

**Bioremediation of Water Contaminated with BTEX,  
TPH, and TCE under Different Environmental  
Conditions**

by

**Lei, Cheng Keng (Elena)**

**A thesis submitted for partial fulfillment of the requirements for  
the degree of**

**Master of Science in Civil Engineering**

**2010**



**Faculty of Science and Technology  
University of Macau**

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by

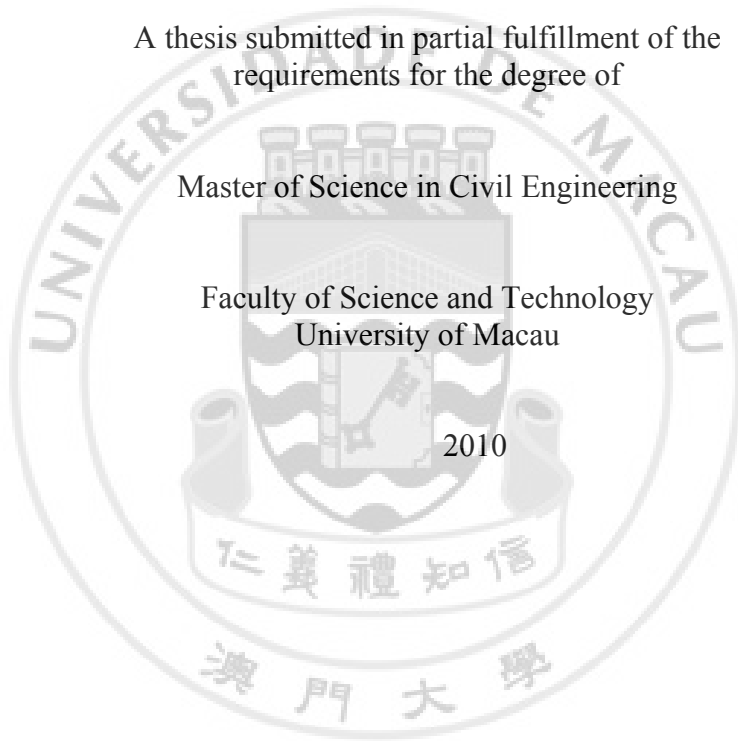
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Approved by \_\_\_\_\_ Prof. H. Shim  
Supervisor

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## CONTENT

VITA.....	iii
ABSTRACT.....	v
LIST OF FIGURES .....	vii
LIST OF TABLES.....	x
LIST OF ABBREVIATIONS.....	xii
ACKNOWLEDGEMENTS.....	xv
Chapter 1: Introduction.....	2
Chapter 2: Literature Review.....	4
Chapter 3: Materials and Methods.....	7
3.1. Soil Samples Collections .....	7
3.2. Chemicals.....	8
3.3. Enrichment:.....	8
3.4. Bacterial Cultures:.....	9
3.5. Batch Experiments and Measurements:.....	13
3.5.1 Batch Experiments.....	13
3.5.2 Measurements.....	14
Chapter 4: Results and Discussions.....	17
4.1. Removal of mixtures of BTEo/m/pX (350 mg/L) and TPH (1,000 mg/L).....	17
4.1.1. Removal of mixtures of BTEoX (350 mg/L) and TPH (1,000 mg/L)at pH 5 / 7 / 9 and 25°C / 35°C.....	18
4.1.2. Removal of mixtures of BTEmX (350 mg/L) and TPH (1,000 mg/L)at pH 5 / 7 / 9 and 25°C / 35°C.....	19
4.1.3. Removal of mixtures of BTEpX (350 mg/L), TPH (1,000 mg/L)at pH 5 / 7 / 9 and 25°C / 35°C.....	20
4.1.4. Removal of mixtures of BTEX (417 mg/L), TPH (1,000 mg/L)at pH 5 / 7 / 9 and 25°C / 35°C.....	20
4.1.5. Conclusion.....	20

