Recent Approaches on the Feasible Mitigations & Clay Dispersal

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Six topics

I. Recent HABs & their impacts

II. Recent approaches on the HAB mitigation

III. Feasibility assessment for the actual application

IV. Clay dispersion and efficiency

V. Evaluation of the clay dispersal

VI. Conclusions and recommendations

I. Recent HABs & their impacts

Globally widespread including PICES region

World population
2005 : 6.4billion
PICES : onequarter

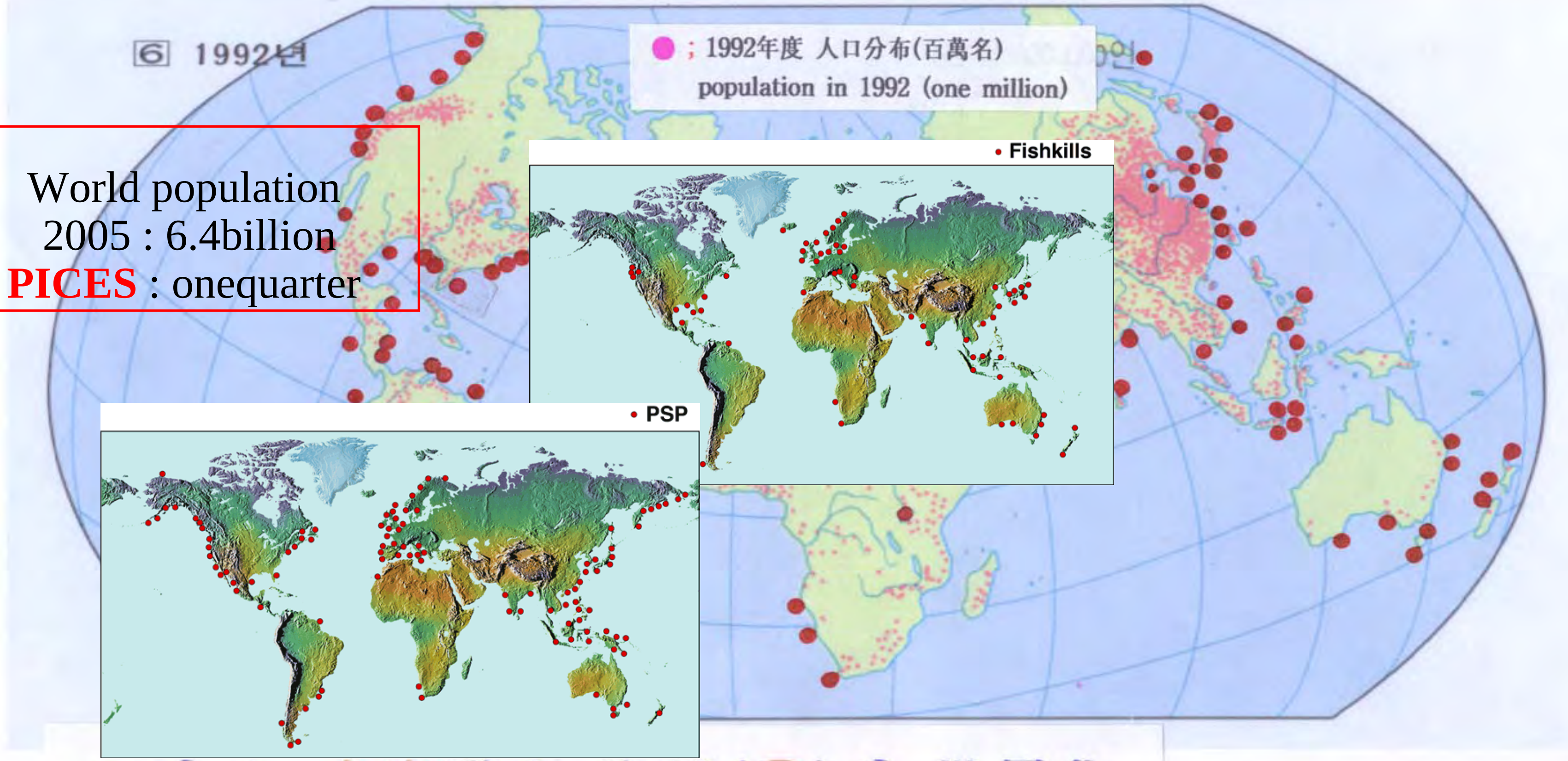
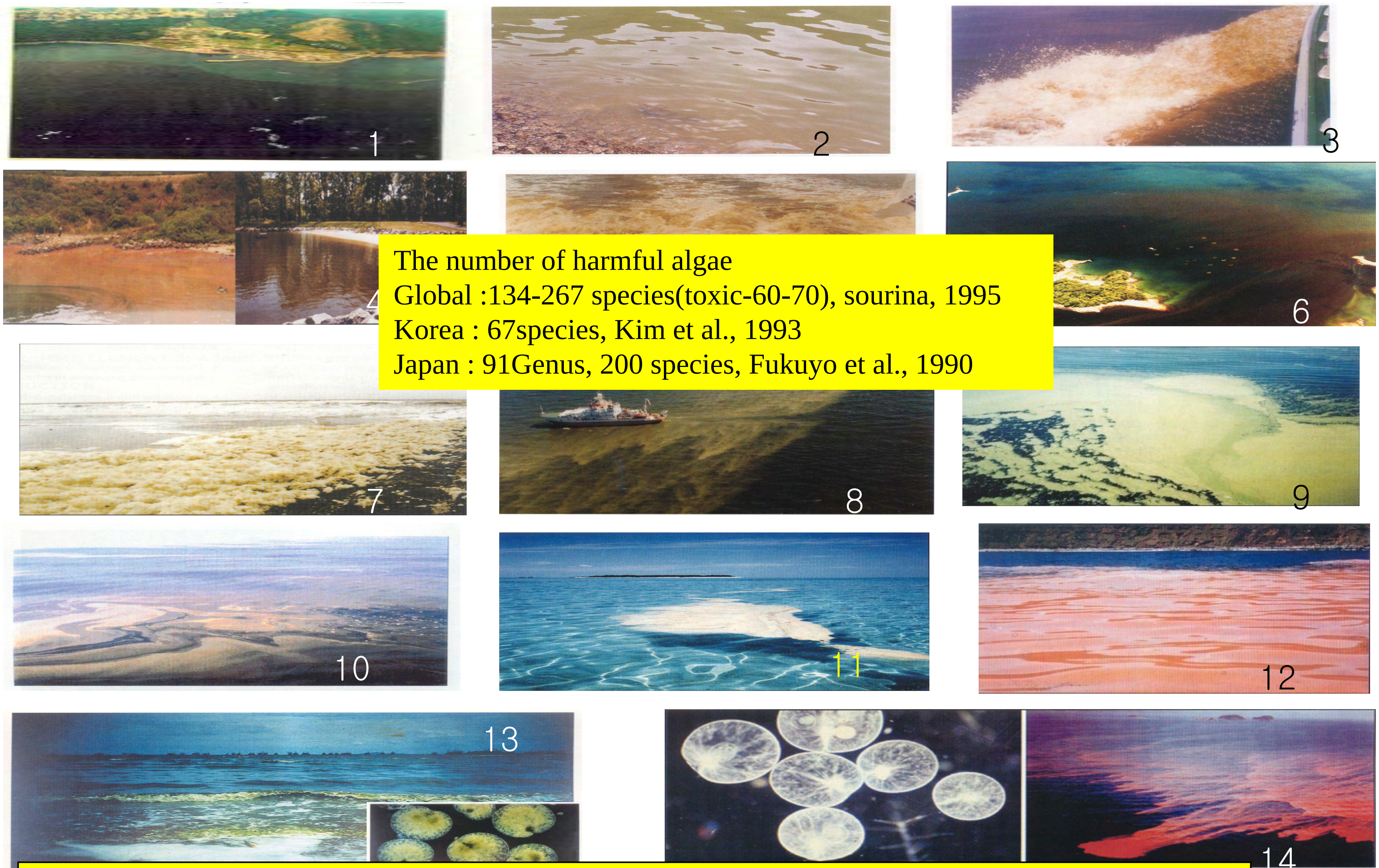


그림 1. 赤潮發生 海域(●)의 世界化
Globalization of HABs



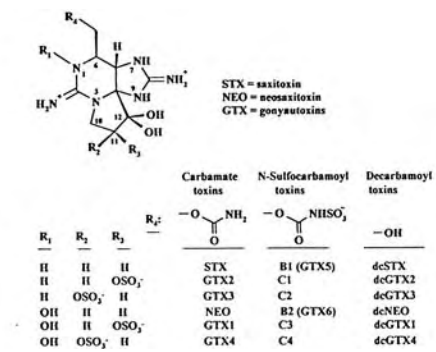
The number of harmful algae
Global :134-267 species(toxic-60-70), sourina, 1995
Korea : 67species, Kim et al., 1993
Japan : 91Genus, 200 species, Fukuyo et al., 1990

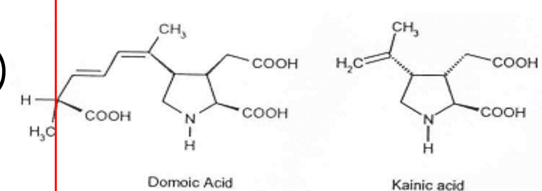
The HABs has many faces and hurt coastal aesthetics

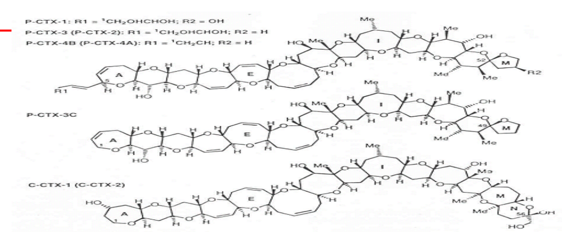
am et al.,
. *mikimotoi*
(한국,1981), 6. *K. mikimotoi* (일본), 7. *Phaeocysitis* (벨기에,1998), 8. Cyanobacteria (북해), 9. Cyanobacteria (북헤), 10. *Tricodesmium* (베트남,1999), 11. *Tricodesmium* (호주), 12. *Noctiluca* (호주), 13. *Noctiluca* (태국), 14. *Noctiluca* (일본,1976)

Variety in toxin profile

- Phycotoxin syndromes : PSP, DSP, ASP, NSP, CFP,PTX, YTX, AZA
- Toxigenic organisms : prokaryotic(blue green algae) to eukaryotic(diatoms, dinoflagellates)
- Toxin transfer pathway
  - Phytoplankton → shellfish → human health
  - Phytoplankton → finfish → human health
  - Phytoplankton → human health (***Pfiesteria***)







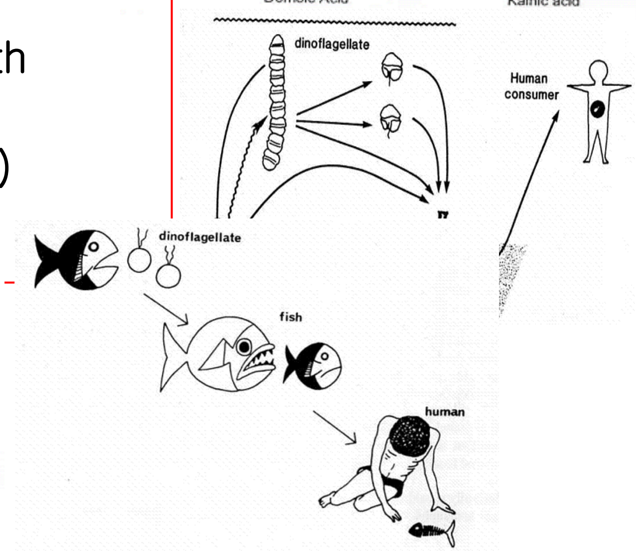


Fig. Transfer of toxins via marine animals to humans(Hallegraeff,1991)

그림 VIII-1. 유해적조 피해(출처 : 1 (한국 2002); 2, 3, 4, 5(GEOHAB, 2001); 6(Anderson, 1994). 1. 어류폐사 (한국,2002), 2. 어패류폐사, 3. 어류폐사(남아프리카, 1994), 4. 어류폐사 (미국,), 5. 가축피해, 6. Humpback 고래 (미국, 1987)

HABs and Mammals (Landsberg, 2008, USA)

Eutrophication in YS ! Is it boon or loom in 2020 ?

