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Introduction and Use of Effective Microorganisms for Bioremediation Processes- A Review

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ABSTRACT

It has been widely studied that activity of microorganisms causes decomposition of organic matter into simpler forms and thus render it less harmful. Studies have shown that in bioremediation, group of microorganisms are more efficient than single species. Effective microorganisms are the group of microorganisms of selected characteristics, which are found to biodegrade the pollutant efficiently. The group of selected microorganisms has enhanced benefits of being non-pathogenic as well as producing end products that are easy to handle. Studies have been carried out for its application in bioremediation of wastewater. The use of effective microorganisms (EM) has been found to reduce volumes of sewage sludge and the process becomes odourless. This makes the process more economical as it reduces the cost of sludge treatment and odour control.

INTRODUCTION

A microbial culture named "Effective Microorganisms" (EM) was developed by Professor Teruo Higa of the University of Ryukyus, Japan after he began his microbial technology research in 1984, with the purpose of improving soil quality, soil health, and the growth, yield and quality of plants[2]. EM consists of approximately 80 species of selected beneficial microorganisms including lactic acid bacteria, yeasts, photosynthetic bacteria, and actinomycetes, among other types of microorganisms such as fungi. EM was originally developed as a microbial enhancer for soil applications and crop production in farming systems[2], but later discovered to have very successful applications in the waste sector [2] .

Effective Microorganisms is a mixture of groups of organisms that have a reviving action on humans, animals, and the natural environment[2] and has also been described as a multi-culture of coexisting anaerobic and aerobic beneficial microorganisms. The microorganisms are not imported or genetically engineered. EM includes both aerobic and anaerobic species of microorganisms which co-exist in an environment of around 3.5 pH.

Production process of Effective Microorganism:

(1) Strain Selection: Purification of Effective Microorganisms (EM):

There are multiple strains of microorganisms inside the mixed cultures of Effective Microorganisms.

Table no. 1 Microorganisms used in Effective Microorganism:

Sr. No.	Microbes involved	Mode of Nutrition	Examples
1	Yeast	Yeast can degrade organic compounds to carbon dioxide and water with the use of free molecular oxygen or as sugars to ethanol in the absence of free molecular oxygen	*Saccharomyces cerevisiae*, *Candida utilis*
2	Lactic acid bacteria	Lactic acid bacteria use sugar as their sole source of carbon through homolactic fermentation and produce lactate as an end product	*Lactobacillus plantarum*, *L. casei*, *Streptococcus lactis*
3	Photosynthetic bacteria	It degrades difficult biodegradable compounds. It decreases sludge production.	*Rhodopseudomonas palustris*, *Rhodobacter sphaeroides*
4	Actinomycetes	With sufficient hydraulic retention time, organic phosphorus compounds are degraded through microbial activity and orthophosphate is released from phosphorus containing compounds.	*Streptomyces albus*, *S. griseus*
5	Fungi	Fungi decompose organic matter rapidly to produce alcohol, esters and antimicrobial substances. These suppress odours of wastewater.	*Aspergillus oryzae*, *Mucor hiemalis* (Diver 2001).

Every single strain of microorganisms has to be selected from the natural environment where it is likely to perform a certain function. Because countless similar microorganisms can be found in nature, one also need to go through a screening process to find out the most effective ones. If a workforce of microorganisms is to be formed by duplicating them; it is necessary to select the elites that have the best performance. In some cases, the more extreme the condition is, it is more likely to find microorganism species that have stronger functionality.

(2) Formulation Design：

Every strain of microorganisms screened may have its specific performing area, the interaction between different species of microorganisms should be taken into consideration. Both anaerobic and aerobic microorganisms should be selected and mixed; which makes it flexible for application and utilization.

