

REVIEWS

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Environmental applications of Effective Microorganisms: a review of current knowledge and recommendations for future directions

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Abstract

Nowadays, beneficial microorganisms are getting wider applicability. One example is referred to as Effective Microorganisms (EM) having its composition kept a secret. EM is a product in liquid form, which consists of a variety of not only effective and beneficial microorganisms but also nonpathogenic ones, with admirable coexistence between aerobic and anaerobic types of microorganisms. The aim of this narrative review is to provide a summary of the different uses and applications of EM, their applications, their benefits, and the expected results when using them in different applications. This is the first review to focus on the uses of EM in environmental engineering systems and processes such as wastewater treatment processes. Originally, EM was manufactured to be utilized in organic farming, but at the moment, this substance is getting wider applications such as in medicine, environment, livestock sector, forestry, and agriculture. When it comes to the protection of the environment, EM helps in waste deodorization, eutrophication control, and wastewater. Investigation on EM use in water quality restoration, wastewater treatment, the treatment of sludge, and composting has been undertaken by researchers. This review provides an overview of the current situation of environmental application of EM in various fields including water quality, wastewater treatment, sludge treatment, and composting.

Keywords: Bioremediation, Sludge, Environmental biotechnology, Wastewater, Water

Introduction

Today, beneficial microorganisms (BMs) are now getting wider applicability or uses. BMs, for instance, can be applied to the environment in three main ways namely the single strain, compound strains, and multiple strains with some synergists [48]. The BM functions by catalyzing the decomposition of organic matter in order to not only maintain microbial ecological equilibrium in water and sediments, thus creating favorable conditions for aquatic life, but also maintain dynamic ecological balance among

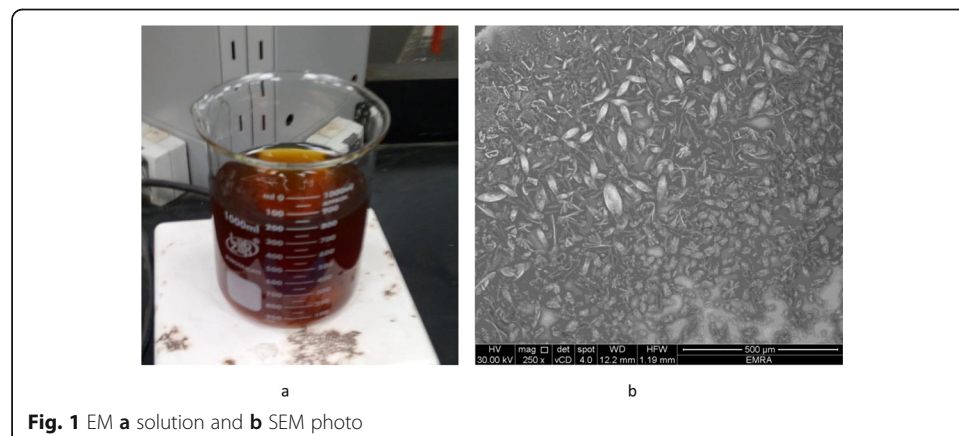


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various organisms from all kingdoms [48]. BMs, therefore, perform several functions in microbes' ecology whether in water and sediments including [48]:

- Adjusting the population of algae in water bodies in order to prevent the deterioration of the quality of water
- Inhibiting the development of fish diseases as well as putrefaction of some aquatic plants during summer
- Bolstering the immune system of aquatic animals, thus enhancing the aquatic animals' resistance to disease
- Suppressing the harmful effects of oxidation through generating antioxidant substances as well as through the accompanying antioxidant emission of waves (that also suppress harmful effects of oxidation). Additionally, BMs can deactivate the occurring free radicals in living organisms and materials
- Helping overcome the challenges of polychlorinated biphenyl and dioxin

