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ABSTRACT

Microbial materials have received much attention recently as a viable bio-remediation tool for environmental pollution. Effective microorganisms (hereafter, EM), a complex microbial material, represents a group of effective microorganisms in which aerobic, facultative anaerobic, and anaerobic microorganisms are mixed symbiotically. When applied to a contaminated environment, it is found that EM and its metabolites (enzymes, nucleic acids, organic acids, antioxidants), together with minerals transform materials such as pesticides and dioxin into harmless substances and enrich the microbial flora of the applied area. The enriched microbial flora facilitates remediation process, and further promotes biological diversity.

EM is a non-toxic, and safe microbial material, so that it can be applied to many different situations. EM serves as a viable means to construct sustainable community that takes advantage of reusable materials.

1. INTRODUCTION

During the last half century, human beings have pursued primarily modernization, industrialization, mass consumption of resources and energy, rapid increase of population, and convenience of life. Also, in order to enhance agriculture, agricultural chemicals and chemical fertilizers have been used, generating the current environmental problems. Pollution of soil, water or air is an international issue, and it is necessary to take the appropriate countermeasure.

To remedy environmental pollution, use of microbial materials may be the most attractive choice. EM is a complex microbial material representing a group of effective microorganisms that consist of aerobic, facultative anaerobic, and anaerobic bacteria. It contains beneficial microorganisms from 3 main genera: phototrophic bacteria, lactic bacteria and yeast. Once EM is applied to nature, through the actions of EM, its metabolites (antioxidant, organic acid, nucleic acid, enzyme), minerals and other components, toxic materials such as agricultural chemical and dioxin can be transformed into non-toxic substances, and the ecological system is even more diversified. Furthermore, the effect of remedying environmental pollution is intensified by complex actions, so that the bio-sphere in the river or sea will be enriched.

In the present study, decomposition of agricultural chemical and dioxin by EM is investigated by on-site validation experiment as well as by pot experiment to confirm the action of EM.

2 ON-SITE VALIDATION EXPERIMENT AND POT EXPERIMENT

2. 1 Decomposition of Agricultural Chemicals by EM(Hoshino et. al 1998)

Under the slogan of agricultural modernization, agricultural chemicals have been developed and used extensively. Consequently, chemical materials such as insecticides, germicides, herbicides are now considered to be one of the main causes that have destroyed natural environment and ecology. Also, the land potential of farmland is degraded by chemical fertilizers and agricultural chemicals, and the effects on agricultural products and/or damages to farmers have been already reported

Agricultural chemicals disseminated in nature are known to be decomposed by soil bacteria, physical and chemical actions, as well as complex interactions. The relevant decomposition reactions are summarized in Table 1 (Japan Society for Soil and Bacteria 1999, Cookson 1997).

Table 1 Reactions of metabolic decomposition of agricultural chemicals by bacteria (Japan Society for Soil and Bacteria 1999, modified)

Reaction mode	Example of reaction
hydrolysis	ester, carbamide, acidic amide, nitrile, hydrolysis of epoxide
oxidation	C-oxidation, β-oxidation, epoxidation, cleavage of aromatic Ring (C-C), cleavage of C=O, C dehydrogenate, N-, O-, S- dealkyl, N-, S-oxidation, S-substitution, ether cleavage
deduction	dehalogen, deduction of nitro radical, deduction of C=C, deduction of S=O
isomerization	isomerization from γ-BHC to α-BHC
conjugation	methylation, acetylation, formylation, glutathione conjugation cystine conjugation
polymerization	halogenated aniline, phenol polymerization

Reference: Japan Society for Soil and Bacteria(1999)

However, in farmland where the phase of living things is monopolized by toxic chemicals such as residues of agricultural chemical, the insect, benthos, amphibian, fish, bird etc., are increased, and near shore sea louse, earwig, crab, etc. are decreased markedly.

The organic phosphorus insecticide, viz. sumichion (fenitrothion: MEP) used in this experiment, has been widely used for not only in agriculture, but also in forests, gardens near city center, roadside trees, and also gardens. MEP exterminates vermin such as tick. Since MEP is detected in air, soil and water, it is one of pollution materials in the environment. The study is conducted at Taiyou Village, Ibaraki Prefecture. Soil samples from a farm that had changed from traditional farming to EM farming three years ago, and samples from a farm that still practices traditional farming using chemical fertilizer and agricultural chemicals are examined to find out the current conditions on site. Properties of soil, bio-diversity, as well as degree of MEP decomposition due to bacteria and its application are investigated.

Experimental method

1) Validation test

This test is conducted at Taiyou Village, Ibaraki Prefecture (test site). Soil samples are collected where traditional farming is still practiced, as well as where EM farming has been practiced for three years using dung of pig fed on EM feed and water, EM bokashi, and EM active liquid. The physical and chemical properties of soil (including structure of grain aggregation, EC, pH), effects on bio-sphere, and decomposition of MEP at farm field are examined.

Isolation of bacteria

A low concentration organic medium (normally 20-50 times diluted) in which actinomyces, bacteria, and mold can survive, is used to classify various bacterial species.

2) Pot test

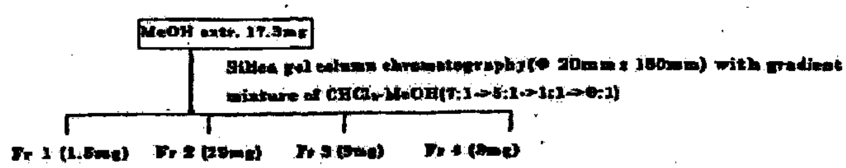
Decomposition test of MEP is conducted with samples collected from traditional farming (residues of MEP: 236 μ g/g) as well as from EM farming. Fifty g of soil sample was collected in a 100-ml PP bottle. The samples are mixed with sumichion (Takeda Pharmaceutical Company: 50% MEP, emulsifier, and solvent) in a slurry state (333 μ g/g). After treatment for 10 days, the residues of agricultural chemicals are analyzed. In addition, the bacterial species were classified.