Yesterday-Yellow Sea

Today-Eutrophic Sea

Tomorrow-Anoxic Sea(?)

What shall we must do against such HABs?

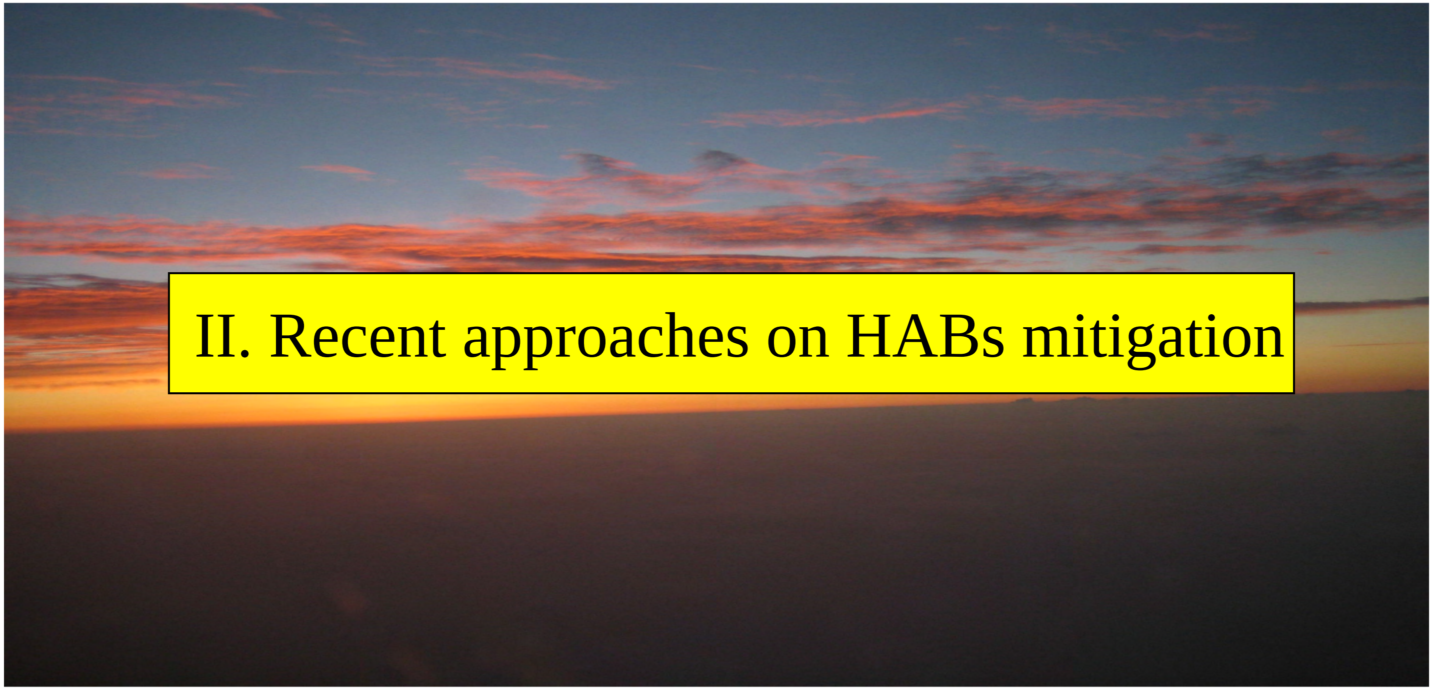
- Globally widespread
- Variety in discoloration
- Threaten whole trophic level
- Variety in toxin profile

- **Difficult to predict**
- **Overlapped with farmyards**
- **No ES practical mitigation**
- **Multi-transfer channels**

Does man can stop or minimize their impacts?

If yes, how to what?

II. Recent approaches on HABs mitigation



1. Principal HABs management & mitigation

- **Keep high environmental quality of no HABs**
  - Assess eutrophic state for coastal management
- **Regular monitoring and prediction**
- **Direct and indirect control of HABs**
  - protect living organisms from HABs
  - Separate HABs from living organisms
- **Subsidiary action to minimize economic loss**
  - Subsidiary money for fish-kill, closures of harvesting

Direct and indirect HABs control and available agents

- **Biological**
  - Grazing (top-down) – Copepods, ciliates, bivalves
  - Algicidal (bottom-up) - Bacteria, viruses
  - Parasites – *Amoebophrya, Parvilucifera*
  - Enzymes - Mannosidase
- **Physical**
  - Destruction – Ultrasound, Aponin
  - Electrolysis – Sodium hypochloride (NaoCl)
  - Filter & screening – centrifugal removal system
  - Dilution – pumping and artificial circulation
  - Wrapping – enclosure – shield curtain
- **Chemical**
  - Flocculants - clay and long-chain polymers
  - Surfactants – sophorolipid, aponin
  - Mucolytic coagulants – Cysteine compounds
  - Metals and lipids – copper, $Mg(OH)_2$. H_2O_2

2. Korean approaches for feasible mitigation

Many appearance of HABs controlling materials

- **When local government dispersed the clay to control *Cochlodinium polykrikoides* bloom, the private sector had an interests in controlling materials. They ask local government to use their products to control HABs.**

- **It needs us to establish a criteria to assess the feasibility of the materials to control HABs.**

참가물질의 적조구제효율

(신청순)

번호	기술 및 물질명	업 체 명	담당도	투입량	구제효율 (%)	준비량
1	소성굴패각	한국해양어장연구소	〃	1%	92	황토와 동일량 준비
2	수산화마그네슘 (세프레마)	포스텍(주)	〃	200ppm	90	황토대비 1/50 준비
3	액체 세라믹	리퀴드세라믹(주)	〃	500ppm	70	황토대비 1/20 준비
4	제오플럭	이앤텍(주)	〃	1,000ppm	90	황토대비 1/10 준비
5	단일광물 (적철석분말)	한국지질자원연구원	〃	1%	95	황토와 동일량 준비
6	탄화숯	한국하이테크(주)	〃	1%	95	황토와 동일량 준비
7	왕겨숯	숯초롱(주)	〃	1%	88	황토와 동일량 준비
8	옥분말	울진광업(주)	〃	0.5%	92	황토대비 1/2 준비
9	젯 스트리머	한국마린테크노(주)	〃	-	-	
10	이온화 산화칼슘	재성칼텍	〃	0.5%	97	황토대비 1/2 준비
11	석청수	석청(주)	〃	0.5%	89	황토대비 1/2 준비
12	Bio H/HGem	한신자원화학,보승형석광업소	〃	1%	96	황토와 동일량 준비
13	석회계개선제 (황금어장 1,2,3호)	-	〃	-	-	황토와 동일량 준비
14	BIO 200	대도세라텍(주)	〃	1%	86	황토와 동일량 준비
15	MOG	삼우하이텍	〃	0.25%	99	황토대비 1/4 준비

적조방제기술 및 물질 현장실험 신청현황

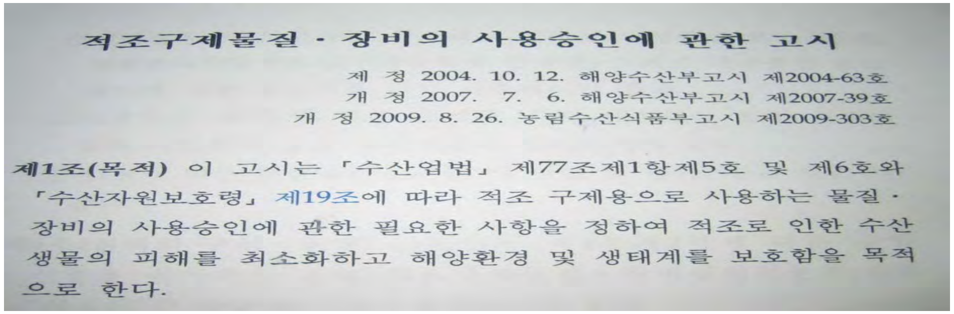
번호	기술 및 물질명	주 소	업 체 명	성 명	연 락 처	담당도
1	해저광물	통영 우체국 사서함 15	명승산업(주)	이정수	055-648-4342 011-9041-9187	경남도
2	소성굴패각, 알루미나	마산 합성 2동 145-3	한국해양어장연구소	박남종	055-295-3953 016-590-3953	〃
3	세프레마	포항 남구 청림동 1-143	포스텍(주)	황원철	054-290-0653	〃
4	순수액체 세라믹	창원 대원 96-5 우신프라자 7층	리퀴드세라믹(주)	김태희	055-237-8833 011-9528-9724	〃
5	제오플럭	울산 울주 웅촌 곡천리 249-1	이앤텍(주)	원종수	052-277-9101	〃
6	적철석분말	대전 유성 가정동 30	한국지질자원연구원	이태섭	042-868-3120	〃
7	황토석가루	대구 남구 대명 3동 2310-10	BLUE JTAR IN.C	예병록	053-651-5275	〃
8	탄화숯	함안 산인 신산 578-10	한국하이테크(주)	박명수	055-582-9960	〃
9	왕겨숯	인천 강화 불은 삼동암리 779	숯초롱(주)	최정원	032-937-3161	〃
10	옥분말	경북 봉화 소천 고선리 340-3	울진광업(주)	박상준	054-674-1333	〃
11	젯스트리머	서울 관악 남현 1506-28 동해빌딩	한국마린테크노(주)	전종우	02-586-0058	〃
12	적토사	경기도 안산시 상록구 본오동 879-15, 태영 APT. 203-1406		최관오	031-407-9586	전남도
13	산화칼슘(이온화 산화칼슘)	서울시 노원구 상계 1동 은빛 APT. 107-203	재성칼텍	소성훈	02-934-3123	〃
14	석청수	부산광역시 해운대구 중 1동 크리스탈비치 1016	석청(주)	김석태	051-742-6513 011-9749-5666	〃
15	Bio H/HGem	서울시 중구 신당동 370-100	한신자원화학,보승형석광업소	신종호	02-2253-6338 054-279-2281	〃
16	석회계개선제	여수시 덕충동 1632-1		양한준	061-662-2734 011-9442-2734	〃
17	비금속광물 (소성황토 및 비금속광물첨가제)	서울시 강남구 신사동 528-4 화인빌딩	대도세라텍(주)	차영준	02-543-8899	〃

What will be feasible mitigation?

- *Remove efficiently – high clearance rate*
- *Secure the stability of coastal ecosystem and the safety of marine animals as well*
- *Easy handling and reasonable price*

Environmentally kind feasible HABs control

For the first time--


적조구제물질 · 장비의 사용승인에 관한 고시

제 정 2004. 10. 12. 해양수산부고시 제2004-63호
개 정 2007. 7. 6. 해양수산부고시 제2007-39호
개 정 2009. 8. 26. 농림수산식품부고시 제2009-303호

제1조(목적) 이 고시는 「수산업법」 제77조제1항제5호 및 제6호와 「수산자원보호령」 제19조에 따라 적조 구제용으로 사용하는 물질 · 장비의 사용승인에 관한 필요한 사항을 정하여 적조로 인한 수산생물의 피해를 최소화하고 해양환경 및 생태계를 보호함을 목적으로 한다.

Ministerial order to allow the use of materials and facilities to control HABs – No. 2009-303

- enacted by MOMAF, October 12, 2004
- amended by MOMAF, July 6, 2007
- amended by Ministry of agriculture, forestry, fisheries, and food processing, August 26, 2009

Major provisions of the ministerial order

- **Objectives**
  - Procedures to issue license for actual application
  - Minimize the impacts on marine organisms
  - Secure the stability of coastal ecosystem

- **Application targets**
  - Materials for the purpose of HABs control
  - Facilities for the purpose of HABs control

Major provisions of the ministerial order

- **Assessment items for feasibility**
  - Analyze chemical constituents of the materials
  - Examine feasibility of the material and facilities to assess removal rate, impacts on marine organisms and ecosystem, handling methods, and economic evaluation

- **Assessment judging Committee**
  - 17 members composed of experts and scientists

- **Authorized organizations to assess the feasibility**
  - 3 institutes for the determination of chemical constituents
  - 10 universities and 1 institute to examine the feasibility of the materials and facilities

Methodology to assess the feasibility of application targets

- **Materials for the purpose of HABs control**
  - **Solid and powder state**
    - Analyze all constituents of the material
    - Classify constituents by natural and artificial
    - Analyze particle size and their composition
  - **Liquid state**
    - Analyze all constituents of the material
    - Analyze all heavy metal, organic matter, macromolecule qualitatively and quantitatively
    - Classify constituents by natural and artificial
  - **Hazardous chemicals**
    - POPs-Cr, As, Cd, Pb, Zn, Cu, Se, CN, Hg, PCB, phenol etc.

