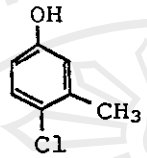
# APPENDIX 1

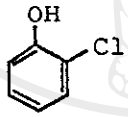
## Appendix 1.1: General Aspects of 11 Priority Pollutant Phenols[62]

**4-chloro-3-methylphenol** (*p*-chloro-*m*-cresol; 6-chloro-3-hydroxytoluene; 4-chloro-3-hydroxytotuene; 4-chloro-1-hydroxy-3-methylbenzene)



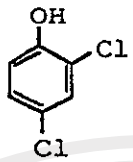

USES: external germicide; preservative for glues, gums, inks, textile and leather goods
PROPERTIES: odorless crystals (when pure); m.w. 142.6; m.p. 66°C; b.p. 235°C: log $P_{oct}$ 3.10
WATER POLLUTION FACTORS:
-Biological degradation:
after 3 weeks of adaptation at 20 mg/l at 22°C: 30% degradation when product is sole carbon source/ 100% degradation with synthetic sewage-aerobic conditions; under anaerobic conditions no degradation with or without synthetic sewage
-Odor threshold: detection: 0.1 mg/kg

**2-chlorophenol** (*o*-chlorophenol, 1-chloro-2-hydroxybenzene)



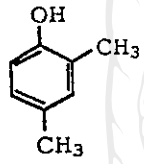

USE: organic synthesis
PROPERTIES: colorless liquid; m.w. 128.56; m.p. 7°C, 0°C, 4.1°C; b.p. 175.6°C; v.p. 40 mm at 82°C, 100 mm at 106°C; sp.gr. 1.241 at 18/15°C; solub. 28,500 mg/l at 20°C; log $P_{oct}$ 2.15/2.19
WATER POLLUTION FACTORS:
-Biodegradation:
decomposition rate in soil suspensions: 14 days for complete disappearance
decomposition period by a soil microflora: >64 days
adapted A.S. at 20°C, product is sole carbon source: 95.6% COD removal at 25.0 mg COD/g dry inoculum/hr
-Reduction of amenities:
approx. conc. causing adverse taste in fish: 0.015 mg/l
faint odor: 0.00018 mg/l
taste threshold: 0.0001 to 0.0006 mg/l
adult bluegills: taste to the flesh at 2.0 mg/l

**2,4-dichlorophenol**



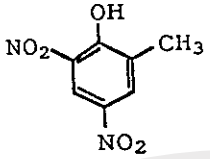

USE: organic synthesis
PROPERTIES: m.w. 163.01; m.p. 45°C; b.p. 210°C; sp.gr. 1.383 at 60/25°C; solub. 4,500 mg/l at 25°C, 4,600 mg/l at 20°C
WATER POLLUTION FACTORS:
- Impact on biodegradation processes
  75% inhibition of nitrification process in non acclimated activated sludge
- Reduction of amenities:
  approx. conc. causing taste in fish: 0.005 mg/l
  odor threshold: average: 0.21 mg/l
  range : 0.02-1.35 mg/l
  T.O.C. = 0.002 mg/l
  odor threshold: 0.00065 to 0.0065 mg/l
  taste threshold: 0.008 to 0.02 mg/l
- Biodegradation:
  decomposition rate in soil suspensions: 9 days for complete disappearance

**2,4-dimethylphenol** (2,4-xylenol)



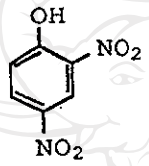

*Manufacturing source:* coal tar fractionation; coal processing.
*Users and formulation:* intermediate in mfg. of phenolic antioxidants; pharmaceutical mfg., plastics and resins mfg.; disinfectant (microbicide) mfg.; solvent mfg., insecticides and fungicides, rubber chemicals, mfg. polyphenylene oxide, wetting agent, dyestuffs; cresylic acid constituent.
*Natural Sources (water and air):* coal.
*Man cause sources (water and air):* asphalt and roadway runoff; general use of pharmaceuticals, fuels, plastics, pesticides; washing of dyed materials; constituent of domestic sewage.
PROPERTIES: colorless needles; m.w. 122.16; m.p. 26°C; b.p. 211.5°C; sp.gr. 1.036 at 20/4°C.
WATER POLLUTION FACTORS:
- $BOD^{30°C,5}$: at 15 mg/l: nil (seed water from phenol-degradation plant)
- Reduction of amenities:
  approx. conc. causing adverse taste in fish (Rudd): 1 mg/l
- Odor threshold conc.: detection: 0.4 mg/l
- Taste threshold conc.: 0.5 mg/l
- Impact on biodegradation processes:
  inhibition of degradation of glucose by *Pseudomonas fluorescens* at: 40 mg/l
  inhibition of degradation of glucose by *E.coli* at: 500 mg/l

