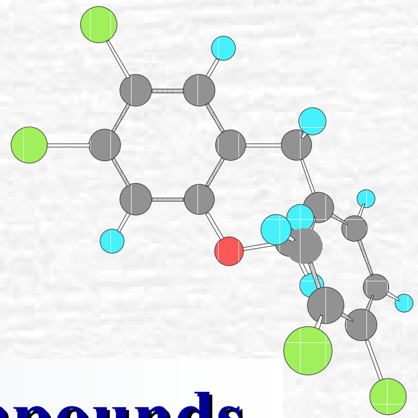


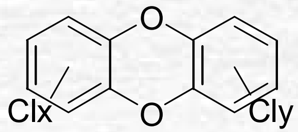
Degradation of dioxin-like compounds by microorganisms

장 윤 석

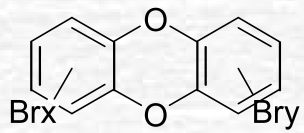
2001. 03.27

Chemical structures of Polychlorinated Dibenzo-p-dioxins (PCDD), and related compounds

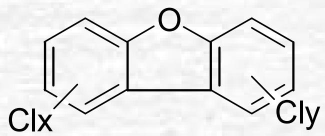
PCDD [75]



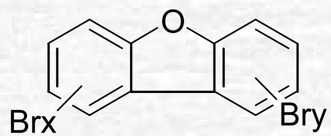
PBDD



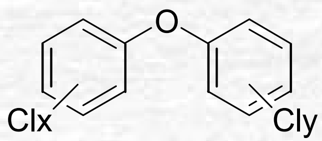
PCDF [135]



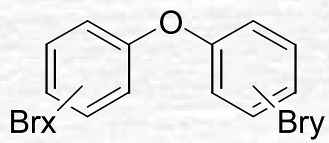
PBDF



PCDE[209]



PBDE



Removal of Dioxins

1. *Catalytic destruction --- TiO_2, V_2O_5, Pt, Pd*
2. *Chemical --- Metal Na, Active carbon*
3. *Physico-Chemical – SWO & Hot electron*
4. *Thermo destruction --- Incineration (>800°C)*
5. *Photo destruction --- UV (250-340 nm)*
6. *Ozone destruction – O_3, H_2O_2*
7. *Biological treatment – Fungi, Bacteria*

Factors most likely responsible for the environmental persistence

1. ***The organisms may lack the enzymatic or biological potential to degrade the compound.***

2. ***The compound may unable to penetrate the cell.***

3. ***The concentration or the physical nature of the compound may be inhibitory to organisms to their enzymes.***

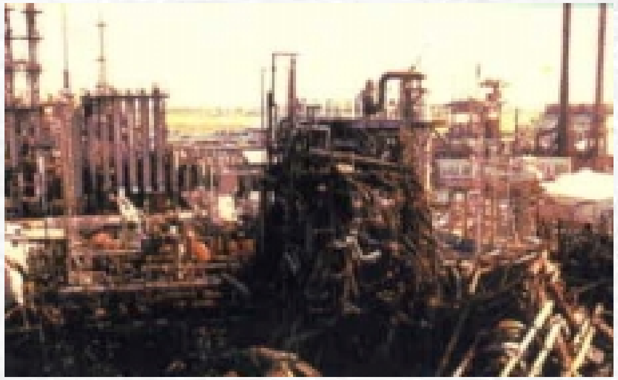
4. ***The steric configuration of the compound, including the position and degree of substitution, may prevent or hinder enzymatic attack.***

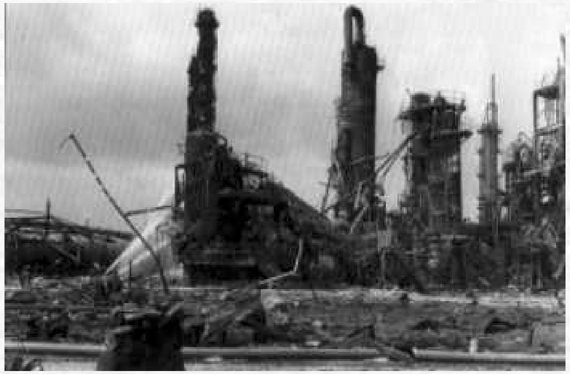
5. ***The environment may be toxic or deficient in some factor essential to support the growth of degradative organisms.***

History

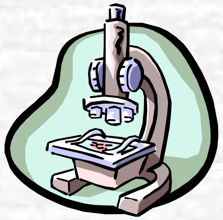
The first investigation : Kearny et .al (1972)

-Persistence and metabolism of chlorodioxins in soils.
-ES & T 6:1010-1017.



