ORGANISMS

1. Classification

The organisms living on the surface of the earth or in the soil have been considered under four headings i.e., Higher plants, Vertebrates, Mesofauna and Microorganisms.

1.1 Higher plants

Higher plants by extending their roots into the soil act as binders, prevent erosion, with grasses being more effective, while growing within cracks in rocks force them apart, and when plants die and roots decay, which form a net work of passages through which water and air can circulate more freely.

One of the greatest contributions of the higher plants is through the addition of organic matter or litter to the surface. Tropical plant communities contribute annually as much as 25 tons ha^{-1}, tall grass prairie 5.0 tons ha^{-1} and pine forest 2.5 tons ha^{-1}. Pine forests may have an accumulation of about 15 cm of organic matter at the surface Prairie grass soils have up to 15 % organic matter incorporated in the mineral soil while the soils of tropical rainforests often contain < 5% organic matter. On the other hand dairy cows produce annually about 3.5–4.5tons ha^{-1}.

1.2 Vertebrates

A few mammals, including rabbits, moles and the prairie dog, are active within the soil, burrow deeply causing considerable mixing, and bring the subsoil to the surface such as crotovinas in many Chernozems and the blind mole rat in European soils. Uncontrolled grazing by animals leave the surface bare for erosion.

1.3 Mesofauna

In this group are included earthworms, enchytraeid worms, nematodes, mites, springtails, millipedes, some gastropods and many insects, particularly termites and ants. Their distribution is dependent upon the food supply, therefore they are concentrated in the top 2 – 5cm soil; only earthworms can penetrate below 10 – 20cm. They require, in general anaerobic environment at around pH 7.0, but can also live in acid and alkaline soils. Under optimum conditions it has been estimated that the biomass of earthworms is about 800 Kg ha^{-1} and nematodes about 5 – 20 million / m^2.

The mesofauna generally ingest both mineral and organic matter after its decomposition and produce faecal material. While transporting material from one place to another they produce passages in the soil, thus improve drainage and aeration. Earthworms generally transport material to the surface while termites transport material to build their termitaria, and harvester ants denude an area 2 – 6 m around their nest.

1.4 Microorganisms

The Roman philosopher Lucretius (about 98–55 B.C.) and the physician Girolamo Fracastoro (1478–1553) suspected the existence of microorganisms, even before they were seen, and suggested that diseases are caused by invisible living creatures. The amateur microscopist Antony van Leeuwenhoek (1632–1723) of Delft, Holland was the first person to accurately observe both the bacteria and protozoa and describe them. Agostino Bassi (1773–1856) first showed a microorganism could cause disease when he demonstrated in 1835 that a silkworm disease was due to a fungus infection. He further suggested that many diseases were due to microbial infections. [Microbiology 2nd edition by Lansing M. Prescott, John P. Harley and Donald A. Klein]

1.4.1 Predominant microorganisms

Microorganisms are too small to be seem clearly by the unaided eye. The predominant microorganisms are bacteria, fungi, actinomycetes, algae and viruses.

1.4.1.1 Bacteria

Bacteria are the simplest organisms found in most natural environments. Bacteria have a much simpler morphology and lack a true membrane-delimited nucleus, thus all bacteria are prokaryotic. Bacteria are spherical or rod-shaped and are commonly several micrometers in linear dimension.

Bacteria are small and can replicate quickly, simply dividing in two by binary fission. Under optimal conditions a single prokaryotic cell can divide every 20 minutes and thereby give rise to 5 billion cells in

< 11 hours. The ability to divide quickly enables to populations of bacteria to adapt rapidly to changes in their environment.

In nature bacteria live in an enormous variety of ecological niches, and they show a corresponding richness in their underlying biochemical composition. Two distantly related groups can be recognized: the *eubacteria*, which are the commonly encountered forms that inhabit soil, water, and large living organisms; and the *archaebacteria*, which are found in such incommodious environments as bogs, oceans depths, salt brines, and hot acid springs.

They are the smallest and most numerous of the free-living microorganisms in the soil, where the distribution is determined by the presence of food supply, therefore they occur in the greatest numbers in the surface horizons which have a teeming mass of biological activity. They number several million per gram with a live weight of 1000 - 6000 Kg ha^{-1} in the top 15 cm.