The area of effective disposal of sewage sludge (in a manner that is eco-friendly) is attracting unprecedented growth and development in technological innovations in order to make disposal of waste conform to the strict environmental demands and regulations [41]. One of such technologies is referred to as Effective Microorganisms (EM) having its composition kept a secret [25]. EM is a brand name for the various products developed by Dr. Teruo Higa, who is a professor of horticulture at the University of Ryukyus, a university located in Okinawa, Japan [44]. EM is a product in liquid form and is consisting of a variety of not only effective and beneficial microorganisms but also nonpathogenic ones, with admirable coexistence between aerobic and anaerobic types of microorganisms [44]. Figure 1 shows the EM solution and SEM photo of it. The advantage of EM is that its process of fermentation is natural and not chemically engineered or genetically synthesized [44]. Consequently, EM technology is not only eco-friendly but also plays the actual role of protecting the environment. This is because EM is safe and organic [41]. EM has several beneficial microorganisms such as five families and ten general as well as more than 80 types of aerobic and anaerobic microbes like lactic acid bacteria, photosynthesis bacteria, fungi, actinomycetes, and yeast that work together to make up EM during the manufacturing process and produce a substance that survives in a mixture of EM cultured in a brown solution containing



100 million active microorganisms per milliliter and under the pH level of 3.5 [6]. It is important to note that the photosynthetic bacteria, being one of the major elements of EM, are critical in working synergistically with other microorganisms in reducing the incidence of pathogenic microorganisms as well as supporting nutritional requirements [29]. Through producing certain substances, the microorganisms can survive unfavorable environmental conditions, thus effectively competing with pathogenic and destructive microorganisms and replacing them [20]. It has been demonstrated that EM produces substances that play the role of antioxidants [25] and thus inhibit harmful microbial species as well as enhance the production/proliferation of organisms that are beneficial to an animal. Moreover, these substances detoxify harmful substances [25].

Originally, EM was manufactured to be utilized in organic farming, but at the moment, this substance is getting wider applications such as in medicine, environment, livestock sector, forestry, and agriculture [6]. When it comes to the protection of the environment, EM helps in waste deodorization, eutrophication control, and wastewater [48]. Because of the rising interest and applicability of EM, its developers have promoted the technology far and wide [29]. Presently, EM has been adopted by over 100 countries across the globe, not on an experimentation basis but for commercial use as well as environmental management [29]. In terms of composition, EM is commercially available as an EM-1[®] suspension concentrate, which is utilized as a basic formulation of various EM preparations obtain through sugar cane, molasses, and water's anaerobic fermentation (EMA), or fermentation of water, sugar cane molasses, and vinegar (EM5), or fermentation of fermentable organic substrate and sugar cane molasses (Bokashi) [25]. EMA and EM5 are spraying substances that are used not only in enhancing soil and manure quality but also in disease control [25]. Theoretically speaking, EM has beneficial organisms that decompose the organic matter into methane (CH₄), carbon dioxide (CO₂), or other useful substances for growth and reproduction [41]. Therefore, EM, in theoretical terms, is very important in the treatment of wastewater as well as improvement of the quality of water discharged in addition to reducing the quantity of sludge that is produced [41]. Moreover, EM can also treat the leachate that is coming out of the garbage besides removing the foul smell from the decomposing garbage [41]. By applying this technology, the menace of mosquitoes and flies is significantly reduced. In addition, EM technology suppresses the harmful gases produced by decomposed garbage [41]. The species that are majorly present in EM include lactic acid bacteria, which have been identified as crucial in cleaning septic tanks as well as algal control [39]. EM can also help prevent the growth of pathogenic bacteria [37].

A review of applications of EM in various environmental fields is essential to fill the information gap in the literature. Thus, the main objective of this review is to provide an overview of the actual situation of environmental applications of EM in different fields including water quality, wastewater treatment, sludge treatment, and composting.

Main text

Water quality restoration using EM

EM has been utilized by several studies for restoring the quality of water in lakes and rivers as shown in Table 1. A study by Ekpeghere et al. [14] employed loess ball with EM to address the contamination of harbor sediments. In their treatment, malodor was

Table 1 Application of EM in restoring water quality

Type of water	Form of EM	Pollutants studied	Ref.
Contaminated harbor sediments	Loess balls containing EM	Acetic acid, propionic acid, valeric acid	[14]
Artificial lake	Solution	COD, TN, TP, TSS, turbidity	[47]
Synthetic polluted water	Solution	NH ₃ -N, TP, COD	[19]
Stream water	Soil balls containing EM	TP, TN, xenobiotic	[31]
Artificial river water	Mudballs containing EM	COD, TSS	[23]

found to be rapidly removed using a concentration of EM shock culture that contained EM loess balls at 4%. Additionally, the malodor was also quickly removed by a 0.1% concentration of EM loess ball containing 0.05% of molasses. In the presence of 0.05% w/w molasses which acted as a carbon nutrient source, propionic acid, acetic acid, and valeric acid were also removed rapidly demonstrating that molasses enhanced EM activity. Using EM to ferment molasses resulted in the production of more acetic acid in comparison to other organic acids—a good percentage of these organic acids were later converted to acetate via the intermediate metabolites. The combination of molasses and other nutrients and EM loess balls was found to remove malodor and therefore contribute to the remediation of polluted marine sediments through the action of the degradation of EM or the use of the organic acids [14].

