Chapter 5

CONCLUSIONS

5.1 Conclusions

The systematic study that was carried to appreciate the behaviour of PAHs and heavy metals in the soils, and groundwater around oilfields of upper Assam revealed the following:

Explicit seasonality was observed in the concentrations of PAHs in soil with the maximum concentrations during the post-monsoon season and the minimum during the monsoon season in both the oilfields. In Borholla oilfield, the seasonal mean concentrations of ΣPAHs were 2840±1770 during pre-monsoon, 534±298 during monsoon and 3920 ± 2810 ng g^{-1} during post-monsoon seasons of 2011. During 2013, the mean concentrations of PAHs were found to be 2800±1870, 549±570 and 3910±2980 ng g^{-1} during pre-monsoon, monsoon and post-monsoon respectively. The variations of mean concentrations of PAHs were not statistically significant between the years. In Nambar oilfield, the mean concentrations ΣPAHs during pre-monsoon, monsoon and post-monsoon were found to be 996±555, 346±187 and 1330 ±729 ng g^{-1} respectively. The variations in the concentrations of PAHs in soil is brought about by several factors – (i) the variations in source strength of PAHs among the seasons e.g. intense biomass and coal burning during the post-monsoon, (ii) heavy rainfall during the monsoon, which wash out the PAHs signature in soil and colloidal facilitated transport of PAHs to the groundwater, and (iii) long range transport and varied atmospheric conditions leading to differential deposition of PAHs.

The concentration of PAHs in the soils around the oilfields also varied spatially and the concentrations of most of the PAHs were found to be higher at roadside locations.

The composition profiles of PAHs in soils around the oilfields did exhibit dominance of LMWPAHs (2-, 3- and 4- ring PAHs) brought about by their strength of source and transport behaviour..

Total mean BaPeq values in different seasons, which provides information about the toxicity of the PAHs, followed the order of pre-monsoon>post-monsoon> monsoon. The toxicity of soil PAHs was found to be maximum near the roadside sampling locations. The minimum CPAHs concentration was observed during monsoon season.

Diagnostic ratios of PAHs revealed that both pyrogenic and petrogenic sources influence the concentrations of PAHs in the soils around the oilfields of upper Assam. The ratios indicated clearly that contributions of PAHs from combustion sources like biomass, and coal combustion, traffic emission and diesel combustion emission prevailed. Principle Component Analysis followed by Multiple Linear Regression (PCA-MLR) also indicated dominance of pyrogenic sources, while the petrogenic contribution was found to be <26% around Borholla and <18% around Nambar oilfield. However, gas flaring in GGS is a likely source of PAHs around the oilfields.

Due to non-equilibrium adsorption between OC and PAHs, OC did not show significant relationships with all the individual PAHs. Linear regression analysis revealed significant association of OC with LMWPAHs. Association between PAHs and BC was more prominent during the post-monsoon season, which indicated co-emission of PAHs and BC from the combustion processes like biomass and fossil fuel burning.

Seasonal variation was also observed in the heavy metal concentrations with the maximum concentration during post-monsoon season. Heavy metal toxicity in soil revealed low to moderate toxicity around the oil fields. The Heavy metals and major ions also showed significant relationship with PAHs. These associations indicate their co-emission sources.

Seasonal variation of PAHs concentrations was observed in groundwater too. In Borholla oilfield, mean ΣPAHs concentrations were found to be 16.5 ± 8 during pre-monsoon, 13.6 ±3 during monsoon and 23.3 ±7 ng ml^{-1} during post-monsoon season of 2011. During 2013, the means were found to be 15.5±6 during pre-monsoon, 14.4±3 during monsoon and 27.6±10 ng ml^{-1} during post-monsoon season. In Nambar oilfield, the mean concentrations were found to be 9.69±4, 6.57±3 and 13.9±5 ng ml^{-1} during pre-monsoon, monsoon and post-monsoon seasons, respectively. Lowering of the water table during post-monsoon period results in increased concentration of PAHs, whereas dilution of PAHs compounds due to rise of water table during monsoon results in decreased concentration of PAHs.

Despite of their hydrophobicity, colloidal movement was the main transport mechanism of PAHs into groundwater. Colloids provide a favourable phase for partitioning of contaminant and acts as an agent for facilitated contaminant transport. Due to high aqueous solubility, LMWPAHs were dominant in groundwater however presence of HMWPAHs signifies there movement through soil colloids.

Diagnostic ratios revealed dominance of pyrogenic sources of PAHs in groundwater of both the oilfields, which again confirms the surface to underground movement of PAHs. However, some ratios indicated petrogenic input of PAHs also. Biomass, wood and coal combustion, traffic emission and diesel emission were the main sources of pyrogenic PAHs identified by analyses of diagnostic ratios.