4.2. Removal of mixtures of BTEo/m/pX (350 mg/L), TPH (1,000 mg/L), and TCE (15 mg/L).....	21
4.2.1. Removal of mixtures of BTEoX (350 mg/L), TPH (1,000 mg/L), and TCE (15 mg/L) at pH 5 / 7 / 9 and 25°C / 35°C.....	21
4.2.2. Removal of mixtures of BTE <sub>m</sub> X (350 mg/L), TPH (1,000 mg/L), and TCE (15 mg/L) at pH 5 / 7 / 9 and 25°C / 35°C.....	22
4.2.3. Removal of mixtures of BTE <sub>p</sub> X (350 mg/L), TPH (1,000 mg/L), and TCE (15 mg/L) at pH 5 / 7 / 9 and 25°C / 35°C.....	23
4.2.4. Removal of mixtures of BTEX (417 mg/L), TPH (1,000 mg/L), and TCE (15 mg/L) at pH 5 / 7 / 9 and 25°C / 35°C.....	23
4.3. Conclusion.....	25
4.3.1. Effect of microorganisms.....	25
4.3.2. Effect of TCE.....	26
4.3.2.1. Effect in mixture of BTEoX and TPH.....	26
4.3.2.2. Effect in mixture of BTE <sub>m</sub> X and TPH.....	27
4.3.2.3. Effect in mixture of BTE <sub>p</sub> X and TPH.....	27
4.3.2.4. Effect in mixture of BTEX and TPH.....	28
4.3.3. Effect of pH.....	28
4.3.4. Effect of temperature.....	29
Chapter 5: Grand Conclusion.....	31
Chapter 6: Suggestion for Future Research.....	33
Bibliography.....	34

## VITA

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### Related Publications:

#### *Journal:*

- Li, J., **Lei, C.**, Dong, S., & Shim, H. (2010). Bioremediation of mixed wastes (BTEX, TPH, TCE, and *cis*-DCE) contaminated water. ASCE's Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management. In revision.

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University of Macau

ABSTRACT

Bioremediation of Water Contaminated with BTEX, TPH, and TCE under Different Environmental Conditions

by

Lei, Cheng Keng (Elena)

Thesis Supervisor: Prof. Hojae Shim

Master of Science in Civil Engineering

Many sites are polluted by a large number of mixed contaminants. As mixed wastes, such petroleum/gasoline compounds as benzene, toluene, ethylbenzene, and three isomers of xylene (BTEX) and such chlorinated compounds as trichloroethylene (TCE) are among the most frequently found subsurface contaminants. Although many technologies have been developed for the remediation of contaminated sites, only a few of these technologies are applicable for mixed contaminated sites. Furthermore, even though lots of studies have been done with the removal of BTEX (singly and in mixtures), total petroleum hydrocarbons (TPH), or TCE (singly and in mixtures with other chlorinated aliphatic compounds; using such substrates as toluene) individually, unfortunately almost no study seems dealing with the interaction (stimulatory or inhibitory to each other's removal) among BTEX, TPH, and TCE when they exist in such mixtures as BTEX/TPH and BTEX/TPH/TCE, especially under different environmental conditions. Even for the BTEX compounds alone, when BTEX were present in mixtures, the interaction results have been shown contradictory.



Since knowing their detailed fates / behaviours during removal process is essential even before the remediation technology can be applied on site for the successful remediation of contaminated environment, BTEX and TPH as the representative petroleum hydrocarbons and TCE as the representative chlorinated hydrocarbon were tested in lab-scale under different conditions for concentration, pH and temperature in this study, to further elucidate the exact interaction during their bio-removal process when they co-exist in mixtures.