Assessment items and criteria for target materials

- **5 assessment items and criteria to give grade point for each items**
  - **5 grades : excellent(5), good(4), passable(3), insufficient(2), inadequate(1)**

- Removal efficiency at the concentration of no impacts on marine organisms (weight 4)
  - Over 90% - 5points, 89-80% - 4points, 79-70% - 3points
- Bioassay toxicity on fish, shellfish, and algae (weight 4)
  - Over 90% of the survival rate of the control test – 5points
- Impacts on marine ecosystem (weight 9)
  - Water quality (2) – changes below 10% after use – 5points
  - Sediment (1) - changes below 10% after use – 5points
  - Plankton species (2) - changes below 10% after use – 5points
  - Plankton density (2) - changes below 10% after use – 5points
  - Benthos and aquaculture animals (2) - changes below 10% after use – 5points
- Handling method (weight 1) – simple and no accessory instrument – 5points
- Economic evaluation (weight 2) – cost 1.5 times of clay – 5points

Assessment items and criteria for target facilities

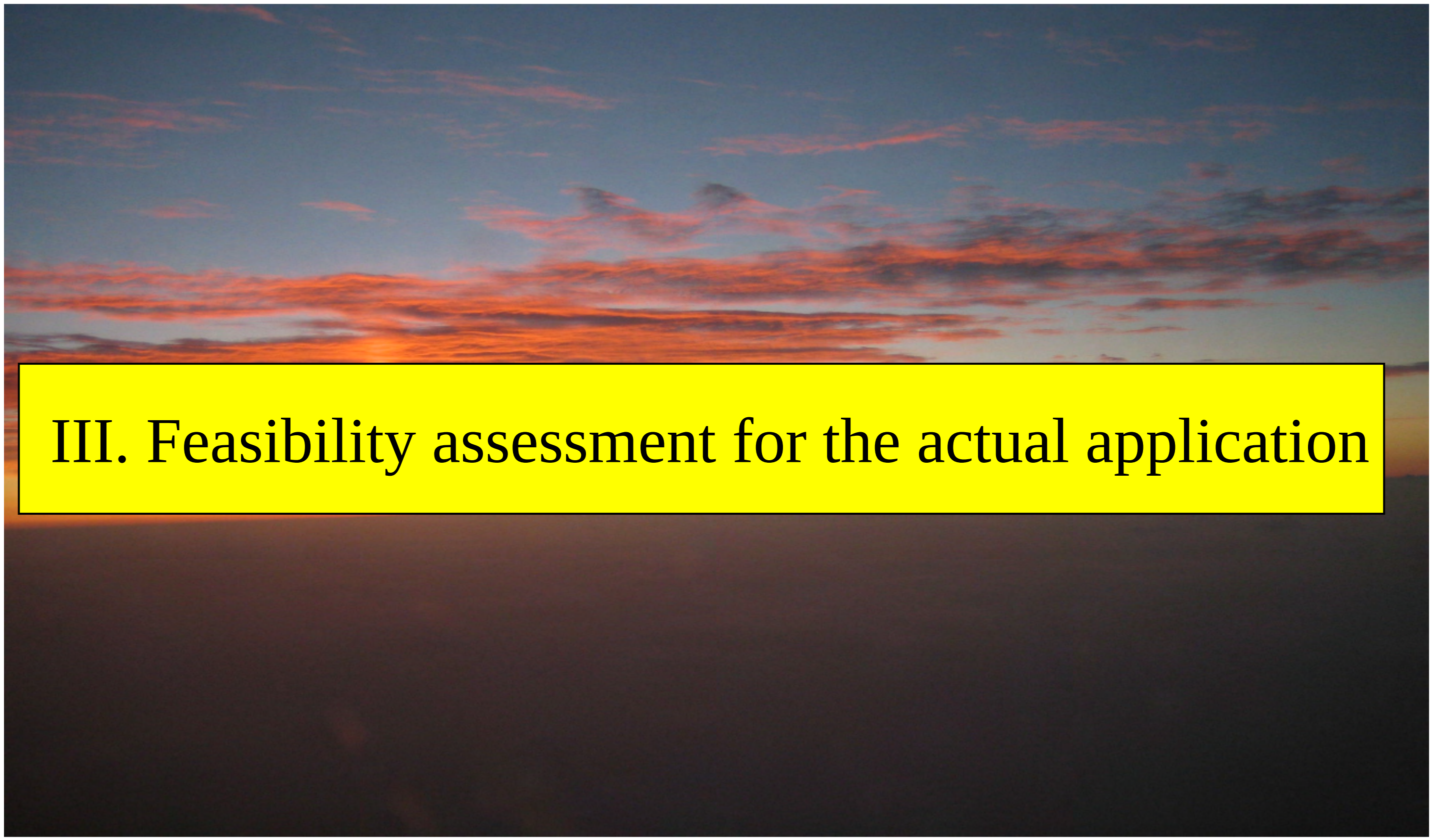
- **4 assessment items and criteria to give grade point for each items**
  – 5 grades : excellent(5), good(4), passable(3), insufficient(2), inadequate(1)

- Removal efficiency after 1 hour operation (weight 5)
  - Over 90% - 5points, 89-80% - 4points, 79-70% - 3points
- Bioassay toxicity on fish, shellfish, and algae (weight 3)
  - Over 90% of the survival rate of the control test – 5points
- Impacts on marine ecosystem & handling methods (weight 10)
  - No impact on marine ecosystem and safe operation - 5points
- Economic evaluation (weight 2) – cost less than clay – 5points

Criteria to judge the feasibility of facilities

- **Over 80 points - Recommend to use for actual application in the sea**
- **70 – 79 points – apply again after complement and supplement**
- **Below 69 points – inconformity with criteria**

- **Even the total grade point exceeds 80 points, the target materials be judged as recommend to use can not be allowed when judging committee assess the materials has a potential negative impacts on marine organisms and marine ecosystem,**


III. Feasibility assessment for the actual application

1. Korean actions for HAB management and mitigations

Category	Before HAB	After HAB

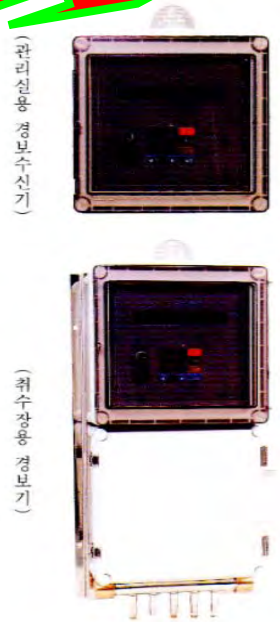
Precautionary impact preventions	■ Regular and emergent monitoring
	■ Real-time fuzzy prediction
	■ Precautionary actions
	  ■ early harvesting
	  ■ provide less feed to fish
	  ■ prepare mitigation facilities
	  ■ pump/aspirator
		■ Emergent actions
		  ■ Move pens to refuge site
		  ■ Enclosure of fish cages
		  ■ Water circulation
		  ■ Oxygenation- aeration
		  ■ Ozonization

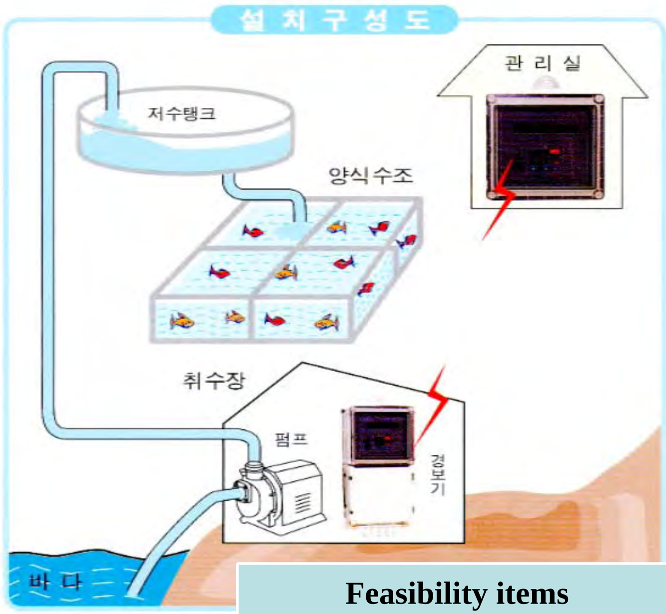
Bloom controls	■ Indirect controls
	  ■ Reduce nutrient inputs
	  ■ Modification of water circulation
	  ■ Transport clay to the site
		■ Direct controls
		  ■ Physical control
		  ■ Chemical control
		  ■ Biological control

2. On-going actual mitigations other than clay

- HAB-alarm system – land –based tank culture
- Centrifugal removing – land based tank culture
- Pumping bottom water to surface – Mari-culture
- Wave resistant offshore cage – Mari-culture

HAB alarm system

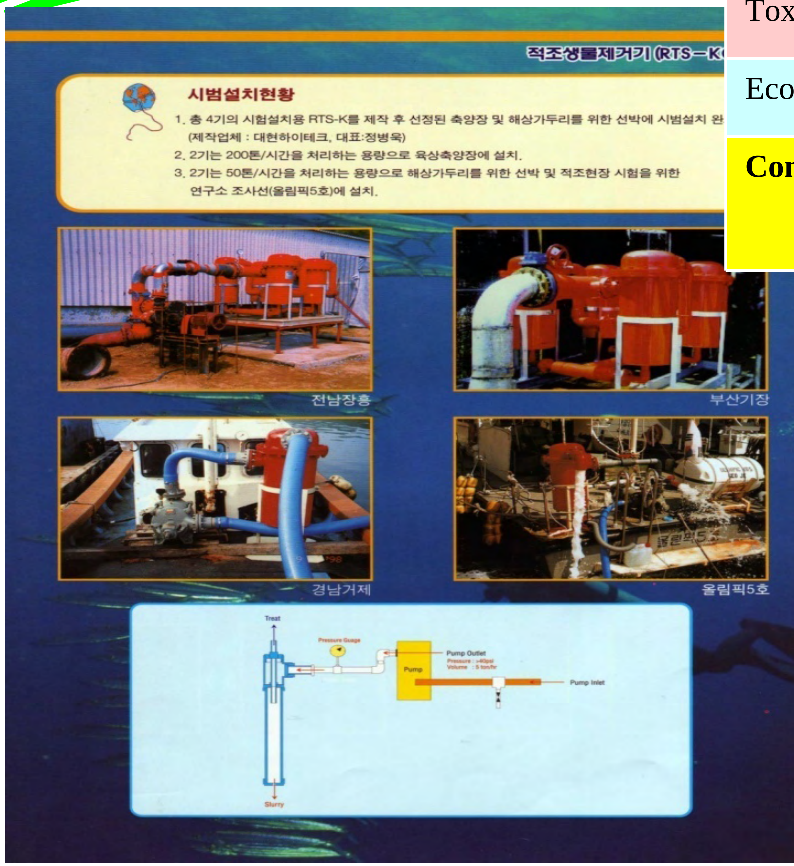




Feasibility items	conformity with instruction
Removal efficiency	Alarm instrument
Impacts on coastal ecosystem	No requirement
Toxicity on fish and shellfish	No requirement
Economic evaluation	1system = 7,000US$
Comments	Land based culture tank

Centrifugal removing

Feasibility items	conformity with instruction
Removal efficiency	Filter target algae
Impacts on coastal ecosystem	No requirement
Toxicity on fish and shellfish	No requirement
Economic evaluation	1system = 20,000US$
Comments	Land based culture tank Supply filtered seawater to tank Hard to treat filtered remnants