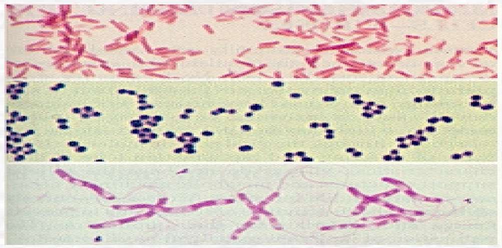


Active research after explosion in chemical plant belonging to the ICMESA firm near Seveso, Northern Italy (July, 10th 1976)



Prokaryotic cells

(Bacteria)



Eukaryotic cells

(Fungi)

Prokaryotic cells:

Aerobic — *Anaerobic (?)*

- *Aerobic*
  - *Mono- (?)*
  - **Di-**
    - *Sphingomonas*
    - *Pseudomonas*

Elbe river

Eukaryotic cells:

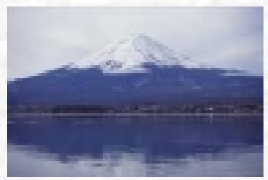
Aerobic — *Anaerobic (?)*

- *Aerobic*
  - **Mono-**
  - **Di- (?)**

By White Rot Fungus

(Phaanerrochaete chrysosporium

Science 1985)



쓰레기 소각장으로부터 나오는 다이옥신을 효율적으로 분해하는 버섯을 후꾸오까현 보건환경연구소와 규슈대학 농학부의 공동팀이 발견했다. 26일부터 도쿄에서 열리는 일본 약학회에서 발표될 예정이다. 부식된 나무에 번식하는 버섯의 일종이다. 오염 토양의 정화나 소각장의 처리 플랜트 등에 실용화 시도를 해볼 계획이다. 발견된 것은 [백색 부슈균]라 불리는 흰버섯의 일종이다. 목재가 부식한 부분에 부착해, 나무의 주성분인 리그닌을 분해한다. 이제까지는 미국의 연구원이 살충제인 DDT 등을 분해하는 능력을 확인한 바 있으며, 이번에는 다이옥신에도 응용을 시도해 본 것이다. ⊙ 배지에서 육성한 2mg의 균에, 소각재로부터 모은 약 2ng의 다이옥신을 투입, 1개월간 배양한 결과, 50～75%의 다이옥신이 이산화탄소와 물로 분해되었다고 한다. 후꾸오까현 보건환경연구소의 다까다 전문 연구원은 "버섯이 내는 효소가 다이옥신을 분해하는데 높은 효능을 가진 것은 아닐까?"라고 추측했다고 한다. ⊙ 다이옥신은 발암성이 지적되고 있으나 분해가 어려워 처리에 곤란을 겪고 있다. 발견된 버섯은 분해 속도는 늦으나, 간단한 설비로 분해가 가능할 것으로 보여져 폭넓은 사용이 기대된다

⊙ 일본 에히메(□□)대학 농학부의 다찌바나(橘) 교수그룹은 쓰레기소각장으로부터 발생하여 암이나 기형의 원인이 되는 유해물질인 다이옥신을 효과적으로 분해하는 균을 발견했다. 이는 버섯의 일종인 목재 부패균으로, 실험에 의하면 고농도의 다이옥신을 90% 가까이 분해한다고 한다. 앞으로 세균융합 등을 통해 더욱 분해능력이 높은 균을 개발, 다이옥신 처리를 위해 실용화할 생각이다.

From : KORDIC news, 2000

*White rot fungus*의 다이옥신 분해율

화합물	분해율(%)		
	P.sordida		***P.chrysosporium***
	(글루코스첨가)	(글루코스무첨가)	(글루코스 첨가)
2,3,7,8-TCDD	22.1±0.0	26.5 ±1.5	37.1 ±5.9
1,2,3,7,8-PeCDD	24.3 ±1.9	26.7 ±6.5	53.9 ±6.8
1,2,3,4,7,8-HxCDD	35.3 ±5.0	43.7 ±4.0	64.9 ±5.7
1,2,3,4,6,7,8-HpCDD	10.3 ±0.6	38.1 ±4.3	53.6 ±7.9
OCDD	6.20 ±2.0	14.2 ±4.1	41.1 ±7.6
2,3,7,8-TCDF	28.6 ±5.6	38.8 ±1.2	27.3 ±8.0
1,2,3,7,8-PeCDF	22.0 ±1.5	24.2 ±3.3	38.5 ±5.7
1,2,3,47,8-HxCDD	41.5 ±1.6	50.4 ±2.6	54.7 ±6.1
1,2,3,4,6,7,8-HpCDD	22.0 ±1.2	39.5 ±3.2	51.9 ±7.1
OCDF	13.7 ±1.0	35.0 ±2.8	58.6 ±12.3

