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Effective Microorganisms (EM) Technology for Water Quality Restoration and Potential for Sustainable Water Resources and Management

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Abstract: Water quality has received considerable attention in allocation processes for maximizing the satisfaction of various sectors. However, pollutant impurities that impede adequate supply of water have a detrimental effect on the quality and harmful for living organisms including aquatic life. For the reduction of water pollution level, various chemical and biological treatments are available but the emergence of an amazing technology of a multiculture of anaerobic and aerobic beneficial microorganisms is presently gaining popularity due to its environmentally friendly nature. This effective microorganism (EM) technology uses naturally occurring microorganisms which are able to purify and revive nature. Applications of EM using the formula known as effective microorganism activated solution (EMAS) have been experimented in several rivers in Malaysia depending on the scale, location, physical and geographical conditions with the principal objective of enhancing and improving the water quality. One of the significant contributions of EM based rehabilitation of polluted and degraded water bodies is to restore aquatic habitats and ecosystems. Existing results of projects via EM technology in solving water quality related problems, and the nationwide campaigns in Malaysia are duly presented. The role of EM-based water restoration approach for sustainability of water resources and prospects of modeling are also discussed. Results clearly demonstrated the effectiveness of this technique for restoration of water quality of degraded/polluted river basin. Valuable lines for further research and acceptance of EM technology for the future are thus suggested as it is believed to be the key to sustained environmental improvement and offers a real opportunity for eco-innovation.

Keywords: Effective Microorganisms (EM); effective microorganism activated solution EMAS; EM mudballs; water treatment.

1.0 INTRODUCTION

With current increasing trends in population growth and socio-economic development, the quality and quantity of water is gaining widespread attention worldwide. This increasing concern about water quality and quantity necessitates the interventions in water systems to meet the objective of sustainable water supply and prevent potential environmental deterioration. Zacharias et al. (2005) emphasized that sustainable water management which incorporates both socio-economic and environmental perspectives is a difficult but essential task in order to prevent potential environmental deterioration. In recent years the large amounts of polluted water are discharged into rivers and causing serious future uncertainty in the water quality. However, method that integrates water quantity and quality in water resource allocation has the potential to add value to decision makers who face these challenges (Zhang et al., 2010). Various conventional methods are in practice for purification of water and removing the pollutant contaminants, but most of them are costly and non-ecofriendly (Dhote and Dixit, 2008). One of the promising ways for improving

water quality of rivers and lakes, is the effective microorganism (EM) technology which has been much appreciated comparative to other conventional methods because of its eco-friendly nature, and requires less inputs, cost and capital. The concept of EM was developed by Professor Dr. Teruo Higa, University of Ryukyus, Okinawa, Japan in 1980. There are three types of microorganisms which are categorized into decomposing or degenerative, opportunistic or neutral and constructive or regenerative. EM belongs to the regenerative category whereby they can prevent decomposition in any type of substances and thus maintain the health of both living organisms and the environment (PSDC, 2009). The basic purpose of EM is the restoration of healthy ecosystem in both soil and water by using mixed cultures of beneficial and naturally-occurring microorganism. Therefore, the EM has great potential in creating an environment most suitable for the existence, propagation, and prosperity of life (Higa & Parr, 1994). It has also been emphasized that the sustainable water supply should include non-excessive use of surface water, non-depletive groundwater abstraction, efficient re-use of treated wastewater, etc. (Downs et al., 2000; Shiklomanov, 2000; Vörösmarty et al., 2000). The EM technology has a great potential for restoring water quality by increasing freshwater supply to meet the demand of various sectors. However, the sustainability of the freshwater supply for domestic, agriculture and industrial use need to be analysed as it would be a critical aspect of sustainable water management.