Isolation and purification of analyzed specimen

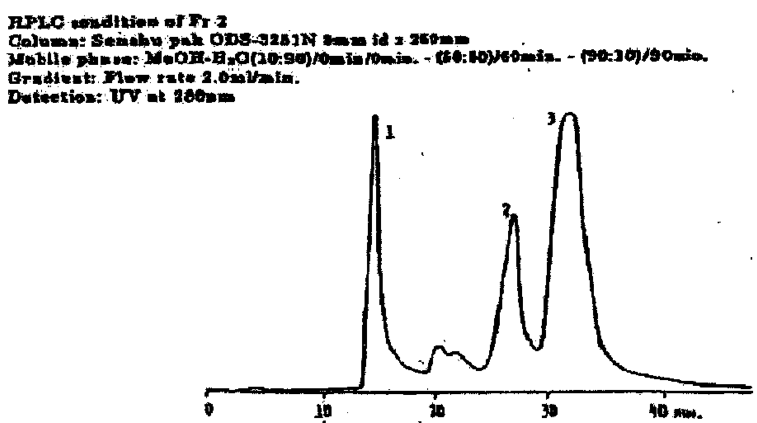
A soil sample of 110 to 130 g is separated using a 300-mesh filter. Then, the specimen was extracted using solvents (1) $CHCl_3$-MeOH, (2) CH Cl_3, and (3) MeOH. The MeOH extract with the highest recovery rate is further separated by HPLC and detected by UV absorption at 280nm. The predominant fraction obtained from HPLC was collected and the chemical structure is analyzed by ^{1}H-NMR, ^{13}C-NMR using Japan Electronics GX-400FT-NMR(Figs.1 and 2).

Analysis by HPCL

Segregation efinement



Fr2(29mg)was fractioned by HPLC



HPCL Profile of ODS Fr.2

Fig. 1 Soil by traditional farming

Variation of soil pH

Sample preparation is the same as that for the observation of bio-sphere. For the soil of EM farming, the pH is about 7 and stable. For the soil of traditional farming, the pH is weakly acidic at 6, but is improved by applying 1% EM-1 to this soil in approximately 15 days (Fig.3).

Result of on-site validation test (Figs.1 and 2)

Segregation refinement

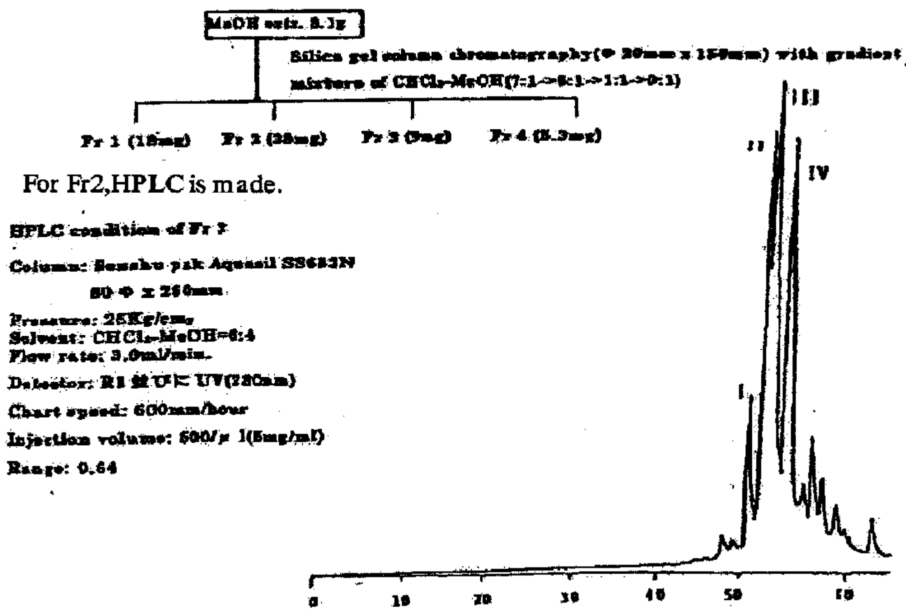


Fig. 2 Soil by EM farming

From the soil of traditional farming, as leucine is the initial material, MEP (236 μ g/g) is detected as residue of agricultural chemicals. Although no organic phosphorus compound is detected from the soil of EM farming, humus components are detected, which are condensing substances of phenyl compound produced from catalysis by metallic oxide compound, clay mineral, and bacterial enzyme.These condensing substances and humin acid materials such as syringa acid and vanillic acid couple with each other as complex compounds, and form dimer, trimer and tetramer.

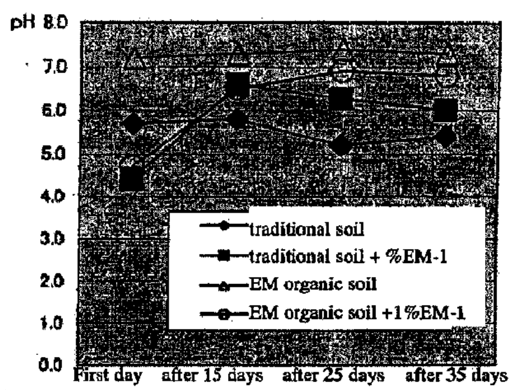


Fig.3 Variation of soil pH

Structural analysis by NMR

Multi-vertical lines in the range of 1,585-1,762 σ ppm, are observed in the highest magnetic field, indicating hydrogen atom (proton) having

