Chapter	Table no.	Table caption	Page no.
1	1.1	State- wise representation in the percentage of total groundwater wells analyzed that were found affected with arsenic contamination	3
3	3.1	Specification of the sensors in HANNA HI9128 multi parameter water quality por meter	57
	3.2	Size of the different grading of sieve sizes used for grain size analysis	63
	3.3	Outline of the SEP for As fractionation in the soil and sediment samples	64
	3.4	Outline of the batch desorption experiment for the soil and sediment samples	67
4	4.1	Descriptive statistics of the hydrochemical parameters spatially and seasonally, ND represents "not detectible"	78
	4.2	Results of XRD analysis showing the mineralogy of the sediments	80
	4.3	Correlation matrix for the groundwater parameters of the north bank	100
	4.4	Correlation matrix for the groundwater parameters of the south bank	101
	4.5	Correlation matrix for pre-monsoon season	102
	4.6	Correlation matrix for post-monsoon season	103
	4.7	PCA of the chemical parameters in the groundwater of the north and the south banks	105
	4.8	PCA of the chemical parameters in the groundwater of the pre and post-monsoon seasons	106
	4.9	SI values obtained by speciation modelling in the pre-monsoon season	110
	4.10	SI values obtained by speciation modelling in the post-monsoon season	111

LIST OF TABLES

List of tables

Chapter	Table no.	Table caption	Page no.
	4.11	Descriptive statistics for monsoon and post- monsoon. The unit for TDS, DO, Na ⁺ , K ⁺ , Ca ²⁺ , Mg ²⁺ , H4SiO ₄ , HCO ₃ ⁻ , Cl ⁻ , SO ₄ ²⁻ , PO ₄ ³⁻ and Fe is mgL ⁻¹ , while the units for EC, ORP and As are μ S/cm, mV and μ gL ⁻¹ respectively. ND stands for "not detectible"	119
	4.12	Correlation matrix for monsoon	131
	4.13	Correlation matrix for post-monsoon	132
	4.14	PCA loadings of the various parameters in the monsoon and the post-monsoon seasons.	133
	4.15	Saturation indices of selected aqueous phases in the monsoon season calculated by using MINTEQ. NF here stands for 'not found'. am, c and s stand for amorphous, crystalline and solid respectively	138
	4.16	Saturation indices of selected aqueous phases in the post-monsoon season calculated by using MINTEQ. NF here stands for 'not found'. am, c and s stand for amorphous, crystalline and solid respectively	139
5	5.1	Summary of descriptive statistics for different variables. The unit for TDS, DO, Na ⁺ , K ⁺ , Ca ²⁺ , Mg ²⁺ , HCO ₃ ⁻ , Cl ⁻ , SO ₄ ²⁻ , PO ₄ ³⁻ and Fe is mgL ⁻¹ , while the units for EC, ORP and As are μ Scm ⁻¹ , mV and μ gL ⁻¹ respectively	151
	5.2	Reported concentrations of As and F^- from selected studies around the world	155
	5.3	Principal component analysis with three principal components	161
	5.4.	Results of XRD analysis showing the mineralogy of the sediments	163
	5.5	Saturation indices of selected aqueous phases in the monsoon season calculated by using MINTEQA2 v 3.1. am, c and s stand for amorphous, crystalline and solid respectively	166
6	6.1	Descriptive data for the different parameters of the soil and sediment samples	180

xvi

List of tables

Chapter	Table no.	Table caption	Page no.
	6.2	Correlation matrix for the soil/sediment parameters and the As fractions extracted by the sequential extraction procedure	184
	6.3	Saturation indices of aqueous phases in the soil and sediment samples	189
	6.4	Details of the sorption and desorption experiment for raw samples at pH 5 and 10	191
	6.5	Details of the sorption and desorption experiment for CBD treated at pH 5 and 10	191
	6.6	Outline of desorption experiment in the soil and sediment samples	192