**4,6-dinitro-2-methylphenol** (4,6-dinitro-o-cresol, 2-methyl-4,6-dinitrophenol)



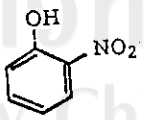
USE: dormant ovicidal spray for fruit trees (highly phytotoxic and can not be acted successfully on actively growing plants)
PROPERTIES: yellow prisms; m.w. 198.13; m.p. 85.8°C; v.d. 6.84
WATER POLLUTION FACTORS:
- Biodegradation: adapted culture: 1% removal after 48 hr incubation
- Impact on biodegradation process:
  inhibition of degradation of glucose by *Psuedomonas fluorescens* at: 30 mg/l
  inhibition of degradation of glucose by *E. coli* at: 100 mg/l
- Odor threshold: 1.3 mg/l

**2,4-dinitrophenol**



PROPERTIES: yellow rhombic crystals or needles; m.w. 184.11; m.p. 111-114°C; v.d. 6.36; sp.gr. 1.683 at 24°C; solub. 5,600 mg/l at 18°C, 43,000 mg/l at 100°C; log $P_{oct}$ 1.51/1.54
WATER POLLUTION FACTORS:
- Biodegradation:
  adapted culture: 2% removal after 48 hr incubation, fee: 200 mg/l
  adapted A.S. at 20°C- product is sole carbon source: 85% COD removal at 6.0 mg COD/g dry inoculum/hr
- Impact on biodegradation processes:
  inhibition of degradation of glucose by *Psuedomonas fluorescens* at: 3 mg/l
  inhibition of degradation of glucose by *E. coli* at: > 100 mg/l
  ~ 50% inhibition of $NH_3$ and $NO_2$ oxidation at 37 mg/l

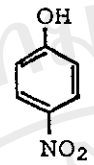
**2-nitrophenol** (*o*-nitrophenol)



USE: intermediate in organic synthesis; indicator
PROPERTIES: light yellow needles or prisms; m.w. 139.11; m.p. 45°C; b.p. 214/217°C, v.p. 20 mm at 105°C, 100 mm at 146°C; sp.gr. 1.657 at 20°C; solub. 2,100 mg/l at 20°C, 10,800 mg/l at 100°C
WATER POLLUTION FACTORS:
- Biodegradation: decomposition by a soil microflora in > 64 days
  adapted A.S. at 20°C-product is sole carbon source: 97.0% COD removal at 14.0 mg COD/g dry inoculum/hr
- Impact on biodegradation processes: inhibition of degradation of glucose by *Pseudomonas fluorescens* at: 20 mg/l

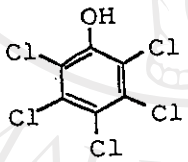
inhibition of degradation by *E. coli:*>1000 mg/l
- Reduction of amenities: T.O.C. = 10 mg/l
detection: 1.7 mg/l
taste threshold conc.: 0.001 mg/l

**4-nitrophenol** (*p*-nitrophenol)



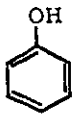

USE: intermediate in organic synthesis; production of parathion; fungicide for leather
PROPERTIES: colorless to yellowish crystals; m.w. 139.11; m.p. 114°C; b.p. 279°C decomposes; v.p. 2.2 mm at 146°C, 18.7 mm at 186°C; sp.gr. 1.479 at 20°C; solub. 16 g/l at 25°C, 269 g/l at 90°C;
WATER POLLUTION FACTORS:
- Biodegradation:
adapted culture: 2% removal after 48 hr incubation, feed: 200 mg/l
decomposition by a soil microflora in 16 days
adapted A.S. at 20°C-product is sole carbon source: 95.0% COD removal at 17.5 mg COD/g dry inoculum/hr

**pentachlorophenol** (PCP; penta)




*Manufacturing source*: organic chemical industry; pesticide mfg. industry.
*Users and formulation*: mfg. insecticides, algicides, herbicides, and fungicides; preservation of wood and wood products; mfg. of sodium pentachlorophenate. Commercial pentachlorophenol (PCP) contains significant quantities of tetrachlorophenol (TCP).
*Man caused sources (water and air)*: agriculture runoff; general use of treated wood; lab use
PROPERTIES: white monoclinic, crystalline solid, technical grade dark grey to brown; m.w. 266.35; m.p. 188/191°C; b.p. 310°C
WATER POLLUTION FACTORS:
- Biodegradation: decomposition rate in soil suspensions: >72 days for complete disappearance
- Reduction of amenities:
threshold odor: 0.857 to 12.0 mg/l; detection: 1.6 mg/l
taste threshold conc.: 0.03 mg/l