## LIST OF FIGURES

Figure 3.1: Soil contaminated with gasoline compounds.....	7
Figure 3.2: pH meter (inoLab).....	11
Figure 3.3: Autoclave (HIRAYAMA).....	11
Figure 3.4a: Orbital shaker (IKA, KS 260 basic).....	11
Figure 3.4b: Orbital shaker (MAXQ 4450).....	10
Figure 3.5: Spectrophotometer (Spectronic, Genesys 2).....	14
Figure 3.6: Gas chromatograph (Agilent, 6890N).....	16
Figure 3.7: Ion chromatograph (Dionex ICS 2500).....	16
Fig A.1.1: Cell growth for microorganism 1 on mixture of BTEoX (350 mg/L) / TPH (1,000 mg/L) / TCE (15 mg/L) in MSM at pH 5/ 25°C.....	50
Fig A.1.2: Cell growth for microorganism 1 on mixture of BTE $m$ X (350 mg/L) / TPH (1,000 mg/L)/ TCE (15 mg/L) in MSM at pH 5/ 25°C.....	50
Fig A.1.3: Cell growth for microorganism 1 on mixture of BTE $p$ X (350 mg/L) / TPH (1,000 mg/L)/ TCE (15 mg/L) in MSM at pH 5/ 25°C.....	51
Fig A.1.4: Cell growth for microorganism 1 on mixture of BTEoX (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 7/25°C.....	51
Fig A.1.5: Cell growth for microorganism 1 on mixture of BTE $m$ X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 7/ 25°C.....	52
Fig A.1.6: Cell growth for microorganism 1 on mixture of BTE $p$ X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 7/ 25°C.....	52
Fig A.1.7: Cell growth for microorganism 1 on mixture of BTEoX (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 9/25°C.....	53
Fig A.1.8: Cell growth for microorganism 1 on mixture of BTE $m$ X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 9/ 25°C.....	53
Fig A.1.9: Cell growth for microorganism 1 on mixture of BTE $p$ X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 9/ 25°C.....	54
Fig A.1.10: Cell growth for microorganism 1 on mixture of BTEoX (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°.....	54
Fig A.1.11: Cell growth for microorganism 1 on mixture of BTE $m$ X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°C.....	55
Fig A.1.12: Cell growth for microorganism 1 on mixture of BTE $p$ X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°C.....	55
Fig A.1.13: Cell growth for microorganism 1 on mixture of BTEoX (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°C.....	56
Fig A.1.14: Cell growth for microorganism 1 on mixture of BTE $m$ X (350 mg/L)/ TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°C.....	56
Fig A.1.15: Cell growth for microorganism 1 on mixture of BTE $p$ X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°C.....	57
Fig A.1.16: Cell growth for microorganism 1 on mixture of BTEoX (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°C.....	57