There are species of bacteria that can utilize virtually any type of organic molecules as food, including sugars, amino acids, fats, hydrocarbons, polypeptides, and polysaccharides. Some are even able to obtain their carbon atom from CO_2 and their nitrogen atoms from N_2. Despite their relative simplicity, bacteria have existed for longer than any other organisms and still are the most abundant type of cell on earth.

1.4.1.2 Actinomycetes

Actinomycetes are second in abundance to bacteria preferring dry warm grassland and neutral conditions. There are a large snumber of genera of which the *streptomycetes* are dominant. They have a characteristic musty odour and produce antibiotics and enzymes that kill bacteria another microorganisms. They are very important as decomposers of organic matter particularly polysaccharides and chitin.

1.4.1.3 Algae
Algae are early colonizers of newly exposed material in wet situations such as paddy fields and the very widespread shallow pools in the arctic. When in sufficient numbers they help to form a crust at the soil surface thereby preventing soil erosion. They are considered as early initiators of the carbon and nitrogen cycle.

1.4.1.4 Viruses
Viruses are generally regarded as parasites in larger animals and plants and nearly every class of microorganisms in the soil is subject to viral attack. Each individual virus has a limited host range, some attack bacteria and others fungi, actinomycetes, algae, protozoa, earthworms, etc. The virus enters through the cell wall of the bacterium and attaches itself by its tail then causes lyses-decomposition of the cell walls.

1.4.2 Classification with respect to sources of C & energy
In order to survive and grow, microorganisms require a source of energy for nourishment. Depending on their sources of carbon and energy they are classified into four classes:

1.4.2.1 Photoautotrophs:
The organisms contain chlorophyll and utilize light as their energy source and CO_2 as their principal source of carbon; they include the blue-green algae some of which can fix atmospheric nitrogen. The higher plants are photoautotrophs.

1.4.2.2 Photoheterotrophs:
This is a very restricted group of organisms that use light as a source of energy and derive much of their carbon from organic compounds.

1.4.2.3 Chemoautotrophs:
These organisms derive their energy from the oxidation of inorganic compounds and use CO_2 as their principal source of carbon. They include several groups of specialized bacteria, including the all important nitrifying bacteria.

1.4.2.4 Chemoheterotrophs:

This is by far the largest group of microorganisms that utilizes organic compounds both as a source of energy and carbon. They include protozoa, fungi, actinomycetes and most bacteria and are of immense importance through their participation in humification and ammonification.

[-- *Introduction to soil science second edition by E A Fitzpatrick*
--*Molecular Biology of the Cell 3rd edition by Bruce Alberts, Dennis Bray, Julian Lewis,*
Martin Raff, Keith Roberts, James D. Watson
--Microbiology 2nd edition by Lansing M. Prescott, John P. Harley and Donald A. Klein]

2. Factors affecting the nourishment of microorganisms

2.1 Chemical factors

To obtain energy and construct new cellular component, organisms must have a supply of raw materials or nutrients. Nutrients are substances used in biosynthesis and energy production, and therefore are required for microbial growth. Analysis of microbial cell composition shows over 95% of cell dry weight is made up of few major elements: C, O, H, N, S, P, K, Ca, Mg, Fe. These are required in larger quantities and are called macronutrients. The first six (C, O, H, N, S, P) are components of carbohydrates, lipids, proteins, and nucleic acids. The remaining four macronutrients exist in the cell as cation and play a variety of role, e.g. K is required for activity by a number of enzymes; Ca among other functions contributes to the heat resistance of bacterial endospores. Mg serves as cofactors for many enzymes and Fe^{2+} and Fe^{3+} is a part of cytochromes. All microorganisms require trace elements (needed in smaller amounts) such as Mn, Zn, Co, Mo, Ni, Cu for their growth and these are a part of enzymes and cofactors, aid in the catalysis of reactions and maintenance of protein structure [Microbiology 2nd edition by Lansing M. Prescott, John P. Harley and Donald A. Klein].

Like all living things bacteria require mineral salts such as Ca, Mg, K, Fe, Cu and others. Some bacteria need sugars, vitamins, amino acids.

Other bacteria can digest proteins down to amino acids and digest complex carbohydrates such as starches and table sugar down to simple sugars. Some bacteria can make their own amino acids and vitamins from carbohydrates. The blue-green bacteria have chlorophyll and can make their own food from light energy + carbon dioxide. Some other bacteria have red chlorophyll and can use light and carbon dioxide to make the sugars they need. In short all the essential nutrients / elements found in the soil or occurring in nature are required for microbial growth. If under certain condition a specific element is required it can be added to the medium.