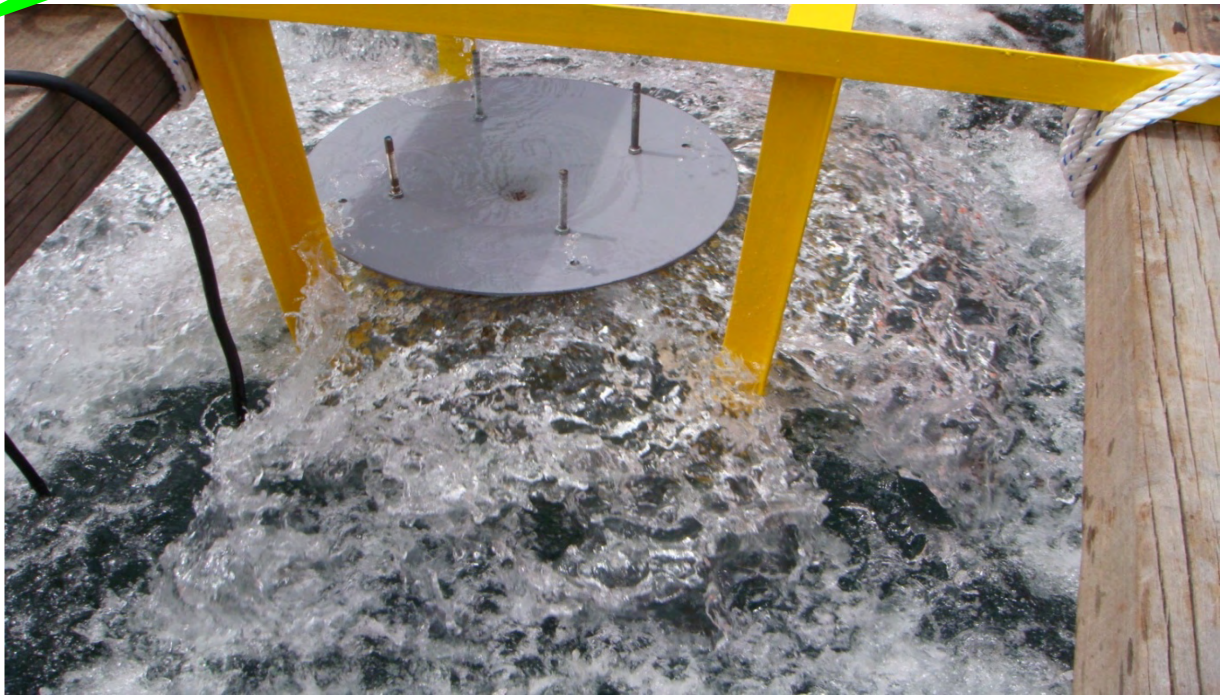


Pumping bottom water to surface

Feasibility items	conformity with instruction
Removal efficiency	Dilute high density
Impacts on coastal ecosystem	No requirement
Toxicity on fish and shellfish	No requirement
Economic evaluation	1set for 4 cages = 10,000US$
Comments	Popular in fish cages

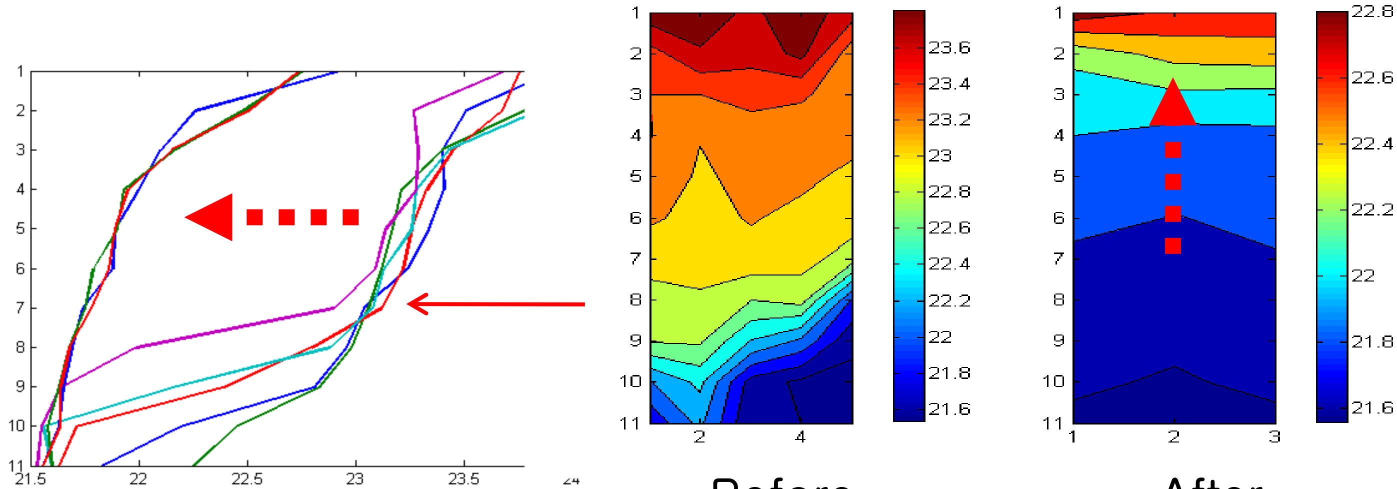
Pumping bottom cold water and spray on the surface of the fish cages

New pumping device



1for 4cages =   14,000US$

The surface warm water replaced by cold bottom water by pumping



Before After

2008.7.14(Yeosu Hwatae-do)

Wave resistant offshore cage

Feasibility items	conformity with instruction
Removal efficiency	Move to zone free of HABs
Impacts on coastal ecosystem	No requirement
Toxicity on fish and shellfish	No requirement
Economic evaluation	1system = 10,000US$
Comments	Wave resistant offshore cage

2. The other candidate mitigations from private sector

Feasibility items	Biocontrol	NaOCl	Zeolite
Removal efficiency	Bacteria : bottom-up Grazer : top-down	High	Efficient
Impacts on coastal ecosystem	Hard to secure the safety of ecosystem	Lethal to protozoa at 0.3ppm	Allowable
Toxicity on fish and shellfish	No requirement	Lethal to fish at 2-5ppm	Allowable
Economic evaluation	Mass production	Available	More expensive than yellow clay
Comments	Promising but need more study	Liquid handling Toxic in cloud	Recommend for emergent use

2. The other candidate mitigations from private sector

Feasibility items	Ultrasonic with O_3	Shield curtain	Sophorolipid
Removal efficiency	Destruct and oxidize at the surface	enclosure	Same as clay
Impacts on coastal ecosystem	Allowable	No requirement	Allowable
Toxicity on fish and shellfish	Allowable	No requirement	Allowable
Economic evaluation	Expensive	Expensive	Acceptable
Comments	Small scale, surface bloom	Fouling organisms	Small scale, Use with clay

IV. Clay dispersion and feasibilities

1. The clay dispersal *in situ* or *in vitro*

- **Shirota, 1980 , Murayama et al., 1987**
- **Kim, 1986**
- **Kim, 1995,   Na et al., 1996,   Choi et al, 1998, 1999**
- **Sengco, et. al., 2000**

Pierce, R.H. et al., 2004	Lewis, M.A. et al., 2003
Beaulieu et al., 2005	Archambault et al., 2004
Atkins et al., 2001	Culter et al., 2004
Hagstrom & Graneli, 2005	Lee et al., 2008

The progress in clay dispersal

Pilot stage : manual dispersing in 1986

Kim,1986

2nd stage :
Disperse clays by oil spill dispersant ship from 1996

그림 8. 황토를 적재한 운반선에 해수를 살수하여 황토가 저절로 바다에 유출되는 장면

First clay dispersal by local government since 1996
Bilateral budget by central and local government since 1998

3rd stage :
Dispersing clays by electrolization system from 1999

Direct shooting

- **Can make direct shooting**
- **Reduce the amount of clay dispersed**
- **More effective in removing target cells**

Photos showing clay disperser equipped with a seawater electrolization system.

The clay dispersing at the rear side of the dispenser

Frontal shooting

2001년 8월 30일 부산일보

유독성 적조가 동해안까지 확산하고 있는 가운데 29일 오후 검붉게 변한 울산시 울주군 서생면 앞바다에서 바지선을 이용한 황토살포 작업이 한창이다.
김경현기자 view@

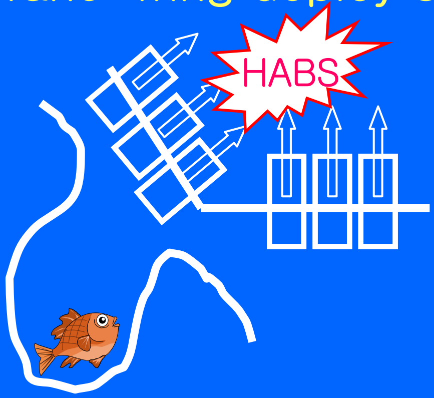
Mouth blockade shooting

Merry-go-round shooting

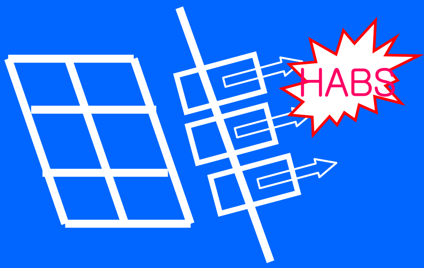
Aerial view of clay dispersion in South Sea

Field strategies for clay dispersion

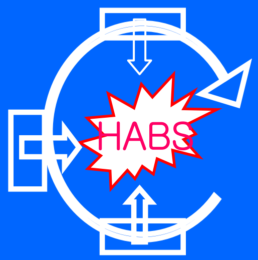
Crane-wing deploy shooting



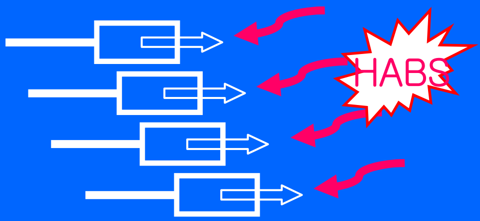
Frontal shooting



Merry-go-round shooting



Parallel shooting



2. The physical and chemical characteristics of the clay

- **pH : 4.3 ~ 6.2**
- **Cation exchange capacity(CEC) : 4~ 13 meq/100g**
- **Major constituents**

- $SiO2$ (43 ~ 76%), - Al_2O_3 (13 ~ 24%)

- Fe_2O_3 (2 ~ 12%), - MgO (0.5 ~ 2.9%)

- K_2O (1.7 ~ 4.8%)

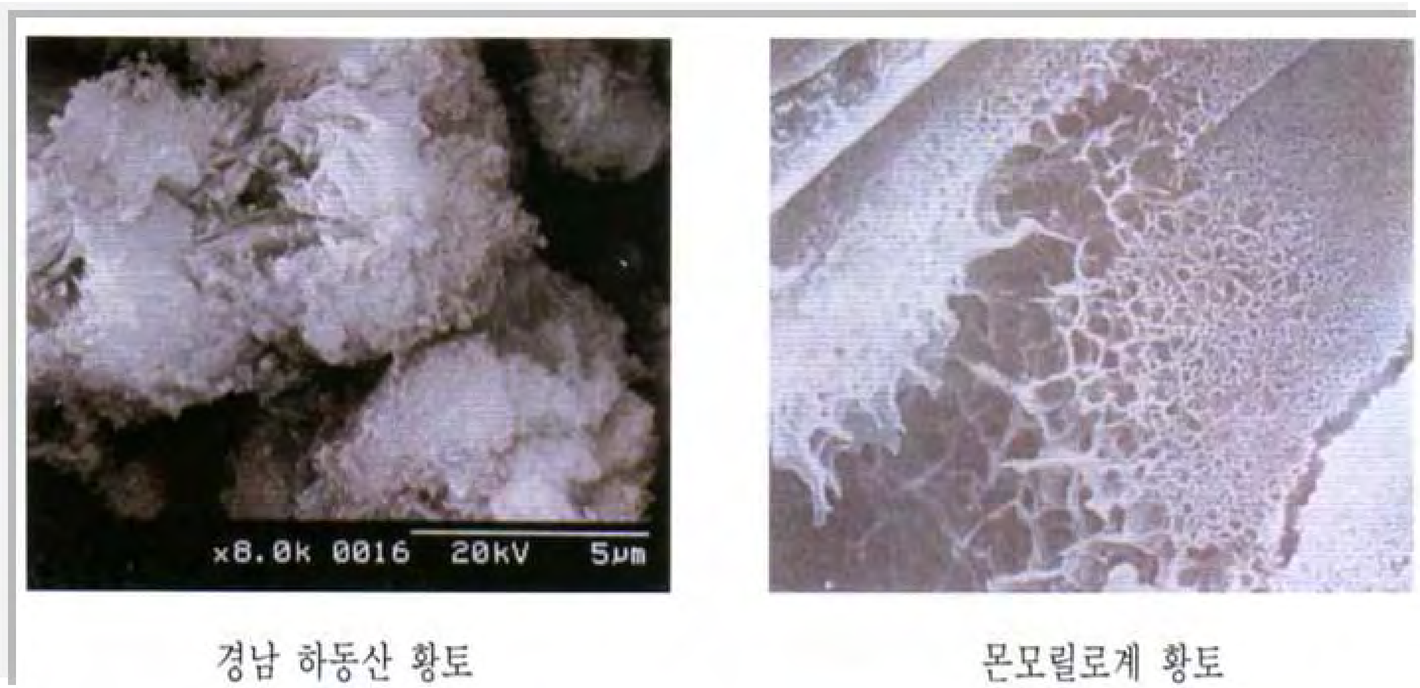


Fig. SEM micrograph of clay crystal, Hadong clay and Montmorillite clay (NFRDI, 2002).