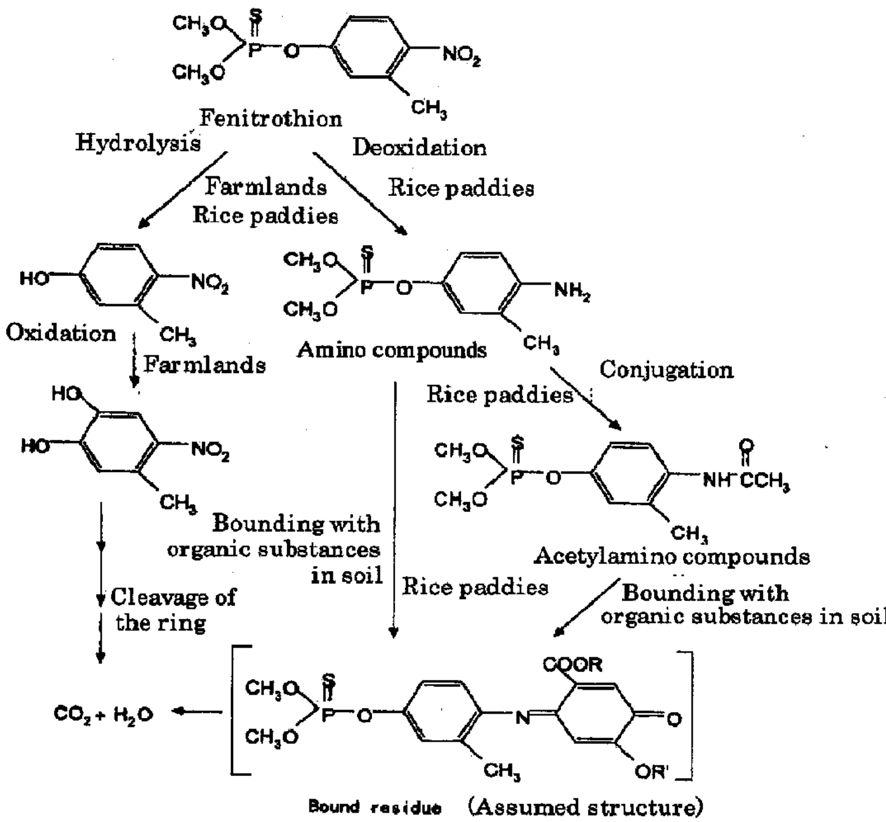


Fig. 4 Decomposition of organophosphorous pesticide fenitrothion in soil

three methyl groups. Based on the integral ratio, they are identified as possessing a total of 9 hydrogen atoms. On one hand, multi-vertical lines in the range of 7,157-7,354 σ ppm indicate five aromatic protons having benzyl groups. Additionally, DEPT measurement for compounds was implemented. In case of C-NMR, signals at high magnetic field indicate three methyl radicals of organic phosphorus residue radicals, while other signals at higher magnetic field are two methyl radicals of leucinol residues. Two methylens of leucinol residues suggest that they contain quaternary carbon.

During the decomposition of MEP by bacteria, hydrolysis of part of phosphorus ester as well as reduction of nitro radical are important. After oxidative decomposition as shown in Fig. 4, MEP is oxidized and becomes carbon dioxide after decomposition (Japan Society for Soil Bacteria 1999).

When chemiluminescence of EM-1 extract and distilled water is examined, because the luminescence intensity reached a level of one million, it is clear that activation energy stronger than that of other living things is emitted. Chemiluminescence here denotes not the heat that is emitted when an atom is changed from an excited state to ground state, but a phenomenon in which energy is emitted as light. Luminescence is known to emit from amino acid, cytochrome, and other compounds. Cytochrome is considered to be related to electron transfer during photosynthesis.

This measuring method is based on the same principle of bio-photon. After taking photographs of living things using CCD camera, they are zoomed up 10-15 times, and then processed in a computer.

In case of EM extract, once the measuring time exceeded 100 sec, the amount of the luminescence increased suddenly and reached a peak near 250 sec. Whereas in case of distilled water, the amount of luminescence is constant until 600 sec. This suggests that the luminescence does not vary.

The rapid increase in luminescence observed with EM extract is assumed to result from effective microorganism, cytochrome, and others. During the normal process of photosynthesis, although luminescence is enhanced by cytochromes a, b, c, and others, cytochrome P450 is considered to be associated with the present emission of activation energy. Cytochrome P450 is produced, and during the chemical reaction with ubiquinone, strong radical reaction occurs within a distance of 10^{-6}-10^{-8}, and an electromotive force is induced. It is considered that the electromotive force would change the chemical materials in farm field, which are disposed by EM into a decomposable condition, and contribute to the decomposition.

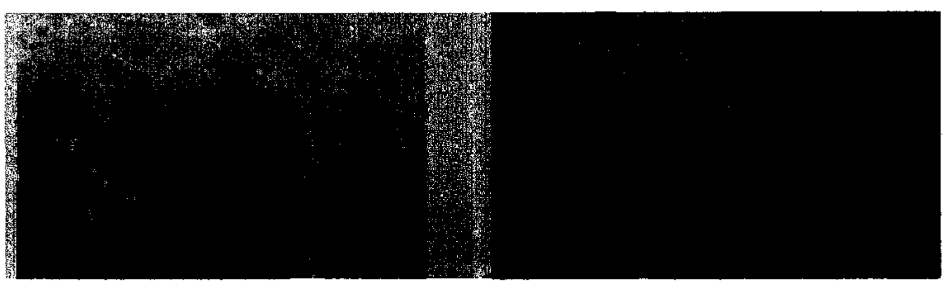
Moreover, as for the bacterial phase, in case of soil applied by EM organic materials, the structure of aggregation is improved, and numerous pores are observed (Fig. 5), and a diversity of bacteria (actinomyces, fluorescent *Pseudomonas,* alga, etc.) are found (Fig. 6). Especially, an increase of actinomycetes group that produce diverse physiological activators is identified. In case of control traditional soil, aggregate structure of soil is under-developed, and bacteria are in the phase that resisted chemicals, and the number of bacterial

Non-organic Organic(EM)

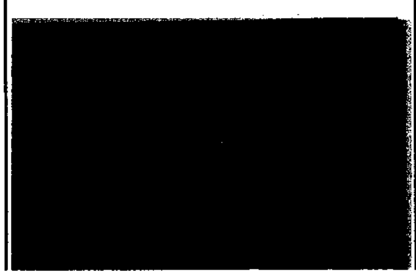
Fig.5 Crumb structure of soil ectromicroscope

species is limited. Thus, by applying EM organic materials to farm field, detoxication of toxic materials is enhanced, and it is suggested that polluted materials can be decomposed and eliminated.