Remediation of water bodies was also studied by Zhao et al. [47] using an eutrophic artificial lake. The remediation technology by Zhao et al. [47] comprised an integrated restoration method which consisted of EM, aquatic vegetation near the lakes, an intermittent aeration system, and fingerlings. Zhao et al. [47] found that this technique removed various substances at varying rates and these include total phosphorus (TP) at 86.87%, total suspended substance (TSS) at 82.36%, and total nitrogen (TN), chemical oxygen demand (COD), and turbidity at 57.36%, 70.12%, and 79.28%, respectively. The study also observed the ratio of duckweed to decrease to 10% from 90%. The integrated restoration technique developed by Zhao et al. [47] was also observed not to cause secondary pollution as compared to conventional methods of water treatment as it maintains good water quality for a long time [47].

The activities of EM as affected by dissolved oxygen (DO) in polluted water obtained from a river were studied by Ji et al. [19]. The efficiency of removal of various substances such as COD, TP, and ammonia nitrogen (NH₃-N) was found to increase with the abundance of DO at 4.59%, 18.18%, and 34.34%, respectively. The findings of this study indicated that under aerobic conditions EM survived and reproduced [19].

A study by Park et al. [31] also sought to improve the quality of water of streams by studying the physical conditions and the diversity of the microorganisms in the water. Park et al. [31] made use of soil balls that contained EM and found that the quality of water was improved by hardener soil balls as it significantly reduced the dissolved oxygen, total nitrogen, and total phosphorus components. The composition of the hardener soil ball and traditional soil ball microbial community was found to differ with the hardener soil balls comprising 0.2% viruses, 27.9% eukaryote, and 71.4% bacteria while the traditional soil ball consisted of 1% archaea, 2.7% eukaryote, and 96.1% bacteria. An assessment of pathways that support the xenobiotic degradation was also performed. An examination at the metagenomic profiles for both the hardened soil and the

traditional soils showed that a certain percentage of the organic waste cleanup was due to the xenobiotic biodegradation [31].

Mudballs containing EM were also applied by a study by Nugroho et al. [23] to examine the impact that temperature had on COD and TSS removal. Artificial river water was treated in batches using the mudballs at temperatures of 25°C and 30°C with COD and TSS levels of 120 mg/L and 100 mg/L. At 25°C, the efficiency of removing COD using the mudballs was found to be 66.7% while at 30 °C it was 59.4%. For TSS, the removal efficiency at these temperatures was 100% and 99.7%, respectively. These results indicate that the efficiency of removing COD is evidently affected by temperature effects, but this was not significant for TSS [23].

In a study conducted by [13], EM was used as a restoration method in shallow Konin Lake (Western Poland) where severe cyanobacterial water blooms were observed. The study lasted for 5 years: 2011–2015, covering the treatment period (2013–2015) and two previous years. Before treatment using EM, protective action was conducted which was the elimination of external nutrient loads with backwater from the river that is discharging in the lake. Changes in water chemistry, phytoplankton structure, and macrophyte distribution were recorded during the 5-year studies. EM application initiated positive changes in the ecosystem by means of excessive organic matter decomposition and increased diversity of phytoplankton, although cyanobacteria blooms were still present due to high nutrient content [13].