Elimination of harmful algae by yellow clay

HAB species		Elimination (%)			
		Elapsed time (min)			
		0	10	30	60
C. Polykrikoides		77 - 79	85 - 88	89 - 91	90 - 92
H. Akashiwo		68 - 74	74 - 78	81 - 85	84 - 89
P. micans		60 - 68	65 - 68	74 - 76	80 - 83
G. impudicam		80 - 84	85 - 89	90 - 92	91 - 93

Cell density : 3000cells/mL, Yellow clay concentration 10g/L

Fig. The live *Cochlodinium polykrikoides* cells before and after the clay dispersal (NFRDI, 2002).

The removal efficiency of clay

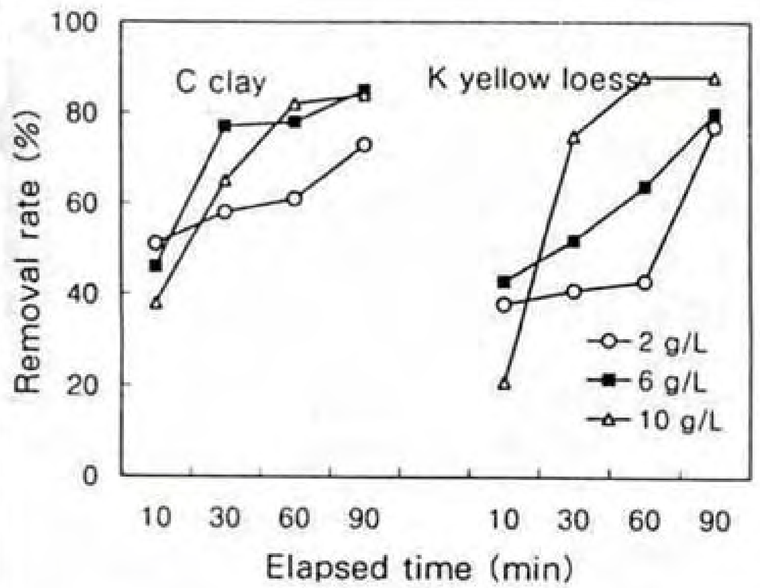


Fig. 2. Removal rate of *C. polykrikoides* according to the elapsed time at different concentration of clay and yellow loess.

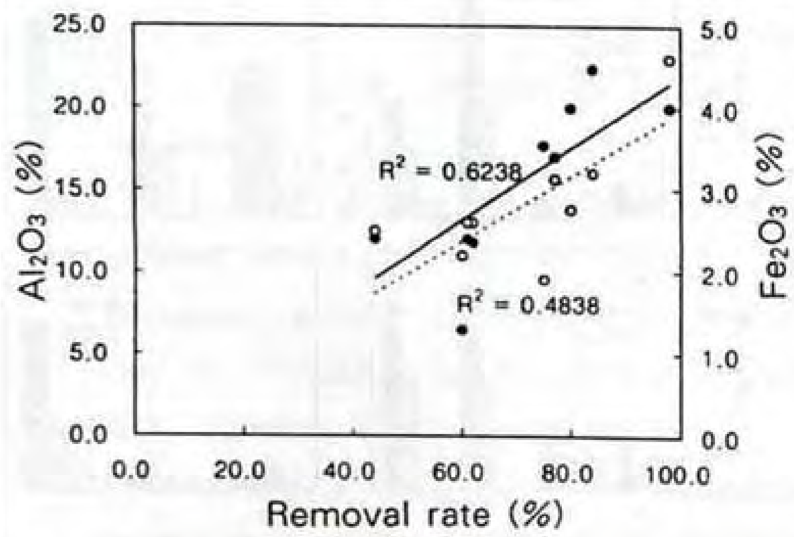


Fig. 3. Correlation between removal rate of *C. polykrikoides* and chemical species of Al_2O_3 (●) and Fe_2O_3 (○) in clays and yellow loess.

Choi *et al*., 1999

The removal efficiency of clay(10g/l) near Tongyong in Sep. 1996.

Table 1. Removal efficiency of Cochlodinium after the dispersion of yellow loess in Tongyong (unit : cells/ml)

Site & Date			*Cochlodinium Density*		
			Before dispersion	10 min after dispersion	30 min after dispersion
Tongyong Sanyang-up	Sep. 19	0 m	900	–	180
Woalmok - Obido	Sep. 23	0 m	1,500	910	420
	〃	3 m	2,500	875	450
	〃	8 m	300	–	55
Minam - ri	Sep. 19	0 m	650	–	120
	Sep. 23	0 m	600	–	100
	〃	3 m	400	–	80
	〃	8 m	300	–	50

Choi *et al.*, 1998

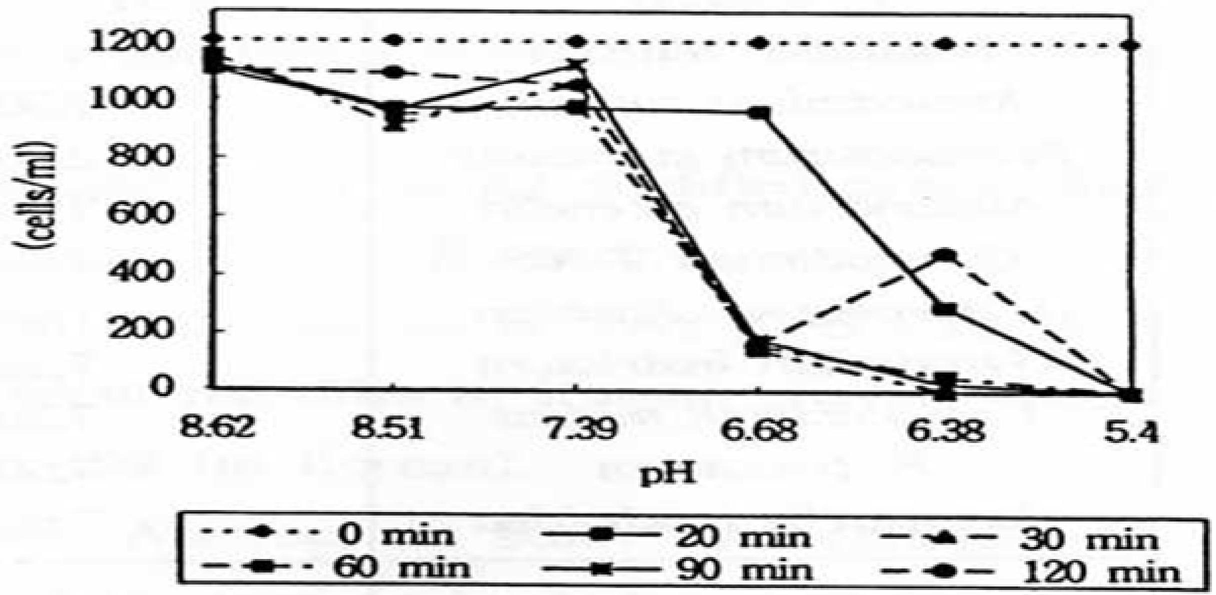


Fig. 4. Removal efficiency *Cochlodinium* with pH.

pH 6(low acid) enhance the removal efficiency of clay

Choi *et al.*, 1998

The removal efficiency of montmorillonite clay

Species	Concentration	Effect
Cochlodinium '78	110 - 400 g/m^3	Good
Chattonella sp.	1,300 - 2,200 ppm	〃
C. antiqua	6,000 - 13,000 ppm	〃
Noctilluca miliaris	mix with seawater	〃
Mesodinium rubrum	7,500 ppm	* 100% destruction
Prorocentrum sigmoidis	2,000 ppm	90% sedimentation
Alexandrium catenella	7,500 ppm	* 89.3% stop moving
Gymnodinium T-'65	7,500 ppm	* 88.9% stop moving
Heterosigma akashiwo	7,500 ppm	* 100% shape change
Gyrodinium instriatum	7,500 ppm	* 78.7% shape change
Prorocentrum micans	7,500 ppm	* 100% stop moving
P. triestinum	7,500 ppm	* 100% stop moving
Scrippsiella trochoidea	7,500 ppm	* 100% stop moving
Leptocylindrus danicus	90 g/m^3	Poor
Ceratium fusus	2,000 ppm	Poor

Shirota, 1987

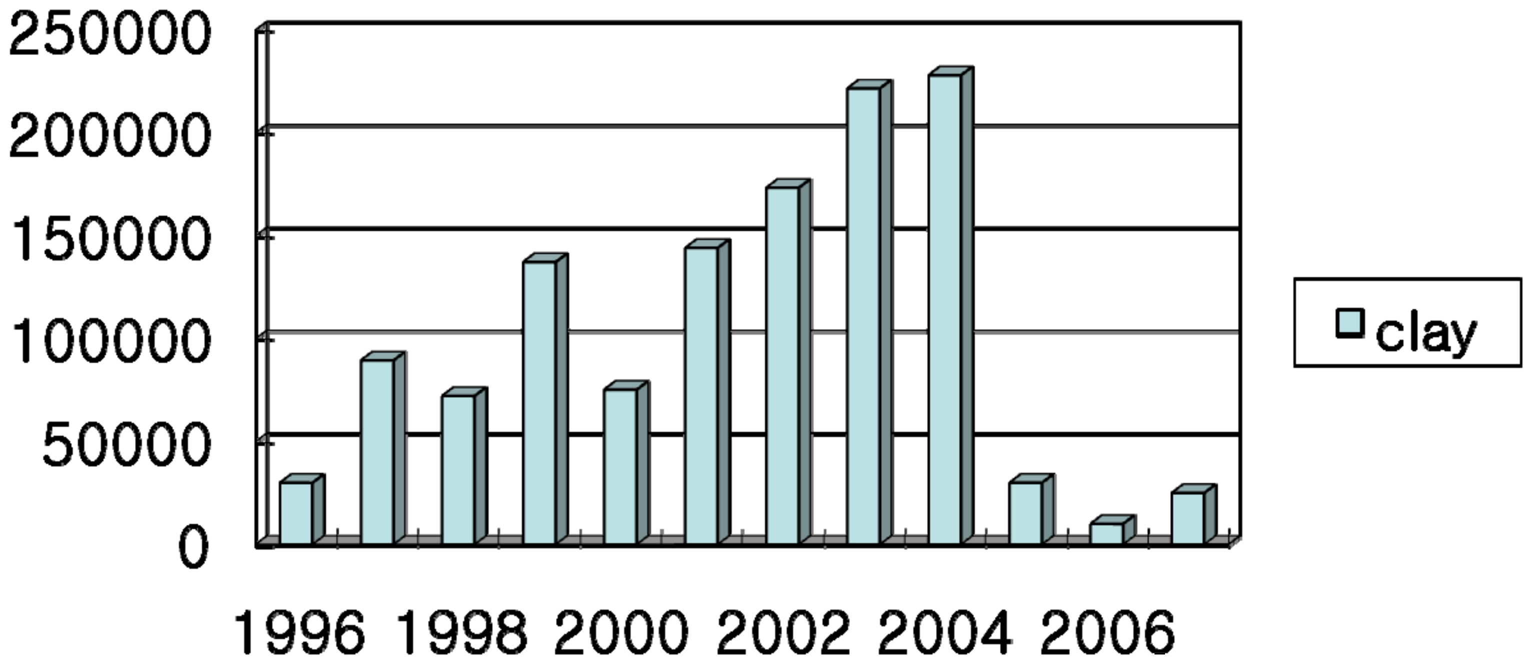


Fig. The annual amount of clay dispersed (ton) since 1996.

