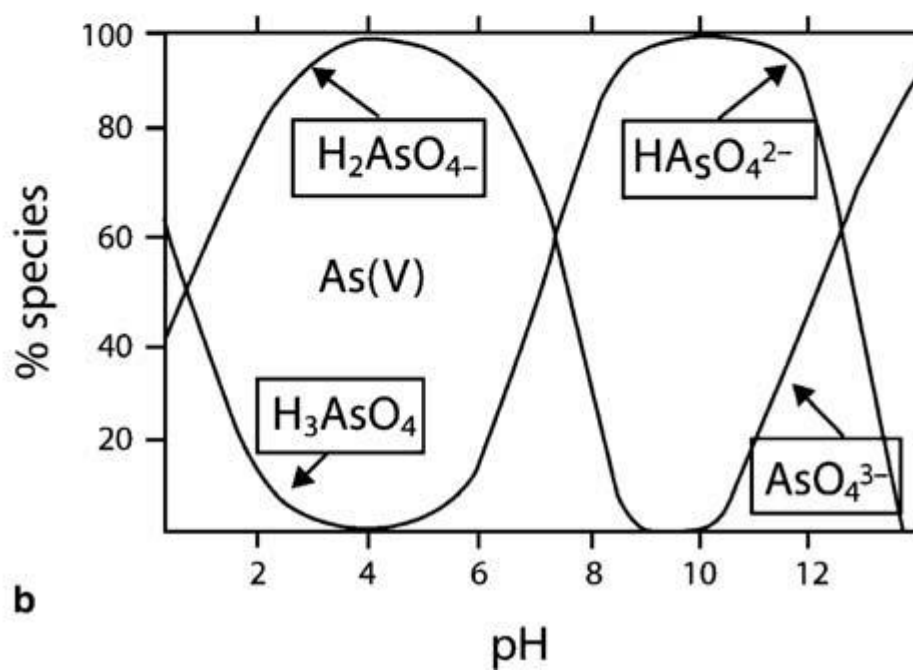
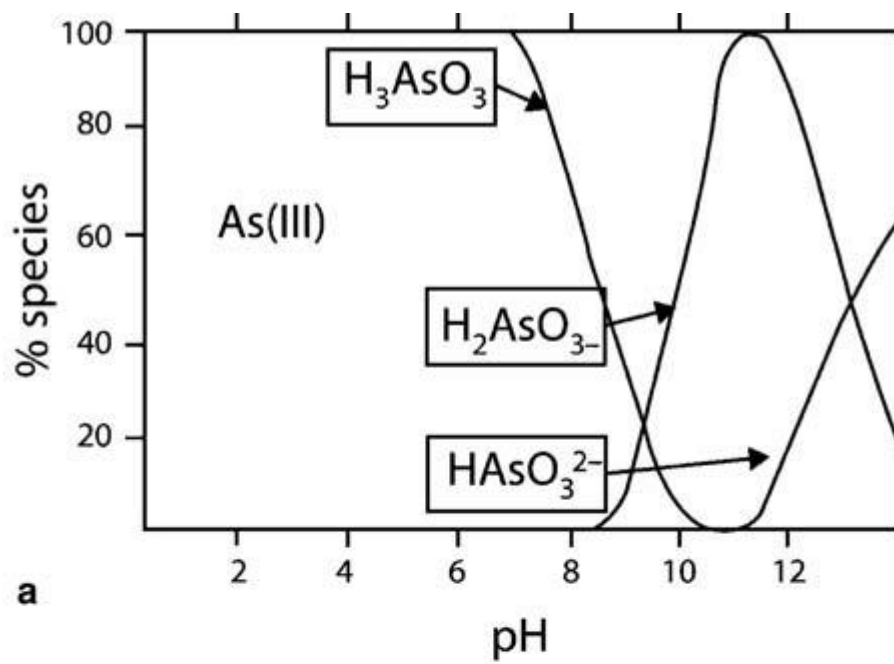