Bioremediation of wastewater using EM

Biological processes are among the main processes used in wastewater treatment [5, 38]. Wastewater treatment has also been done using EM. A summary of previous studies is shown in Table 2. The damage caused by heavy metal ions (As^{3+} , Cd^{2+} , Cr^{3+} , Cu^{2+} , Hg^{2+} , Pb^{2+} , and Zn^{2+}) to the DNA of EM and the effectiveness of these EM on treating the wastewater when their DNA was damaged were tested in 2008. The study found a negative correlation between the damage of the DNA of the EM and their capability to treat the wastewater. Additionally, the maximum tolerant concentrations of these metals to the EM were found to be 0.2 mg/L for Hg^{2+} , 1 mg/L for Pb^{2+} and Zn^{2+} , 0.05 mg/L for As^{3+} , and 0.5 mg/L for Cd^{2+} , Cr^{3+} , and Cu^{2+} [49]. The removal of carbon and nitrogen from municipal wastewater simultaneously using EM mixed with polyvinyl alcohol (PVA) hydrogel beads was also studied by Lee and Cho [22]. A sequencing batching reactor was applied. The results of the study indicated that about 93% of the COD and 73% of the total nitrogen were removed with the optimal conditions of removing these being at a COD loading rate of lower than 2.4 g COD/L day and the ratio of aerobic time to anoxic time being 3:1 [22]. Embaby et al. [15] also conducted a study to treat industrial wastewater discharged by a beet sugar factory in Egypt. Embaby et al. [15] found that using EM leads to the improvement in the quality of the water of the plant by decreasing COD, biochemical oxygen demand (BOD), phosphates, and nitrates but led to an increase in total dissolved solids (TDS). Odor was well controlled with the water having no environmental problems when drained in an agricultural drainage system or reused in irrigation [15].

The use of EM to reduce alkalinity, TDS, COD, and BOD in domestic sewage was evaluated by Namsivayam et al. [28]. A significant reduction in these parameters was

Table 2 Applications of EM in wastewater treatment

Type of wastewater	Pollutants studied	Process/reactor	Ref.
Samples from the sewage pipe	Heavy metals	Batch	[49]
Municipal wastewater	COD, TN	Sequencing batch reactor	[22]
Beet sugar wastewater	COD, BOD, TDS	Batch	[15]
Domestic sewage	Alkalinity, TDS, BOD, COD	Batch	[28]
Raw sewage	BOD, COD, TDS, TSS	Batch	[26]
Primary settled municipal wastewater	COD, BOD, TSS, NH ₃ , TP	Anaerobic sequencing batch reactor	[4]
Synthetic wastewater	Heavy metals	Adsorption	[45]
Rubber processing wastewater	COD, BOD, turbidity, TSS	Anaerobic sequencing batch reactor	[7]
Aquaculture wastewater	NH ₃ , TP	Batch	[21]
Raw sewage	COD, BOD, TP	Modified contact stabilization activated sludge	[35]
Gray water	TSS, COD, BOD, oil, and grease	Jar test	[2]
Sago industry wastewater	COD, TSS	Hybrid upflow anerobic sludge blanket	[32]
Synthetic wastewater	Basic dyes	Adsorption	[8]
Domestic wastewater	COD, BOD, TSS, TDS, NO ₃	Batch	[40]
Primary settled municipal wastewater	COD, TAN	Moving bed biofilm reactor	[36]

found after testing. However, the tests showed that the yeast population and total heterotrophic bacteria increased, but there were no changes in the population of actinomycetes as well as the fungal population. The results of this study therefore indicated that EM can be used to treat domestic wastes [28]. The treatment of sewage using EM was studied by Karthik et al. [26]. Three milliliters per liter of EM solution was added to the sewage under aerobic conditions, and this led to the reduction of TSS, BOD, COD, and TDS by 91%, 85%, 82%, and 55%, respectively, when treated for 3 days. The findings of this study indicated that formulating EM can help in the treatment of sewage and thereby decrease its impact on the environment [26]. The effect of using effective microorganisms in a bench for primary settled wastewater treatment was studied by Ahmed et al. [4] using an anaerobic sequencing batch reactor. Ahmed et al. [4] observed that there was an increase in the efficiency of removing substances and this occurred at various rates as follows: ammonia, soluble COD, total phosphorus, COD, BOD, and TSS at 50.4%, 61.5%, 62.5%, 72.1%, 75.7%, and 80.9%, respectively. The removal rates of these substances increased with reaction time and temperature. The experiment was conducted at 35 °C for 24 h. Additionally, total coliform, as well as *Salmonella*, was removed very well; there was also a reduction of ammonia and sulfate-reducing bacteria [4]. Another study conducted by Ting et al. [45] investigated the ability of EM free-cells and alginate-immobilized cells to remove metals and found that Cr³⁺, Cu²⁺, and Pb²⁺ were removed. Free-cells of EM were found to be less efficient compared to alginate-immobilized EM. For Cr³⁺, Cu²⁺, and Pb²⁺, alginate-immobilized EM removed 0.940, 2.695, and 4.011 mg/g while free-cells of EM removed 0.160, 0.859, and 0.755 mg/mL, respectively [45]. EM effectiveness in treating wastewater from a rubber processing plant using an anaerobic sequencing batch reactor was investigated by Anwar et al. [7]. For every one unit of EM, 1000 units of wastewater were treated