Fungi VS Bacteria

Advantages of fungal metabolism

1. No adaptation to specific chemicals.
2. Acting on whole compound classes.

Disadvantages of fungal metabolism

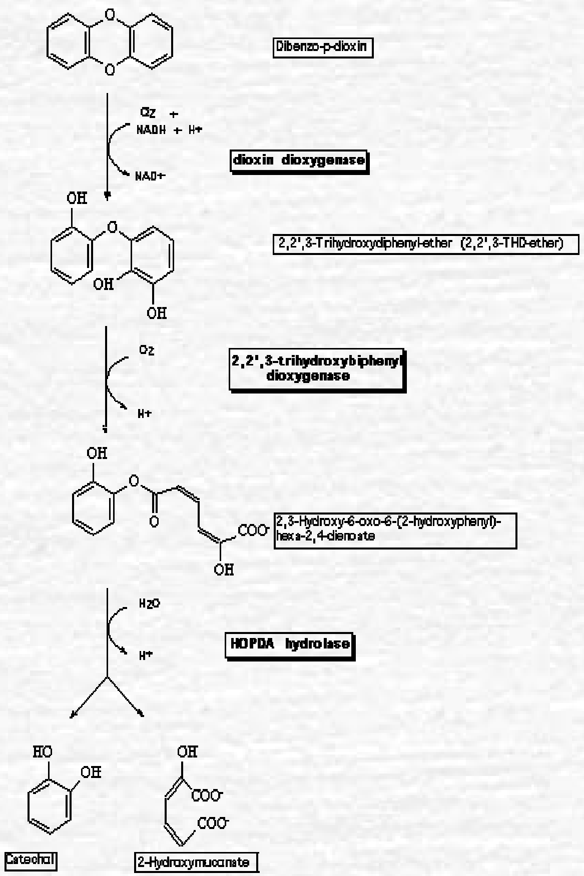
1. Complex nutritional requirement.
2. Low specificity (Low yield).
3. High oxygen demand.
4. Difficult industrial application.

Aerobic microorganisms able to degrade dioxins

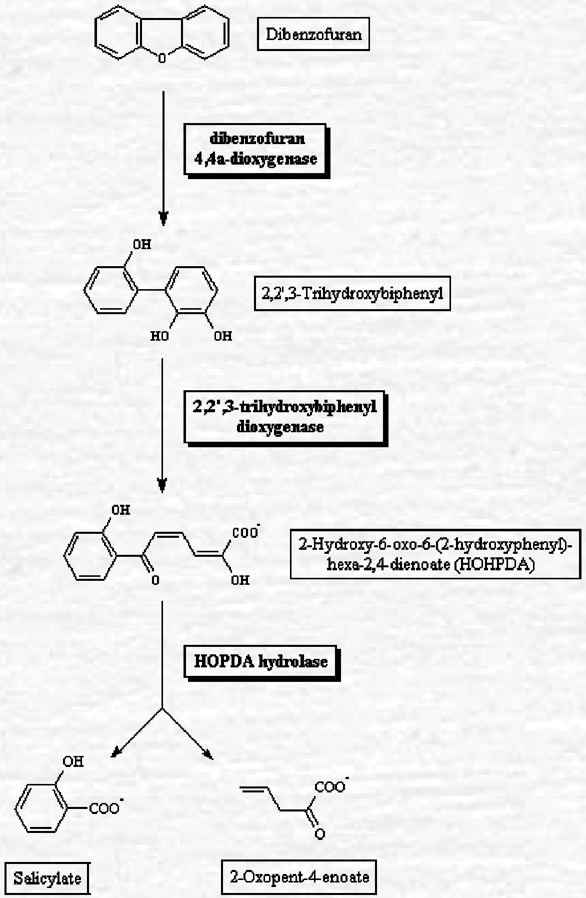
Strain	Substrate
Bacillus megaterium	TCDD (?)
Escherichia coli	4-nitro-DE
Pseudomonas cepacia	DE
P. cruciviae	DE
P. delafieldii	3-POB,4-POB
P. pseudoalcaligens	3-POB,4-POB
P.sp.	DD,DF
Sphingomonas sp.	DD.DF
Staphylococcus auriculans	DD
Terrabacter sp.	DF
White Rot Fungus.	TCDD

