Study on Bioremediation of Water Contamination Caused by Nargis Cyclone around Mawlamyinegyun Area, Ayeyarwady Delta

Myo Thant Tyn[1,2,*], Kyaw Myint Oo[1,2], Kyaw Nyein Aye[2,4], Than Oo[2], Aung Myo Thaik[2], Tin Than[2], Win Maung[3], Aye Pe[3], Thazin Lwin[3], Tun Aung[3], Myint Aung[3], Nyein Nyein Hlaing[3], Bay Dar[3], Aye Aye Myint[3], Kay Lwin Tun[3], Yee Yee Nwe[3], Naung Lwi[3] and Myint Lwin[5]

Abstract

On 2 and 3 May 2008, Cyclone Nargis struck the coast of Myanmar and moved inland across the Ayeyarwady Delta and southern Yangon Division, causing many deaths, destroying livelihoods, and disrupting economic activities and social conditions. Apart from these catastrophic disasters, the cyclone left the Delta with losses of natural habitats and environmental pollution. In order to solve these problems, the application of EM (Effective Microorganisms) Technology for the remediation efforts has been employed in the disaster struck areas by a concerned group called Envir-Klean Technologists' Associates (EKTA). During May to August in 2008, the EKTA visited the sites located in Mawlamyinegyun Township, which are among the severe hit areas to conduct microbiological and physico-chemical investigations on water samples from the selected Nargis Cyclone affected areas. The results of water contamination were surprisingly found beyond the maximum contaminant level (MCL) that the total plate count (TPC) for preliminary on site data shows in the range of 7.5 x 10^9 to 17.5 x 10^9 cfu/ml for the selected points tested within a month after the cyclone. After monthly visits to the study areas, the microbiology and physico-chemical contaminations were reduced to certain extent due to natural effect, environmental factors and biotreatment by effective microorganisms. With the EM application, the total plate counts were not always reduced because the bacteria may come from applied microbes. However, the pathogenic bacteria were significantly reduced by effective microorganisms. Physico-chemical properties such as organic constituents and heavy toxic metals were also checked before and after EM treatment and the results show wide range of effectiveness. The overall investigation on microbiology and physico-chemistry has proved that bioremediation attempt was successful in the counter measure of water contamination caused by tropical cyclone Nargis around Mawlamyinegyun area, Ayeyarwady Delta, Myanmar.

Key Words: Bioremediation, Effective Microorganisms, Heavy Toxic Metals, Mawlamyinegyun, Nargis Cyclone, Organic Constituents, Water Contamination

---

1. **Myanmar Academy of Arts and Science, Ohndaw Hall, Hlaing University P.O., Hlaing Township, Yangon, Myanmar.**
2. **Envir-Klean Technologists' Associates, Room 21, Building 3, Pan Hlaing Housing, Kyeemyindine Township, Yangon, Myanmar.**
3. **Yangon University, University P.O., Kamayut Township, Yangon, Myanmar.**
4. **Yangon Technological University, Insein Road, Gyogone, Yangon, Myanmar.**
5. **Yezin Agricultural University, Yezin, Naypyitaw, Myanmar.**

*** Corresponding Author: Email: myotyn@gmail.com**

Introduction

The cyclone Nargis that struck several areas around Ayeyarwady Delta on May 2 and 3, 2008 in Myanmar has left losses and damages of natural habitats and living things causing environmental pollution. As the cyclone swept the delta, many freshwater sources and fertile soils have been mixed with sea water. This has left many farms such as rice and shrimp with extreme salinity. There was much foul odor emanating from decaying bodies during a few months after the cyclone. The contamination could take place in the areas several months. It is possible for the spread of infectious diseases like malaria and other waterborne diseases.

Fresh waters are extremely important as source of drinking water. In many locations the contamination of surface and subsurface waters by natural and man-made disasters causes environmental problems. Lakes and rivers provide microbial environment that are different from the larger oceanic systems in many important ways. Microorganisms are constantly mixing and being added to waters. A critical adaptation of microorganisms in aquatic system is the ability to link and use resources that are in separate or that are available at the same location only for short intervals such as during storms (Prescott *et al.,* 2003).

The damage and losses in the water sector resulting from Cyclone Nargis are estimated at around Kyats 8.5 billion. The destruction of housing during the cyclone led to the loss of many household rainwater harvesting systems, while the storm surge and flooding that followed the cyclone led to the salination of many community rainwater ponds, affecting up to 43% of ponds in Ayeyarwady Division (PONJA, 2008).

In order to solve these problems, the application of EM (Effective Microorganisms) Technology for the remediation efforts can be employed in the disaster struck areas. The technology of EM has been developed since early 1980s, in searching natural alternatives to agrochemicals. Apart from agriculture, the success paved the way for using EM in environmental management, both solids and liquids, especially water. EM was used in modern natural disaster management such as successful mitigation of foul odors and elimination of pathogens in the late 2004 when Tsunami affected in Asia (Higa, 1996 and APNAN, 2005).

During May to August 2008, the effective microorganisms had been utilized in Bioremediation of Nargis affected Ayeyarwady Delta, specifically at selected sites of Mawlamyinegyun Township. The Envir-Klean Technologists' Associates (EKTA), which is affiliated with Myanmar Ceramic Society (MCS), has been conducting a Bioremediation Project for the sake of proper rehabilitation works being done by Nargis victims. EKTA visited the sites located in Mawlamyinegyun Township, which are among the severe hit areas. First visit was to conduct preliminary Environmental Impact Assessment (EIA) in those sites during the fourth week of cyclone aftermath. The water samples were collected at 38 points around the villages on 30th May, 2008. The second visit was made to take water samples and to be carried out bioremediation at the most contaminated 12 sites selected among 38 points. During that trip, these sites were sprayed with EM, on the 9th July, 2008. In addition to the contaminated sites, there was a drinking water purification system at Kyonlamugyi village where from two additional samples were taken before and after purification. On 13th August, 2008, the third trip was made to proceed water sampling and to find out the extent of effectiveness by the treatment. The objectives of the present study are to investigate the microbiological and physico-chemical parameters of the water bodies in the selected areas and to study the effectiveness of bioremediation on water contamination caused by Nargis cyclone around Mawlamyinegyun area, Ayeyarwady Delta.

