

Title of the Thesis	i
Certificate	ii
Declaration by the candidate	iii
Certificate by the supervisor	iii
Copyright transfer certificate	iv
Dedication	v
Acknowledgment	vi-viii
Contents	ix-xvi
List of abbreviations	xvii-xviii
List of figures	xix-xxii
List of tables	xxiii-xxiv
Preface of the thesis	xxv-xxix
CHAPTER - 1 INTRODUCTION AND LITERATURE REVIEW	1-73
1.1 ENVIRONMENT AND ENVIRONMENTAL POLLUTION	1
1.2 TYPES OF POLLUTION	2
1.2.1 Air pollution	2
1.2.2 Noise pollution	2
1.2.3 Soil pollution	3
1.2.4 Radioactive pollution	3
1.2.5 Water pollution	3
1.3 TYPES OF WATER POLLUTION	5
1.3.1 Inorganic Pollutants	6
1.3.2 Organic Pollutants	6

1.3.3 Biological Pollutants	6
1.3.4 Radioactive pollutants	6
1.3.5 Thermal pollutants.	6
1.4 Water Pollution by Fluoride and its toxicity	7
1.4.1. Sources of fluoride contamination	8
1.5 Water Pollution by Lead and Its Toxicity	9
1.5.1 Sources of lead contamination	10
1.6 Methods used for removal of ionic impurities from Water	11
1.6.1 Chemical precipitation	12
1.6.2. Ion-exchange	12
1.6.3. Membrane filtration	12
1.6.4. Coagulation-flocculation	13
1.6.5. Flotation	13
1.6.7. Electrochemical treatment	13
1.7. Adsorption	14
1.7.1 Physical Adsorption	14
1.7.2 Chemical Adsorption	14
1.8. Mechanism of Adsorption	15
1.9. Factors affecting the rate of adsorption	15
1.9.1 Nature of adsorbent	15
1.9.2. Nature of adsorbate	16
1.9.3. Effect of pH	16
1.9.4. Effect of concentration	17
1.9.5. Effect of temperature	17
1.10. Advantages of the Adsorption Process	18

1.11. Conventional adsorbents for the Fluoride and lead Removal	18
1.12 NANOMATERIAL OVERVIEW-UNIQUE PROPERTIES AND APPLICATION	47
1.12.1 Classification of nanostructured materials	47
1.12.2 Unique properties of nanostructured materials	51
1.13 Classification of Nanomaterials as Nanoadsorbent	52
1.14 Nanoadsorbent For Fluoride and Lead removal	53
1.15 Carbon-Based Nanoadsorbents	67
1.15.1 Graphene and its derivatives as adsorbent	67
1.16 Metal oxide nanoparticles	70
1.17 Nanocomposite	71
1.18 Objective of the present work	72
CHAPTER - 2 MATERIALS AND METHOD	74-106
2.1 INTRODUCTION	74
2.2 MATERIALS	74
2.3 SYNTHESIS OF GRAPHENE OXIDE	76
2.4 CHARACTERIZATION OF THE ADSORBENT	76
2.4.1 Determination of Zero point charge (pHzpc) of the adsorbent	76
2.4.2 Scanning Electron Microscopy (SEM) Analysis	77
2.4.4 Energy Dispersive X-ray Analysis (EDX)	77
2.4.5 X-ray Diffraction (XRD)	78
2.4.6 Fourier Transform Infrared Spectroscopy (FTIR)	80
2.4.7 X-ray photoelectron spectroscopy (XPS)	80
2.4.8 Surface area measurement (BET)	81

2.4.9 Raman Spectroscopy	82
2.5 EXPERIMENTAL PROCEDURE	83
2.5.1 Batch adsorption studies	83
2.5.2 Adsorption Isotherms	84
2.5.2.1 Langmuir adsorption isotherm	85
2.5.2.2 Freundlich sorption isotherm	86
2.5.2.3 Dubinin–Radushkevich isotherm model	87
2.5.3 Adsorption Kinetics	88
2.5.3.1 Pseudo-First-Order kinetic model	89
2.5.3.2 Pseudo-Second-Order kinetic model	89
2.5.3.3 External mass Transfer	90
2.5.3.4 Intraparticle diffusion	91
2.5.3.5 Richenberg model	92
2.5.4 Thermodynamic studies	92
2.5.5 Column adsorption studies	93
2.5.6 Fixed bed column adsorption experiments	96
2.5.7 Desorption and column regeneration studies	97
2.5.8 Modelling And Analysis Of Column Data	98
2.5.8.1 Breakthrough Curve	98
2.5.8.2 Bed Depth Service Time (BDST) model	101
2.5.8.3 Thomas model	104
2.5.8.4 Yoon-Nelson Model	104
2.6 Regeneration and reuse of the adsorbent	105
2.7 Analysis of fluoride and lead in aqueous solution	106