Total organic carbon content in groundwater positively correlated with PAHs, indicating that organic carbon could have played a significant role in availability of PAHs in groundwater by affecting their solubility. As such, PAHs partition to the organic phase of the soil with ease. Thus, the transport of PAHs from the surface to the groundwater could takes place through binding to the organic particles phase. The heavy metals and some major ions also showed correlation with PAHs. The signatures of PAHs of surface soil showed good significant correlations with the signatures in groundwater during all the seasons could also justify that colloidal transport of PAHs from soil is the main contributor of PAHs in groundwater.

5.2 Future prospects

The present study is the first comprehensive one with respect to the assessment of PAHs and heavy metals in surface soil and groundwater around oilfields of North east India. Continuous and detailed study on distribution of PAHs in various land use types, their source apportionment along with meteorological data will provide more elaborate information about PAHs behavior around oilfields. Further study will be planned to apportion the PAHs sources with more reliable models like Positive Matrix Factorization (PMF) and UNMIX etc. which will provide more accurate information regarding PAHs sources. More concentrated study on secondary PAHs like nitro PAHs, oxygenated PAHs and sulfur containing PAHs will also plan. Future study will emphasize on the role of naturally occurring organic colloids in partitioning and co-transporting PAHs into groundwater.

ANNEXURES

Annexure A: TEF values of 16PAHs compounds.

Names of PAHs	Abbreviation	TEF value
Naphthalene	Nap	0.001
Acenaphthylene	Any	0.001
Acenaphthene	Ane	0.001
Fluorene	Flu	0.001
Phenanthrene	Phe	0.001
Anthracene	Ant	0.01
Fluoranthene	Fla	0.001
Pyrene	Pyr	0.001
Benzo(a)anthracene	BaA	0.1
Chrysene	Chr	0.01
Benzo(b)fluoranthene	BbF	0.1
Benzo(k)fluoranthene	BkF	0.1
Benzo(a)pyrene	BaP	1
Dibenzo(a,h)anthracene	DaA	1
Benzo(g,h,i)perylene	BgP	0.01
Indeno(1,2,3-c,d)pyrene	IcdP	0.1

Annexure B: Drinking water guidelines given by WHO (2008) and BIS (2012).

Parameters	WHO (2008)		BIS (2012)	
	Acceptable limit	Permissible limit	Acceptable limit	Permissible limit
Cd	-	0.005	0.003	-
Cr	-	-	0.05	1.5
Cu	0.5	1	0.5	1.5
Fe	0.3	1	0.3	1
Mn	0.1	-	0.1	0.3
Ni	0.02	-	0.02	-
Pb	-	0.05	0.01	-
Zn	-	-	5	-
Ca^{2+}	75	200	75	200
Mg^{2+}	30	100	30	`150
Na^{+}	-	200	-	200
K^{+}	-	12	-	-
Cl^{-}	200	600	250	1000
NO_3^{-}	-	-	45	-
SO_4^{2-}	200	400	200	400

Publications

- Deka, J, Sarma, K.P. and Hoque, R.R. Application Of Multivariate Statistical Approach To Identify Heavy Metal Sources In Oilfield Soil of Brahmaputra Valley, Int. J. Bio-res. Env & Agri. Sci. **1**(4), 199--215, 2015.
- Deka, J, Sarma, K.P. and Hoque, R.R. Source contributions of PAHs in soils around oilfield in the Brahmaputra Valley. Ecotoxicology and Environmental Safety, doi 10.1016/j. ecoenv. 2016.07.031.

Conferences/ Seminars attended

- Deka, J., Sarma, K.P. and Hoque, R.R. "Assessment of Polycyclic Aromatic Hydrocarbons in surface soil of oilfield and its surrounding areas of Jorhat District, Assam." International Conference on harnessing natural resources for sustainable development: global trends. 29th-31st January, 2014, Cotton College, Guwahati, India.

- Deka, J., Sarma, K.P. and Hoque, R.R. "Distribution, sources and risk assessment of Polycyclic Aromatic Hydrocarbons in surface soil of Jorhat District, Assam." National seminar on Recent trends of Research in Science and Technology, 29th March, 2014, Assam Science Society, Cotton College, Guwahati, India.

- Deka, J., Sarma, K.P. and Hoque, R.R. "Spatial distribution and source apportionment of Polycyclic Aromatic Hydrocarbons in drinking water and soil of surrounding areas of Borholla oilfields of Jorhat, Assam." National seminar on Burning Environmental Issues: Risk to biodiversity and human health with special reference to North East. Saint Mary's College, Shillong.

- Deka, J., Devi, U., Sarma, K.P. and Hoque, R.R. "Source apportionment of Polycyclic Aromatic Hydrocarbons around oilfield soil of Brahmaputra Valley." National Seminar on Climate Change and Society, 24-25th February, 2017 Department of Environmental Science, Tezpur University.