LIST OF FIGURES

Chapter	Figure no.	Figure caption	Page no.
1	1.1	Schematic diagram of probable As-F- interaction	4
	1.2	Map of the Hanoi area depicting arsenic, groundwater heads, peat and ammonium levels Berg et al [45] Effects of proximity on groundwater As level is clearly visible	5
	1.3	Map showing arsenic afflicted regions in parts of Uttar Pradesh [46]. Proximity plays important role in groundwater distribution	6
	1.4	Schematic diagram for the design of research in our study	8
	1.5	Organization of the thesis	9
2	2.1	Distribution of As species in different ranges of Eh-pH [6]	21
	2.2	(a) Arsenite species versus pH and (b) arsenate species versus pH [6]	22
3	3.1	Formation of the Brahmaputra Valley through tectonic compaction the Himalayas in the north and the Naga Hills in the south	50
	3.2	Geological base map of Assam modified from Geological Survey of India showing the different geological formations	51
	3.3	Lithologs from [9], shows the succession of different fractions (clay, silt and clay) in sediments from Bongaigaon (B1, B10 and B30) and Darrang (D15) districts	53
	34	Map of the study area, shows Jorhat district as part of Assam and India. The points with the prefix J1 are monsoon samples while those with the prefix J2 depict post-monsoon samples	54
	3.5	Map of the BFP showing the groundwater samples and the sediment sampling sites	56
4	4.1	XRD diffraction patterns for BRS-1, 2 and 3	81
	4.2	XRD diffraction patterns for BRS-4, 5 and 6	82

List of figures

Chapter	Figure no.	Figure caption	Page no.
	4.3	XRD diffraction patterns for BRS-7 and 8	83
	4.4	Piper diagram showing the different groundwater types in the (a) north, (b) south banks of the BFP, (c) pre-monsoon and (d) post-monsoon seasons. The red solid circles indicate groundwater samples with As level > $10 \ \mu g L^{-1}$	85
	4.5	Gibbs plots showing that rock-water interaction controls the groundwater chemistry both (a, b) spatially and (c, d) seasonally	86
	4.6	Scatter plots for investigating the hydrochemistry of the north and the south banks. (a) NO3 versus K, (b) NO3 versus Cl, (c) EC versus Na/Cl molar ratio, (d) Cl versus Na, (e)Tz ⁺ versus Na+K and, (f) Tz ⁺ versus Ca+Mg	87
	4.7	Scatter plots for investigating the hydrochemistry of the pre and post-monsoon. (a) NO_3 versus K, (b) NO_3 versus Cl, (c) EC versus Na/Cl molar ratio, (d) Cl versus Na, (e)Tz ⁺ versus Na+K and, (f) Tz ⁺ versus Ca+Mg	90
	4.8	Scatter plots for investigating the spatial occurrence of carbonate weathering in the BFP	91
	4.9	Scatter plots for investigating the seasonal trends of carbonate weathering in the BFP	93
	4.10	Comparison of As behaviour with other parameters spatially and seasonally	95
	4.11	Comparison of F^- behaviour with other parameters spatially and seasonally	97
	4.12	Hierarchical cluster analysis (a, b) spatially; and (c, d) seasonally	108
	4.13(a)	Contour map of As distribution in the pre- monsoon season in the BFP	113
	4.13(b)	Contour map of As distribution in the post- monsoon season in the BFP	114
	4.14(a)	Arsenic recharge and distribution in pre- monsoon (Raster format)	115

List of figures

Chapter	Figure no.	Figure caption	Page no.
	4.14(b)	Arsenic recharge and distribution in post- monsoon (Raster format)	116
	4.15	Influence of river proximity on As and F^- distribution in the BFP	117
	4.16	Piper plot showing the samples of monsoon and post-monsoon. The black dots and the hollow dots represent monsoon and post-monsoon samples respectively, while the black and hollow triangles represent samples with As level > 10μ gL ⁻¹ in monsoon and post-monsoon respectively	121
	4.17	Durov plot showing the samples of monsoon and post-monsoon. The black dots and the hollow dots represent monsoon and post- monsoon samples respectively, while the black and hollow triangles represent samples with As level > 10μ gL ⁻¹ in monsoon and post-monsoon respectively	122
	4.18	Schoeller diagram for monsoon season, the red triangles represent samples with with As level > $10\mu g L^{-1}$	122
	4.19	Schoeller diagram for post-monsoon season, the red triangles represent samples with with As $level > 10 \mu g L^{-1}$	123
	4.20	Gibbs plots for (a) monsoon and (b) post- monsoon	124
	4.21	Scatter plots representing the hydrochemical trends (a). Tz ⁺ vs (Na+K), (b) Tz ⁺ vs (Ca+Mg), (c) HCO ₃ vs Ca, (d) (Ca+Mg) vs (HCO ₃ +SO ₄), (e) SO ₄ vs Ca and (f) (Na/Cl) vs EC	125
	4.22	Hydrochemistry and behaviour of As with. (a) pH, (b) HCO ₃ , (c) ORP, (d) Fe, (e) SO_4^{2-} , (f) H ₄ SiO ₄ , (g) PO ₄ and (h) depth	128
	4.23	Loadings plots for the PCA with three components in (a) monsoon and (b) post-monsoon seasons respectively	135
	4.24	Dendrogram for hierarchical cluster analysis in the monsoon season	135