**Phenol** (carbolic acid, hydroxybenzene, phenic acid, phynelic acid)



USE: As a general disinfectant, for toilets, stables, cesspools, floors, drains; the manufacture of colorless or light-colored artificial resins, many medical and industrial organic compounds and dyes; as a reagent in chemical analysis

PROPERTIES: colorless till brown-black; m.w. 94.11; m.p. 41°C, b.p. 182.0°C; v.p. 0.2 mm at 20°C, 1 mm at 40°C; v.d. 3.24; sp.gr. 1.07; solub. 82 g/l at 15°C; sat. conc. 0.77 g/cu m at 20°C, 2.0 g/cu m at 30°C; log $P_{oct}$ 1.46

WATER POLLUTION FACTORS:

- Reduction of amenities:

taste and odor of fish is affected at: 15-25 mg/l

tainting of the flesh of fish and other aquatic organisms:

phenol: 1-10 mg/l

phenol in polluted river: 0.02-0.15 mg/l

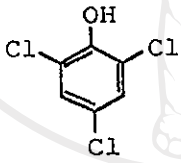
taste in trout and carp: 25 mg/l; 1.0 mg/l

odor threshold: average: 5.9 mg/l: range: 0.016-16.7 mg/l

taste and odor threshold: (tentative): 0.15 mg/l

organoleptic limit: USSR 1970: 0.001 mg/l

**2,4,6-trichlorophenol**




*Manufacturing source:* organic chemical industry: pesticide mfg.

*User and formulation:* mfg. antiseptics, bactericides, fungicides, germicides; mfg. wood and glue preservatives; used as anti-mildew agent for textiles.

PROPERTIES: needles; m.w. 197.46; m.p. 68°C; b.p. 244.5°C; sp.gr. 1.490 at 75/4°C; solub. 800 mg/l at 25°C, 2,430 mg/l at 96°C

WATER POLLUTION FACTORS:

- Biodegradation:

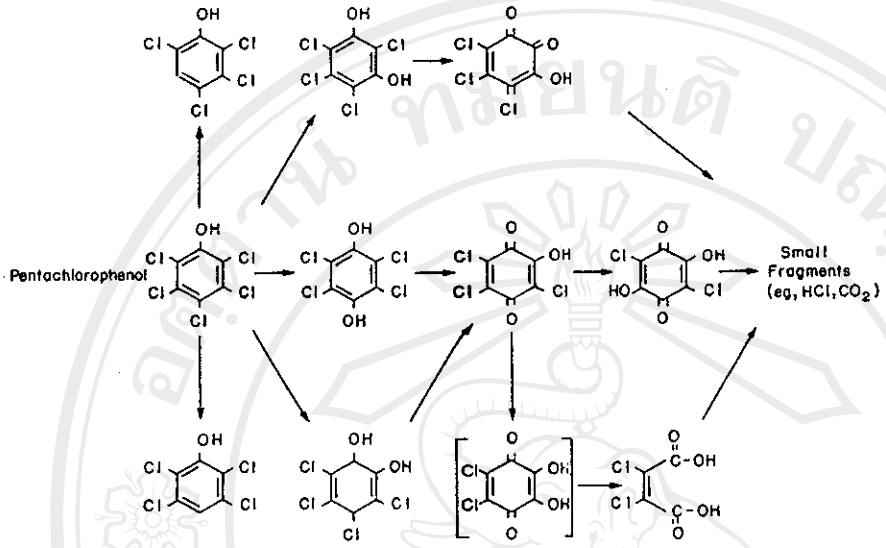
decomposition in soil suspensions: 5 days for complete disappearance

- Reduction of amenities:

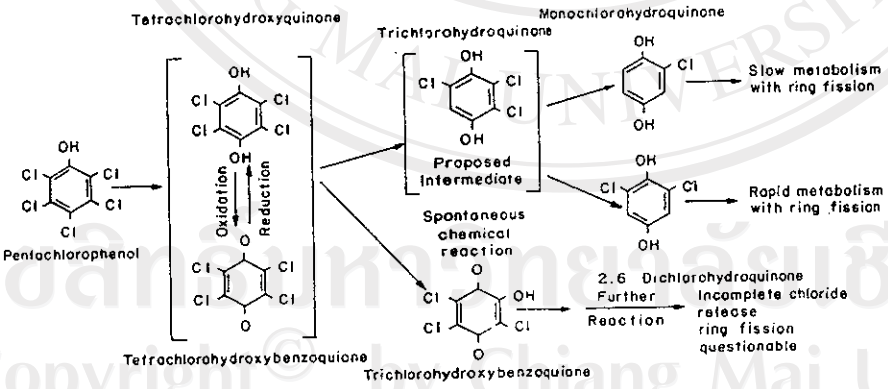
odor threshold: 0.10-1.0 mg/l; 0.3 mg/l (detection)

taste threshold: > 1.0 mg/l; 0.002 mg/l (detection)