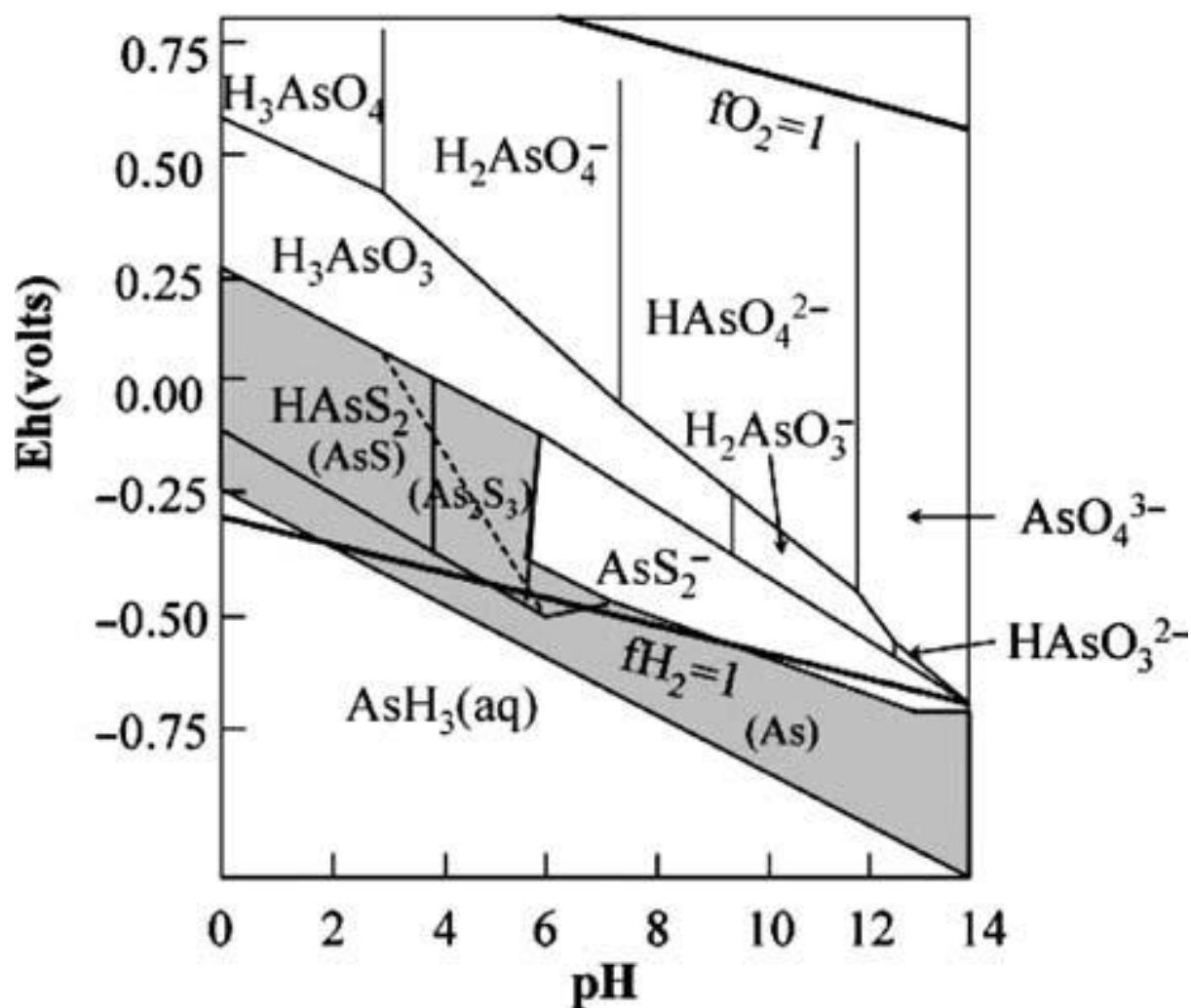