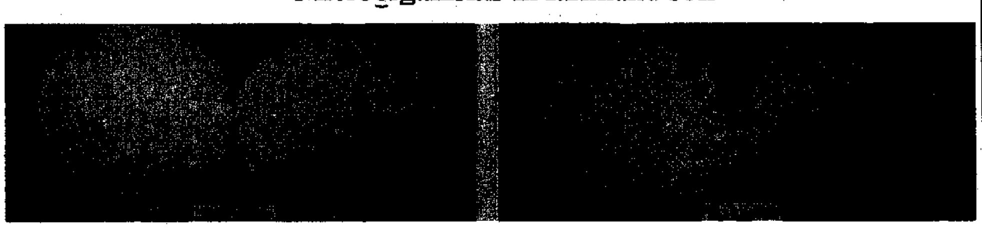
Organic soil (EM)



Non-organic soil



Microorganisms in farmland soil



Non-organic EM

Fig. 6 Microbial flora and fauna

Results of pot test

Table 3 Results of MEP decomposition experiment

Specimen	MEP residue μ g/g	Residue/MEP addition %
traditional soil	569.0	171
organic EM soil (+1% EM soil, EM-Z ceramics)	92.8	28
organic EM soil	76.4	23
MEP addition (blank)	333.0	100

Non-organic soil

Organic soil(EM) +1%EM-1,Z ceramics

Organic soil(EM) +1%EM-1

Organic soil(EM)

Fig. 7 Tests on microbial flora and fauna

In case of soil of traditional farming, because MEP is normally applied to the soil, the original bacterial count is low. With a further addition of MEP at 330 μ g/g, no bacteria are detected (Fig. 7). Also, the concentration of MEP residue is high, at 569 μ g/g

(171%).

In case of soil that has been transformed into EM farming, the residual MEP was 76 μ g/g (23%), showing 77% decomposition in 10 days. However, in case of EM soil to which 1% EM-1 and EM ceramics is added, no enhanced decomposition is noted (Table 3).

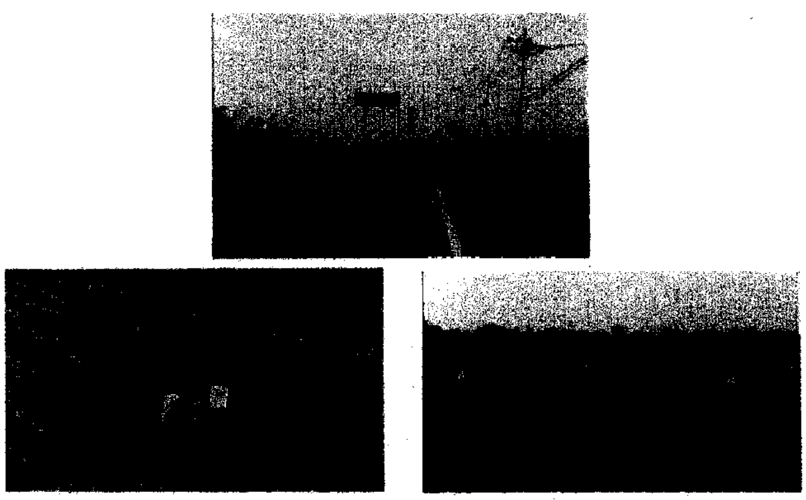
Among the strains isolated, *Pseudomonas* species that are motile and produced fluorescent pigment are detected (Fig.7). In general, the half-life time of MEP is considered to be of 8-30 days in the soil of farm field (Japan Society for Agricultural Chemicals 1996, revised edition).

Therefore, 77% MEP decomposition in 10 days in the present pot test suggests that the resultant bio-diversity enhances MEP decomposition.

2. RESEARCH ON DIOXIN DECOMPOSITION BY EM(Hoshino et al 1999)

Pollution of the soil, air and water is caused by human activities generating substances such as dioxin, agricultural chemical including emulsified material, solvent, and synthesized chemical. Some of these materials may act as endocrine disturbing chemical (EDC), and will be concentrated biologically through the food chain.

In the present test, decomposition of soil in rice field and/or field of EM farming



Control(Non-organic rice paddy) EM treated(rice paddy)

Fig.8 Sampling sites in Ryugasaki-shi Ibaraki-prefecture(March 5,1999)

(EM organic materials and a small amount of agricultural chemicals) using EM soil improvement materials around garbage plant or garbage incineration disposal plant, as well as that in fields of traditional farming (chemical fertilizers and agricultural chemicals), were examined on site. Also, as pot test, the effects of EM on dioxin decomposing and behavior of living things, as well as mechanisms of action are investigated.

Test site of on-site validation study and collection of soil specimens (Environmental Agency 1999 , Japan Chemical Society 1998)

1) Soil in rice field within a circle of a radius of 2 km from Shiratori Garbage Plant is studied. According to a research by Setsunan University, the soil at the bottom of storage tank in the incineration plant has shown dioxin level of 1,580 pg-TEQ/g, and the soil at a 200 m distance downwind of the factory shown 250 pg-TEQ/g, and the level in the blood fat of humans living in this area is abnormally high at 102-463 pg-TEQ/g.

Specimen: soil of traditional rice field and that of EM-treated rice field in Ryugasaki-city within 2 km in the south-west direction from the garbage plant (Fig. 8).

2) Tokorozawa-city, Saitama-prefecture (Table 4)

The dioxin level of 14-40 pg-TEQ/g (mean value of 30pg-TEQ/g) is greater than that in the soil at 12 sites around Mt. Kunugi, Tokorozawa-city.

Specimen: Soil in traditional field, and that in EM raw garbage compost from home garden, around Mt. Kunugi , in which industrial garbage plants are distributed.

Table 4 On-site actual condition investigation around incineration plant

Concentration of PCDD and PCDF in soil

Nose-machi, Osaka-prefecture		
	A area(n=6)	B area(n=10)
Mean value	66	9.2
Standard deviation	140	15
Central value	8.2	2.9
Range	2.9-340	2.1- 48
Saitama-prefecture		
	A area (n=9)	B area(n=6)
Mean value	32	7.5
Standard deviation	16	2.2
Central value	30	7.7
Range	9.0-55	4.4- 11

A area: Sites in an area smaller than a radius of 2 km from cleaning center, Tounou-gun.

B area: Sites in an area greater than a radius of 2 km far from cleaning center, Tounou-gun.

Reference: Result of dioxins long-term air exposure impact assessment (Environmental Agency 1999)

3) A town in Okayama Prefecture

At 6 areas around a incineration plant, the dioxin concentration is high at 2.9-340 pg-TEQ/g (mean value of 66pg-TEQ/g).

Specimen: Soil at traditional farm field, and EM-treated field at circles of radii 200 m, 500 m, and 1,000 m, respectively, from the incineration plant at a town in Okayama Prefecture.