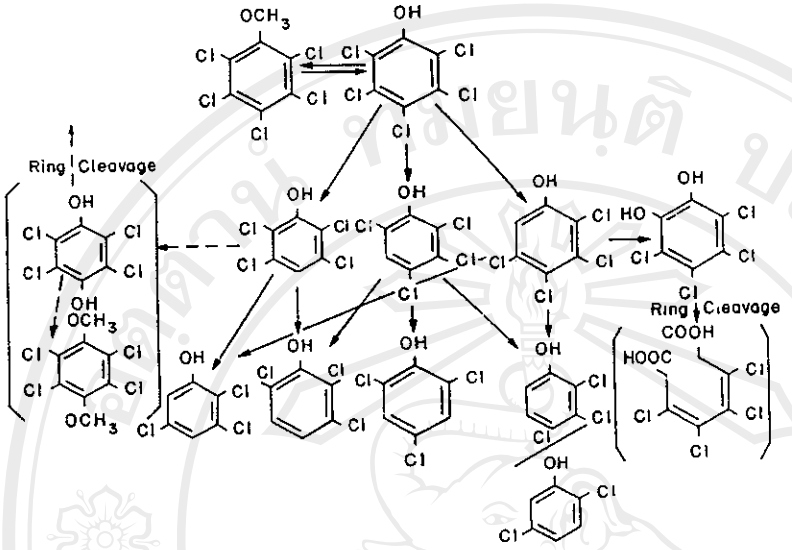
Appendix 1.2.1: Proposed Pathways for Photolytic Degradation of Pentachlorophenol in Aqueous Solution[15]



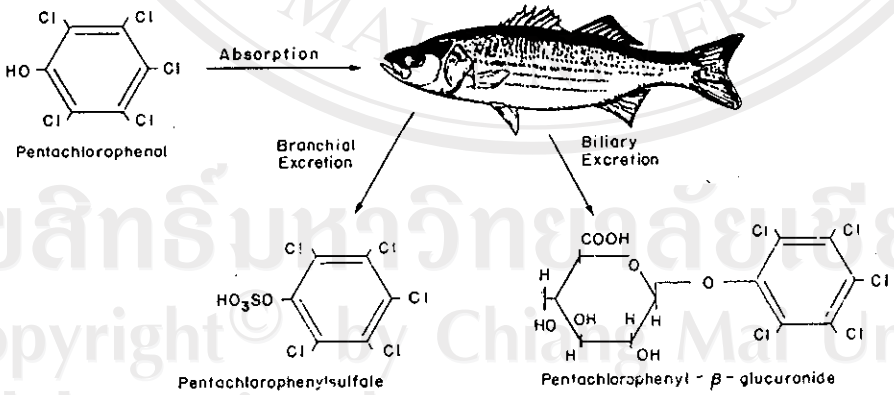

Appendix 1.2.2: Proposed Pathway for the Microbial Degradation of Pentachlorophenol in a Bacteria Culture[16]



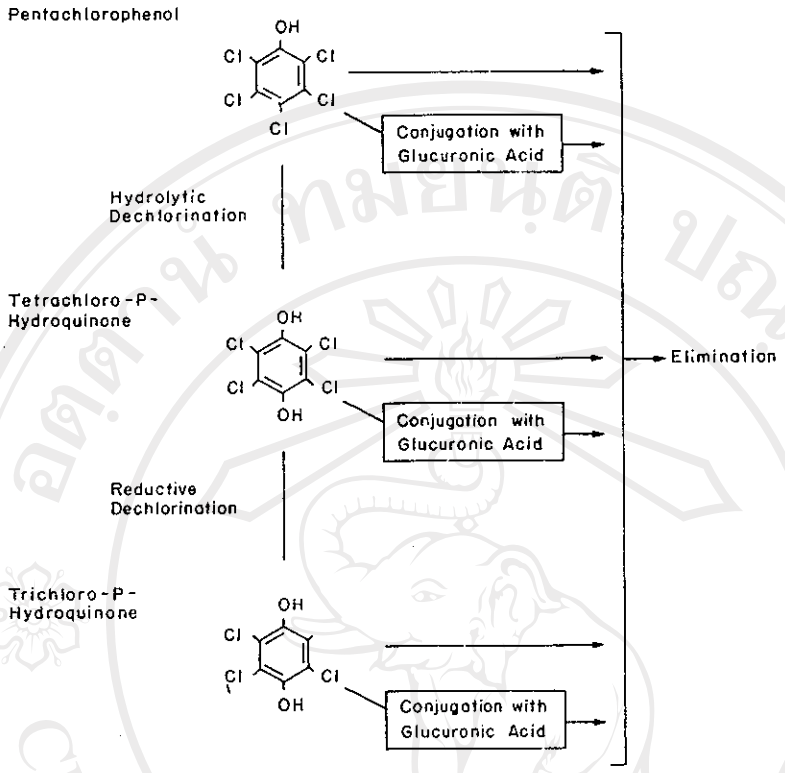
Appendix 1.2.3: Proposed Pathway for the degradation of Pentachlorophenol in Soil[17]