and this led to an 84%, 62%, 62%, and 60% reduction in TSS, turbidity, BOD, and COD. The final concentrations of these pollutants were 557 mg/L COD concentration, 255 NTU turbidity, 226 mg/L BOD concentration, and 75 mg/L TSS concentration. The findings of this study indicated that utilizing effective microorganism technology to treat wastewater in an anaerobic environment is capable of enhancing the quality of treated rubber wastewater [7].

EM bioremediation, as well as microalgae (MA) bioremediation, was studied independently by Lananan et al. [21], and the relationship between them was investigated. The need for an additional supply of oxygen and carbon dioxide for the sustenance of growth and improving the efficiency of treatment was also examined as well as the omission of these requirements in symbiotic bioremediation attributed to the associate relationship between the two bioremediation techniques. EM bioremediation was found to consume oxygen and generate carbon dioxide while microalgae did the opposite. Both MA and EM were observed to degrade organic matter. The symbiotic relationship between MA and EM was found to remove 99.15% of phosphorus at a rate of 0.534 mg/L day in comparison to the 49.73% and a rate of 0.130 mg/L day for the traditional MA bioremediation. However, the removal of ammonia was not significant in the symbiotic MA-EM bioremediation following EM inoculation. More benefits of the symbiotic relationship between EM and MA would be realized with the optimization of the inoculation volume as well as the bioremediation mode; such optimization would lead to a more robust, economical, and least maintenance design for wastewater treatment system [21]. EM was also used as an enhanced biological phosphorous removal (EBPR) by Rashed and Massoud [35] to investigate the removal efficiency of pollutants from wastewater. The EBPR was applied in a modified contact stabilization activation sludge system with an uptake and release zone for phosphorus. The thickener tank acted as a release zone while the contact tank acted as the uptake zone. Total phosphorus, BOD, and COD were removed at efficiencies of 90%, 93%, and 93%, respectively [35]. Various hybrid treatment processes for greywater (unrestricted use) handling were studied by Abdel-Shafy et al. [2] who also investigated if EM addition to the sedimentation process improved the efficiency. Abdel-Shafy et al. [2] first conducted a pilot study without the use of EM at both 3.0- and 4.5-h settling time. This was aerated for 90 min. It was observed that COD, TSS, BOD, and oil and grease were removed at rates of 63.1%, 70.8%, 70.6%, and 63.5%, respectively. EM was then added at 1.2 mg/L to improve the efficiency of the treatment process. The EM dose was further increased to 1.5 and settling time to 4.5h to allow investigation of further improvement. Aeration was maintained at 90 min. It was found that the removal rates of COD, TSS, BOD, and oil and grease reached 91.1%, 98.1%, 96.1%, and 96.2%, respectively [2]. Hybrid upflow anaerobic sludge blanket (HUASB) reactors were evaluated by Priya et al. [32] in the anaerobic treatment of sago industry wastewater using EM. Removal efficiencies of 77% and 88% for TSS and COD were found in an EM-HUASB reactor with an organic loading rate (OLR) of 9 kg COD/m³ day in comparison with a non-EM HUASB reactor which attained removal efficiencies of 68% and 76% with an OLR of 9 kg COD/m³ day in the steady-state period. For the EM-HUASB reactor, 2.8 L/day of gas was produced while for the HUASB reactor without EM, a gas production of 2 L/day was attained [32]. EM was also applied as a biosorbent to remove basic dyes from an aqueous solution based on the water hyacinth compost technique by Pushpa et al. [33]. The basic dyes that