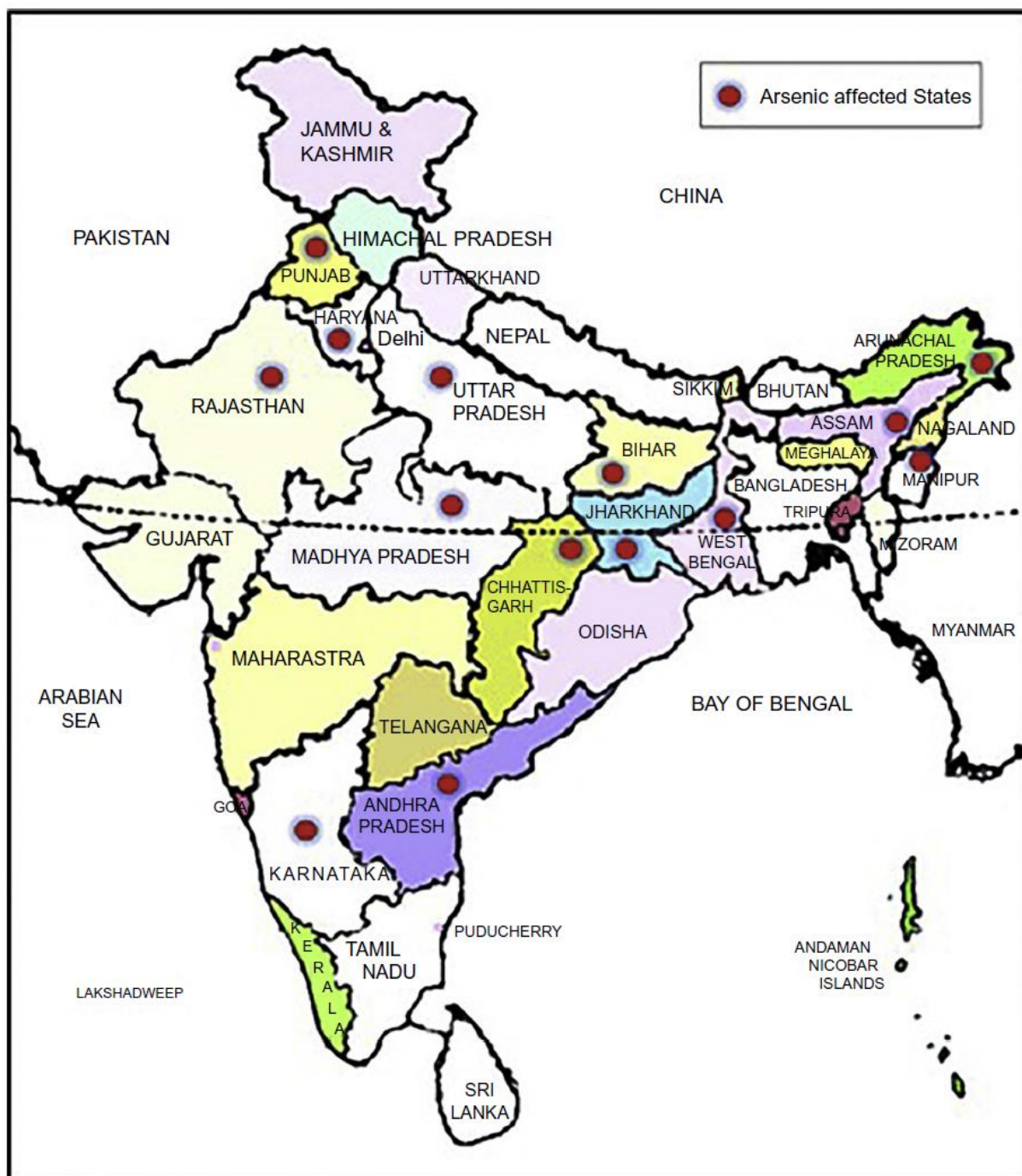
Supplementary Fig. 1 Arsenic (As) cycle in the environment and potential exposure to human [20]



