

TABLE OF CONTENTS

| Contents | Page |
|--|-------------|
| Acknowledgement | III |
| Abstract | V |
| List of Tables | XII |
| List of Figures | XIII |
| Chapter 1: Introduction | 1 |
| 1.1. Introduction | 1 |
| 1.2. Rationale and hypothesis | 3 |
| 1.3. Purposes of study | 4 |
| 1.4. Research period | 4 |
| Chapter 2: Literature Review | 5 |
| 2.1. Roles of heavy metals | 5 |
| 2.2. Sources of heavy metal release into the environment | 6 |
| 2.3. Heavy metal pollution from coal mining and power plants | 11 |
| 2.4. Research at Mae Moh Mine and Power Plant | 13 |
| Chapter 3: Study Site | 14 |
| 3.1. Location | 14 |
| 3.2. Geological description | 14 |
| 3.2.1. Topography | 14 |
| 3.2.2. Drainage system | 14 |
| 3.2.3. Geological conditions | 19 |
| 3.2.4. Lithostratigraphic succession | 21 |
| 3.3. Climatic condition | 23 |
| 3.4. Site description | 24 |
| 3.4.1. Mae Kham Reservoir | 27 |
| 3.4.2. Mae Moh Reservoir | 28 |
| 3.4.3. Ang kaset | 29 |
| 3.4.4. Ground water sites in the north of Mae Moh basin | 30 |

| | Page |
|---|-------------|
| 3.4.5. Ground water sites inside mining operation area | 30 |
| 3.4.6. Ground water sites in the south of Mae Moh Mine and Power Plant | 32 |
| 3.4.7. Ground water in control sites | 33 |
| Chapter 4: Materials and Methods | 34 |
| 4.1. Materials | 34 |
| 4.1.1. Chemicals | 34 |
| 4.1.2. Apparatus | 35 |
| 4.2. Methodology | 36 |
| 4.2.1. Site selection | 36 |
| 4.2.2. Sample collection and preservation | 36 |
| 4.3. Sample Analysis | 37 |
| 4.3.1. Procedure for analysis As, Pb, Hg, Se, Fe, Cr, Mn, and Mo | 37 |
| 4.3.2. Calculations of element concentration in the samples | 39 |
| 4.3.3. Water quality control | 40 |
| 4.4. Data Analysis and Interpretation | 40 |
| 4.5. Monitoring and Risk Assessment | 40 |
| Chapter 5: Results and Discussions | 41 |
| 5.1. Physical - Chemical Characteristics of Water | 41 |
| 5.1.1. Temperature of surface and ground water | 41 |
| 5.1.2. pH value of surface and ground water | 44 |
| 5.1.3. Conductivity of surface and ground water | 47 |

| | Page |
|---|-------------|
| 5.1.4. Total dissolved solids of surface and ground water | 51 |
| 5.1.5. Dissolved oxygen of surface and ground water | 54 |
| 5.1.6. Total alkalinity of surface and ground water | 57 |
| 5.1.7. Acidity of surface and ground water | 60 |
| 5.1.8. Total hardness of surface and ground water | 63 |
| 5.2. Concentration of Heavy Metals in Surface and Ground Water | 67 |
| 5.2.1. Arsenic | 67 |
| 5.2.2. Lead | 72 |
| 5.2.3 Mercury, chromium, and molybdenum | 75 |
| 5.2.4. Manganese | 75 |
| 5.2.5. Iron | 79 |
| 5.3. Risk Assessment for Potential of Heavy Metals Contamination in Surface and Ground Water | 83 |
| 5.3.1. Surface water | 83 |
| 5.3.2. Ground water | 89 |
| Chapter 6: Conclusions and Recommendations | 95 |
| 6.1 Conclusion | 95 |
| 6.1.1 Physical-chemical characteristics of surface and ground water | 95 |
| 6.1.2. Risk of selected elements in surface and ground water | 100 |
| 6.2. Recommendation | 104 |
| References | 106 |
| Appendices | 113 |
| Curriculum vitae | 134 |