List of figures

Chapter	Figure no.	Figure caption	Page no.
	4.25	Dendrogram for hierarchical cluster analysis in the post-monsoon season	136
5	5.1	Piper plot depicting water type, the red dots represent samples with $As > 10 \ \mu g L^{-1}$	153
	5.2	Scatter plots of As versus F ⁻ for (a) selected previous studies and (b) BFP. SA and AA represent "shallow aquifers" and "all aquifers" respectively	156
	5.3	Scatter plots showing the behaviour of As and F^{-} with (a) pH, (b) ORP, (c) Depth, (d) $SO_4^{2^-}$, (e) HCO_3^{-} and (f) Fe	158
	5.4	Three dimensional representations of the PCs in a loading plot obtained from PCA using Varimax rotation. The loadings are shown for the three components	161
	5.5.	Dendrogram from HCA obtained by Ward's linkage show the proximity of the different parameters to each other	162
	5.6	Concentration of (a) As and (b) F ⁻ in groundwater from two different years	165
	5.7	Plots of SI values of selected species versus depth. (a) SI-arsenolite versus depth (b) SI- As_2O_5 versus depth (c) SI-FCO ₃ Apatite versus depth and (d) SI-NaF versus depth	167
6	6.1	Map depicting the soil/sediment sampling points	178
	6.2	Scatter plot for clay percentage versus total organic carbon shows a highly linear relationship, indicating that clay content determines the organic carbon content of soils and sediments to a great extent	181
	6.3	Energy dispersive X-Ray (EDX) spectroscopy of the soil and sediment samples illustrating As as a part of the mineral phases in all the sample	182
	6.4	a) Percentage and (b) absolute As content in soil and sediment show Fe (hydr)oxide phase as the most dominant contributor of groundwater As	183

List o	f figures
--------	-----------

Chapter	Figure no.	Figure caption	Page no.
	6.5	Bar diagram showing K_{d2} of each of the five samples indicate low mobilization of As from the sediment samples compared to the soil samples	188
	6.6	Scatter plot showing the behaviour of As and F^- with pH	190
	6.7	Results of desorption experiment at pH 5 for: (a) As and (b) F^- (b) at pH 5 from raw and CBD treated soil/sediment samples normalized to a weight of 1 kg, Experiment B: Desorption of (c) As and (d) F^- at pH 10 from raw and CBD treated soil/sediment samples	193
	6.8	Presence of Fe (hydr)oxides positively affects the co-evolution of As and F^- from the sediments and the process is enhanced by increasing pH	194

LIST OF ABBREVIATIONS

A.R	Analytical Reagent
AAS	Atomic Absorption Spectrometer
AP1	Activator Protein 1
APHA	American Public Health Association
ATP	Adenosine Tri Phosphate
AWWA	American Water Works Association
BCR	Bureau of Reference
BFP	Brahmaputra Flood Plains
BGS	British Geological Survey
BRS	Brahmaputra River Sediment
BVP	Barak Valley Plains
CBD	Citrate-Bicarbonate-Dithionate
CBE	Charge Balance Error
CEC	Cation Exchange Capacity
CGWB	Central Groundwater Board
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DPHE	Department Of Public Health Engineering
EC	Electrical Conductivity
EDX	Energy Dispersive Xray Spectroscopy
EH	Reduction Potential
EPA	Environmental Protection Agency
GIS	Geographical Information System
GPS	Global Positioning System
GW	Groundwater
HCA	Hierarchical Cluster Analysis
IAP	Ion Activity Product
IC	Ion Chromatograph
ICDD	International Center For Diffraction Data
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometer

List of Abbreviations

JCPDS	Joint Committee On Power Diffraction Standards
MAP	Mono Ammonium Phosphate
МСР	Mono Calcium Phosphate
MGP	Middle Gangetic Plains
MML	Mott Macdonald Limited
ND	Not Detectible
NERIWALM	North Eastern Regional Institute For Water And Land Management
NF	Not Found
ORP	Oxidation Reduction Potential
PC	Principal Component
PCA	Principal Components Analysis
PHED	Public Health Engineering Department
PKA	Protein Kinase A
РТН	Parathyroid Hormone
PZC	Point Of Zero Charge
SD	Standard Deviation
SEM	Scanning Electron Microscope
SEP	Sequential Extraction Procedure
SH	Thiol group
SI	Saturation Indices
SSAAB	South And Southeast Asian Arsenic Belt
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
UNICEF	United Nations Children's Fund
USA	United States Of America
UV	Ultra Violet
WHO	World Health Organization
XRD	Xray Diffraction