The site for on-site validation study is selected from a farm field in which dioxin has accumulated to a large amount. The following specimens are analyzed: soil of EM farming in which EM materials such as bokashi, dung of livestock, raw garbage, etc. are included, are applied at 200-300 kg per 10 are for 1-2 years; and soil of traditional rice field or field in which chemical fertilizer and agricultural chemical are included, are applied and collected at depths of 5 cm and 30 cm, by the method of mixing 5 points. In particular, in the case of soil in rice field, weed-killer dioxin such as chloronitrophen (CNP) is detected, so that it is assumed that dioxin may accumulate at places other than incineration plants.

According to an investigation (Table 5) of 13 rice fields in Ehime-prefecture, the mean concentration of dioxin is high at 120 pg-TEQ/g. Therefore, in Japan where rice is eaten as a staple food, pollution of rice field may be a major concern today.

Table 5 Concentration of PCDD and PCDF in soil at each place in Japan

Prefecture (year examined)	Site of collection		Concentration (pg-TEQ/g)
Osaka (1996)	Playground at a university, Maikata-city		6.7
Osaka (1996)	Garden, Maikata-city		16
Osaka (1996)	Garden, Osaka-city		18
Wakayama (1996)	Tanabe-city		5.1
Nara (1996)	Takanohara, Nara-city		12
Fukuoka (1992)	Garden at a big city		4.4
Fukuoka (1992)	Garden around a big city		1.7
Fukuoka (1992)	Garden around a middle class city		6.9
Fukuoka (1992)	Garden located in the center of industrial city		35
Fukuoka (1992)	Sugibayashi		65
Ehime (1997)	City garden in castle	7 positions	5.5*
Ehime (1997)	Areas in mountain	13 positions	4.5*
Ehime (1997)	Areas in shrine precinct	4 positions	35*
Ehima (1997)	Rice field	13 positions	120*

Reference: Japan Chemical Society (1998). *mean concentration

Experimental method

Soil samples are collected from the following sites: rice fields and fields located in Ryugasaki-city, Ibaraki-prefecture (around Shiratori cleaning factory), a town in Okayama Prefecture, and Tokorozawa-city, Saitama Prefecture (garbage disposal plant, around Mt. Kunugi); soil that has changed from traditional farming to EM farming in the last four years; and as control, the soil in the surrounding traditional farm land.

Associated with properties of soil, the biological phase and decomposition of dioxin and CO-PCB are analyzed using GC-HR-MS.

Soil collection at area for on-site validation:

1. Soil of rice field in Ryugasaki-city, Ibaraki Prefecture (Fig. 8), at 1000 m and 1800 m to the south-west of Shiratori Garbage Plant,
2. Soil of a field in a town in Okayama-prefecture, at 200 m, 500 m, and 1000 m from a garbage plant.
3. Soil of a field for growing home vegetables, in Tokorozawa-city, Saitama Prefecture, at 800 m to the south-west of Mt. Kunugi, where incineration plants are located.

In the above three areas, soil is collected from the surface of ca. 5cm, and at a depth of ca. 30-35 cm, by the 5-point mixing method.

Method of observation for living things

Fifty g of soil is collected from rice fields at the control area (traditional farm field) and at the test site (EM disposed farm field)and put into transparent 500-ml bottles. After adding 300 ml of tap water, the bottles are shaken and placed next to a glass window. The biological phase is observed using a magnifying glass and/or microscope at room temperature of 24-36ºC during August to October.

Progress of biological observation

1. Characteristics of soil disposed by EM in rice field (Figs.9-11)

(1) Because of the progression of soil aggregation, and the sedimentation rate of soil after shaking for 30 seconds is speeded up. The liquid from test site becomes transparent after 2 days, while the liquid from control site clears after 9 days.

(2) From the third day, algae such as *Chlorella* are observed, and water flea(Daphnia) and germination of plant appear. They grow subsequently.

(3) From the ninth day, green algae with apparent root and filamentous alga are observed on the surface of soil.

(4) From the twelfth day, diatoms are observed to adhere to the surface of bottle, and grow subsequently.

(5) The other groups of living organisms such as bacteria, motile cryptophyte algae, floating algae, protozoa, and micro-metazoa live symbiotically.

(6) After three months, even if water lost due to evaporation is replenished, the living organisms co-exist continuously. At the present, after one year, a cyclic food chain consisting of bacteria, algae, planktons, protozoa, and plants is still maintained.

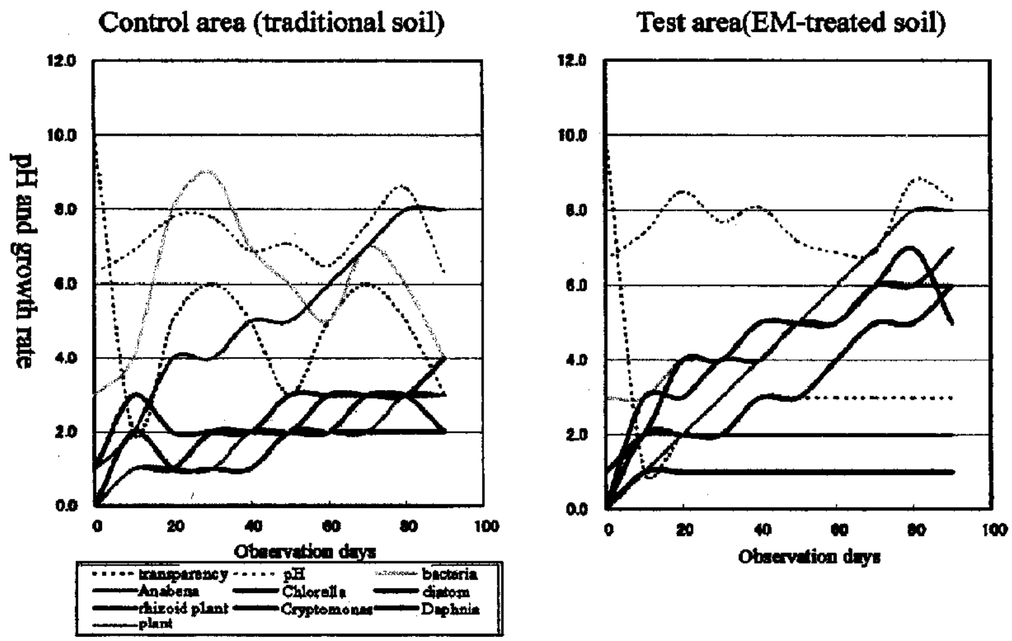


Fig.9 Progress of biological phase

In case of organic soil treated by EM, once water is added, bacteria grow and at the same time living organisms such as micro-algae (*Chlorella*、 diatom, *Spirulina*), protozoa (ciliate, water flea), plants with apparent root, water-weeds, and weeds develop and grow. Then, food chain with increased bio-diversity is observed (Fig. 10: 28 and 42 days). Especially, once diversity of bacteria is established, the phase of another living organisms also diversifies. As a result, various enzymes are produced, and the potential of synthesis and decomposition is also elevated. Therefore, it is expected that EM soil may be useful to decompose intractable chemicals. Hence, it is considered that EM can be a bio-remediation technology which is useful to dispose polluted soil on-site.