3. Ecological impacts and assessment

Water and sediment samplings

The water quality before and after the dispersal of clay (10g/l) near Tongyong in Sep. 1996.

Site	Layer (m)	Dispersion	W.T (℃)	pH	DO	COD	SS	Chl.a	DIP	NH_4-N	NO_2-N	NO_3-N	DIN	SiO_2-Si
					(mg/ℓ)			(μg/ℓ)	(μM)					
Woalmok - Obido	0	Before	24.65	7.79	10.33	3.01	10.5	7.93	0.45	10.41	0.30	1.13	18.84	12.14
		After	24.70	7.89	8.85	1.70	11.5	6.46	0.47	7.81	0.04	0.51	8.36	10.89
	3	Before	23.91	7.80	9.02	3.47	12.5	10.74	0.18	3.26	0.04	0.51	3.81	13.31
		After	23.72	7.81	8.68	1.61	13.0	4.51	0.44	4.13	0.04	0.24	4.41	10.62
	8	Before	23.60	7.75	9.02	0.83	7.8	2.84	0.62	6.94	0.02	0.67	7.63	13.31
Minam-ri	0	Before	23.00	7.84	8.28	0.47	7.8	6.80	0.52	7.37	0.03	0.29	7.69	9.37
		After	22.94	7.86	8.22	0.69	10.3	3.01	0.44	3.98	0.59	0.19	4.76	9.81
	4	Before	23.02	7.86	8.17	0.99	11.5	8.85	0.63	6.58	0.07	0.85	7.50	12.32
		After	22.29	7.80	7.74	0.44	13.5	5.29	0.52	4.05	0.13	1.89	6.07	14.56

Decrease COD and dissolved nitrogen

Choi *et al*., 1998

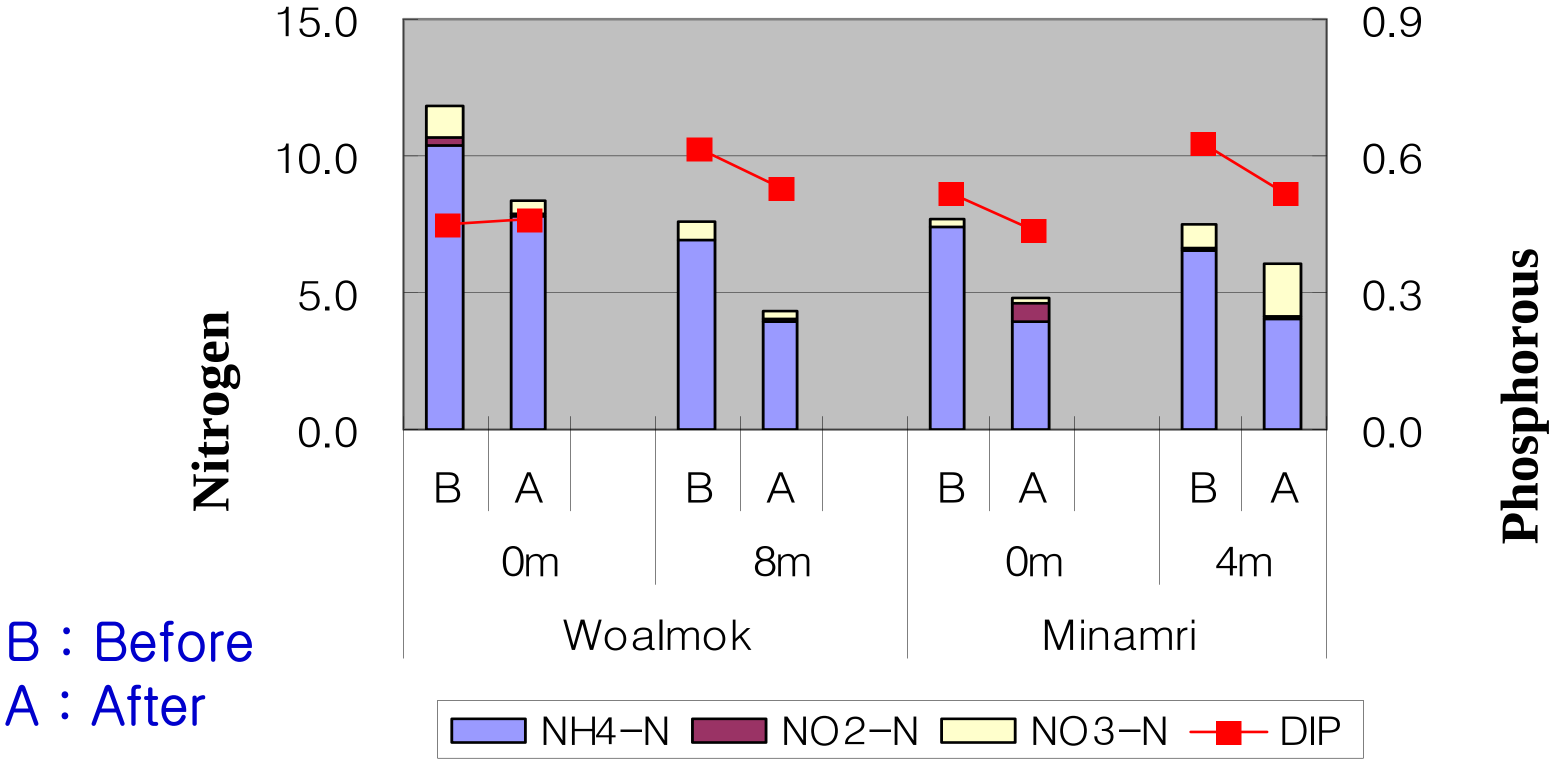
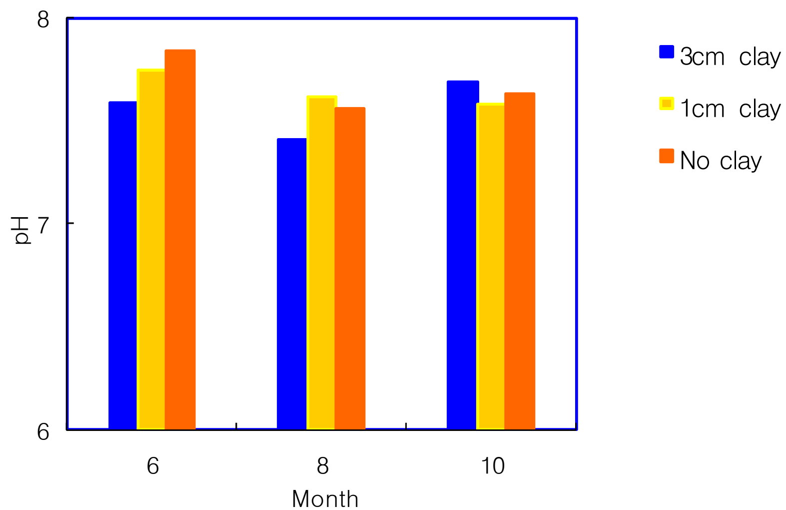


Fig. Effects of yellow clay on water quality

pH of surface sediment and distribution of AVS



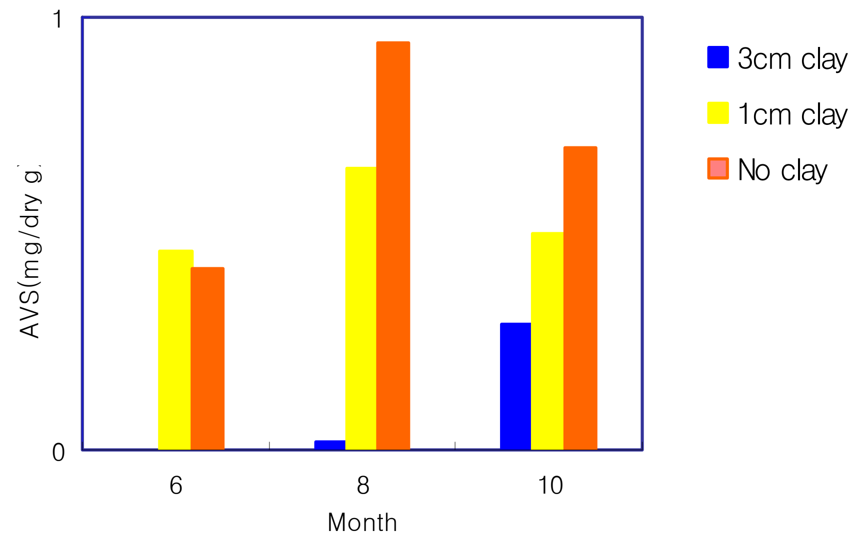
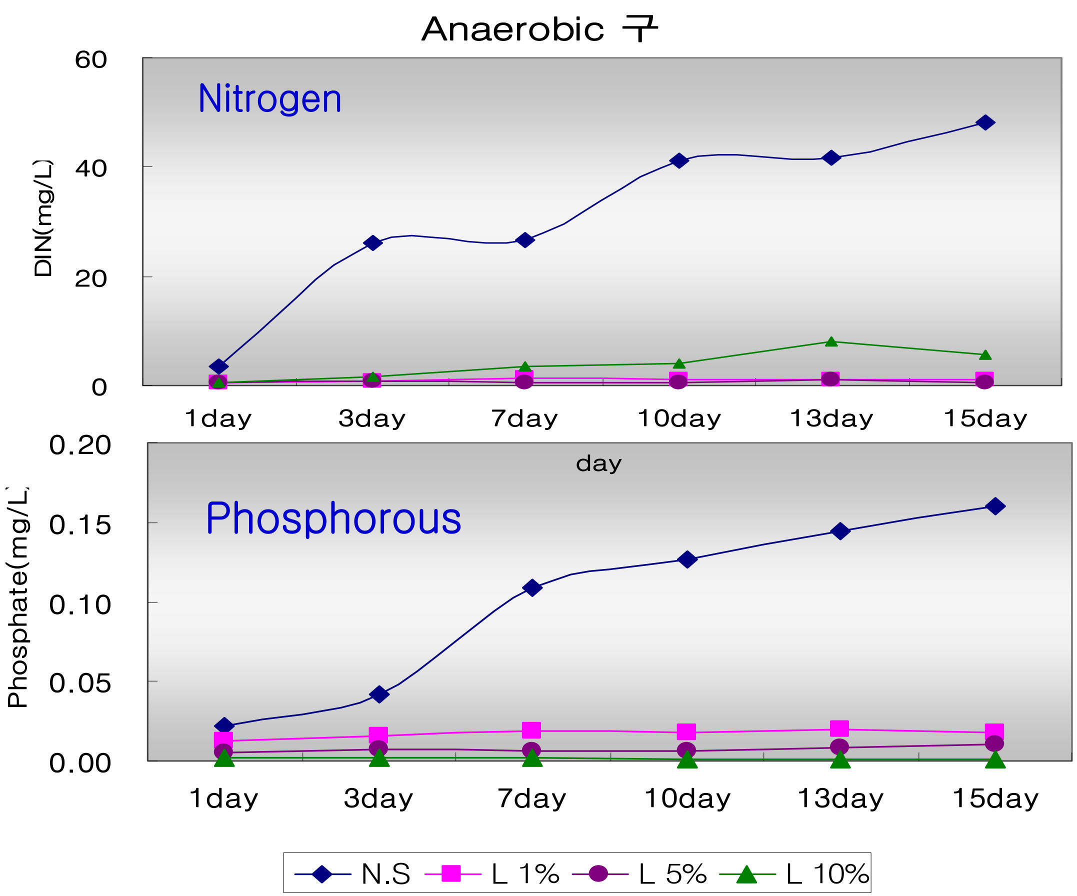


Fig. Effects of yellow clay on benthic environment

설명 : 거제 장목해역에 인위적으로 황토를 1, 3cm두께로 살포와 미살포해역을 조성하여 pH와 산휘발성황화물 조사



Constrain N.P. release from the sediments

Fig. Effects of yellow clay on the release of nutrients during the anaerobic incubation on the sediment