Non-Chloro

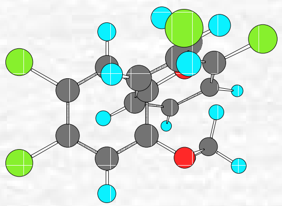
Dibenzo-p-dioxin

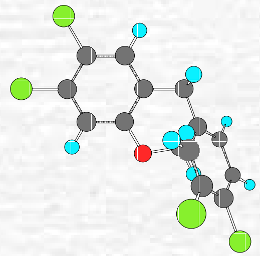


Dibenzofuran

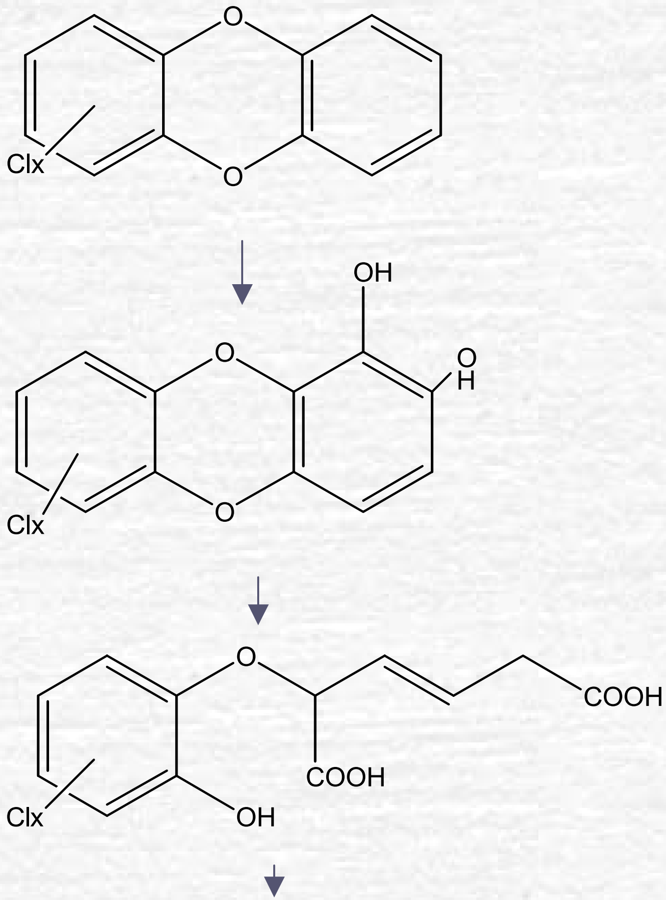


Mono, di, tri-Chloro

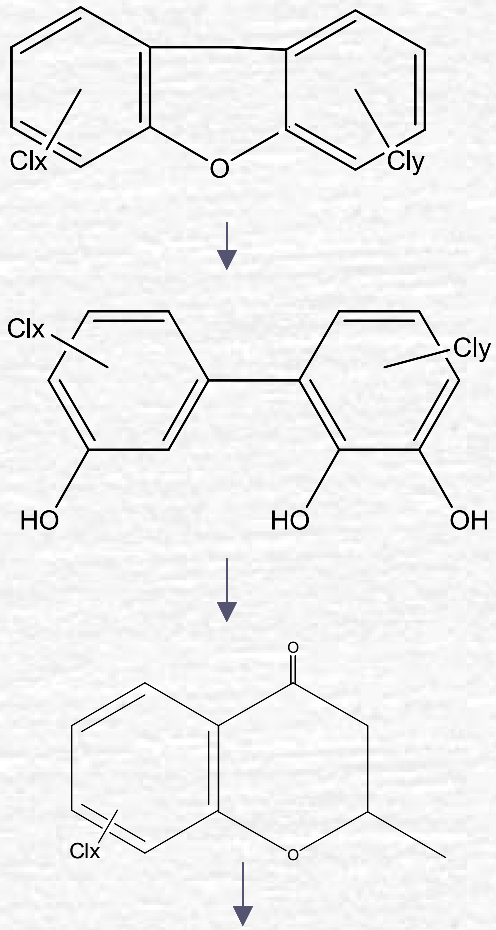




Dibenzo-p-dioxin

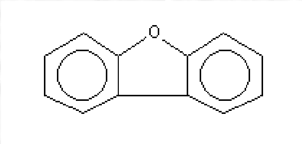


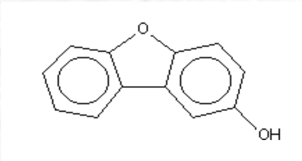
Dibenzofuran

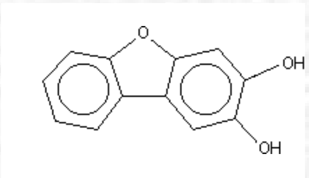


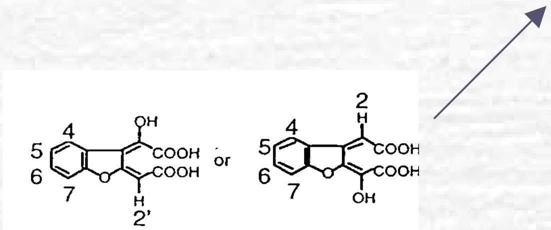
Chlorocatechol ⟶ $CO_2 + H_2O$ ⟵

Mono-oxygenation

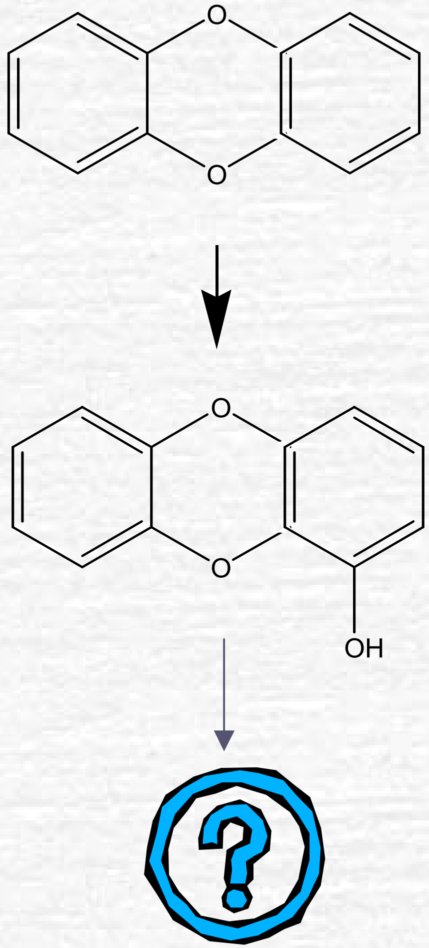




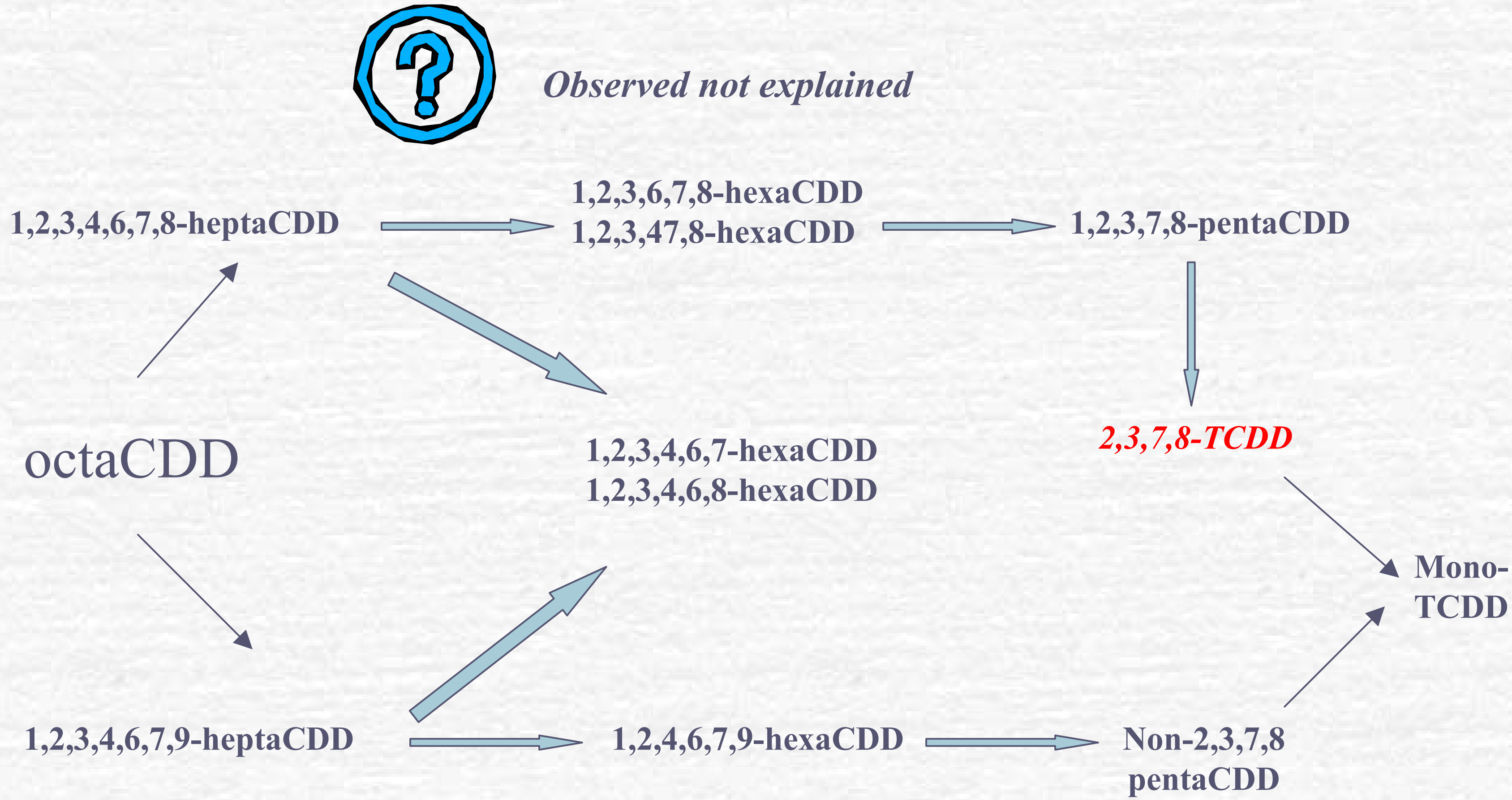




Dead end product
(Pseudomonas **and Fungi)**