Supplementary Fig. 2 Arsenic (III and V) predominance diagrams [34,37]



Supplementary Fig. 3 Redox (Eh)-pH diagram for arsenic at 25 °C and 1 atm with total As = $10^{-5.3}$ mol/L and total S = 10^{-3} mol/L. Solid species depicted in parentheses in grey (shaded) area [34,37]



Supplementary Fig. 4 Arsenic contaminated states in India [98]

Supplementary Table 1 Natural sources of Arsenic (As) heavy metal [34]

Mineral	Composition	Occurrence
Native arsenic	As	Hydrothermal veins and deposits that contain other arsenic minerals
Niccolite	NiAs	A minor component of Ni-Cu ores in high-temperature hydrothermal veins
Safflorite	(Co,Fe)As ₂	Hydrothermal veins
Realgar	AsS	Vein deposits often associated with orpiment, clays, and limestones, deposits from hot springs
Orpiment	As ₂ S ₃	Hydrothermal veins, hot springs, volcanic sublimation products
Cobaltite	CoAsS	Medium-temperature hydrothermal deposits, metamorphic rocks
Arsenopyrite	FeAsS	Arsenopyrite FeAsS The most abundant arsenic mineral, dominantly in veins of hydrothermal origin, found in pegmatites, high-temperature gold, quartz and tin veins, in contact metamorphic sulphide deposits, also in gneisses, schists and other metamorphic rocks
Arsenian pyrite	Fe(As,S) ₂	Hydrothermal veins, accessory mineral in igneous rocks, pegmatites and contact metamorphic deposits
Lollingite	FeAs ₂	Mesothermal deposits associated with other sulfides and calcite gauge
Tennantite	(Cu, Fe) ₁₂ As ₄ S ₁₃	Hydrothermal veins and contact metamorphic deposits
Enargite	Cu ₃ AsS ₄	Hydrothermal vein deposits formed at medium temperatures
Arsenolite	As ₂ O ₃	Secondary mineral formed by oxidation of FeAsS, native arsenic and other arsenic minerals
Scorodite	FeAsO ₄ .2H ₂ O	Secondary mineral formed by oxidation of arsenic-bearing sulfides
Annabergite	(Ni,Co) ₃ (AsO ₄) ₂ .8H ₂ O	Secondary mineral formed by the alteration of Co-Ni-bearing arsenides and sulfides, in the oxidized zone of hydrothermal mineral deposits
Hoernesite	Mg ₃ (AsO ₄) ₂ .H ₂ O	Secondary mineral, in limestone blocks and volcanic tuff
Symplectite	Fe ²⁺ ₃ (AsO ₄) ₂ .8H ₂ O	Secondary mineral in the oxidized zone of some arsenic-rich hydrothermal mineral deposits
Conichalcite	CaCu(AsO ₄)OH	Secondary mineral in the oxidized zone of Cu deposits, an alteration product of enargite
Pharmacosiderite	Fe ₃ (AsO ₄) ₂ (OH) ₃ .5H ₂ O	Secondary mineral formed by oxidation of FeAsS and other arsenic-bearing sulfides

Supplementary Table 2 Anthropogenic sources of arsenic (As) contamination occurs all around the world [34,36]

Country	Arsenic source	Arsenic concentrations
Mindanao Island, Philippines	Geothermal power plant suspected source	Matingao and Marebl Rivers contaminated, 0.1 mg/L
Nakajo, Japan	Waste water from a factory producing arsenic sulfide	0.025–4.00 mg/L in local well water
Toroku and Matsuo villages, Japan	Arsenious acid and white arsenic produced from FeAsS	-
Behalla area, South Calcutta, India	Industrial effluent discharge from a factory manufacturing copper acetoarsenite (Paris-Green)	0.05–58 mg/L in well water
Czech Republic	Burning of arsenic contaminated coal	-
Toronto, Ontario Canada	Secondary lead smelters	-
Guizhou Province, China	Burning of arsenic rich coal	-
Srednogie, Bulgaria	Copper smelter processing high arsenic sulfide ores	Air pollution and soil contamination, local river: 0.75–1.5 mg/L
Anaconda, Montana	Copper smelters	As ₂ O ₃ emitted to the air, contamination of local vegetation and soils, arsenic in soils: 212–236 mg/Kg
Ghana	Gold mining, arsenic rich mine tailings	0.90–8.25 mg/L arsenic in water samples; 942–10,200 mg/kg arsenic in sediments
Lavrion, Greece	Lead mining and smelting	Soils contamination. arsenic in garden soils and house dusts: up to 14,800 and 3800 mg/kg respectively
Mae-Moh Valley, Northern Thailand	Lignite mining and power generation	Arsenic-rich sediments in streams, 1.2–325 g/ L arsenic in surface waters, groundwater from deep tube wells in Mae Moh mine area – average 364 g/ L As.
Nitra Valley in central Slovakia	Coal burning power station	8.8–139.0 mg/kg arsenic in garden soils and 2.1–170 mg/kg in house dusts