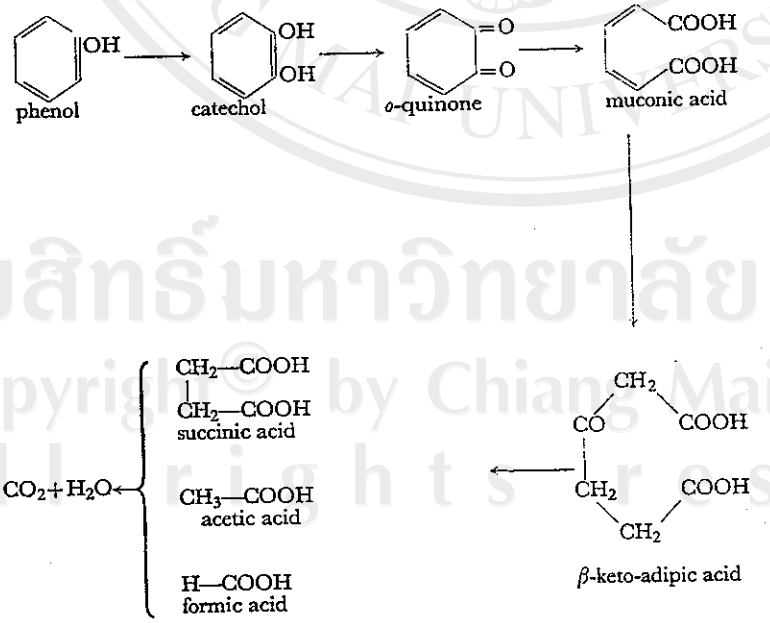

Appendix 1.2.4: Metabolic Pathways for Pentachlorophenol in Fish[18]



Appendix 1.2.5: Pathways for Metabolic Degradation of Pentachlorophenol in Rats[19]

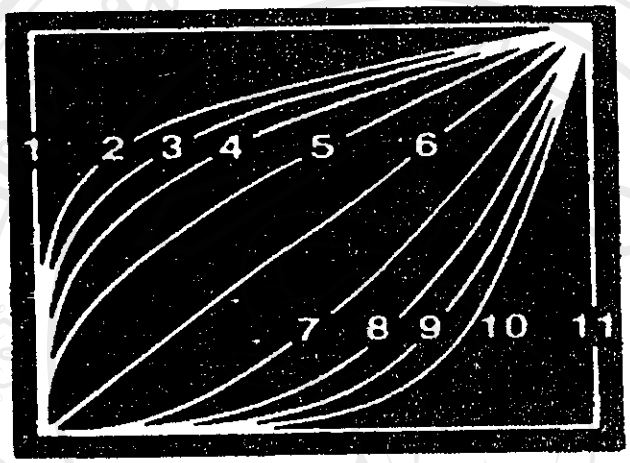



Appendix 1.2.6: Oxidative Degradation of Phenol by Anaerobic Bacteria[20]