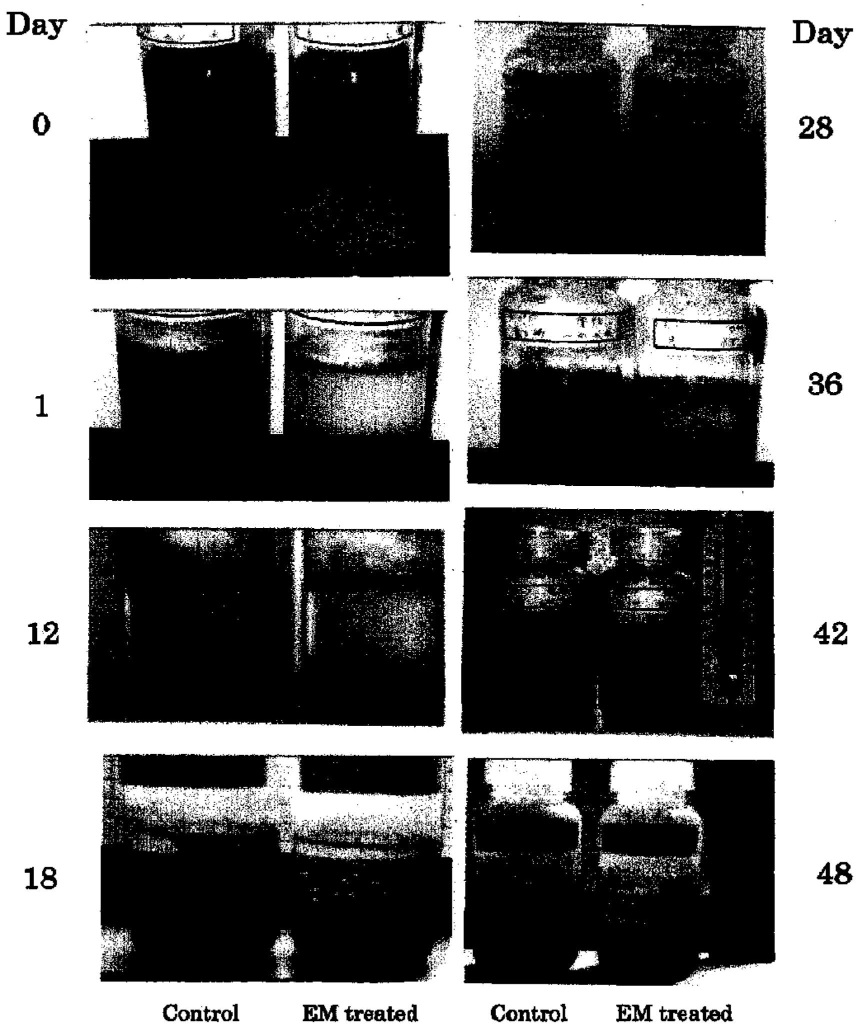


Fig. 10 Biota of rice paddy soil(Ryugasaki-shi)

In case of soil in traditional farm field, once metazoa such as water fleas die, the transparency decreases due to the growth of bacteria (Fig. 10). This is considered to be caused by residual germicide and/or herbicide. In case of EM soil, although generation changes, since living things never die completely, the transparency does not vary markedly.

2. Characteristics of soil in traditional farm field using chemical fertilizers and

agricultural chemicals (Figs.10 and 11)

In case of soil in traditional farm field, living organisms not only develop and grow slowly, but they decrease or die sometimes. This is probably one of the reasons why environmental pollution occurs, the number of living things decreases continually.