The impacts *in situ* of the clay on benthos

- **Field assessment**
  - Place 1 : Mijo Bay (12times/4 sts.) q
    - Target animals :Benthos,Bacteria
    - Sampling : 1999 – 3,6,7,9,10,12 ,

      2000 – 2,4,6,8,9,11

  - Place 2 : Saryang Island (4times/5sts)–benthos and bacteria
    - Target animals : Benthos, bacterial flora
    - Sampling : 2000, 4,7(before clay), 9(clay), 10(after clay)

Before the clay **After the clay**

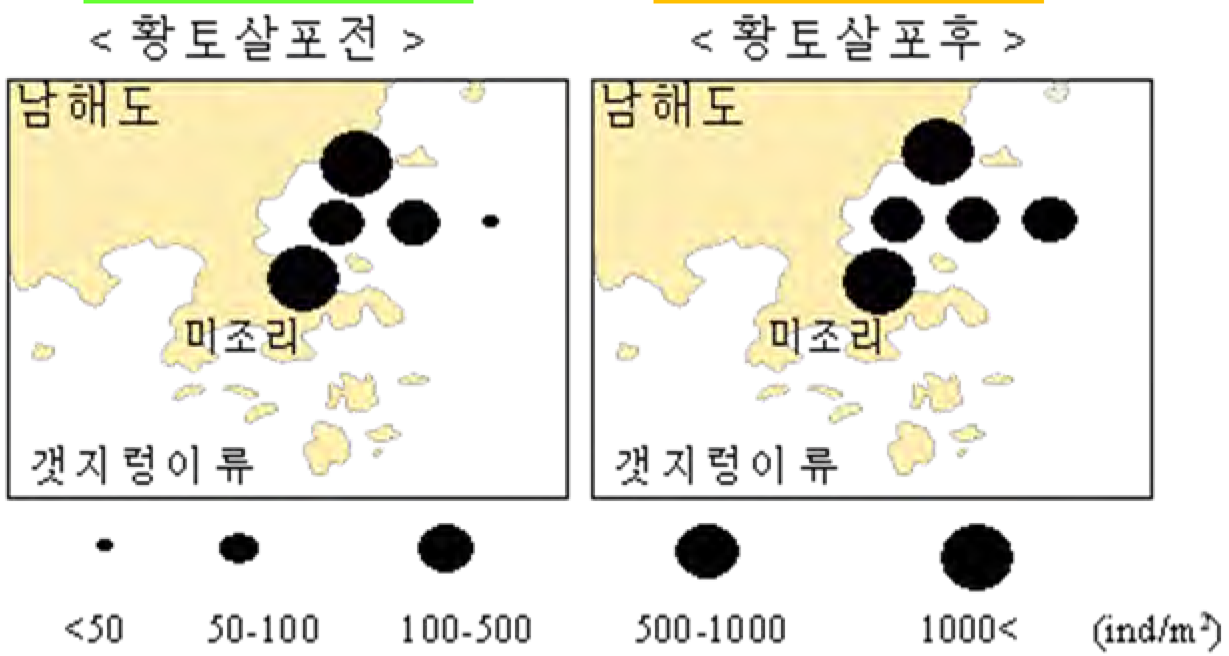


Fig. Effects of yellow clay on the distribution of benthic polychaeta.

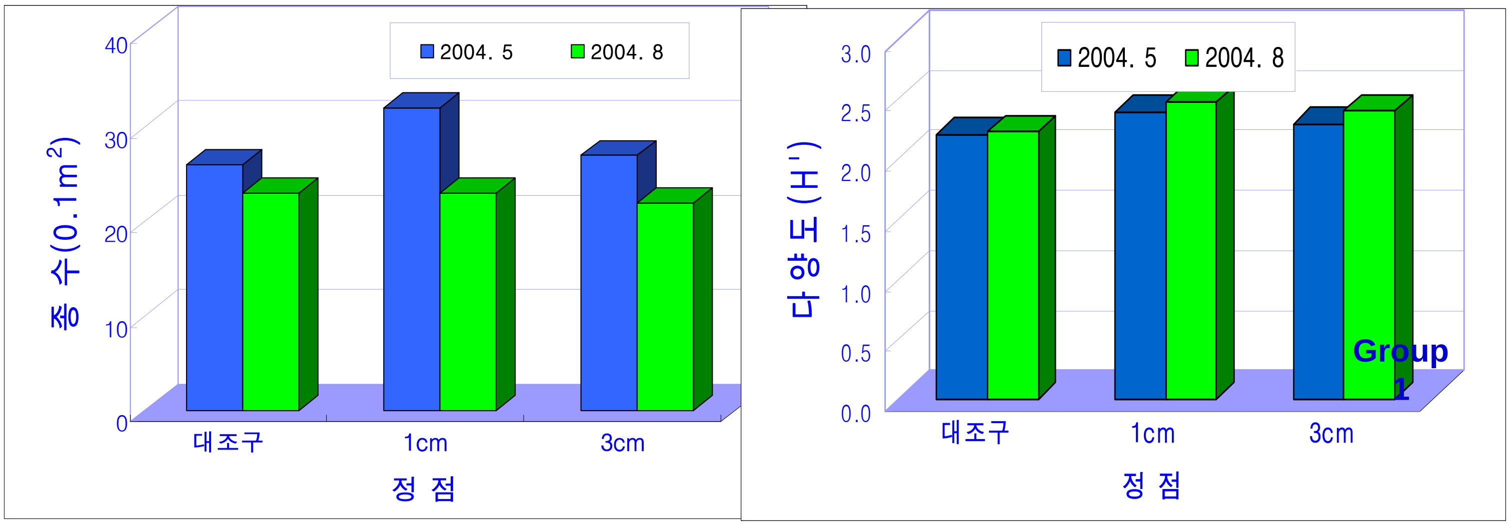


Fig. The variation on the distribution of the number of species and diversity of benthic organisms before and after the clay dispersal.

The impacts assessment of clay in 2007

- **Lab. assessment**
  - Ark shell : D-type juvenile
    - Clay conc. : 1, 2, 3, 4%
    - Survival rate in 48 hrs : exceeds more than 91% of the rate in control except 85% at 4% clay
- **Benthos -** Feb. May Jul. Aug. Sep. 2007
  - Site : Tongyong, Gejo Jangmok
  - Benthos : no change in diversity and production
  - Chemical factor : no big difference in Eh(oxidation-reduction potential), AVS, and pH of the sediment

Mortality of fish exposed to the clay

Fish species	density algae+clay	mortality (%) 24h	mortality (%) 48h	threshold lethal time(h)
Red sea bream	20g/L	0	–	–
	10g/L	0	–	–
	3.000cells/mL+10g/L	0	–	–
Black scraper	20g/L	0	–	–
	10g/L	0	–	–
	3.000cells/mL+10g/L	0	–	–
Flounder	20g/L	0	–	–
	10g/L	0	–	–
	3.000cells/mL+10g/L	0	–	–
Control	0	0	–	–

Impacts of yellow clay on invertebrates

Organisms	Yellow clay	Survival rate
Shellfish	1~60g/L	88%-100%,
Sea urchin	1~60g/L	100%
Clam	10g/L ~50g/L	100%
Earthworm	1~11g/60cm^2	100%
Porphyra	10g/L	No big change in photosynthesis (Fv/Fm) (control: 0.449, 0.5%: 0.483, 1%: 0.508)

Clay deposit and clearance by shellfish

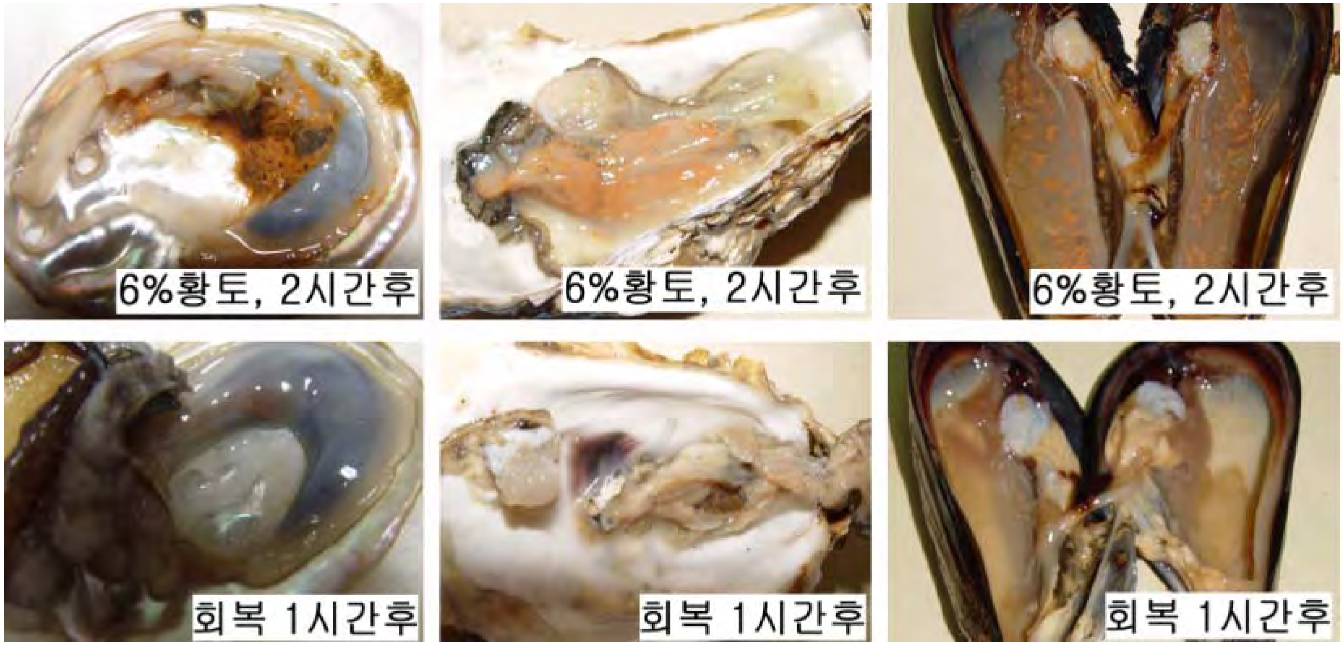
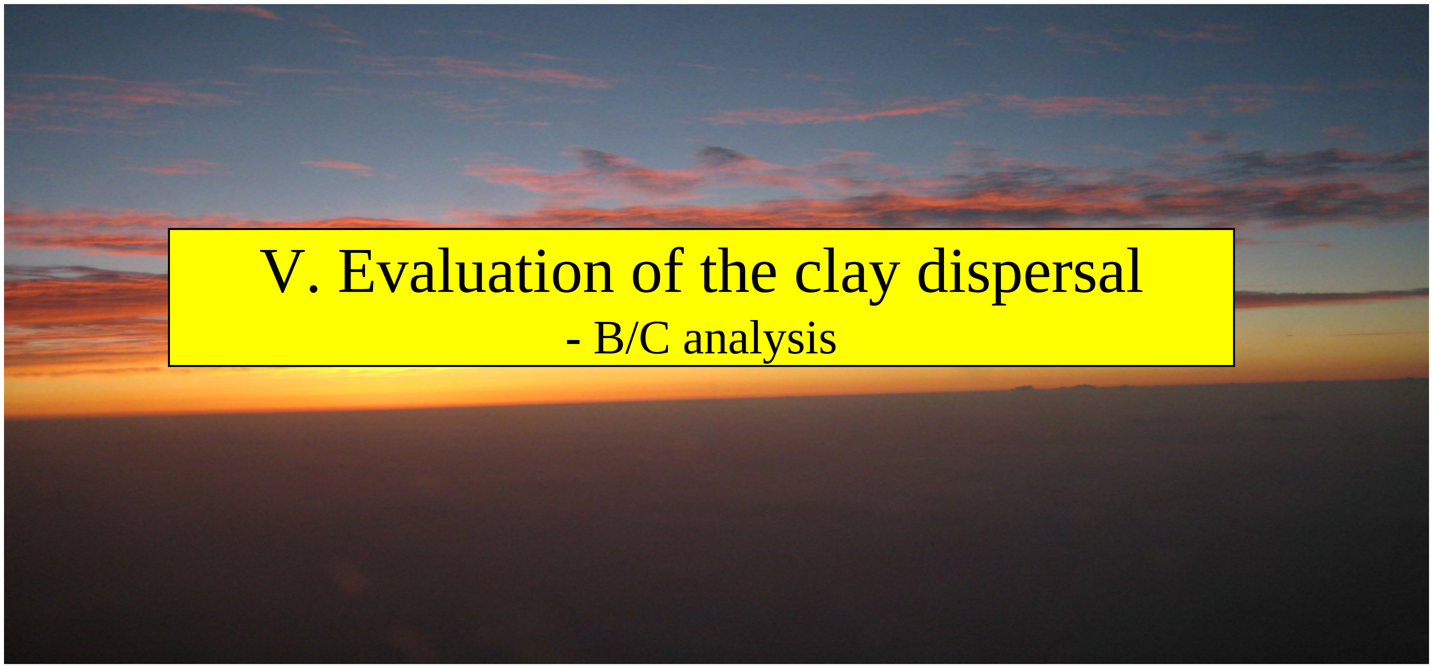