2.0 EM TECHNOLOGY

EM consists of a wide variety or multiculture of effective, beneficial and nonpathogenic microorganisms coexisting together (EM Trading, 2000). Essentially it is a combination of aerobic and anaerobic species commonly found in all ecosystems. According to Higa (1998), EM contains about 80 species of microorganisms divided into photosynthesizing bacteria, lactic acid bacteria, yeasts, actinomycetes and fermenting fungi which are able to purify and revive nature. The main species involved are normally the *Lactobacillus plantarum*, *L. casei* and *Streptococcus lactis* (lactic acid bacteria), *Rhodopseudomonas palustris* and *Rhodobacter spaeroides*, (photosynthetic bacteria), *Saccharomyces cerevisiae* and *Candida utilis* (yeasts), *Streptomyces albus* and *S. griseus* (actinomycetes), and *Aspergillus oryzae*, *Penicillium sp.* and *Mucor hiemalis* (fermenting fungi) (Diver, 2001).

The different species of EM have their respective functions. EM can be applied to many environments to break down organic matter. EM are not-genetically-engineered (non-genetic modification organism), not pathogenic, not harmful and not chemically synthesized. When EM is introduced into the natural environment, the individual microorganism effects are greatly magnified in a synergistic fashion. EM technology involves growing, applying, managing and re-establishing high populations of the beneficial microorganisms in an environment or system. It is a natural and organic technology that has been found to be useful in numerous ways to benefit mankind. It was discovered that EM exhibits very thorough effects, and its use now spreading into applications various fields is ambitiously promoted as a means of solving many of the world's problems. Some of the claims of EM applications include sustainable agricultural, industrial, health (livestock, pets and human), odour control, waste management and recycling, environmental remediation and eco-friendly cleaning (EM Technology, 1998).

The interest in the application of EM technology has indeed brought revolution in the environmental aesthetic value.

3.0 APPLICATION OF EM TECHNOLOGY IN MALAYSIA - EM ACTIVATED SOLUTION (EMAS) AND EM MUDBALLS

The principle of EM is the conversion of a degraded ecosystem full of harmful microbes to one that is productive and contains useful microorganisms. This simple principle is the foundation of EM technology in agriculture and environmental management (Higa, 1993). There are currently many different versions of "how to use EM" formulas. While some are

difficult to understand, some are outright confusing. Nevertheless, the EM applications are generally similar, depending on the type and scale of the application, location, physical and geographical conditions.

The product most suitable and widely used in Malaysian rivers is known as EMAS EM1 which also is commonly applied in gardening, indoor plants, laundry, fish pond, etc. (PSDC, 2009). EM1 is the original solution required for the production of EMAS. It is a liquid concentrate of fermented EM whereby the microorganisms are alive but dormant. To activate the microorganisms, the concentrated solution is needed to be diluted with water, and further activation can be performed by addition of a certain amount of molasses, acting as a food source. Fundamentally, the activated EM suspension (EMAS) is a mixture of molasses (sugar cane) and EM in non-chlorinated water or rice rinse water (which provides the minerals for the multiplication of the microorganisms). The product is kept in a warm place of 20°C to 35°C. Fermentation process occurs after the second day and EMAS is ready for use 7-10 days of incubation. At this point of time, the suspension has a pH between 3.5 - 4.0, releases a pleasant sweet –sour smell, appears yellowish brown in colour, and needs to be utilized within two weeks.

Projects of water treatment and sustainability in Malaysia are via the irrigation or spraying of EMAS or throwing in of EM mudballs. However most campaigns use EM mudballs to attract active participation of the society. The EM mudballs are made by mixing ordinary clay, red earth or top soil with EMAS, thoroughly kneading them and forming into the size of tennis balls. Some mudballs have an additional mix of Bokashi, a fermented organic matter made using rice bran, oil cake, fish meal, sawdust, etc.. Bokashi, a Japanese word meaning "Fermented organic matter", has been used by Japanese farmers as traditional soil amendments to increase the microbial diversity of soils and supply nutrients to crops (Kurihara, 1990). After drying for about a week, the mudballs are ready for use.