Materials and Methods

Materials

Effective Microbes (EM) containing total plate count of 8.02 x10^7 cfu/ml which may consist of photosynthesis bacteria, lactic acid bacteria and yeast was used in the present study. The microbes are cultured in molasses as Bio Feed and provided by Golden Taunggyi Bio Product Group, Taunggyi, Myanmar. Bio Feed is to be applied in the wastewater and targeted ponds at the ratio of 1: 5000 to 10000 according to the extent of the contamination.

Culture media

The following culture media were used in this research to culture the bacterial isolates for identification; the Alkaline Peptone Water (APW), Nutrient broth, Plate count agar, MacConkey agar, Thiosulphate Citrate Bile Sucrose (TCBS) agar, Salmonella-Shigella (SS) agar, Eosin Methylene Blue (EMB) agar, Triple Sugar Iron (TSI), Simmon's Citrate (SC) agar, Urea broth, Mehtyl-Red-Voges-Proskauer (MR-VP), Sulphide Indole Motility (SIM) medium (HiMedia Manual, 2003).

Methods

Sampling

Sampling was done according to Salle (1999). Water samples from the river, creek, ponds and other sources were collected around Mawlamyinegyun area. These studied areas include Nathmu, Myinkakone, Kyonlamugyi, Kyar-hone creek, Kyetshar, Aung Thu Kha, Ye-gyaw-tain creek, Kyunchaung, Thankhanauk and Mawlamyinegyun jetty (16˚ 9′ N to 16˚ 22′ N and 95˚ 11′ E to 95˚ 17′ E; Fig 1).

Fig. 1. Sampling sites in Mawlamyinegyun Township, Ayeyarwady Delta

The water samples were collected in clean, sterile 500 ml screw-cap bottles. The samples were kept in an ice box during the transport to the Microbiology Laboratories of Zoology and Botany Department, Yangon University and Quality Control Laboratory, Department of Fisheries, Ministry of Livestock Breeding and Fisheries, Union of Myanmar.

Sample Preparation for Microbial Tests

The sample bottles were shaken vigorously at least 25 times to obtain a uniform distribution of organisms. Serial dilution and pour plate culture methods (Collins *et al.* 1995, Atlas, 1995) were used to enumerate the contaminated bacteria, where one ml of sample was diluted into 10 fold serial dilution. One ml from each dilution was used in pour plate culture. After incubation for overnight at 37°C the colonies were counted.

Standard plate count (Heterotrophic plate count) Method

Viable count also called standard plate count method is one of the indirect count methods for the enumeration of bacteria. The plates with 10^{-1} – 10^{-8} dilutions were used for viable count. After counting, the number was calculated to the probable number of bacteria per ml in the original sample. Calculation needed only to multiply the number of bacterial colony by reciprocals of dilution and of the volume used (Atlas, 1995 and Dubey and Maheshwari, 2002).

Isolation of Bacteria and Identification

One ml of water sample in 9 ml of Nutrient broth and two ml of water sample in 8ml of alkali peptone water were prepared for isolation of *Vibrio* spp. These tubes were incubated at 37°C for overnight. Streak plate method (Bradshaw, 1992) was used to get a pure culture of respective bacteria. According to the streak plate method, one loopful of inoculum was streak on the surface of EMB agar, SS agar, MacConkey agar and TCBS agar plates. These plates were incubated at 37°C for over night. After incubation, the colonies growing on the surface of the agar plates were examined for colonial morphology and Gram stain. Confirmation of bacteria by biochemical reactions was based on the methods as given by Collins *et al.* (1995), Bisen and Verma (1998) and HiMedia (2003).

The characteristic features of the isolates like colonial morphology, Gram staining nature and biochemical tests so far studied during the work were compared with those described by Breed *et al.* (1957) and Cowan (1975).

Microbiological organisms such as Coliform and *E.coli* were detected and enumerated by multiple tube method based on most probable number (MPN) technique. (Collins *et al.*, 1995)

Physico-Chemical Investigation

Physico-chemical properties such as physical and aggregate properties, (pH, alkalinity, hardness, total dissolved solids, and dissolved oxygen.) inorganic constituents (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, and SO_4^{2-}), metallic constituents (B, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Sn, Pb, U), nutrients (NH_3-N, NO_2-N, NO_3-N and PO_4-P), and organic constituents (chemical cxygen demand, COD; biochemical oxygen demand, BOD; and dissolved organic carbon, DOC) were investigated for each study site (A.P.H.A *et al.* 2008, Montaser, 1987, Chapman, 1992).

All chemical and instrumental analyses were performed at two Institutions: Chemistry Department at University of Yangon and Research Centre of Karlsruhe (GERMANY).