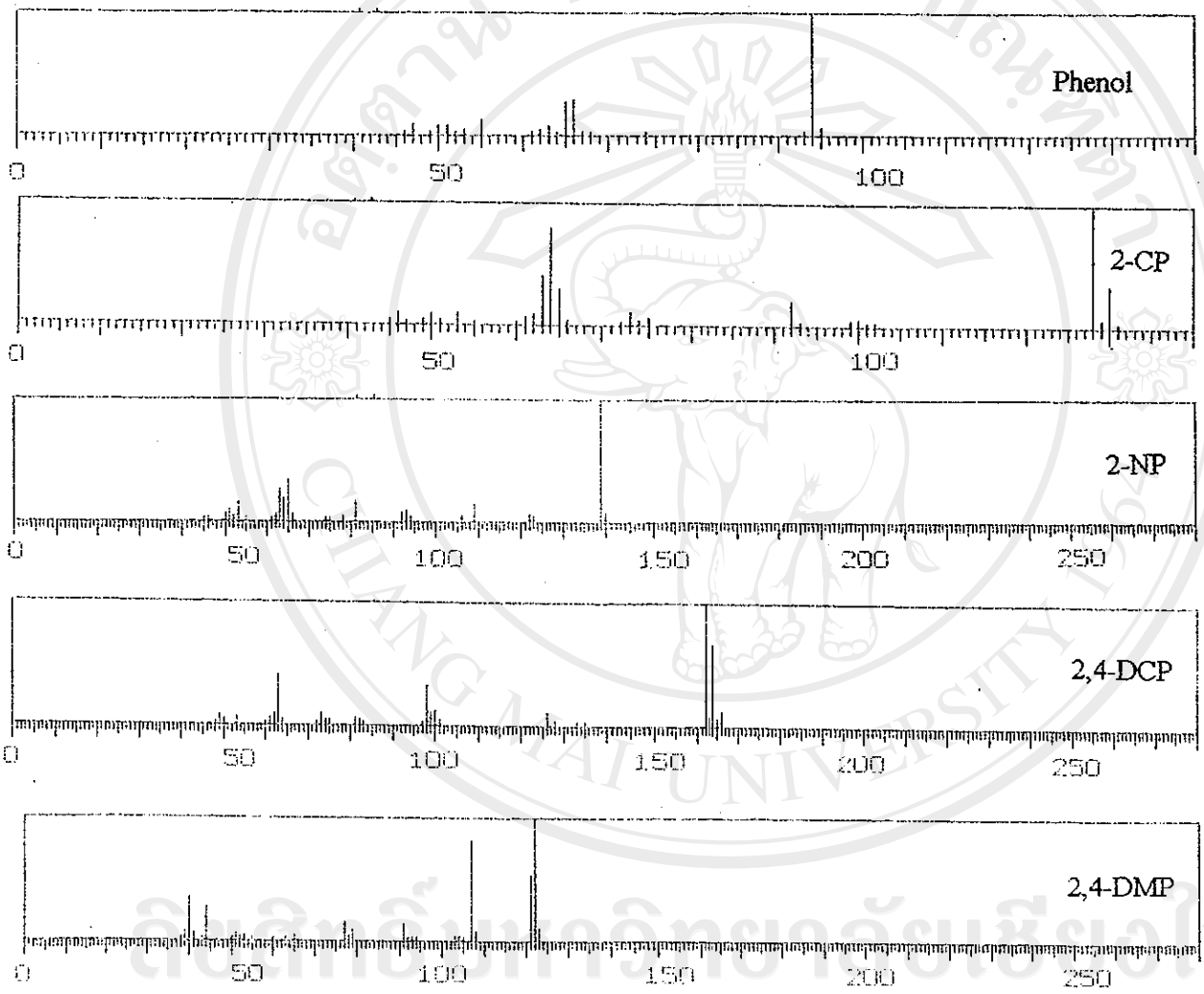
# APPENDIX 2

Appendix 2.1: Gradient Curve Shapes[55]