For all of the projects, the main aims of the mudballs include to stop the growth of algae, to break down sludge, to suppress pathogens, and to eliminate the foul smelling odours caused by high levels of ammonia, hydrogen sulfide and methane. In addition to these, research and development are in progress to control the levels of total suspended solids (SS), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD) and pH. The EM technology acts as an alternative to the conventional chemical-based solutions with the hope to revive the dead rivers. By educating the society and involving private sectors on EMAS and EM mudball usage, the government hopes to eventually create the awareness amongst everyone to play the respective roles in improving the river water quality. The initial idea is to get all individuals to use especially the EMAS, at home and then pouring it down to the drains whereby the solution will then be flowed from the drains to rivers, thus indirectly cleaning the waters in the process.

4.0 PRELIMINARY STAGES OF DEVELOPMENT

The river systems in Malaysia are an integral part of the water resources system. There are more than 100 river systems in Malaysia, contributing more than 90 per cent of the raw water supply. Decades of rapid modernization and industrialization have inevitably led to the severe deterioration of the river water quality. Recently EM have become a successful weapon in the cleaning of water in nature, especially in regions of Asia. It is through the activity of these EM that the river pollutants in Malaysia are also starting to be broken down and cleaned. The EM technology has and is being applied in different domains nationwide beginning 2008.

An earlier effort in December 18th 2008 at Sungai Kelian in the state of Perak, EM mudballs were dramatically found to improve the water quality of the river whereby six months after throw in of the mudballs, the river was cleared of sludge; in fact the base of the river appeared to be filled with beach sands (Fig.3). Measurements taken of six parameters (SS, DO, COD, BOD, ammonical nitrogen and pH) showed that the water quality has improved from Class IV (suitable only for irrigation) to Class III (suitable for water supply, with extensive treatment) (STAR Online, Sept 2009).

On August 8th 2009, an event celebrated in the state of Penang named as “One Million Apologies for Mother Earth”, saw one million EM mudballs thrown into the seafront of Gurney Drive in a move to resuscitate the aquatic life. The experiment also served as a demonstration to motivate more than 10,000 people in realizing the benefits of managing water quality, and to ensure of the program’s sustainability and continuity. Also in the state of Penang, the Penang Skills Development Centre (PSDC) has just introduced its Greening Penang Initiative on October 31st 2009, to mobilize the adoption of EM as a sustainable mediator for the continuous pollution. Through the Greening Penang Initiative, the PSDC aims to encourage and inculcate the adoption of EM Activated Solution (EMAS) among the nearby residents. Meanwhile Golden Sands Resort by Shangri-La, Penang has become the first resort in Malaysia to set up a Research and Development Centre to study the EM technology. The resort’s corporate social responsibility effort was themed “Pollution to Solution – Save the River Campaign” started with a mud ball making competition amongst the resort’s guests. They participated in the activity to contribute to the environmentally worthy cause and managed to mould up 1,407 mud balls made within an hour, to clean up the rivers nearby the Resort. The mixture made up of a combination of earth, EM treated rice-rinsed water and Bokashi was patted into balls for slow and even disbursement into the river. The mud ball was quoted as being like a magic ball which did wonders to the environment. The concoction is extremely effective in breaking down harmful bacteria and had been claimed to be used successfully in cleaning up 150 rivers in Japan (STAR Online, March 2009). The resort agreed to adopt the polluted river and helps in its rehabilitation using the EM mud balls as an initial step. This was part of the resort’s initiative which everybody’s cooperation is needed to improve the river condition, and ultimately preserve it.

A pilot project by school students of Sekolah Kebangsaan Seri Kelana also started to throw 1,100 EM mudballs into lakes as an initiative to cleanse and conserve the water ecosystem. Themed "Green & Global", the event saw Motorola Malaysia employees and 27 pupils from the school's Smart Rangers getting their hands dirty in a workshop where they moulded the EM mudballs made of soil, fermented rice bran and EM solution. Before the mudballs were thrown, EM solution was poured into the lake to improve its water quality and clarity, and revive the ecosystem. The mudballs then are believed to help reduce sludge, remove odour from the lake and control the growth of algae. In next two months, another 2,200 mudballs were placed in the lake, because according to the experimenters one mudball is needed for every one square metre and the size of the lake involved is 1,100 square meters. Evaluated of assessing the effectiveness and the improvement of water quality is in progress. The Global Day of Service however has achieved the government’s goal of better education, social support and protection of our environment (Malay Mail Online, 2009).