(3) Individual Fermentation：

The characteristics and ideal condition for every microorganism are different, it is suggested to culture each individual species in isolated condition to ensure they all reach target microbial count before mixing them together. Each microorganism needs to be cultured separately to ensure proper development of each individual one, there is a limit as to the numbers of species that can be produced for a given product in a given production cycle. [8]

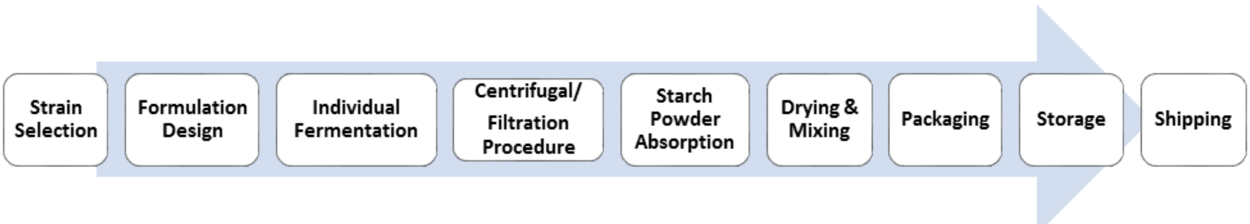

Fig. 1. : Process Flowchart for production of Effective Microorganisms

Types of Fermentation:

i. Batch culture: It consists of a limited volume of broth culture in a flask inoculated with the bacterial or microbial inoculum and follows a normal growth phase. It is a closed-culture system because the medium contains a limited amount of nutrients and will be consumed by the growing microorganisms for their growth and multiplication with the excretion of certain metabolites as products. The nutrients are not renewed and the exponential growth of cells is limited to a few generations.

ii. **Fed-batch culture:** The batch culture can be made into a semi-continuous culture or fed-batch culture by feeding it with fresh media sequentially at the end of the log phase or in the beginning of the stationary phase without removing cells. Because of this, the volume of the culture will go on increasing as fresh media is added. This method is especially suited for cultures in which a high concentration of substrate is inhibitory to cell multiplication and biomass formation. In such situations, the substrate can be fed at low concentrations to achieve cell growth. This method can easily produce a high cell density in the culture medium, which may not be possible in a batch fermenter or shake flask culture.

iii. **Continuous culture:** Bacterial cultures can be maintained in a state of exponential growth over long periods of time using a system of continuous culture, designed to relieve the conditions that stop exponential growth in batch cultures. Continuous culture, in a device called a chemostat, can be used to maintain a bacterial population at a constant density, a situation similar to bacterial growth in natural environments. In continuous culture, the nutrient medium including the raw material is supplied at a rate equal to the volume of media with cells and product removed from the culture. The volume removed and the volume added is the same, so that there is no change in the net volume as well as the chemical environment of the culture.[7]

(4) Centrifugal/Filtration Procedure：

In the liquid fermentation tank, microorganisms only take up a small portion of the liquid, and the rest is mostly water. In order to allow better efficiency during the drying procedure, the use centrifuge or filter to remove most of the water content is crucial. Then these more concentrated liquid can be dried much more efficiently.

(5) Starch Powder Absorption：

Starch powders are used as medium. Refined starch powder is water-soluble. If the powder is too coarse; it might clogs the system.

(6) Drying and Mixing :

The starch with microorganisms is dried and mixed together. Low temperature drying process is performed to prevent the vitality of these microorganisms being affected. Then these effective microorganisms are mixed together according to the proportion of our proprietary formula. Once the drying and mixing are completed, microorganisms are in dormancy state and ready for packaging.

(7) Packaging :

Effective microorganisms are packaged in sealed foil bags to prevent the microorganisms being directly exposed to sunlight. This also marks another difference between liquid and powder form effective microorganisms since that most liquid effective microorganisms are bottle with plastic bottles that are not completely opaque and may be more or less exposed to sunlight. In comparison, foil packaging is able to block most of the sunlight since it is reflective and opaque.

(8) Storage :

Once packaging is completed, effective microorganisms are stored in the refrigerated warehouse under low temperature before being shipped out. Although refrigeration is not necessary as long as the storage location is cool, dry and not subject to direct sunlight, but refrigerated condition is even better.