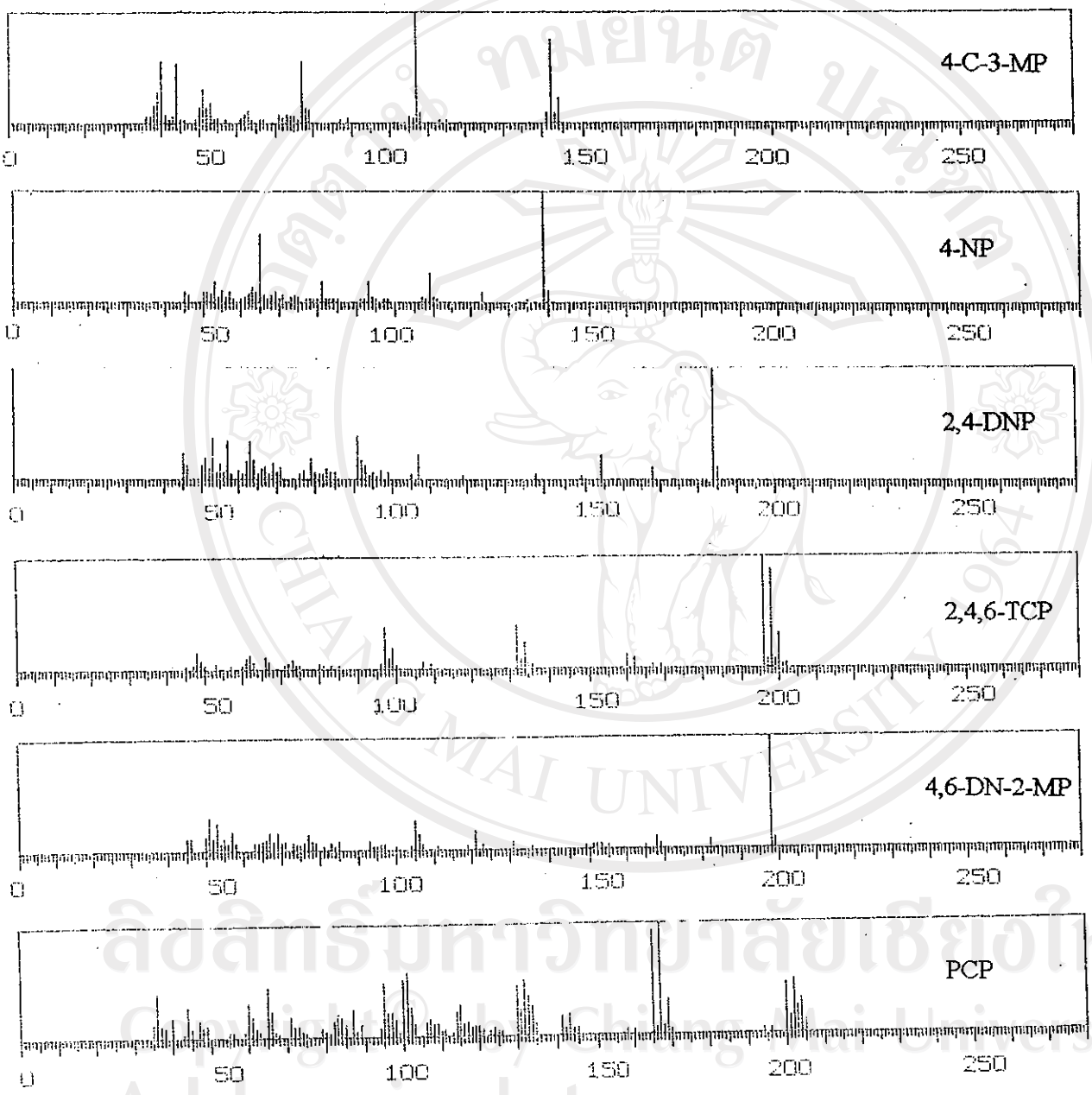


# APPENDIX 3

Appendix 3.1: Fragmentation Pattern of 11 Priority Pollutant Phenols from GC-MS Technique



Appendix 3.1: Fragmentation Pattern of 11 Priority Pollutant Phenols from GC-MS Technique (continued)



Appendix 3.2: Water Quality Standard by Means of Phenol Contents in Thailand[57]

| Type of Water | Standard Values (mg/l) |
|---|---|
| Drinking Water | 1.0 (0.002) |
| Bottling Drinking Water | 0.001 |
| Surface Water | 0.005 (for class 2-4)** |
| Coastal Water* | 0.03 |
| Industrial Effluent (phenol & cresols) | 1.0 |
| | - |

Note ( ) proposed value
* This include the one purpose in;
-conservation of coral community
-conservation of natural area
-aquaculture
-shellfish
** see Appendix 3.3

Appendix 3.3: Water Classifications[57]

| Classifications | Objectives Condition and Benefit Usages |
|---|---|
| Class 1 | Extra clean fresh surface water resources using for:<br>(1) conservation, of necessary pass through water treatment processes require only ordinary process for pathogenic destruction<br>(2) ecosystem conservation which basic living organisms can spread breeding naturally |
| Class 2 | Very clean fresh surface water resources using for:<br>(1) consumption which require the ordinary water treatment process before use<br>(2) aquatic organism conservation for living and assisting for fishery<br>(3) fishery<br>(4) recreation |
| Class 3 | Medium clean fresh surface water resources using for:<br>(1) consumption but have to pass through an ordinary treatment process before uses<br>(2) agriculture |
| Class 4 | Fairly clean fresh surface water resources using for:<br>(1) consumption but require special water treatment process before uses<br>(2) industry |
| Class 5 | The resources which are not classified in class 1-4 and using for<br>(1) navigation |