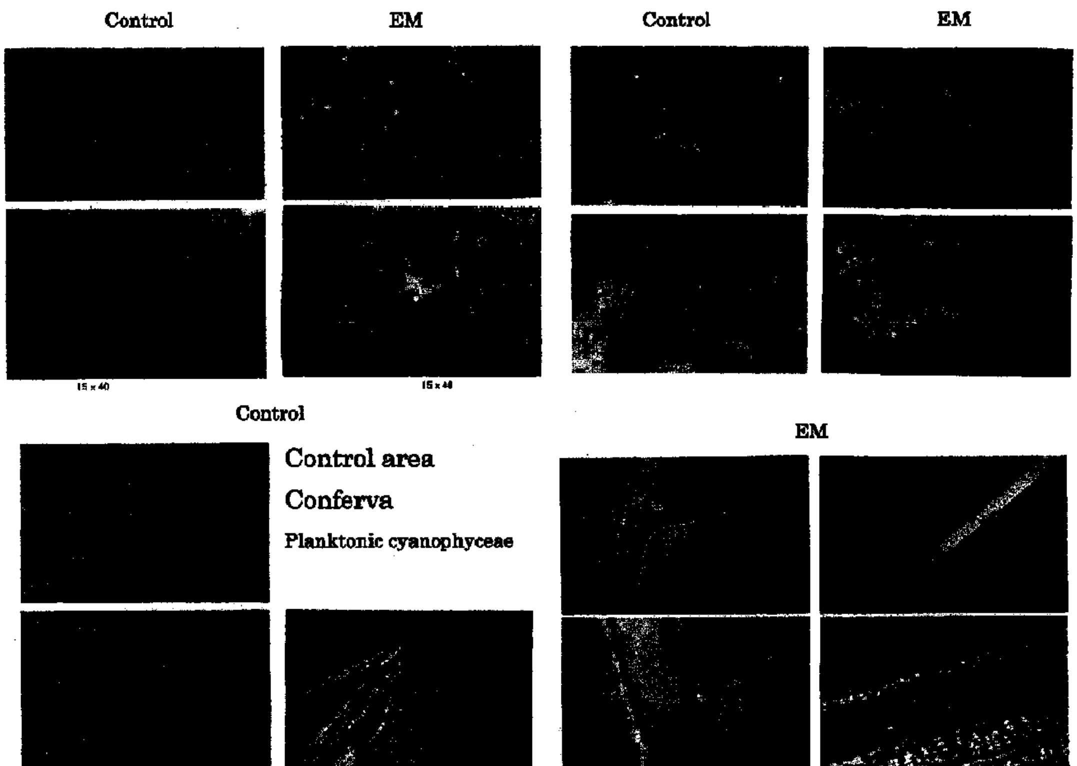


Fig. 11 Living organisms in case of soil

In particular, since alga is not noticeable on the surface of soil, there must be an impact due to herbicide. Moreover, although the growth of 'anabaena' is noted, the variety of other living organisms is small, and growth of weeds is inhibited. After three months, except for one weed and algae, no activity of other living organisms is observable with naked eye or using a magnifying glass.

According to the study of phase of living things, various living organisms such as plants, insects, fishes and shellfishes, amphibians and reptiles are found in the soil treated by EM. This bio-sphere resembles to that observed during the era when large amounts of fossil fuel and chemicals had not been used. Therefore, a sound ecology seems to have been restored (Table 6).

Table 6 Investigation of bio-phase at EM organic rice field

Result of field observation at a rice field that has changed from traditional farming to EM organic farming in the last 3-5 years.

Plants:	floating weed (remina), alga (Chlorella), filamentous alga (green alga such as hybimidro, spirina etc), weeds (Deccan grass observed in old time).
Insects and small animals:	dragonfly, water mantis, Japanese diving beetle, giant water bug, pond skater, grasshopper, rice water billbug, spider, leech,
Fishes and shellfishes:	killifish, loach, mud snail, crab, crawfish, lobster
Amphibian and reptiles:	frog (hyla, tree frog, toad, leopard frog), newt, lizard, snake, tortoise
Birds:	swallow, duck, sparrow (harvest time), heron

Soil of rice field: grey soil, grey lowland soil

Reference: Examined in 1999 (Hoshino et al 1999)

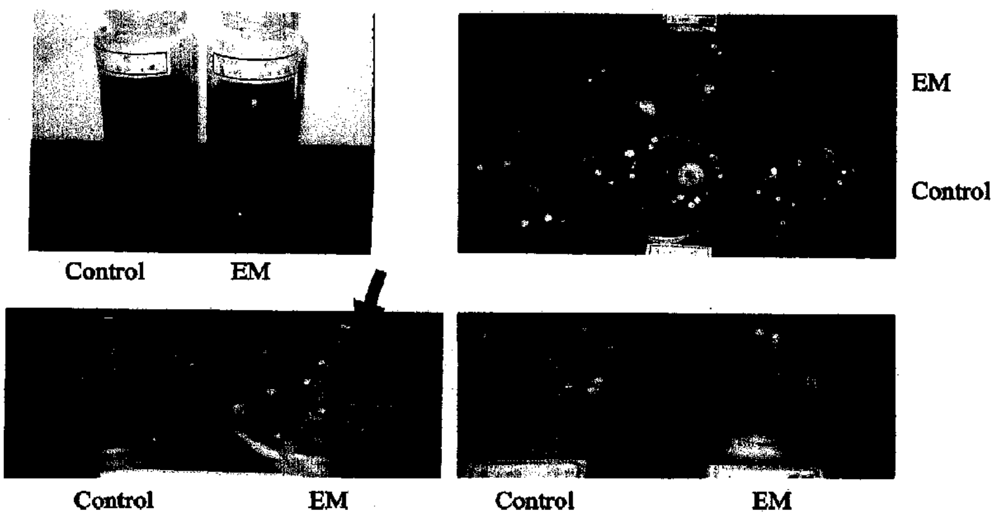


Fig. 12 Isolated plates of rice paddy soil(Ryugasaki-shi)

Even in dioxin-polluted area, in the soil of rice field where the farming method has been changed from traditional farming to EM organic one, a great variety of living things such as water weed, dragonfly, spider, killifish, mud snail, frog, and heron and so on, which were often observed in field trips 10 years ago, have been noted. Also, in the case of pot test (Fig. 12), growth of bacteria such as actinomyces and fluorescent *Pseudomonas* (Fig.11) as well as micro-algae such as chlorella or 'criputo' alga and

Moina sp. is observed. This fact may indicate that toxic materials such as agricultural chemicals have been transformed to non-toxic materials by EM..

Result of on-site validation test (Table 7)

Soil samples are taken from rice field or field within a radius of 2 km from an incineration plant that causes pollution problem due to dioxin, as well as from control area of traditional farming where chemical fertilizers and agricultural chemicals have been used. Then, dioxin and CO-PCB are measured. Furthermore, using both soils samples from the rice field and laboratory, phase of living things are observed. The results of the two samples are compared and discussed.

Result of validation test

Table 7 Actual state of dioxin pollution around incineration plant

Survey area	Ryugasaki-city (Shirotori)		a town in Okayama Prefecture*		Tokorozawa-city (Mt. Kunugi)	
Specimen (soil)	rice field		field		field	
Surface layer (0~5cm)	Control	EM	Control	EM	Control (home garden)	EM
Dioxin (pg-TEQ/g)	110	7.6 (93%)	74	14 (81%)	19	12 (37%)
CO-PCB (Pg-TEQ/g)	1.1	0.55 (50%)	NT		NT	
Depth (30cm)						
Dioxin (pg-TEQ/g)	NT		NT		12	8 (33%)
CO-PCB (Pg-TEQ/g)	NT		NT		NT	

NT: not tested

*distance from the incineration plant in Okayama Prefecture to site of soil sample collection	control measurement	control TEQ	EM measurement	EM TEQ
500m	NT		1,700	15
1000m	NT		1,200	9.4

Dioxin decomposition test in soil of rice field

Preparation for specimen and result

1. Results of GC-HR-MS analysis for dioxin as well as CO-PCB are shown in Table 7. In a farm field to which EM has been applied sufficiently for 2-3 years, the amount of dioxin is decreased by 80-93%, or at 7.6-15 pg-TEG/g. Moreover, in home vegetable garden, in which less amount of EM materials has been applied, dioxin

decreases by 37%, or at 12pg-TEQ/g (Table 7).