Results and Discussion

Microbiological Investigation

Viable counts of bacteria before treatment

Among the samples collected from 14 sampling sites, the highest bacteria count was found in the sample from the site of Aung Thu Kha pond water (III B) which had been contaminated from decay bodies (4 x 10^5 cfu/ml). The count values of the samples from the sites from Thankhanauk and Kyunchaung villages (IV B, IV C), Kyonlamugyi creek (VA) and Water purifying system (VB) were 1.8 x 10^3 cfu/ml, 2.13 x 10^4 cfu/ml, 7.6 x 10^4 cfu/ml and 7.66x10^3 cfu/ml respectively. The count values of remaining sites were relatively low and remarkable differences were not found among them (Table 1). According to EPA drinking water standards (2008), all samples were regarded as contaminated and most of the sampling sites were found to be higher than maximum contaminant level (MCL: the highest level of a contaminant that is allowed in drinking water, MCL of the Heterotrophic Plate Count = No more than 500 bacterial colonies per milliliter) (EPA, 2008).

Viable counts of bacteria after treatment

The viable count values of the all sampling sites were not remarkably different with that of before EM treatment except the sites at Kyetshar (IIIA), Kyonlamugyi creek and Water purifying system (VA and VB). The count values of the samples from site of Nathmu drinking water tank (IA) recorded before and after treatment were nearly the same. Site IA is a concrete tank where the rain water is stored for drinking purpose, and tightly covered to protect from contamination. The EM was, therefore, sprayed only around the concrete tank, not directly into the drinking water. The viable count of bacteria after treatment from site Nathmu creek (IB) and Kyonlamugyi river water (IIB) were higher than that of before treatment, and it may be due to the increase of *Proteus* species as detected in the laboratory experiment (Table 1).

The samples from still water (i.e., from ponds) showed variable counts decreasing after treatment whereas both increased and decreased values in flowing water were observed probably due to the nature of the running condition. Although they were treated by EM, the viable counts from some sampling sites were found higher than drinking water standard values (EPA, 2008). Therefore, the EM treatment should be carried out necessarily and chlorination or boiling treatment should also be recommended prior to drinking.

Determination of bacterial isolates before treatment

The specific selective media, MacConkey agar, Salmonella – Shigella agar, Thiosulphate Citrate Bile salt Sucrose agar and Eosin Methylene Blue agar, were used to culture the respective bacteria and recorded the existing species. Colony morphological features like, colony shape, elevation, margin surface etc, were variable in different media of isolated bacteria. The results obtained from testing with the isolates using oxidases, catalase, gelatinase, indole formation, H_2S production, Methyle red, Voges- Proskauer, citrate utilization, sugar fermentation and urease. The bacteria under the group of Enterobacteriaceae, *Vibrio* spp. were recorded in all samples except that of the sites Kyar-hone creek and Kyunchaung drinking water pond (IIC and IVC). *Salmonella* species was found only in that of Thankhanauk pond water (IVB) (Table 1).

Determination of bacterial isolates after treatment

The bacteria *E. coli*, most of which are pathogenic species, were not detected in all studied sites after treatment except Kyonlamugyi creek (Table 1). The bacteria *Proteus* spp. and *Pseudomonas* spp. were found in most of the samples. *Aeromonas* spp. was found in the sample from the site of Kyar-hone creek (IIC) and Aung Thu Kha (IIIB), and these species were assumed to be fish pathogenic bacteria. Pathogenic bacteria were not detected in the samples from sites of Kyunchaung drinking water pond (IVC) and Purification system (VB). The pathogenic species, *Vibrio* spp., recorded in the sample from site of Ye-gyaw-tain creek (IIIC) was not found after treatment showing the effectiveness of the EM.

The *Vibrio* species was recorded in the samples from site Thankhanauk pond water (IVB) before and after treatments. It was predicted that the occurrence of *Vibrio* species after treatment may be concerned only with unskillful application of EM by local villagers. However, according to interviewing with local people, the foul odor of the sewage pond was significantly gone three days after EM treatment.

Prescott *et al*, (2003) mentioned that aquatic environments can serve as reservoirs and transmission routes for disease-causing microorganisms. A major goal of aquatic system management is to control pathogen survival and transfer. Salle (1999) reported that the majority of bacteria found in water belong to the following groups: (1) fluorescent bacteria (*Pseudomonas, Alginomonas,* etc.), (2) chromogenic rods. (*Xanthomonas* etc.), (3) coliform group (*Escherichia, Aerobacter* etc.), (4) *Proteus* group, (5) non-gasforming nonchromogenic non-spore-forming rods, (6) sporeformers of genus *Bacillus* and (7) pigmented and non pigmented *cocci* (*Micrococcus*). The report of Salle (1999) was in agreement with the present findings, where *Pseudomonas* spp., *Escherichia* spp. and *Proteus* spp. were recorded.

During the field trips to Mawlamyinegyun Township, the samples were immediately checked their bacterial counts on site. With the courtesy of Department of Botany, Yangon University, the Total Plate Count of water samples were found in the range of 7.5×10^9 to 17.5×10^9cfu/ml after four weeks of cyclone Nargis. The test method in the field was done as described by Collins *et al*. (1995).

The water samples were also sent to the quality control laboratory of Department of Fisheries and the results revealed that the contamination was the highest in May, 4 weeks after the cyclone Nargis hit the selected study sites.