On January 25th 2010, a group named Go Green Team launched an environment remediation to rehabilitate a 3 acre polluted lake at Malaysia National Zoo (EM Research Organisation, 2010). The mission was to create a healthier, cleaner sustainable environment in and around the lake, providing a pleasant visit for the hundreds of visitors. To rejuvenate the lake by improving the quality of the water, the Go Green team used the EM technology. Mudballs with its proven water purification properties, were tested upon, with support from Natural Resources & Environment Ministry. With previous successful projects, the EM containing beneficial microbes are again tested to demonstrate and prove that water could be kept fresh and odourless. The mechanism via breaking down of organic material and eliminating bad bacteria as well as reducing sludge & turbidity, will then enable the animals in the zoo to live in and drink good, clean water from the lake. The specific program has entailed volunteers into making tens of thousands of mudballs, fermenting them for a few weeks and throwing them into the lake. This endeavour has indeed created greater awareness about environmental protection and preservation and set an example for others to help create healthy, clean and sustainable surroundings. According to Higa & Chinen (1998), the basis for using EM technology is that it contains various organic acids due to the presence of one of the EM species, which is the lactic acid bacteria. The bacteria secrete organic acids, enzymes, antioxidants and metallic chelates, creating an antioxidant

environment, thus assisting in the enhancement of the solid-liquid separation, which is the foundation for cleaning water.

5.0 SUSTAINABLE WATER RESOURCES MANAGEMENT AND EM TECHNOLOGY

Water resources are crucial to human health and the natural environment, and play a key role in economic growth and development. Satisfying the increased demand for water has become the major objective of water resources management today. Globally, the demand of fresh water is on rise and its sufficient supply is considered vital as water quality is mainly decreasing due to pollution. Degradation of water quality creates water scarcity and limits its availability for human use and ecosystem and thereby impacts the optimum management of water resources (Rao and Mamatha, 2004). In this context, the preservation of satisfactory water quality in rivers, lakes, reservoirs, etc is necessary to protect public health and ecosystems (Sevionovic, 1997). To this end, water authorities have to satisfy the increased industrial, domestic, and agricultural demand, as well as the requirements for environmental protection and ecological improvement (Xu et al., 2002). The deteriorating water quality of most rivers will cause serious environmental problems which can impede the regional sustainable development. Smith and Zhang (2004) emphasized that water quality is one of the most important components of water sustainability, and provided an overview of key indicators for sustainable water resources management. Some other comprehensive studies also highlighted sustainability issue in water resources management (Kranz et al., 2004; Heintz, 2004).

The biological treatment, especially the use of microorganisms to improve polluted water quality is effective and widespread due to low capital and cost compared to chemical treatments. Therefore, in recent years there has been a growing interest in the use of biological purification techniques for water as the best alternative option environmentally and economically. The EM technology is a low cost alternative to improve water quality and has great potential to improve chemical and physical properties of the water. Through this technology, the rehabilitation of polluted and degraded water bodies which restore aquatic habitats and ecosystems will certainly lead to sustainable water resource management in the region concerned. Besides, the potential of EM in creating sustainable practices for agriculture, animal husbandry, nature farming, environmental stewardship, construction, human health and hygiene, industrial, and community activities is well recognized (www.ibiblio.org).