(9) Shipping :

Most of the time, the effective microorganisms products can be shipped without refrigeration during transportation and still maintain its effectiveness as long as there is no exposure to severe high temperature for long period of time. Refrigerated containers are strongly recommended for long distance oversea shipments to prevent the heat from building up during the voyage. [8]

Table no. 2 Types of EM and their applications:

Types of EM	Mode of preparation	Application
EM-A	It is produced by mixing 5 % of EM1 (Effective Microorganisms) together with an equal volume of sugarcane molasses and keeping it at a constant temperature around 30˚C in a sealed container during one to two weeks. The pH should be below 3.5 and the smell is sweet and sour.	It is most widely used. It is used to alleviate bad smells in sewage treatment plants, where it also helps to reduce the volume of mud and increase the sedimentation activity as it accelerates the organic decomposition of the material.
EM- Bokashi	It is made by mixing EM-A with fresh and good quality organic material such as rice bran, wheat bran or fish meal etc. Then it is left to ferment for up to two weeks in a sealed container.	Accelerating the fermentation and anaerobic decomposition of organic waste materials when making compost.
EM- Compost	Animal dung, organic kitchen waste, garden cutting leaves etc., when mixed with EM-A and left covered to promote anaerobic fermentation.	It is used in composting and widely in agriculture.
EM-5	It is a mixture of EM1, molasses, vinegar, strong distillation alcohol (more than 30%) and water, which is then fermented in a sealed container for more than 30 days until it produces no more fermentation gas.	EM-5 can be applied to all plants, preventing invasions of destructive insects as well as strengthening the natural immune system against disease.
EMX	It is special version of EM liquid.	It has been certified for human consumption, reduces free radicals in the body greatly improving immune system and serving to reduce the possibility of cancer cells being produced.

Application of Effective Microorganisms in wastewater treatment:

In the current wastewater treatment process, microorganisms play a significant role. Many different organisms live within the wastewater itself, assisting in the breakdown of certain organic pollutants [3].Within on-site systems, microorganisms play a significant role in the decomposition of organic wastes, however, some microorganisms can cause health concerns to humans. These include bacteria and viruses present in the wastes produced [3]. The basis for using these EM species of microorganisms is that they contain various organic acids due to the presence of lactic acid bacteria, which secrete organic acids, enzymes, antioxidants, and metallic chelates [2]. The creation of an antioxidant environment by EM assists in the enhancement of the solid-liquid separation, which is the foundation for cleaning water [2]. One of the major benefits of the use of EM is the reduction in sludge volume. The beneficial organisms present in EM decompose organic matter by converting it to carbon dioxide (CO_2), methane (CH_4) or use it for growth and reproduction. Literature suggests Effective Microorganisms significantly reduce volumes of sewage sludge produced while removing the associated odours. Therefore, this tends to suggest an improvement in the digestibility of sludge and other solids in septic tanks and therefore the efficacy of septic systems. [4]

Advantages of Effective Microorganisms:

1. Odour control

2. Faster composting and more complete composting

3. Compost with a higher growth index

4. Reductions in pathogens during and at the end of the composting process

5. Bioremediation of the sludge during the process

6. Improvements in the quality of water and leachate coming from the process. [1]

Methods of application:

Wastewater treatment comprises of three treatments namely primary, secondary and tertiary. The secondary treatment of wastewater consists of treatment with microorganisms. General outline of secondary treatment is as given in fig. 2. The microbes can be in suspended form, as in Activated Sludge process (fig. 3), Upflow Aerobic Sludge blanket etc., or in the form of

Biofilm as in the case of Trickling Filter (fig. 4) of Rotating biological Contractors (fig. 5). Microbes in suspended form are more widely used. The advantage being, in suspended form, the microorganisms are supplied with sufficient amount of oxygen and the nutrients are also easily available to the microorganisms. Thereby making the process aerobic.