By *S.auriculans DBF63*



Branched pathway of PCDD microbial dechlorination

** Reproduced from : AEM, 1996, 4556-4562*

Conclusion and prospects

1. ***The attack by bacterial angular dioxygenase seems to be restricted to all mono- and some di or tri chlorinated DD and DF.***

2. ***Extension of the substrate range of DD- and DF- mineralization has to be achieved.***

3. ***A process based on anaerobic dehalogenation of PCDD/F and subsequent degradation of less halogenated products in aerobic should be recommended.***

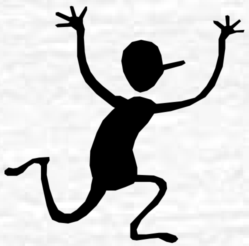
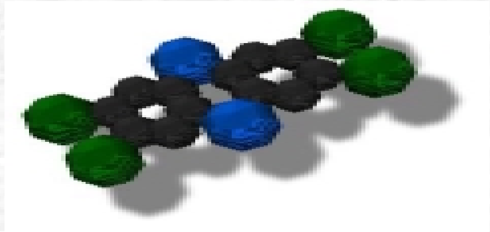
4. ***Provided that biodegradation rates can be increased significantly by the use of (bio-) emulsifiers.***

SEAL 포항공대 환경공학부 환경분석연구실
Scientific environmental analysis lab

DIOXIN LAB

Biosorption vs. Biodegradation
(for the treatment of inert organic compounds)

	Biosorption	Biodegradation
Advantage	1. Nontoxic byproducts 2. Rapid	1. Ultimate goal 2. No secondary treatment
Disadvantage	1. Secondary treatment required	1. Slow 2. Toxic byproducts in some cases


A. Bio-degradation

Isolation of Microorganisms

1. Nutrient broth (180 colonies from soil, waste drain and hood)
2. Minimal salts Medium with 1,2,3,4-TCDD/F or 2,3,7,8-PCDDs (9 strains)