Fig. 2hrs of yellow clay deposit and clearance of the deposited clay after 1hour in shellfish such as abalone, oyster, and mussel



V. Evaluation of the clay dispersal

- B/C analysis

Fish mortalities exposed on *C. poly*. After 6hrs

Target fish	C.p. density	Death rate	First death
File fish	8,000 cells/ml	100 %	2 hrs
	5,000	100	3.5
	3,000	30	6
Sea bream	8,000	100	2
	5,000	60	3
	3,000	20	10
Sea flounder	8,000	30	12
	5,000	0	

Example of fish cage : 20 cages and 72 cages

Expected estimates of damages at sea bream cages

- C. p. bloom of 3000cells/ml – 20%

72cages x
3000kg x
8$ x 20% =
345,600$

20cages x
3000kg x
8$ x 20%
= 96,000$

Expenses of clay dispersal for 20 cages for a week

Total expenses of clay dispersal for a week : 6,363 – 6,552 US$

A. Clay expenses for 7days : 63 -252US$ (15US$/ton)
   1. Total surface area of cages : $25m^2$x20cages = $500m^2$
   2. Total surface area for clay dispersal : 3times of 1
   3. Dispersing concentration of clay : 100 - $400g/m^2$
   4. Daily frequency of clay dispersal : 4 times(30 - 60 minutes interval)
      - Daily amount of clay = 600 – 2,400 kg
      - Clays for 7 days = 4.2 - 16.8ton

B. Facilities : Ships = 500US$ /day x 7days = 3,500US$

C. Labor cost : 2persons x 200US$ x 7days = 2,800US$

Rough estimation of loss from fish kill and expenses of clay dispersal for 7 days at 20 cages

Loss estimates by fish kill : 96,000 US$

Total expenses of clay dispersal for a week : 6,363 – 6,552 US$


VI. Conclusions and recommendations

Conclusion – 1

It is a time to have practical mitigation, because HABs become a risk to the nature and public health.

- **Widespread and long persistent**
- **Varieties in discoloration and toxin profiles**
- **Increase of harmful and toxic species**
- **No practicable mitigation reagents**

⇒ **Economic loss**

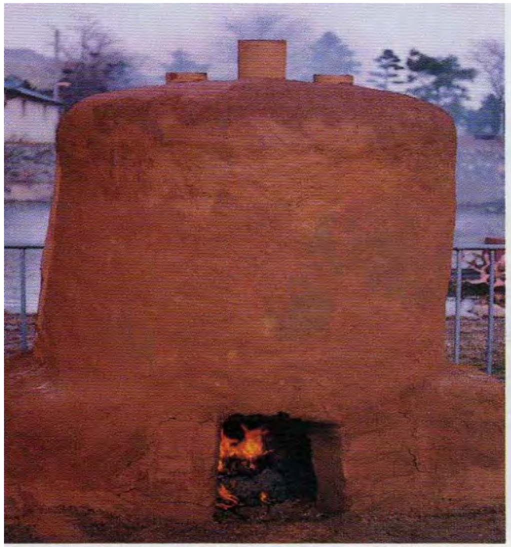
Conclusion – 2

In Korea, marine culture is one of important industries.

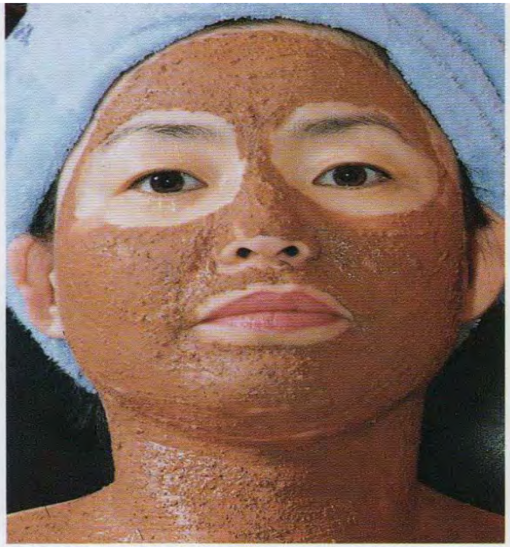
To keep aquaculture from HABs, we have to have practical mitigation. Hereupon, clay dispersal has been considered as feasible materials.

Use of clay to remove dinoflagellates from seawaters

Clay type	Target dinoflagellates	Observations	Remarks
Montmoillnite	*Prorocentrum minium*	Very effective	Kim et al., 1987
Residual clay	*Cochlodinium polykrikoides*	Very effective	Choi et al., 1994, Na et al., 1996, Bae et al.,1998, Lee et al., 2008
Phosphatic clay	*Karenia brevis*	Show utility of natural clay as a means of reducing adverse effects from HAB including toxin	Pierce, R.H. et al., 2004. HA, 3(2004), 141-148
Phosphatic clay	*Heterocapsa triquertra*	Effective at removing algal cells from water column	Beaulieu et al., 2005, HA 4(2005) 123-138
Bentonite			Murayama et al., 1987; Shirota 1989
Clays	Microcystis	effective	Atkins et al., 2001, Water Sci. Technol. 43(9), 107-114
Phosphatic clay	*Prymnesium parvum*	Successfully removed by spraying the surface with clays	Hagstrom & Graneli, 2005, HA 4(2005) 249-260

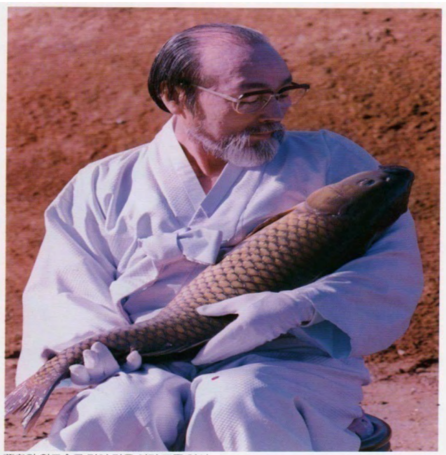


죽염을 구워 내는 竹鹽爐



피부 미용에 좋은 黃土 맛사지

Human friendly clay, clay-salt, face packing,



著者와 황토수를 먹여 키운 어미 토종 잉어

황토수를 먹여 키운 용연 1호

우리 나라의 토종 잉어인 참잉어

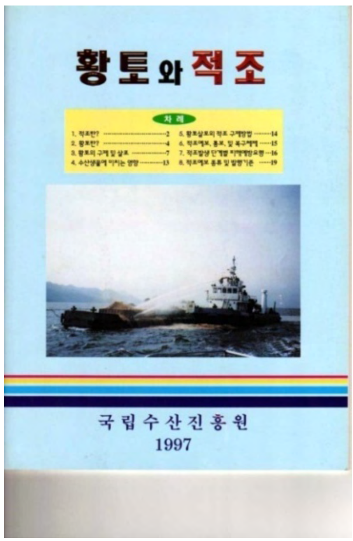
Common carp reared with clay and wild one without clay

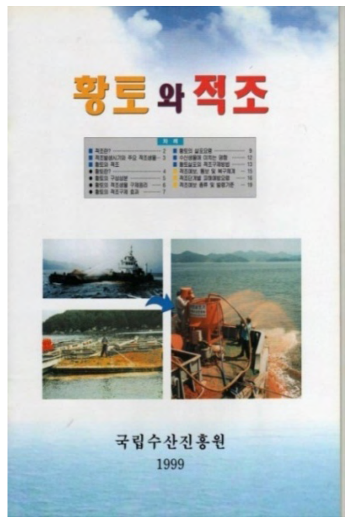
Korean are very familiar with clay, this is why we can enjoy Sashimi even they disperse the clay over the fish cages.

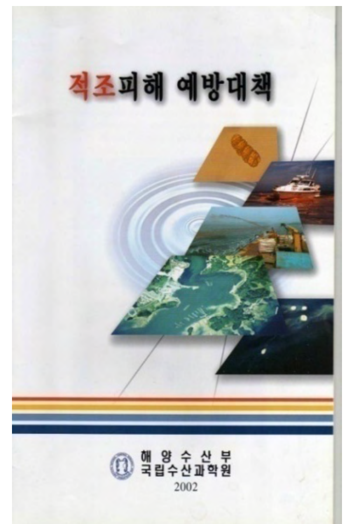
▲ 황토에서 자라 약성이 뛰어난 우리 나라 인삼(5년근)

Korean ginseng cultivated with clay

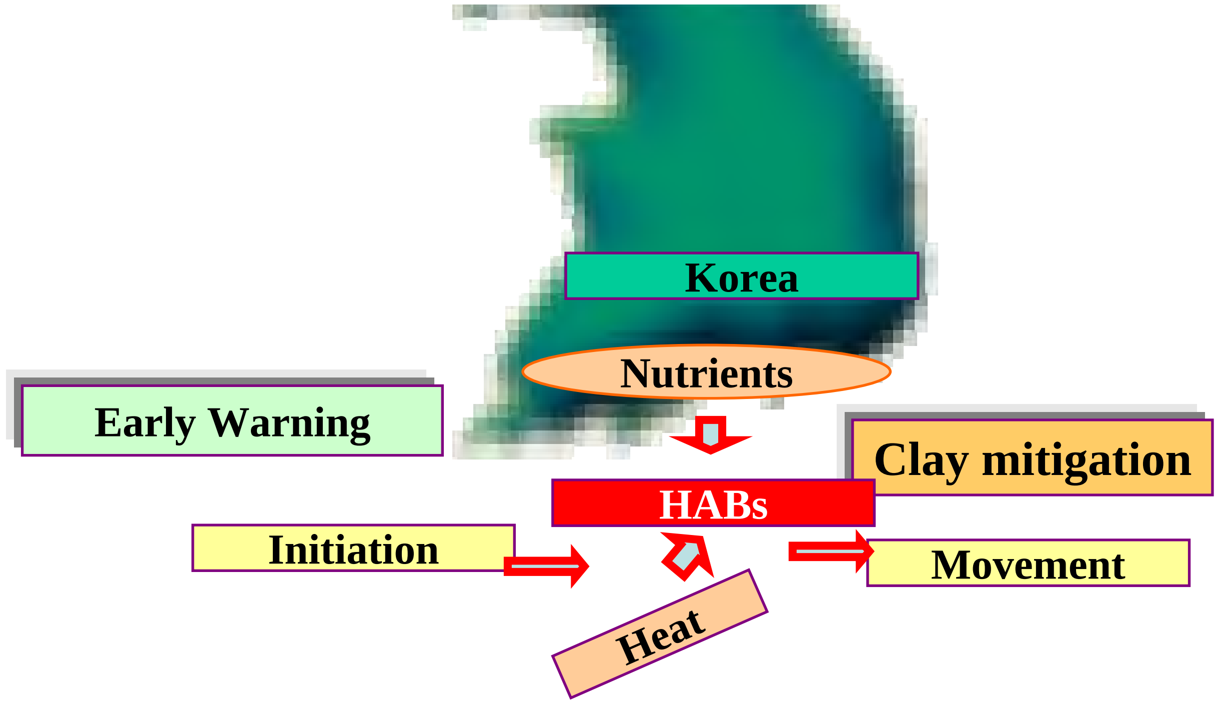
Manual for clay dispersion in Korea







Present mitigation system in Korea



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