Fig A.1.17: Cell growth for microorganism 1 on mixture of BTE <i>m</i> X (350 mg/L)/ TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°	58
Fig A.1.18: Cell growth for microorganism 1 on mixture of BTE <i>p</i> X (350 mg/L) / TPH (1,000 mg/L), TCE (15 mg/L) in MSM at pH 5/35°C	58
Fig A.1.19: Cell growth for microorganism 1 on mixture of BTE <i>o</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/25°C	59
Fig A.1.20: Cell growth for microorganism 1 on mixture of BTE <i>m</i> X (350 mg/L)/ TPH (1,000 mg/L) in MSM at pH 5/25°C	59
Fig A.1.21: Cell growth for microorganism 1 on mixture of BTE <i>p</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/25°C	60
Fig A.1.22: Cell growth for microorganism 1 on mixture of BTE <i>o</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/25°C	60
Fig A.1.23: Cell growth for microorganism 1 on mixture of BTE <i>m</i> X (350 mg/L)/ TPH (1,000 mg/L) in MSM at pH 5/25°C	61
Fig A.1.24: Cell growth for microorganism 1 on mixture of BTE <i>p</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/25°C	61
Fig A.1.25: Cell growth for microorganism 1 on mixture of BTE <i>o</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/25°C	62
Fig A.1.26: Cell growth for microorganism 1 on mixture of BTE <i>m</i> X (350 mg/L)/ TPH (1,000 mg/L) in MSM at pH 5/25°C	62
Fig A.1.27: Cell growth for microorganism 1 on mixture of BTE <i>p</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/25°C	63
Fig A.1.28: Cell growth for microorganism 1 on mixture of BTE <i>o</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/35°C	63
Fig A.1.29: Cell growth for microorganism 1 on mixture of BTE <i>m</i> X (350 mg/L)/ TPH (1,000 mg/L) in MSM at pH 5/35°C	64
Fig A.1.30: Cell growth for microorganism 1 on mixture of BTE <i>p</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/35°C	64
Fig A.1.31: Cell growth for microorganism 1 on mixture of BTE <i>o</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/35°C	65
Fig A.1.32: Cell growth for microorganism 1 on mixture of BTE <i>m</i> X (350 mg/L)/ TPH (1,000 mg/L) in MSM at pH 5/35°C	65
Fig A.1.33: Cell growth for microorganism 1 on mixture of BTE <i>p</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/35°C	66
Fig A.1.34: Cell growth for microorganism 1 on mixture of BTE <i>o</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/35°C	66
Fig A.1.35: Cell growth for microorganism 1 on mixture of BTE <i>m</i> X (350 mg/L)/ TPH (1,000 mg/L) in MSM at pH 5/35°C	67
Fig A.1.36: Cell growth for microorganism 1 on mixture of BTE <i>p</i> X (350 mg/L) / TPH (1,000 mg/L) in MSM at pH 5/35°C	67
Fig A.2.1: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, TCE, and TPH in mixtures of BTE <i>o</i> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C	68

Fig A.2.2: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, TCE, and TPH in mixtures of BTE <sub>o</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	68
Fig A.2.3: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, TCE, and TPH in mixtures of BTE <sub>m</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	69
Fig A.2.4: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, TCE, and TPH in mixtures of BTE <sub>m</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	69
Fig A.2.5: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, TCE, and TPH in mixtures of BTE <sub>p</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	70
Fig A.2.6: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, TCE, and TPH in mixtures of BTE <sub>p</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	70
Fig A.2.7: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, and TPH in mixtures of BTE <sub>o</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	71
Fig A.2.8: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, and TPH in mixtures of BTE <sub>o</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	71
Fig A.2.9: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, and TPH in mixtures of BTE <sub>m</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	72
Fig A.2.10: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, and TPH in mixtures of BTE <sub>m</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	72
Fig A.2.11: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, and TPH in mixtures of BTE <sub>p</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	73
Fig A.2.12: Removal efficiencies of microorganism 1 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, and TPH in mixtures of BTE <sub>p</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	73
Fig A.2.13: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, TCE, and TPH in mixtures of BTE <sub>o</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	74
Fig A.2.14: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, TCE, and TPH in mixtures of BTE <sub>o</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	74
Fig A.2.15: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, TCE, and TPH in mixtures of BTE <sub>m</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	75

Fig A.2.16: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, TCE, and TPH in mixtures of BTE <sub>m</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	75
Fig A.2.17: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, TCE, and TPH in mixtures of BTE <sub>p</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	76
Fig A.2.18: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, TCE, and TPH in mixtures of BTE <sub>p</sub> X/TPH/TCE after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	76
Fig A.2.19: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, and TPH in mixtures of BTE <sub>o</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	77
Fig A.2.20: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>ortho</i> -xylene, and TPH in mixtures of BTE <sub>o</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	77
Fig A.2.21: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, and TPH in mixtures of BTE <sub>m</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	78
Fig A.2.22: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>meta</i> -xylene, and TPH in mixtures of BTE <sub>m</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	78
Fig A.2.23: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, and TPH in mixtures of BTE <sub>p</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 25°C.....	79
Fig A.2.24: Removal efficiencies of microorganism 2 for benzene, toluene, ethylbenzene, <i>para</i> -xylene, and TPH in mixtures of BTE <sub>p</sub> X/TPH after 144 hours of incubation in MSM with conditions of pH 5/7/9 and 35°C.....	79