Table. 1 Viable count and diversity of isolated bacteria genera in the collected water samples around Mawlamyinegyun Area (Before and After treatment of EM)

Sr No.	Sampling Site	Code	Treatment	Date of Sampling	Viable count cfu/ml	Tentative genera
1.	Nathmu concrete drinking water tank	IA	Before	10.7.08	1.45×10^2	*E.coli, Klebsiella*
			After	13.8.08	1.15×10^2	*Pseudomonas*
2.	Nathmu creek water	IB	Before	10.7.08	4.3×10^2	*E. coli*
			After	13.8.08	6.58×10^2	*Proteus*
3.	Myinkakone river water*	IIA	Before	11.7.08	1.8×10^2	*E. coli*
			After	14.8.08	8×10^2	-
4.	Kyonlamugyi river water	IIB	Before	11.7.08	1×10^2	*E. coli*
			After	14.8.08	1.8×10^3	*Proteus*
5.	Kyar-hone creek water	IIC	Before	11.7.08	5.9×10^2	-
			After	14.8.08	1.25×10^2	*Aeromonas*
6.	Kyar-hone pond water	IID	Before	11.7.08	3.5×10^2	*E. coli*
			After	14.8.08	2.43×10^2	*Proteus*
7.	Kyetshar drinking water pond	IIIA	Before	11.7.08	7×10^2	*E.coli, Klebsiella*
			After	13.8.08	0.5×10^2	*Pseudomonas*
8.	Aung Thu Kha pond water	IIIB	Before	11.7.08	4×10^5	*E. coli*
			After	13.8.08	2.43×10^2	*Aeromonas*
9.	Ye-gyaw-tain creek water	IIIC	Before	11.7.08	6.95×10^3	*Vibrio, E. coli*
			After	13.8.08	2.58×10^2	*Proteus*
10	Mawlamyinegyun jetty*	IVA	Before	11.7.08	2.9×10^2	*E.coli*
			After	14.8.08	1.6×10^2	-
11.	Thankhanauk pond water	IVB	Before	10.7.08	1.8×10^3	*Salmonella, Vibrio, E.coli*
			After	14.8.08	9×10^2	*Salmonella, Vibrio, Proteus*
12.	Kyunchaung drinking water pond	IVC	Before	10.7.08	2.13×10^4	-
			After	14.8.08	1.42×10^3	-
13.	Kyonlamugyi creek water (Water-purifying system Inlet)	VA	Before	11.7.08	7.6×10^4	*E.coli, Klebsiella*
			After	14.8.08	4×10^2	*E. coli, Pseudomonas*
14.	Water-purifying system (Outlet)	VB	Before	11.7.08	7.66×10^3	*Klebsiella*
			After	14.8.08	2.5×10^2	-

(Courtesy of Microbiology Laboratory, Zoology Department, Yangon University)
* Results adopted from those tested by DOF Quality Control Laboratory

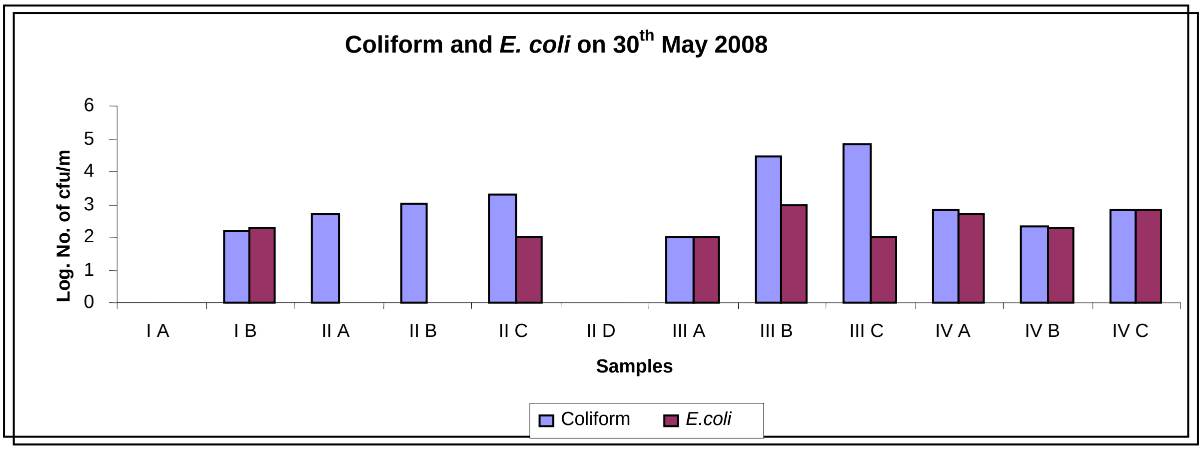

Fig. 2. Coliform and *E. coli* counts of the samples from selected sampling sites (4 weeks after cyclone) (Analyzed by DOF QC laboratory)

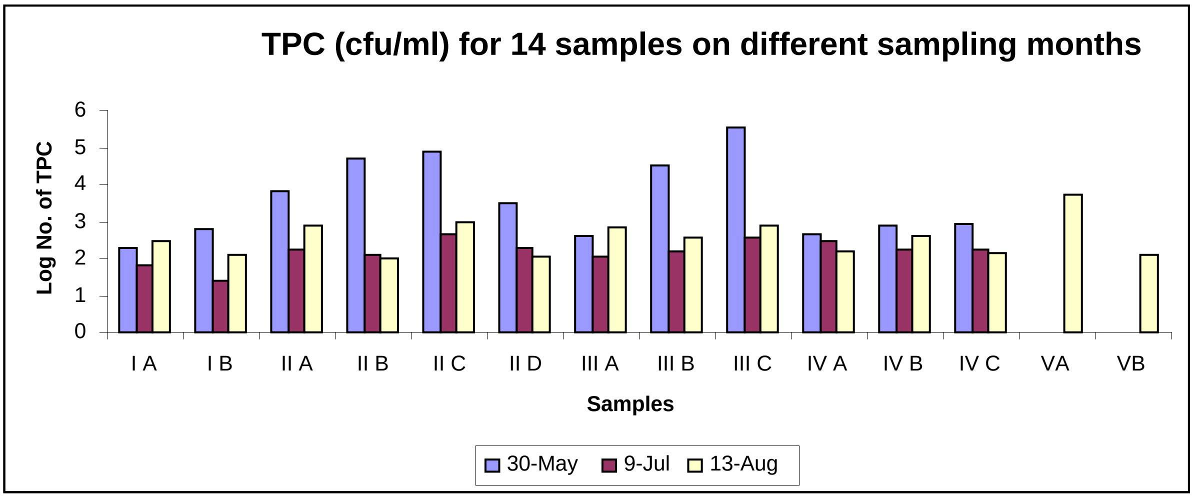

Fig. 3. Comparison of Total Plate Counts in different sampling months (Analyzed by DOF QC Laboratory)