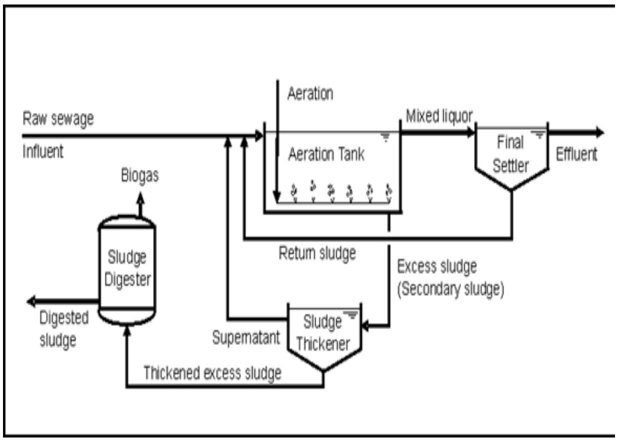

Fig. 2. General outline of Secondary treatment of wastewater [12]

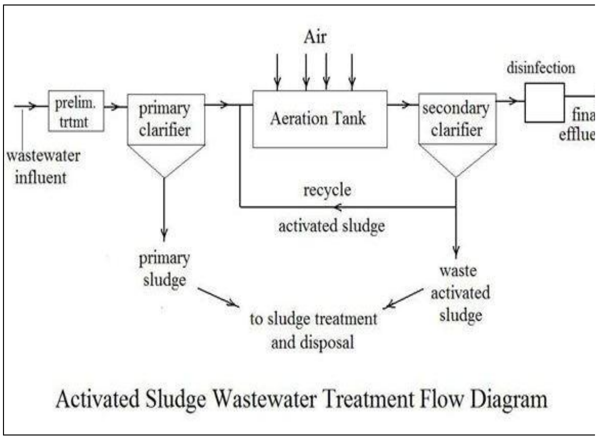

Fig. : 3. Activated Sludge process [10]

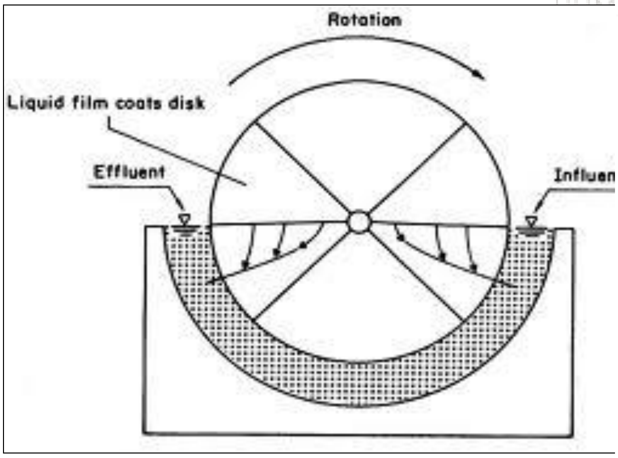

Fig 4. Rotating Biological Contractor [1]

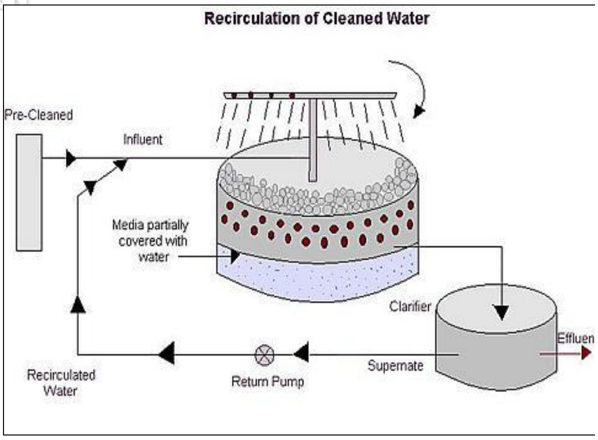

Fig.5 Trickling filter [11]

Other applications of Effective Microorganisms:

Studies have suggested that EM may have a number of applications, including agriculture, livestock, gardening and landscaping, composting, bioremediation, cleaning septic tanks, algal control and household uses (EM Technology 1998).

CONCLUSION

Effective microorganisms are found to be very advantageous for the treatment of wastewater. They have been found to reduce sludge, making a good compost. Thereby the overall treatment cost is reduced. They have additional advantage of being non-pathogenic and also making the bioremediation process odourless. Effective microorganism technology has good potential to solve many environmental issues. More studies should be carried out to check its susceptibility and also to construct Effective Microorganisms with other group of bacteria.

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