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## LIST OF TABLES

Table A.1: Composition of crude oil and refined products (LUST, 1988).....	38
Table 4.1.1: Removal efficiencies (%; average of replicates) of Microorganism 1 (Macao) for BTEX (350 mg/L) and TPH 1000 mg/L mixtures at different temperatures and pHs..	39
Table 4.1.1a Removal efficiencies (%; average of replicates) of Microorganism 1 (Macao) for BTEompX 417 mg/L and TPH 1000 mg/L mixtures at 25/35°C and pH 5/7/9.....	39
Table 4.2.1: Removal efficiencies (%; average of replicates) of Microorganism 2 (Xiamen) for BTEX 350 mg/L and TPH 1000 mg/L mixtures at different temperatures and pHs. ....	40
Table 4.1.2: Removal efficiencies (%; average of replicates) of Microorganism 1 (Macao) for BTEX 350 mg/L, TPH 1000 mg/L and TCE 15 mg/L mixtures at 25°C and pH 5/7/9 along with generated chloride concentrations (in mg/L).....	41
Table 4.1.3: Removal efficiencies (%; average of replicates) of Microorganism 1 (Macao) for BTEX 350 mg/L, TPH 1000 mg/L and TCE 15 mg/L mixtures at 35°C and pH 5/7/9 along with generated chloride concentrations (in mg/L).....	42
Table 4.1.3a Removal efficiencies (%; average of replicates) of Microorganism 1 (Macao) for BTEompX 417 mg/L, TPH 1000 mg/L and TCE 15 mg/L mixtures at 25/35°C and pH 5/7/9 along with generated chloride concentrations (in mg/L).....	43
Table 4.2.2: Removal efficiencies (%; average of replicates) of Microorganism 2 (Xiamen) for BTEX 350 mg/L, TPH 1000 mg/L and TCE 15 mg/L mixtures at 25°C and pH 5/7/9 along with generated chloride concentrations (in mg/L).....	44
Table 4.2.3: Removal efficiencies (%; average of replicates) of Microorganism 2 (Xiamen) for BTEX 350 mg/L, TPH 1000 mg/L and TCE 15 mg/L mixtures at 35°C and pH 5/7/9 along with generated chloride concentrations (in mg/L).....	45
Table 4.3.1: Dissolved oxygen difference (%; average of replicates) of MO 1 (Macao) and MO 2 (Xiamen) for BTEX 350 mg/L, TPH 1000 mg/L and TCE 15 mg/L mixtures at different temperatures and pHs.....	46

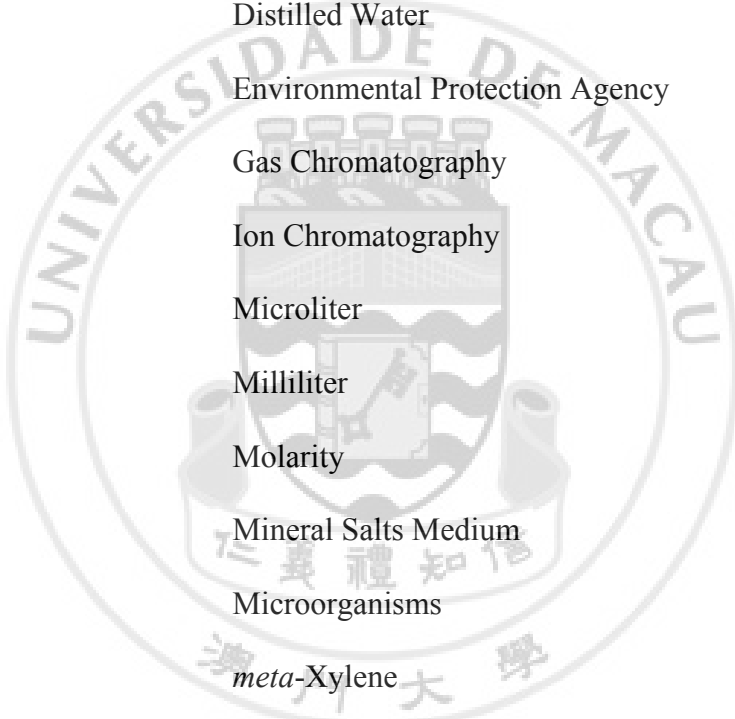
Table 4.3.2: Dissolved oxygen difference (%; average of replicates) of MO 1 (Macao) and MO 2 (Xiamen) for BTEX 350 mg/L - 417 mg/L and TPH 1000 mg/L mixtures at different temperatures and pHs.....47