E.coli and coliform bacteria were detected in the selected samples before treatment (May, 2008) (Fig.2). The *E. coli* counts were detected to be <1 in all the samples by Quality Control Laboratory test in July and August. The global standard for *E.coli* count is 0 to 1 MPN/ 100 ml (for drinking water), 200 MPN / 100 ml (for swimming) and 2000 MPN / 100 ml (for boating and recreation) (Collins *et al.* 1995). Total plate count (TPC) values varied among the sampling sites, and remarkable difference was not found between before and after treatments (May and August, 2008) (Fig. 3). The count values after treatment were higher than those of before treatment in some study sites, and that may be due to the increase of some bacteria species other than *E.coli* and coliform bacteria, which were recorded as <1 cfu/ml after treatment.

Physico-chemical Investigation

For physical and aggregate properties of all sampling sites, the determinant values (Table2) were found to be more or less within the assimilative capacity as recommended by EPA standard values (2008). However, in the case of DO, it is much higher than the allowable limits. The high DO values may enhance the survival of the marine and biological communities in aquatic system (Cunnigham, 2008).

For inorganic constituents, most of the parameters (Table 2) were higher than permissible levels of EPA-guidelines (EPA, 2008). The presence in the form of Ca^{2+}, Mg^{2+}, HCO_3^- suggests that the water bodies of studied areas are more under the category of temporary hardness, rather than the permanent hardness as once anticipated. The increased concentration levels of the monovalent cations (Na^+, K^+) obtained are possibly due to the sewage and industrial effluents and run-off from agricultural land. The increased concentration of $SO_4^=$ can arise from atmospheric precipitation, leaching of sulphate minerals, accidental industrial discharge and the alluvial soil condition and high content of Cl^- is also due to the sewage pollution and the soil condition in the studied areas. Thus, these make water unpalatable and therefore, unfit for human consumption (Hammer, 1986).

The presence of metallic constituents is important for the physiological function of living tissue and regulates many biochemical processes. But, in some cases, it can cause severe toxicological effects in human and aquatic ecosystems (WHO, 2008). The highly toxic metals detected together with other metals (Table 3 and Fig. 4) were found to be higher than the guidelines of EPA standard (EPA, 2008). It is indicative that the studied areas are in the threshold of pollution. It can be suggested that these metal concentrations are pre-concentrated in other season (i.e., winter) and become more or less dispersed or transported in the studied season (i.e., rainy) (Thazin Lwin, 1998). These toxic metals are released from rocks by weathering, are carried by runoff into rivers, or percolate into groundwater aquifers. The higher levels than natural background levels are due to mining, processing, using and discarding of minerals. Myanmar's cyclone-devastated Ayeyarwady delta are now facing high risks of some toxic metals in river water and ground water that could cause cancer and other diseases in residents.

Pollution stress of the water body was also supported by the presence of nutrients (Table 3) which are known to be above the guidelines of EPA standards (2008). The nitrate rich waters encourage algae growth which indicates eutrophic conditions. The high concentration of phosphate may be due to the dissolving of fertilizers and run-off agricultural lands.

For the major parameters (COD, BOD, DOC) representing the organic matter contaminated in surface waters in all study sites, COD are greater than BOD and DOC (Table 3 and Fig. 5). The high values of COD are indicative of organic materials which can be oxidized by a strong chemical oxidant, whereas BOD measures the biochemically degradable organic matter. As organic constituents are directly related to microbial content in the water, the results from microbiology determination can be comparable to the BOD values.

Table 2 Variations of the quality parameters (Physical and Aggregate Properties, Inorganic Constituents) in the collected water samples around Mawlamyinegyun area

Parameter (ppm)	Sampling Month (2008)	Sampling Site														Standard EPA Value (2008)
		IA	IB	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IVA	IVB	IVC	VA	VB	
pH (no unit)	July	7.8	7.9	7.8	7.8	7.6	7.5	7.7	7.4	7.5	7.4	7.7	7.8	7.7	7.6	6.2 – 8.4
	August	7.6	7.4	7.4	7.5	7.5	7.4	7.6	7.9	7.8	7.5	7.9	7.4	7.5	7.7	
TDS	July	500	510	490	480	500	460	500	470	460	480	450	465	460	490	< 600
	August	450	48	460	430	410	380	390	410	415	450	430	410	390	420	
DO	July	11.6	10.9	11.2	10.8	11.5	11.4	11.2	10.4	10.9	11.5	10.8	11.1	11.2	10.7	4 - 6
	August	9.5	8.9	9.6	9.8	9.4	9.3	9.4	9.5	9.2	8.8	9.4	9.3	8.9	9.1	
HCO_3^-	July	30.9	33.4	36.5	32.4	37.3	33.5	38.3	31.6	30.5	32.4	30.8	33.5	32.4	36.5	30.5
	August	29.3	28.9	25.3	29.1	24.5	24.3	23.4	29.3	25.4	26.7	24.5	23.4	25.3	25.1	
Cl^-	July	6.8	6.7	6.9	6.8	7.1	6.7	6.8	6.8	6.9	7.1	6.7	6.3	6.5	6.4	3.9
	August	6.6	6.3	6.4	5.9	6.1	6.0	5.9	6.4	6.3	6.1	6.2	6.5	6.4	6.3	
$SO_4^{=}$	July	39.4	38.4	39.3	34.5	38.5	35.4	39.9	39.4	38.4	39.1	37.4	33.5	34.9	35.3	4.8
	August	30.5	30.9	31.5	32.3	32.3	34.5	33.8	30.9	31.4	32.3	33.8	30.6	34.1	33.9	