were investigated included Malachite Green (MG), Methylene Blue (MB), and Basic Blue 41 (BB41). The study found that BB41, MG, and MB had maximum experimental removal efficiency of 89.1%, 98.9%, and 98.4%, respectively. Through their experiment, Pushpa et al. [33] confirmed that the water hyacinth compost technique based on effective microorganisms can be effectively used as a biosorbent to remove basic dyes [8]. Additionally, using EM to improve sewage water quality was investigated by El Shafei and Abd Elmoteleb [40] in Al-Gabal Al-Asfar, Egypt. El Shafei and Abd Elmoteleb [40] utilized different doses of EM in an experiment including 5, 10, 50, and 100 mL per liter of sewage water. Various substances were removed from the sewage water in varying percentages as follows: TSS (98.5%), nitrate (NO_3) (85.9%), COD (76.6%), BOD (75.9%), and TDS (11%). The most probable number for fecal and total coliform was 99.8% and 99.9%, respectively, at 5-mL concentration after an incubation period of 20 days [40]. EM was also used to improve moving bed biofilm reactor (MBBR) performance in the treatment of settled wastewater by Safwat [36]. Safwat [36] made a comparison of two MBBR systems; one system had EM mixed with activated sludge while the other was inoculated with activated sludge only. The comparison was made under steady-state conditions, organic loadings as well as hydraulic shock loadings. Addition of EM to the activated sludge improved slightly particulate COD and total nitrogen. On the other hand, no improvement was found for soluble COD. The removal efficiencies of particulate COD and total ammonia nitrogen were about 68% and 46%, respectively, for MBBR without EM, while they were about 76% and 57%, respectively, for MBBR with EM. MBBR with EM was not as good as MBBR without EM under shock loadings [36]. Abdel Megeed and El Nakieb 2008 studied the use of EM in the degradation of dimethoate—an organophosphorus pesticide. Lab experiments were conducted in 250-mL sterilized Erlenmeyer flasks using mineral salt medium (MSM), different concentrations of dimethoate (0, 20, 40, 60, 70, 80, 90, 100, 120, 140 mg/L), 5-mL EM liquid concentrate, pH = 7, and the flasks were incubated at 25 °C and shaken at 100 rpm. Dimethoate concentration decreased gradually in samples collected at 24 and 48 h and disappeared after 3 days [1]. According to [34], dairy wastewater was treated for 3 months in a pond divided into 4 sections: control section, EM section, Duckweed plant section, and finally EM and duckweed section. The use of EM and duckweed plants together significantly removed the ammonium nitrogen, total phosphorus, total suspended solids, and biological oxygen [34].

Bioremediation of sludge using EM

Investigation on EM use in the treatment of sludge has been undertaken by researchers. Gates et al. [18] conducted a test on the culture of EM in the form of inoculum that influences waste treatment efficiency and the production of biogas. He came to the conclusion that it is possible for a small EM concentration in the substrate to have an advantage over the anaerobic digestion [18]. Souza et al. [42] also confirmed this conclusion [42]. The EM application is made by Boruszko and Butarewicz [10] in low-outlay's sewage sludge treating methods which takes place upon the treatment of dairy sewage. The application of EM led to a decrease in the number of possible pathogenic bacteria (*E. coli*) [10]. Boruszko [9], using EM, undertook a study of the anaerobic stabilization effect of different dairy sewage sludge on the biodegradation of PAHs. The

application of Effective Microorganisms to dairy wastewater sewage sludge fermentation resulted to the bringing down by 70.9% in extra sludge and the quantity of 16 examined PAHs down by 65.7% in extra mixed sludge [9]. EM was applied by Doas et al. [12] in the treatment of industrial wastewater brought about by Egypt's Abu Qurqas Sugar Factory. This study's results are an indication of improvement of the quality of the wastewater EM through reduction of the solid contents, which, in turn, is an indication of lessening of the sludge content. The results are also an indication that approximately 20 days is to be the ideal period of EM application in reducing the sludge content [12] [3]., studied mixing raw petroleum refinery waste sludge with EM in order to reuse it as a biofertilizer and the results were compared with the use of farm yard manure (FYM). The EM biofertilizer has given more yield of onions grown in the plot where it was used compared to the FYM plot with a larger onion size produced in the EM-treated plot. N, P, and K concentrations had increased from their initial values in the soil where EM sludge was used, while organic matter was observed to decrease [3].