CHAPTER-3 STUDIES ON ADSORPTIVE REMEDIATION OF FLUORIDE	
USING rGO/ZrO₂ NANOCOMPOSITE BY BATCH SYSTEM	107-144
3.1 INTRODUCTION	107
3.2 MATERIAL AND METHOD	109
3.2.1 Synthesis of rGO/ZrO ₂ nanocomposite	109
3.2.2 Experimental methodology	110
3.3 CHARACTERIZATION OF rGO/ZrO ₂ NANOADSORBENT	110
3.3.1 FTIR Analysis	110
3.3.2 XRD Analysis	111
3.3.3 XPS Analysis	113
3.3.4 SEM and EDX Analysis	116
3.3.5 Raman analysis	121
3.3.6. Surface area measurement (BET)	122
3.4.7 Determination of pH _{Zpc}	122
3.4 BATCH ADSORPTION STUDIES	123
3.4.1 Effect of pH and mechanism of fluoride adsorption	123
3.4.1.1 Mechanism of the fluoride adsorption	124
3.4.2 Effect of contact time and rGO/ZrO ₂ dose on the uptake capacity	127
3.4.3. Effect of initial concentration and temperature on the uptake capacity	129
3.5. KINETIC STUDIES	130
3.5.1 Pseudo-first-order and pseudo-second-order kinetic models	130
3.5.2 Mass transfer studies	131
3.5.3 Intra particles diffusion model	133
3.5.4 Richenberg Model	134
3.6 ISOTHERM STUDIES	137

3.6.1 Freundlich Isotherm	137
3.6.2 Langmuir Isotherm	138
3.6.3. D-R Isotherm	140
3.7 THERMODYNAMICS STUDIES	142
3.8 CONCLUSIONS	144

**CHAPTER-4 STUDIES ON ADSORPTIVE REMEDIATION OF FLUORIDE
USING rGO/ZrO₂ NANOCOMPOSITE BY FIXED-BED UP-FLOW
CONTINUOUS COLUMN SYSTEM 144-162**

4.1 INTRODUCTION	145
4.2 MATERIAL AND METHOD	145
4.3 RESULT AND DISCUSSION	146
4.3.1 Effect of bed height	146
4.3.2 Effect of flow rate	148
4.3.3 Effect of fluoride concentration	149
4.3.4 Application of bed depth service time model (BDST)	152
4.3.5 Application of Thomas and Yoon–Nelson models	155
4.3.6 Regeneration	158
4.3.7 Adsorption column life factor	160
4.4 CONCLUSION	162

**CHAPTER-5 STUDIES ON ADSORPTIVE REMEDIATION OF LEAD
USING GO/MgO NANOCOMPOSITE BY BATCH SYSTEM 163-202**

5.1 INTRODUCTION	163
5.2 MATERIAL AND METHOD	164

5.2.1 Synthesis Of GO/MgO Nanocomposite	164
5.2.2 Experimental methodology	166
5.3 CHARACTERIZATION OF GO/MGO NANOCOMPOSITE	166
5.3.1 FTIR Analysis	166
5.3.2 XRD Analysis	167
5.3.3 XPS Analysis	168
5.3.4 SEM and EDX Analysis	171
5.3.5 Raman analysis	177
5.3.6 Surface area measurement (BET)	178
5.3.7 Determination of pHzpc	179
5.4 BATCH ADSORPTION RESULTS	179
5.4.1 Effect of pH and mechanism of lead adsorption	179
5.4.1.1. Mechanism of the Lead adsorption	181
5.4.2 Effect of contact time and GO/MgO dose on the uptake capacity	185
5.4.3. Effect of initial lead concentration and temperature on the uptake capacity	186
5.5. KINETIC STUDIES	187
5.5.1 Pseudo-first-order and pseudo-second-order kinetic models	188
5.5.2 Mass transfer studies	190
5.5.3 Intra particles diffusion model	191
5.5.4 Richenberg Model	192
5.6 ISOTHERM STUDIES	195
5.6.1 Freundlich Isotherm	195
5.6.2 Langmuir Isotherm	196
5.6.3. D-R Isotherm	197

5.7 THERMODYNAMICS STUDIES	200
5.8 CONCLUSION	202
CHAPTER-6 STUDIES ON ADSORPTIVE REMEDIATION OF LEAD	
USING GO/MgO NANOCOMPOSITE BY FIXED-BED UP-FLOW	
CONTINUOUS COLUMN SYSTEM	203-221
6.1 INTRODUCTION	203
6.2 MATERIAL AND METHOD	203
6.3 RESULT AND DISCUSSION	204
6.3.1 Effect of bed height	204
6.3.2 Effect of flow rate	206
6.3.3. Effect of lead ion concentration	207
6.3.4. Application of bed depth service time model (BDST)	210
6.3.5. Application of Thomas and Yoon–Nelson models	213
6.3.6. Regeneration	217
6.3.7 Adsorption column life factor	219
6.4 CONCLUSION	221
 SUMMARY	 222
FUTURE RECOMMENDATIONS	228
REFERENCES	229-265