Table 3 Variations of the quality parameters (Metallic Constituents, Organic Constituents) in the collected water samples around Mawlamyinegyun area

Parameter (ppm)	Sampling Month (2008)	Sampling Site														Standard EPA Value (2008)
		IA	IB	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IVA	IVB	IVC	VA	VB	
As	July	1.49	1.34	1.39	1.43	1.23	1.34	1.39	1.48	4.74	1.23	1.23	1.49	1.11	1.04	0.05
	August	1.23	1.10	1.40	1.39	1.28	1.49	1.38	1.21	1.34	1.21	1.31	1.36	1.29	1.34	
Cd	July	0.006	0.007	0.006	0.008	0.007	0.004	0.007	0.008	0.01	0.006	0.008	0.005	0.00	0.004	0.005
	August	0.004	0.003	0.002	0.001	0.003	0.002	0.001	0.00	0.002	0.001	0.003	0.003	0.002	0.001	
Cr	July	6.12	6.14	6.32	5.32	5.92	5.90	5.86	5.36	5.54	5.44	5.32	5.86	6.10	5.59	0.005
	August	4.93	5.32	5.14	5.29	4.47	4.40	4.39	4.14	4.39	4.86	4.74	4.23	4.23	4.35	
Pb	July	0.08	0.07	0.08	0.08	0.06	0.06	0.05	0.06	0.08	0.06	0.07	0.04	0.08	0.05	0.05
	August	0.05	0.04	0.05	0.04	0.03	0.03	0.05	0.05	0.04	0.03	0.01	0.02	0.03	0.02	
COD	July	9.82	9.23	9.31	9.02	9.23	9.54	9.54	9.23	9.39	9.25	9.54	9.34	9.84	9.51	10
	August	7.94	7.41	7.89	7.89	7.24	7.23	7.86	7.23	7.34	7.1	7.38	7.84	7.25	7.92	
BOD	July	5.29	5.23	5.14	5.23	5.29	5.49	5.86	5.23	5.41	5.5	5.39	5.42	5.42	5.48	5
	August	4.11	4.06	4.10	4.11	4.23	4.08	4.19	4.12	4.32	4.14	4.08	4.23	4.11	4.12	
DOC	July	4.81	4.28	4.87	4.35	4.67	4.91	4.59	4.23	4.06	4.89	4.35	4.74	4.23	4.12	4.2
	August	3.42	3.12	3.98	3.76	3.48	3.23	3.23	3.24	3.47	3.98	3.76	4.12	3.96	4.04	