Using the EM technology, the water of polluted water sources can be improved and converts into a water supply source. There are growing evidences that with the development of society and economy, most rivers become polluted to a various extent and affected optimum management of water resources. In this situation the EM technology will help managers and policy makers to make decisions about water improvement measures and do some adjustments at water allocations between different users. In addition, using EM- based water quality improvement techniques, new and alternative sources of water supply (e.g. waste water reuse and water recycling and use of marginal quality water) can be developed. So the optimal distribution of water quality and quantity will help in meeting the increasing domestic, industrial and agricultural demand and ensure sustainability of water resource in Malaysia. This will not only fulfill the current increasing freshwater demand but also will ensure long term availability of freshwater resources for the future.

6.0 PROSPECTS OF SUSTAINABLE WATER RESOURCE MODELLING

Nowadays with growing scarcity and quality deterioration of water resources, a comprehensive understanding of multi-purpose nature of river basins and their sustainable management has become crucial. The water resource sustainability modelling has received considerable attention in recent times and some studies highlighted the specific sustainability criteria that are incorporated into a long term optimization model of river basin (Cai et al., 2002).

To evaluate the sustainability of the water resource system Xu et al. (2002) developed a Water Resources System Dynamics (WRSD) model and sustainability index to explore a variety of water – supply scenarios for the Yellow River basin in China. The authors suggested that the system dynamics approach is more beneficial for indicating how different changes of basic elements affect the dynamics of the system in the future.

Similarly, in considering the EM-based sustainability of water resources, a system dynamics model as described by Xu et al. (2002) for water resources planning can be adopted to evaluate the sustainability of the water resource system in the particular river basin in Malaysia. The system dynamics simulation is a tool that aids description of system structure, provides explicit incorporation of feedback relationships among many system components, and supports the participation of stakeholders in the model development process. The EM-based water quality improvement essentially envisage stakeholders participation in development of approaches that can help value water in a sustainable way since the water quality and quantity are equally important for water utilization. Some applications of the system dynamics approach in the field of water resources include river-basin planning (Palmer *et al.*, 1999), long-term water resource planning and policy analysis (Simonov and Fahmy, 1999) and reservoir operation (Ahmad and Simonovic, 2000).

In order to implement and test the WRSD model, data on water quality parameters and the pollution assessment for addressing the sustainability issue of target river basin is important. Data on real time monitoring of water quality parameters can be obtained from water quality monitoring stations located in various positions within river basin. Following the standard approaches, the baseline (pre-EM) data can be collected on certain important parameters such as DO, BOD, COD, SS, NH₃-N, PO₄, temperature, pH, turbidity, conductivity etc. Subsequently, data on pollution reduction after applying EM can also be recorded to know the reduction in water pollution level. This systematic monitoring with a monthly frequency can provide useful information about the EM-based water quality improvements, whilst the sustainability issue of water supply can be addressed by exploring various water supply scenarios for the region. Further the sustainability of water resources in the target river basin can be analyzed for meeting the increasing domestic, industrial and agricultural demand and suggest possible pathways to ensure sustainability of water resources in Malaysia.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Perceiving bacteria as dangerous is now turning towards greater awareness of the microbial world as a fundamental element of life. EM technology and the philosophies of Dr. Teruo Higa are currently being used as a model to demonstrate the successful implementation of genuinely sustainable technologies. In Malaysia, the EM technology is gaining considerable attention for its potential to reduce nutrient levels of polluted water and restoring water quality. The Malaysian government has realized that environmental consciousness is the most critical element in laying the foundation of sustainable development, and is urging everyone to begin taking action before our rivers and wetlands are treated as wastelands and become a continuous flood zone.

The EMAS and EM mudballs adopted locally are emerging as one of the environmental solutions towards reducing water pollutants and thus improving water quality in our rivers and drains. The results of the projects nationwide have demonstrated the effectiveness of EM technology in the river protection, and will be continually used as a basis for the extension of EM technology in Malaysia in helping to recover, reinforce and sustain our river nature. EM is easy and convenient for use, safe, unharmed, low cost and economically effective and this has increases the effectiveness of application of this technology. Moreover, the regular monitoring of water pollution level of river basin, appropriate purification treatment and community participation in water resources management will certainly help managers in taking informed decisions for water resources sustainability and management.

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