Analysis

1. GC analysis
2. GC-MS analysis

Dibenzofuran

1 strain

1,2,3,4-TCDD/F

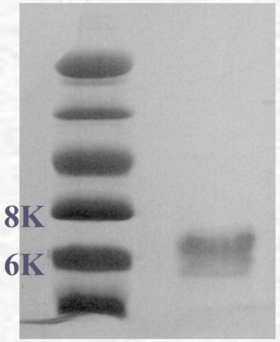
6 strains

2,3,7,8-PCDD/Fs

2 strains

B. Bioadsorption

8K
6K

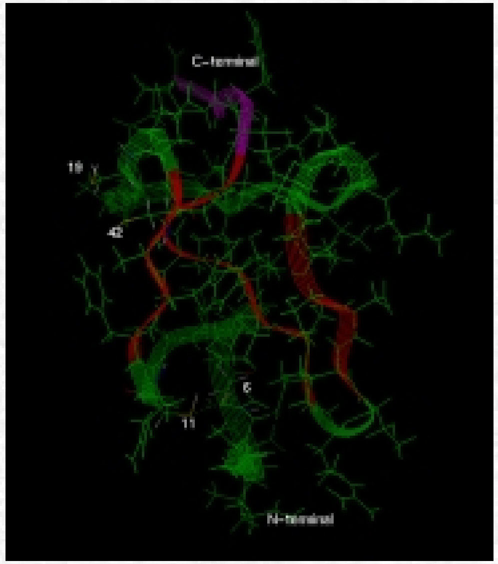


From *Bacillus Pumilus* PH-01

Protein Sequence

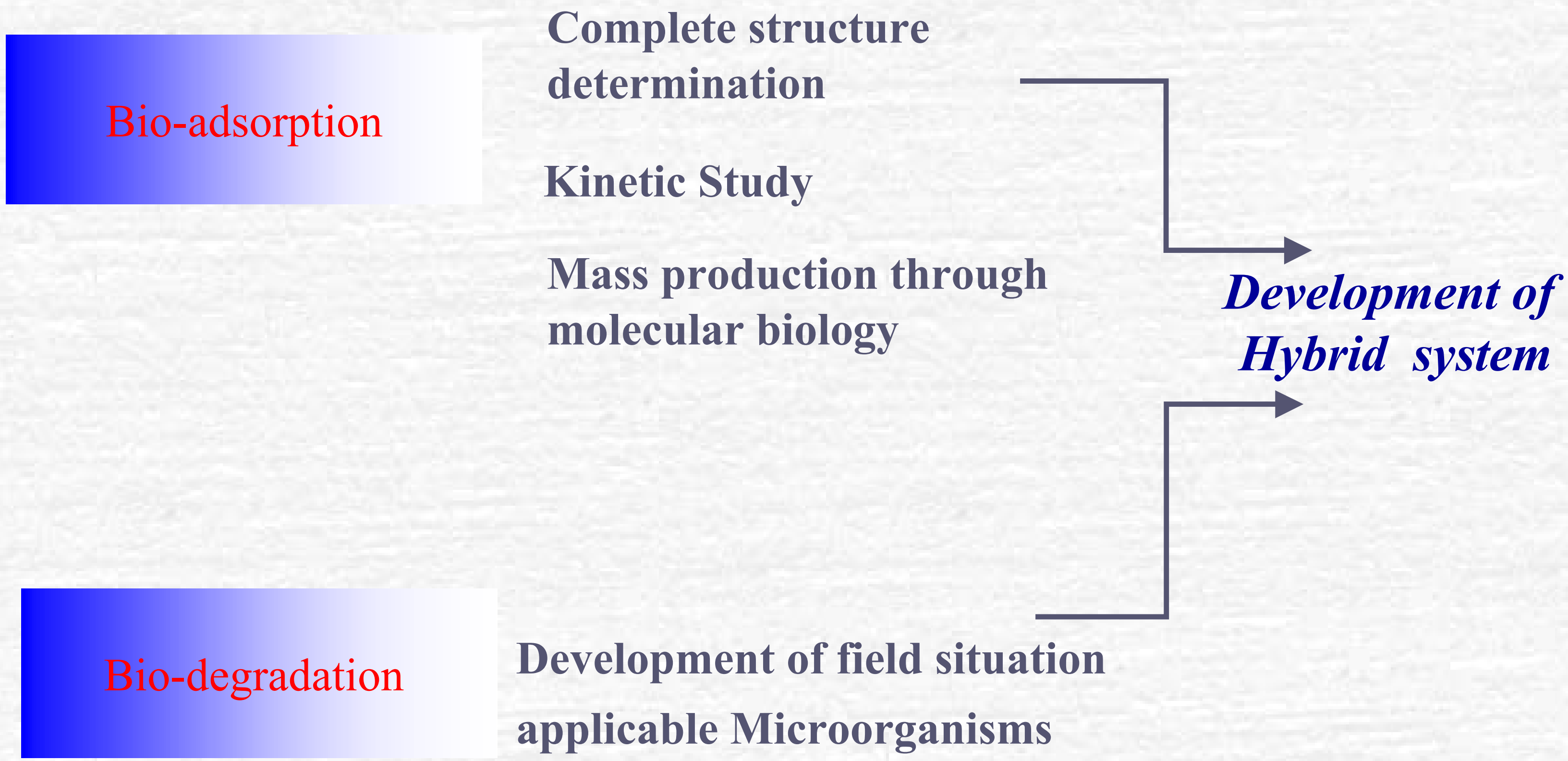
n-AQNVLCEVNSCR
FWADNSCTASTIK
IGK
STMTDVTR
NAETDCETFETQ-c

Results of Protein Molecular Modeling

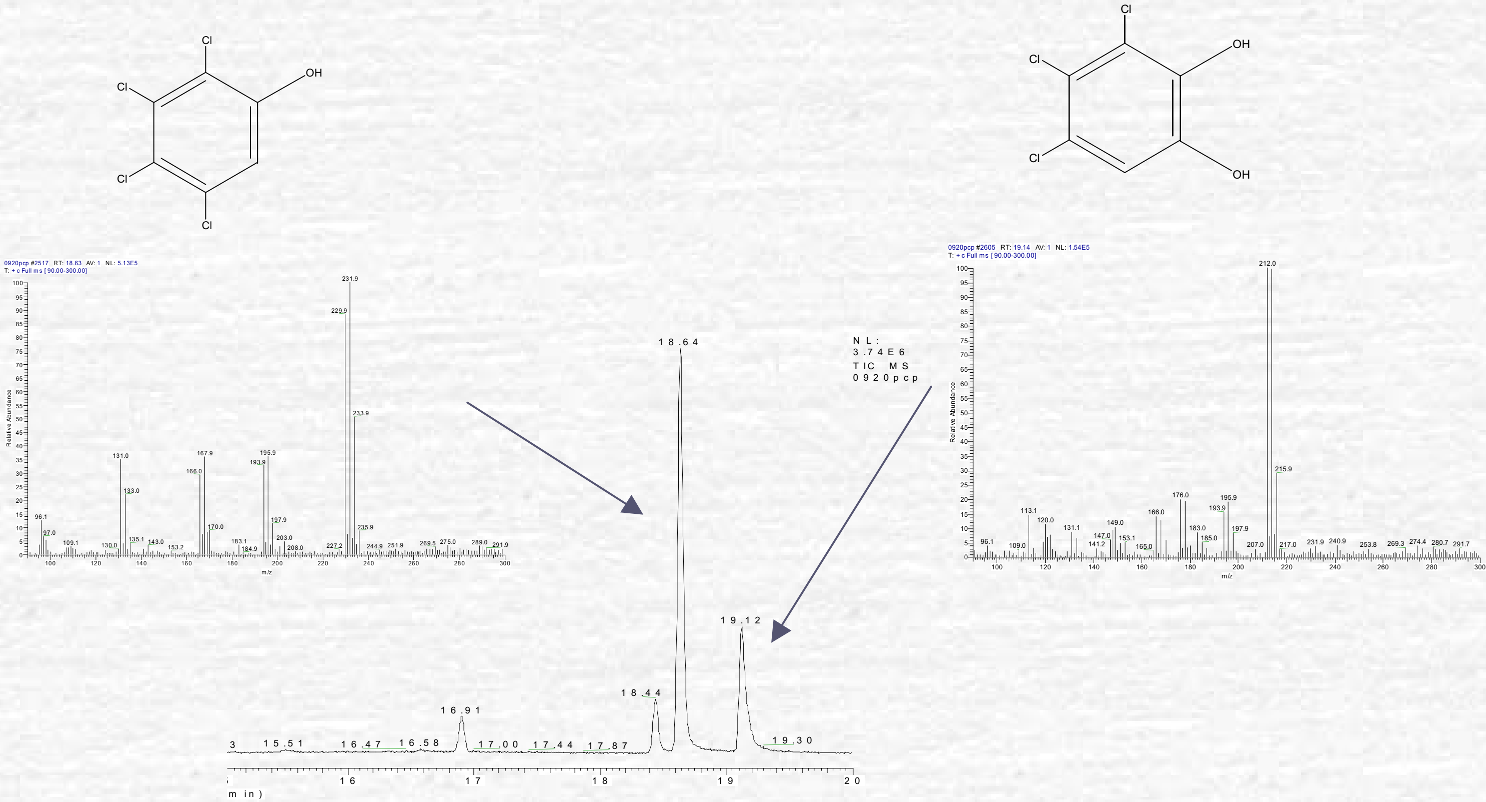


Adsorption of another dioxin isomers

Research on going



Bio-transformation of PCP by mixed culture



After 3months of incubation

다이옥신 관련 화합물을 분해 할수 있는 호기성 세균의 초기 효소, 기질, 공동 기질

세균	초기효소	기질(공통기질)
Acinetobacter sp. PE7	N.D	4-클로로-DE
Alcaligens Jb1	N.D	2-클로로-DD
Bacillus denitrificans (ATCC 13368)	N.D	TCDD
*Beiferinck*ia sp. B8/B6	디옥시게나제	DF,DD