Supplementary Table 2 (continued)

Country	Arsenic source	Arsenic concentrations
Australia	Manufacture of: fertilizers, paint, electronics; gas works; mining (mainly gold deposits); power stations; transport; and wood preservatives	-
Japan	Wastewater from a factory producing arsenic sulfide, production of arsenious acid, manufacture of insecticides	-
SW England	Mining and smelting activities	Over 700 km ² of agricultural and urban land estimated as contaminated with arsenic. Soil contamination with concentrations up to 10% by mass reported at some mining sites Elevated arsenic concentrations in stream waters around former mining sites (5–30 g/L total As)
Patancheru, Andhra Pradesh state, India	Production of veterinary chemicals and pharmaceuticals, pesticide industries	Arsenic in groundwater: 0.14–7.35 mg/L; arsenic in surface water: 0.30–8.95 mg/L

Supplementary Table 3 Arsenic occurrence in various types of minerals [31,34]

Mineral	Arsenic concentration (mg/kg)
Sulfide minerals	
Arsenopyrite	46% by mass
Pyrite	100–77,000
Pyrrhotite	5–100
Marcasite	20–126,000
Galena	5–10,000
Sphalerite	5–17,000
Chalcopyrite	10–5,000
Oxide minerals	
Haematite	160
Fe oxide (undifferentiated)	2,000
Fe III oxyhydroxide	76,000
Magnetite	2.7–41
Ilmenite	<1
Silicate minerals	
Quartz	0.4–1.3
Feldspar	<0.1–2.1
Pyroxene	0.08–1.17
Carbonates	
Calcite	1–8
Dolomite	<3
Siderite	<3
Other minerals	
Apatite	<1–1,000
Fluorite	<2

Supplementary Table 4 Arsenic contents in the soils of various countries [20,21]

Country	Concentration (mg/kg)
India	16-417
Bangladesh	3.6–26
Argentina	0.8–22
China	0.01–626
France	0.1–5
Germany	2.5–4.6
Italy	1.8–60
Japan	0.4- 38.2
Mexico	2215–2675
South Africa	3.2–3.7
Switzerland	2–2.4
United States	280
Brazil	200–860
Chile	489
Poland	18,100
Spain	23
Turkey	660
United Kingdom	2–17

Supplementary Table 5 Some major aquatic systems (rivers, lakes, estuaries, and seas) on the globe have high arsenic concentrations [21]

Aquatic systems and location	Arsenic concentrations (average/range (µg/L))
Biwa Lake, Japan	2.2 (0.6–1.7)
Moir Lake, Ontario, Canada	20.4 (22.0–47.0)
Mono Lake, California, USA	10,000–20,000
Bunnefjord, Norway	0.5–1.9
Coastal Malaysia	1.0 (0.7–1.8)
Coastal Nakaminato, Japan	3.1
Deep Pacific and Atlantic	1.0–1.8
Krka Estuary, Yugoslavia	Yugoslavia 0.1–1.8
Rhone Estuary, France	2.2 (1.1–3.8)
Saanich Inlet, B.C., Canada	1.2–2.5
Schelde Estuary, Belgium	1.8–4.9
Southern coast, Australia	1.3 (1.1–1.6) (inorganic)
Southeast coast, Spain	1.5 (0.5–3.7)
Tamar Estuary, UK	2.7–8.8
Uranouchi Inlet, Japan	22.0–32.0
Vestfjord, Norway	0.7–1.0
Ashanti, Ghana	284 (<2–7900)
Cordoba, Argentina	7–114
Dordogne, France	0.7
Madison and Missouri rivers, USA	44 (19–67), 10–370
Mole River, NSW, Australia	110–600 (upto 13900)
Owens River, CA, USA	85–153
Po River, Italy	1.3
Ron Phibun, Thailand	218 (4.8–583)
Waikato, New Zealand	32 (28–36)