Composting of organic matter using EM

A lot of studies were undertaken in order to conduct investigations on the use of EM for organic composting. Ong et al. [30] made use of nine broiler manure windrow piles with conditions that were both non-ideal and non-aerated in conducting a composting trial with no adjustments made to carbon/nitrogen in studying the EM effect on the process of composting and emission of ammonia. The adding of EM failed to lessen the period of composting. No evidence exists based on ammonia emission result to suggest the reduction of odor resulting from the adding of EM [30]. The pine bark composting was investigated by Mupondi et al. [27] using goat manure or sewage sludge with and without inoculated EM. The use of EM in inoculation failed to influence the composting pine bark procedure alone or when combined with the two tested organic materials in a positive manner [27]. The effects of adding EM on banana residue decomposition were investigated by Formowitz et al. [17], and the result revealed the fact of EM not having any influence [17]. The use of EM for improvement of biogas production using solid pyrethrum remains for co-composting after pyrethrins have been extracted was investigated by Mwegoha [46]. Results revealed the maximum biogas production at 1:500 v/v EM ratio. On the other hand, the highest methane yield for biogas produced was placed at 1:250 v/v EM ratios. It was also discovered that the ratios of carbon to nitrogen (C/N) fall within the ideal range of 10:1 to 15:1 for all mixtures, in contrast to the control, which failed to fall within the range. It is also possible to utilize composted pyrethrum waste at every ratio in the form of biofertilizer, considering the fact that the final COD of the compost falls within the 134 g/L average. This is ideal for the conditioning of the soil (W [46]). A study on the use of EM in quickening the composting process was made by Saad et al. (2013). Yard waste and food waste were the two types of organic waste being used in this composting procedure. In conclusion, the compost quality for this research was good, and the EM was a proper solution in reducing composting [24]. Assessment of the influence of EM application on the composting procedure for rice straw combined with goat manure and green waste and evaluation of the quality of two compost treatments were made by Lokman et al. (2013). This study points to the fact that EM application is appropriate in increasing

the mineralization in the composting procedure [11]. Pushpa et al. [33] used EM in comparing four matured composts obtained from different waste organic materials like kitchen waste and leaf waste, as well as paper waste and water hyacinth. Results coming from every one of the four matured composts revealed better quality [33]. Bakari et al. [43] conducted an investigation on EM inoculated household organic waste compost. Organic waste gathered from 50 households located in Tanzania was used in the preparation of the compost. This research points to the fact that EM application is appropriate in improving the decomposition procedure and in influencing the compost's physicochemical properties [43]. An evaluation of the EM effect of the home measure co-composting of food waste and rice bran, as well as dried leaves, was undertaken by Fan et al. (2017). The total results point to the fact of positive effects made available by EM, particularly, in odor control and humification [16].

Conclusion

This review provides detailed information about the current environmental applications of EM technology. The research conducted during the time that was taken into consideration in this paper is an indication that the precise EM components are still unidentified. Different opinions, on the basis of the literature with regard to the EM application in environmental bioremediation applications, abound. EM generally revealed good performance in the restoration of the water quality and wastewater treatment, together with sludge volume reduction. The results, nonetheless, failed to turn out good when it comes to composting. It is possible to say, as a general conclusion, that, in certain cases, EM technology has demonstrated to be a very encouraging alternative when it comes to conventional treatment procedures. It is essential to perform further researches regarding the application of EM due to the lack of precise information about its behavior. Studies of several parameters such as temperature, pH, hydraulic retention time, dose, and its performance in aerobic and anaerobic environments should be performed to be able to apply this technology in a full scale.

Abbreviations

As³⁺: Arsenic; BB41: Basic Blue 41; BMs: Beneficial microorganisms; BOD: Biochemical oxygen demand; Cd²⁺: Cadmium; CH₄: Methane; CO₂: Carbon dioxide; COD: Chemical oxygen demand; Cr³⁺: Chromium; Cu²⁺: Copper; DO: Dissolved oxygen; EM: Effective Microorganisms; Hg²⁺: Mercury; HUASB: Hybrid up-flow Anaerobic Sludge Blanket; MA: Microalgae; MB: Methylene Blue; MG: Malachite Green; NH₃-N: Ammonia nitrogen; NO₃: Nitrate; Pb²⁺: Lead; PVA: Polyvinyl alcohol; TAN: Total ammonia nitrogen; TDS: Total dissolved solids; TN: Total nitrogen; TP: Total phosphorus; TSS: Total suspended solids; Zn²⁺: Zinc

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