LIST OF TABLES

| | Page |
|---|-------------|
| Table 5.1.1. Temperature of surface and ground water | 42 |
| Table 5.1.2. pH value of surface and ground water | 45 |
| Table 5.1.3. Conductivity of surface and ground water | 49 |
| Table 5.1.4. Total dissolved solids in surface and ground water | 52 |
| Table 5.1.5. Dissolved oxygen in surface and ground water | 55 |
| Table 5.1.6. Total alkalinity of surface and ground water | 58 |
| Table 5.1.7. Acidity of surface and ground water | 61 |
| Table 5.1.8. Total hardness of surface and ground water | 64 |
| Table 5.2.1. Arsenic in surface and ground water | 68 |
| Table 5.2.2. Lead in surface and ground water | 73 |
| Table 5.2.3. Manganese in surface and ground water | 76 |
| Table 5.2.4. Iron in surface and ground water | 80 |
| Table 5.3.1. Comparison concentration of selected elements in surface water with standards | 85 |
| Table 5.3.2. Comparison concentration of selected elements in ground water with standards | 90 |
| Table 6.1.1. Variation of physical - chemical characteristics of surface and ground water | 96 |
| Table 6.1.2. Variation of concentrations of selected elements in surface and ground water | 101 |

LIST OF FIGURES

| | Page |
|--|-------------|
| Figure 3.1. Map of the location of Mae Moh Mine and Power Plant | 15 |
| Figure 3.2.1. Topographic map of the Mae Moh Mine | 16 |
| Figure 3.2.2a. Drainage and waste management system of Mae Moh Mine | 17 |
| Figure 3.2.2b. Water supply system at the Mae Moh Mine and Power Plant | 18 |
| Figure 3.2.3. Geological map of Mae Moh Lignite Mine | 19 |
| Figure 3.2.4. Lithostratigraphic sequences of Mae Moh Mine | 22 |
| Figure 3.3. An average monthly rainfall from May to September, 1998 | 24 |
| Figure 3.4. Map of sampling sites at Mae Moh | 26 |
| Figure 3.4.1a. Mae Kham Reservoir - site MKR1 | 27 |
| Figure 3.4.1b. Mae Kham Reservoir - site MKR2 | 28 |
| Figure 3.4.2 Mae Moh Reservoir - site MMR3 | 29 |
| Figure 3.4.4. Iron pipe well, site N1 | 31 |
| Figure 3.4.5a: Iron pipe well RH86, site M1 | 31 |
| Figure 3.4.5b. Seepage SP1 | 32 |
| Figure 3.4.6a. Southern shallow well - site S1 | 33 |
| Figure 5.1.1. Temperature of surface and ground water | 42 |
| Figure 5.1.2. pH value of surface and ground water | 46 |
| Figure 5.1.3. Conductivity of surface and ground water | 50 |
| Figure 5.1.4. Total dissolved solids in surface and ground water | 53 |
| Figure 5.1.5. Dissolved oxygen in surface and ground water | 56 |
| Figure 5.1.6. Total alkalinity of surface and ground water | 59 |
| Figure 5.1.7. Acidity of surface and ground water | 62 |

| | Page |
|---|-------------|
| Figure 5.1.8. Hardness of surface and ground water | 65 |
| Figure 5.2.1. Arsenic in surface and ground water during the study period | 69 |
| Figure 5.2.2. Lead in surface and ground water during the study period | 74 |
| Figure 5.2.3. Manganese in surface and ground water during the study period | 77 |
| Figure 5.2.4. Iron in surface and ground water during the study period | 81 |
| Figure 5.3.1a. Manganese in surface water | 86 |
| Figure 5.3.1b. Iron in surface water | 86 |
| Figure 5.3.1c. Lead in surface water | 87 |
| Figure 5.3.1d. Arsenic in surface water | 87 |
| Figure 5.3.1e. Manganese in Mae Moh reservoir | 88 |
| Figure 5.3.1f. Iron in Mae Moh reservoir | 88 |
| Figure 5.3.1g. Arsenic in Mae Moh reservoir | 89 |
| Figure 5.3.2a. Manganese in ground water | 91 |
| Figure 5.3.2b. Iron in ground water | 92 |
| Figure 5.3.2c. Arsenic in ground water | 93 |