The numerous pieces of bacteria live in an astonishing variety of place and live on every food you can imagine. Some can eat gasoline and other hydrocarbons.

2.1.1 Source of nutrients

The main source of nutrients in the soil is organic matter. Under natural conditions trees, shrubs, grasses and other native plants supply large quantities of organic residues. The other sources are earthworms, centipedes, ants, etc, crop residues, farmyard manure (FYM), poultry manure (PM), green manures, filter cake of sugar industry and various types biofertilizers inclusive of Bokashi. The composition of manure and dry plant tissues is given in table -1.

Table –1. Composition of a Manure and Dry Plant Tissues*

Compounds		Percentage
Carbohydrates:	Sugar and starches Celluloses Hemicelluloses	01 – 05 20 – 50 10 – 28
Proteins	Simple water soluble and crude	01 – 15
Fats, Oils, waxes, tannins etc		01 – 08
Lignins		10 – 30

- *Principles of soil science third edition by M M Rai.*

The carbohydrates are complex substances and range from simple sugar to very complex celluloses and are made of C, H and O. The fats and oils are glyceride esters of fatty acids such as butyric, stearic and oleic etc. They are more complex than carbohydrates. They are also made of C, H and O. Protein are most complicated substances and contain C, H, O, N, S, Fe, P and a few other substances in lesser amounts. They are formed by a number of amino acids united to each other by peptide linkage.

The microorganisms derive their energy from the oxidation of carbohydrates, proteins and fats present in tissues of plants as well as in dead microbes. The common simple products which are formed due to the activity of soil microorganisms are (*Principal of Soil science by M M Rai*):

Carbon compounds: CO_2, CO_3, HCO_3, CH_4, C
Nitrogen compounds: NH_4, NO_2, NO_3, N
Sulfur compounds: S, H_2S, SO_3, SO_4, CS_2
Phosphorus compounds: H_2PO_4, HPO_4, PO_4
Other simple products: O_2, H_2, H_2O, H, OH, K, Ca, Mg, etc

2.2 Physical / Environmental Factors

The temperature, food supply, oxygen level and pH of the medium are critical in the successful cultivation / growth of microorganisms.

The microorganisms occur in the greatest numbers in the topsoil due to the presence of good food supply, optimal temperature and oxygen level, therefore they exhibit maximum biological activity. Among the organisms in the soil there exists and extremely complex inter-relationship for seldom does a single type of organism exist or operate separately from the others. Some highly contrasting organisms co-exist while others are predators, competitors or parasite. Earthworms and bacteria co-exist.

2.2.1 Temperature

Most microorganisms grow well at the normal temperatures favored by man, higher plants and animals. However, certain bacteria grow at temperatures (extremely hot and cold) at which few higher organisms can survive. Depending upon their preferred temperature range, bacteria are divided into three group:

Psychrophiles (cold-loving microorganisms): They have an optimum growth temperature between 0^oC and 15^oC and a maximum growth temperature of not more than 20^oC.

Mesophiles (moderate-temperature-loving bacteria): They are found in water, soil and in higher organisms. Their optimum growth temperature ranges between 25^oC and 40^oC. The optimum temperature for many pathogenic bacteria is 37^oC, thus the mesophiles constitute most of our common pathogenic bacteria and disease microbes.

Thermophiles (heat-loving microbes): They are capable of growth at high temperatures with an optimum above 60^oC. Most thermophiles cannot grow below 45^oC but some grow even above 100^oC.

2.2.2 pH

Most bacteria grow best in an environment with a narrow pH range near neutrality between pH 6.5 and 7.5. These are classified as:

Acidophiles (acid-loving). They grow at pH values below 4 with some bacteria still active at a pH of 1.
Alkalinophiles (base-loving). They prefer pH values of 9-10 and most cannot grow in solutions with a pH at or below neutral.

Often during bacterial growth organic acids are released into the medium, which lower its pH and so interfere with or totally inhibit further growth. Although common media ingredients such as peptones and amino acids have a small buffering effect, an external buffer is needed in most bacteriological media to neutralize the acids and maintain the correct pH. Phosphate salts are the most commonly used buffer because they buffer in the growth range of most bacteria, are non-toxic and provide a source of phosphorus, and essential nutrient element.