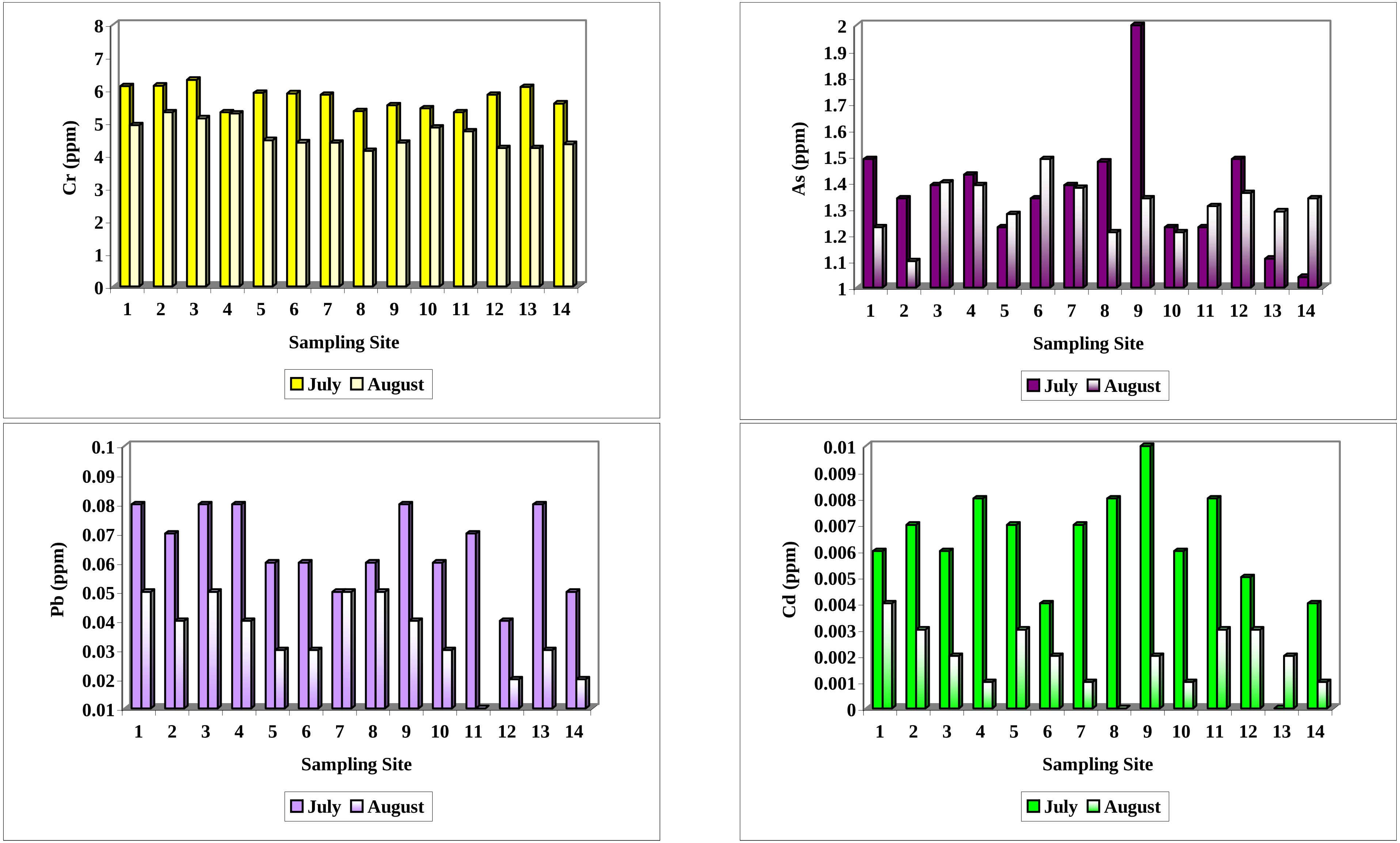

Fig. 4 Elemental distribution of metallic constituents in the collected water samples for 14-sampling sites around Mawlamyinegyun area (Locations cited in Table-1)

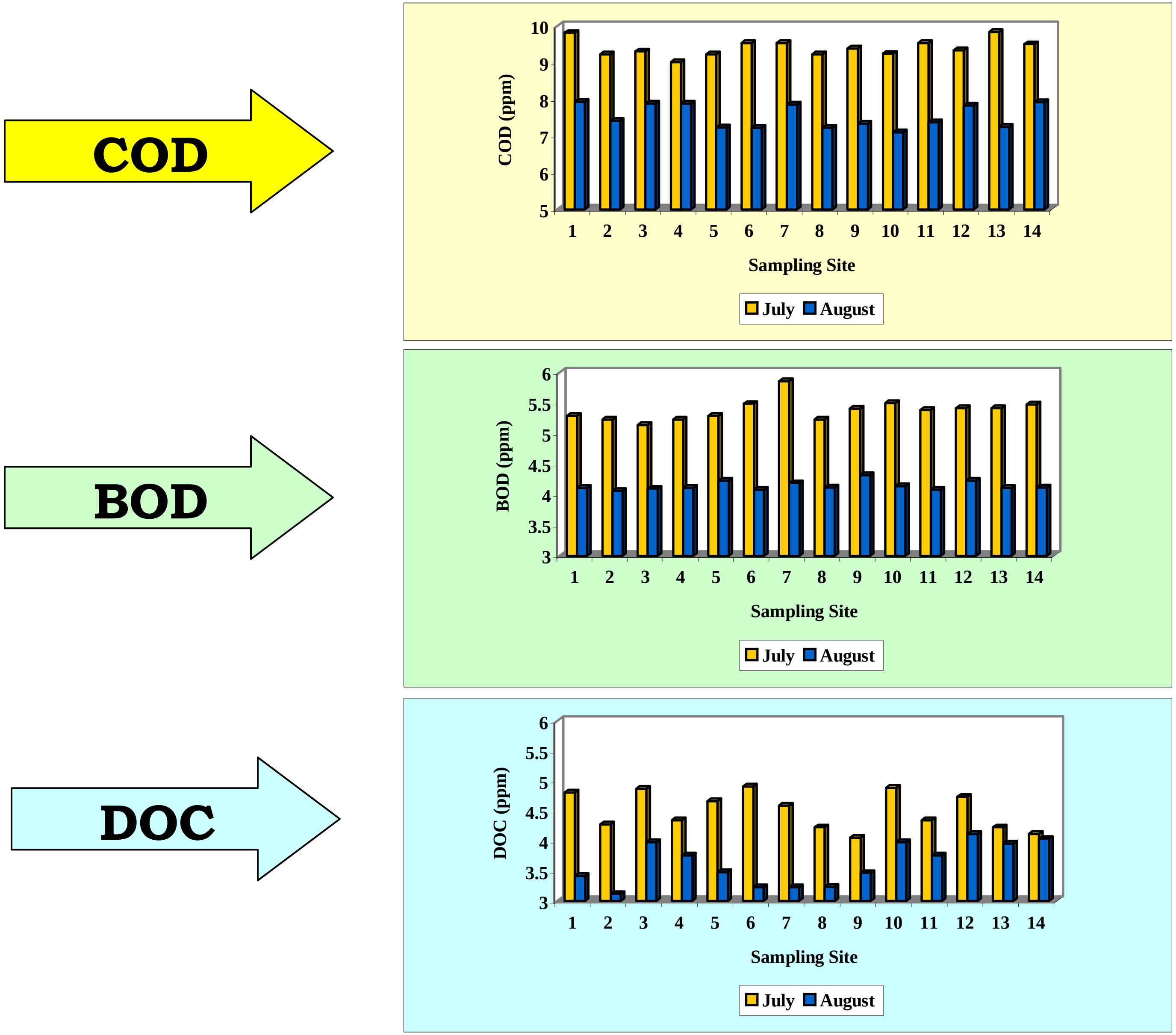

Fig. 5 Variations of organic constituents in the collected water samples for 14-sampling sites around Mawlamyeingun Area

Conclusion

The present study clearly indicates that the cyclone affected areas are more or less suffering environmental pollution stresses. This is mainly confirmed by physico-chemical and microbiological results obtained during four months of the study undertaken. The attempt of bioremediation on the environmental pollutants has shown the effectiveness of beneficial microbes (EM) satisfactorily by the pilot study at selected sampling sites. This study may also be preventive measure of the environmental problems that can occur in the future and supportive for the preparedness against natural disasters in these regions.