Appendix 3.4: Chiang Mai-Rainfall During May to December 1994[61]

| Day | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.1 | 8.5 | 17.0 | 4.6 | 0.0 | 0.0 | 0.0 |
| 2 | - | 0.3 | 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.0 | 0.0 | 0.4 | 16.5 | 46.6 | 0.0 | 0.0 | 6.9 |
| 4 | 0.0 | 29.6 | 0.0 | - | 0.0 | 0.4 | 0.0 | 0.0 |
| 5 | 0.1 | 15.0 | - | 15.1 | 1.4 | 9.3 | 0.0 | 0.0 |
| 6 | 3.9 | 18.7 | 1.0 | 0.0 | 2.0 | 14.7 | 0.0 | 20.6 |
| 7 | 0.0 | 2.8 | 1.7 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 |
| 8 | 11.6 | - | 26.3 | 0.0 | 5.2 | 0.0 | 0.0 | 0.0 |
| 9 | 5.8 | 0.1 | 0.2 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 38.9 | 6.2 | 2.9 | - | - | 0.0 | 0.0 | 0.0 |
| 11 | 20.9 | 4.0 | 0.6 | 0.0 | 28.4 | 4.4 | 0.0 | 0.0 |
| 12 | 0.5 | 8.1 | - | 0.0 | 13.5 | 0.0 | 0.0 | 0.0 |
| 13 | 0.0 | - | - | - | - | 0.0 | 0.0 | 0.0 |
| 14 | 0.0 | - | 0.6 | 9.3 | 52.9 | 0.3 | 0.0 | 0.0 |
| 15 | 25.0 | - | 0.0 | 41.0 | 4.6 | 0.0 | 0.0 | 5.0 |
| 16 | 4.6 | 0.3 | 3.1 | 3.6 | 25.6 | 0.0 | 0.0 | 14.6 |
| 17 | 0.0 | 1.7 | 0.0 | 9.4 | 24.6 | 40.3 | 0.0 | 1.3 |
| 18 | 10.7 | 1.1 | 2.3 | 8.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| 19 | 0.0 | 1.9 | 7.6 | 15.9 | 0.4 | 0.0 | 0.0 | 0.0 |
| 20 | 11.3 | 0.0 | 0.1 | 59.5 | 0.0 | 6.0 | 0.0 | 0.0 |
| 21 | 4.6 | 1.7 | 0.3 | 23.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | 1.4 | 0.0 | - | 12.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | 0.0 | 2.1 | 5.1 | 7.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | 0.0 | - | 0.3 | 4.9 | - | 0.0 | 0.0 | 0.0 |
| 25 | 0.0 | - | 3.5 | 16.4 | 18.4 | 0.0 | 0.0 | 0.0 |
| 26 | 0.0 | 8.0 | 0.7 | - | - | 0.0 | 21.1 | 0.0 |
| 27 | 30.1 | 0.0 | 8.6 | 27.1 | 0.7 | 0.0 | 22.8 | 0.0 |
| 28 | 5.1 | 8.5 | 0.6 | 1.8 | 14.0 | 0.0 | 3.0 | 0.0 |
| 29 | 3.0 | 10.9 | 0.0 | 7.7 | 4.8 | 0.0 | 0.2 | 0.0 |
| 30 | 21.3 | 7.8 | 5.3 | 8.7 | 4.5 | 0.0 | 0.6 | 0.0 |
| 31 | 1.0 | | 66.4 | 26.9 | | 0.0 | | 0.0 |
| Total | 199.8 | 128.9 | 146.1 | 332.5 | 258.1 | 75.4 | 47.7 | 48.4 |
| Average | 6.4 | 4.3 | 4.7 | 10.7 | 8.6 | 2.4 | 1.6 | 1.6 |

# VITA

**Name:** Ms. Yupin Peetragorn

**Gender:** Female

**Date of Birth:** February 22, 1972

**Place of Birth:** Phitsanuloke

**Academic Status:** Primary school certificate holder from Saint Nicholas School, Phitsanuloke, 1983

High school certificate holder from Chalermquansatree School, Phitsanuloke, 1989

B.Sc. (Chemistry) degree holder from Chiang Mai University, 1993

**List of Publications:**

Y. Peetragorn, 1993. **In Vitro Biodegradation of Some Aliphatic Polyesters: Factor Effecting the Property Loss Profile,** Faculty of Science, Chiang Mai University, Chiang Mai.

Y. Peetragorn, K. Grudpan and S. Wangkarn, 1994. **Preliminary Survey on Phenols Content in Water in and around Chiang Mai City,** 20th Conference on Science and Technology of Thailand, Bangkok.