2. Soil sample is collected at sites within a radius of 2 km to the south-west direction from Shiratori Garbage Plant. According to the data collected by a research group at Setsunan University in June 1997, this area is polluted to the extent that the total amount of dioxin per g of soil is 250 pg-TEQ/g at 200 m from the garbage plant. However, the amount of dioxin is 110 pg-TEQ/g in the control soil collected by us from traditional rice field in March 1999, and 7.6pg-TEQ/g in the soil of EM-applied area, which mean that dioxin is decreased by 93%. The amount of CO-PCB is 0.55pg-TEQ/g, which means a decreases of 50%.

We therefore verified that the amount of dioxin is decreased to a great extent in the soil of rice field that has changed from traditional farming to EM one.

Soil sample is collected from a traditional rice field in Ryugasaki-city by the 5-point mixing method. The soil (250 g) was mixed with 2.5ml (1%) of EM-1 of, 7.5g (3%) of EM bokashi, and 5 mg of EM-X ceramics. The liquid is applied at room temperature for 12 and 50 days, and dioxin is measured by GC-HR-MS analysis. Table 8 shows the values of decrease after 12 and 50 days.

Table 8 Results of pot test

	Prior to EM application	12 days after	50 days after
Dioxin (pg-TEQ/g)	170	150 (12% less)	130 (24% less)

Transformation of toxic material to harmless substances

From EM materials, more than 40 kinds of minerals can be detected, which include photo-catalyst and oxidation titanate. These also exist in nature. It is considered that toxic materials dispersed in the environment are probably decomposed by oxidation strongly, and then transformed to harmless materials (Fig. 13) (New Photo-catalyst 2000).

3. DISCUSSION

Human beings have produced extensive environmental pollution on the earth in the last ten years. Today, we believe that to preserve the global environment without completely depending on national and local governments, each of us must act locally to improve or restore it. For example, everyone must recognized that once toxic chemicals such as germicides and/or detergent materials are discharged into the environment, they will never be degraded but are sequentially concentrated through the food chain in the body of higher-order living things such as humans.

In case of some dioxin and/or organic chlorine agricultural chemical, they are normally absorbed, and then transported to the river, lake or sea. Because these chemicals are digested by benthos, fish and shellfish, and are condensed biologically, the impact to higher-order living organisms such as birds and/or animals becomes so serious that some of the species would be completely killed off. Humans are not exempted from such impact; over 100 kinds of chemicals are sometimes detected in blood, and 30-40% of newly born babies have some form of allergy, so that even the survival of human beings is questionable.

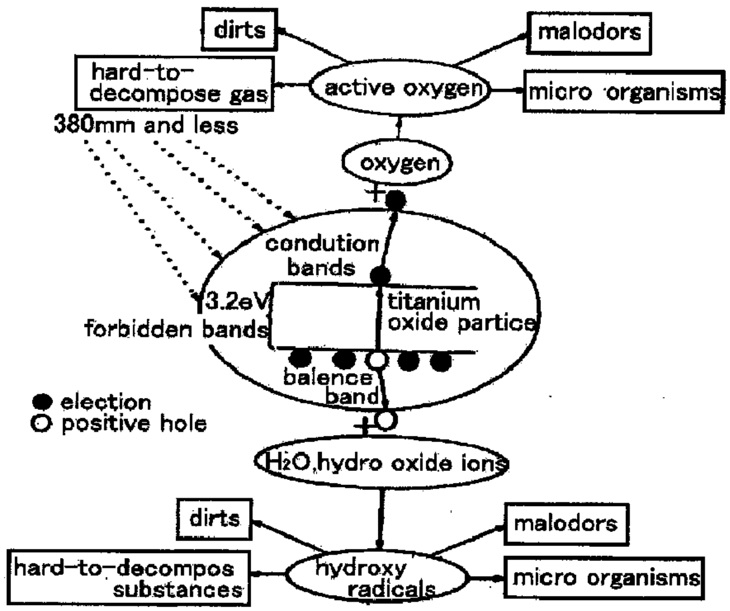


Fig. 13 Oxidative decomposition by the photocatalyst

It must be noted that all living things on earth are related to each other, possessing common genes. In an environment where other living things cannot survive, humans also are impossible to continue to exist. It is therefore urgent to take proper actions to improve the current environment. For example, use of chemicals, especially germicide, should be restricted to the minimum. The quantity of raw garbage reaches almost half of the domestic rubbish if restaurant and commercial refuse is included, and amounts to ca. 30 million ton per year. By decomposing this garbage using EM and appling the fertilizer to improve soil, not only is the amount of incineration decreased, but generation of dioxin is also reduced. Furthermore, all of us should make full use of beneficial bacteria to reconstruct a rich bio-sphere as well as a green sphere on earth, and to remedy the present environment and to create such an ideal society in which human beings live symbiotically in harmony with all of the rest of the living things.

Conclusion

New findings through the present study are summarized as follows:

1. Application of EM materials in soil enriches bio-diversity of the soil.
2. EM enhances transformation of toxic materials into harmless substances.
3. EM can be used and applied to solve a wide variety of issues such as countermeasure of environmental pollution, preservation of environment, and construction of a cyclic type society.

4. CONCLUDING REMARK

Restoration of natural system and technology of preservation using EM

EM materials are no more than compound materials consisting of effective microorganisms that survive in nature, so that organic and inorganic materials can be disposed of on-site safely and cheaply.

When EM materials are applied to soil on-site, a bio-sphere consisting of an almost haploid phase may change to one with rich biological phase. It has been also observed that a variety of living things are generated from soil treated by EM, and they can survive in 300 ml of water for over one year. Since the natural system around the site is remedied, the mechanism of self-purification is restored. Hence, it is quite possible that EM could play a great role in constructing a sustainable society. At present, EM has been already used to improve quality of soil and/or purify the water in river not only in Japan but also in many other countries (Higa 1991, Higa 1997, Higa 2000).

ANNONCEMENT

During the presentation of "Restoration and Preservation of the Natural System using EM" at the 3rd Meeting of the Japan Symbiosis Society, the site of specimen collection for on-site validation study of dioxin was mistakenly stated as Nose-machi, Osaka Prefecture. The correct site should be a city in Okayama Prefecture.

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