DPO220	DF 4,4a-디옥시게나제	DF
Erwinia (mutated) CU3614	N.D	4-니트로-DE
E.coli JM107i	N.D	4-니트로-DE
P.cepacia	N.D	DE
P.cruciviae 593B1	N.D	DE
P. delafieldii ET1	N.D	3,4-POB
P. Pseudoalcaligens POB310	POB 1,2- 디옥시게나제	3,4-POB
P. B13-D5	POB 1,2- 디옥시게나제	3,4-POB
P. B13-D5C	POB 1,2- 디옥시게나제	3,4-POB
P. HL7B	N.D	DF
P. N.C.I.B 9816	디옥시게나제	DD
P. NSS2	POB 1,2- 디옥시게나제	3-POB, 4-POB
P. pBS3	N.D	DF
Rhodococcus sp. HH19K	N.D	DF
S. HH19K	DF 4,4a-디옥시게나제	DF
S. HH69	DF 4,4a-디옥시게나제	DF
S. RW1	DF 4,4a-디옥시게나제	DD,DF
S. SS3	DE 1,2-디옥시게나제	DE
S. SS31	DE 1,2-디옥시게나제	DE
S. SS33	DE 1,2-디옥시게나제	DE
Staphylococcus auriculans BDF63	DF 4,4a-디옥시게나제	DF
Terrabacter sp. DPO360	DF 4,4a-디옥시게나제	DF
Terrabacter sp. DPO1361	DF 4,4a-디옥시게나제	DF

참고: 첨단 환경기술 2000.12
약어
N.D : Not Detected　DE: 디페닐에테르　DD: 다이벤조-p-다이옥신　DF: 다이벤조퓨란　POB : 페녹시안식향산
P : *Pseudomonas*　S: *Sphingomonas*