Table 4.3.3: pH difference (%; average of replicates) of MO 1 (Macao) and MO 2 (Xiamen) for BTEX 350 mg/L, TPH 1000 mg/L and TCE 15 mg/L mixtures at different temperatures and pHs.....48

Table 4.3.4: pH difference (%; average of replicates) of MO 1 (Macao) and MO 2 (Xiamen) for BTEX 350 mg/L - 417 mg/L and TPH 1000 mg/L mixtures at different temperatures and pHs.....49



## LIST OF ABBREVIATIONS



BH medium	Bushnell-Haas medium
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
DO	Dissolved Oxygen
D.W.	Distilled Water
EPA	Environmental Protection Agency
GC	Gas Chromatography
IC	Ion Chromatography
μL	Microliter
mL	Milliliter
mol	Molarity
MSM	Mineral Salts Medium
MOs	Microorganisms
<i>mX</i>	<i>meta</i> -Xylene
NB	Nutrient Broth
OD	Optical Density
ORE	Overall Removal Efficiency
<i>oX</i>	<i>ortho</i> -Xylene
<i>pX</i>	<i>para</i> -Xylene
rpm	Revolutions Per Minute
TPH	Total Petroleum Hydrocarbons



UST	Underground Storage Tank
UV	Ultra Violet
v/v	Volume / Volume
w/w	Weight / Weight



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## Chapter 1: Introduction

In recent decades, the rapid industrialization and urbanization increased the usage of organic compounds, and the accidental spillage and leaking of these compounds as environmental contaminants is unavoidable. Major causes of crude oil-contaminated soil include leaking storage tanks and pipelines, land disposal of petroleum waste, and accidental or intentional spills. Those sites are usually polluted by a large number of mixed contaminants, for examples. Such petroleum/gasoline compounds as benzene, toluene, ethylbenzene, and three isomers of xylene (*ortho*-, *meta*-, and *para*-), known as BTEX, and such chlorinated compounds as trichloroethylene (TCE) are among the most frequently found subsurface contaminants.

Among all those remediation technologies available to remove contaminants from water and soil, bioremediation is considered one of the most economical and environmentally sound sustainable treatments. Bioremediation is using indigenous microorganism to degrade the contamination in the environment and the microbes under applicable environmental conditions will clean up the pollutants.

Although many studies have been developed for the remediation of contaminated sites, only a few of these studies are applicable for mixed contaminated sites, which is more practical to the real situation of environmental contamination. Furthermore, even though lots of studies have been done with the removal of BTEX (singly and in mixtures), Total Petroleum Hydrocarbons (TPH), or TCE (singly and in mixtures with other chlorinated aliphatic compounds; using toluene as substrates) individually, almost no study seems dealing with the interaction (stimulatory or inhibitory to each other's removal) among BTEX, TPH, and TCE when they exist in mixtures, especially under different environmental conditions. It is very important and necessary to know the detailed behaviors during removal process, which will help for applying the remediation technology on site for the successful remediation of contaminated environment.