It is concluded that the microbial contamination with pathogenic bacteria can be effectively controlled by beneficial bacteria that have already known to environmental engineers who are experts in multiplication and application of this technology. Envir-Klean Technologists' Associates (EKTA) primarily aim to preserve the natural environment and to protect its degradation as well as to remediate the polluted sites. By implementing microbiological treatments, the heavy toxic metal contamination in the water body can also be reduced while biohazards are lowered.

The sustainable and extended objectives need to be proposed and developed so as to provide a quality water bodies to be used for all purposes, especially in the Nargis cyclone affected Ayeyarwady delta region. This should also be supported by a strong environmental awareness campaign to help the people in these rural communities to participate positively in efforts to protect and manage the quality of their water resources.

Hence, in order to make an effective use of the water bodies as a quality water resources; it would be advisable to develop cost-effective and efficient water treatment and monitoring processes located near the affected areas. It is hoped that the present work will be "a primary source of information", to show how bioremediation actions and pollution control have been undertaken, and to confirm the certain extent of the effectiveness of EM has achieved.

Acknowledgements

The authors would like to thank to the Ministry of Progress of Border Areas and National Races and Development Affairs, the focal ministry of Mawlamyinegyun area who has sponsored the whole field visit to the study area. Many thanks also go to the Ministry of Education and Ministry of Agriculture and Irrigation for their continuous supports. Moreover, Myanmar Academy of Arts and Science, Department of Fisheries, Myanmar Fisheries Federation, Myanmar Shrimp Association, Nargis Action Group, Pale Nadi Company, Shwe Taunggyi Bio Product Group and other helpful organizations those cannot be mentioned all here. Last but not the least, the EKTA and authors of this paper extend their gratitude to Asia-Pacific Nature Agriculture Network (APNAN), the organization that encouraged to do such a remarkable bioremediation activities when our nation was in need.

References

A.P.H.A, A.W.W.A. and W.P.C.F., (2008), *Standard Methods for the Examination of Water and Wastewater*, Washington, D.C.

APNAN (2005), Kyusei Nature Farming and Technology of Effective Microorganisms Guidelines for Practical Use, Asia-Pacific Nature Agricultural Network

Atlas, R. M., (1995), *Microorganisms in Our World*. Mobsy, Year Book, Inc.

Bisen, P. S., and K. Verma, (1998), *Handbook of Microbiology*. CBS Publishers & Distributors, New Delhi – 110002 (India)

Bradshaw, L. J., (1992), *Laboratory Microbiology*. Saunders Colleague Publishing Florida.419 pp.

Breed, R. S., E. G. D. Murry and N. R. Smith (1957), *Burgey's Manual of Determinative Bacteriology*. The Williams and Wilkins Company. USA.

Chapman, D., (1992), *Water Quality Assessments*, Chapman & Hall Ltd., London

Collins, C. H., P. M. Lyne and J. M. Grange, (1995), *Microbiological Methods*. Butterworth-Heinemann Ltd, Oxford, London.

Cowan, S. T., (1975), *Cowan and Steel's Manual for the Identification of Medical Bacteria*. Cambridge University Press, London.

Cunnigham, W.P., (2008), *Environmental Science*, 10^{th} Edition, Mc Graw-Hill, New York

Dubey, R. C and D. K. Maheshwari, (2002), *Practical Microbiology*. S.chand and Company Ltd. Ram Nagar, New Delhi – 110 055.

EPA (2008), Environmental Protection Agency of United States: Drinking Water Standards, http://www.epa.gov/safewater/index.html (retrieved in August 2008)

Hammer, M. J., (1986), *Water and Wastewater Technology*, 2^{nd} Ed., John Wiley and Sons, Inc., New York

Higa, T. (1996), *Effective Microorganisms -their Role in Kyusei Nature Farming and Sustainable Agriculture*. In Proceedings of the Third International Conference on Kyusei Nature Farming. Ed. J.F. Parr et al., USDA, Washington, USA:20-24.

HiMedia (2003), *The HiMedia Manual Microbiology and Cell Culture Laboratory Practice*, HiMedia Laboratories Pvt. Ltd., India Mumbai, India.

Montaser, A., C (1987), *Inductively Coupled Plasmas in Analytical Atomic Spectrometry*, VCH publishers, Inc., New York

PONJA (2008), Post-Nargis Joint Assessment: A Report Prepared by Tripartite Core Group Comprised of Representatives of the Government of Union of Myanmar, Association of the South East Asian Nations and the United Nations with the support of the Humanitarian and Development Community (July 2008)

Prescott, L. M., J. P. Harley, and D. A. Klein (2003), *Microbiology*. 5th edition. McGraw-Hill Companies.Singapore. pp. 774.

Salle, A. J. (1999), *Fundamental Principles of Bacteriology*. Ta Ta McGraw-Hill Publishing Com. Ltd., New Delhi.

Thazin Lwin, (1998), *Assessment of the Water Quality from some Selected Regions of the Ayeyarwady River*, Ph.D. Dissertation, Department of Chemistry, University of Yangon, Myanmar

WHO, (2008), *Guidelines for Drinking Water Quality*, World Health Organization, Geneva