3. Advantages and disadvantages of microorganisms

3.1 Advantages / benefits

They exist everywhere i.e. in the air, water and soil, and in the body of human beings and other creatures. Society benefits from microorganisms in many ways. They are necessary for the production of bread, cheese, bear, antibiotics, vaccines, vitamins, enzymes, and another important products. Microorganisms are indispensable components of our ecosystem. They make possible the carbon, oxygen, nitrogen, and sulfur cycles that take place in terrestrial and aquatic system, and are a source of nutrients at the base of all ecological food chains and webs. Their benefits are enormous in the field of agriculture and in bioremediation of polluted resources.

3.1.1 Fixation of atmospheric nitrogen

In the field of agriculture atmospheric nitrogen is fixed by *Rhizobium* (rhizobia) bacteria in the nodules of legumes in the form of complex compounds of nitrogen (glutamic acid); it is about 250 – 300 Kg ha^{-1} $year^{-1}$ in case of Alfalfa and 70 – 80 Kg ha^{-1} $year^{-1}$ in case of Pea (Fertilizers, a text book, by Ranjan Kumar Basak). Some bacteria are free-living organisms and have the capacity to absorb atmospheric N_2 to synthesis organic nitrogenous compounds. These organisms (non-symbiotic nitrogen fixing organisms) are bacteria, algae and fungi and are aerobic, anaerobic, heterotrophic, autotrophic, photosynthetic.

3.1.2 Mineralization of organic nitrogen compounds

Mineralization of nitrogen is the conversion of organic form nitrogen to inorganic / mineral form of nitrogen such as NH_4^+**,** NO_2^- and NO_3^-. It takes place in three steps i.e., 1. Aminization, 2. Ammonification and 3. Nitrification.

- **i)** **Aminization:** the protein breaks down to yield amines, amino acids, carbon dioxide, energy and other products. This process is brought about by some heterotrophic soil microorganisms. They are mostly bacteria and fungi and possibly actinomycetes.

- **ii)** **Ammonification:** in this case the amines and amino acids released by aminization process are converted to ammonia, NH_3. The conversion is caused by another group of heterotrophic of soil microorganisms such as bacteria, fungi and actinomycetes.

- **iii)** **Nitrification:** this process is completed in two steps i.e., in the first step nitrite (NO_2^-) are form and in the second step NO_3^- are formed. These two steps are caused by two enzymes, dehydrogenase and oxidase, secreted obligate autotrophic bacteria such as Nitrosomonas, nitrosococcus, nitrosocystis, nitrosospira and nitrosogloea.

From the above it can be concluded that life within soil exceeds the life above the soil in terms of numbers of living organisms and total metabolic activity (Thomson, LM and Troeh, FR. 1978, soil and soil fertility, McGraw Hill Book Company, NY., 516 P). Soil is a unique environment as it contains a vast array of bacteria, actinomycetes, fungi, algae and protozoa, which are important group of micro flora in soils. They are unicellular, of numerous genera and perform vast variety of specialized functions. The important bacteria belong to symbiotic-N-fixation, no symbiotic-N-fixation, Aminization, ammonification and nitrification, P-solubilizer, S-oxidizers and H_2S

oxidizers. Some important bacteria from plant nutrition point of view are listed in table –2.

Table –2: IMPORTANT BACTERIA FROM PLANT NUTRITION POINT OF VIEW*

Sr. #	Name of bacteria	Function
1.	Rhizobium sp	symbiotic N fixation
2.	Bradyrhizobium	symbiotic N fixation
3.	Cyanobacteria (BGA)	biological N fixation
4.	Azotobacter sp	biological N fixation
5.	Azospirillum sp	biological N fixation
6.	Nitrobacter sp	nitrification
7.	Nitrosomonas sp	nitrification
8.	Pseudomonas	denitrification
9.	Bacillus sp	denitrification
10.	Paracoccus	denitrification
11.	Thiobacillus	denitrification
12.	T. thioparus	denitrification
13.	Bacillus megaterium	P solubilizer
14.	B. circulans	P solubilizer
15.	B. subtilis	P solubilizer
16.	Pseudomonas straita	P solubilizer
17.	P. rathonis	P solubilizer
18.	Escherichia freundla	P solubilizer
19.	Thiobacillus thioxidans	oxidizes S
20.	T. thioparus	oxidizes S
21.	T. copraliticus	oxidizes S
22.	T. ferrooxidans	oxidizes S
23.	Beggiatoa	oxidizes H_2S to S
24.	Thiothrix	oxidizes H_2S to S

- *Dictionary of Soil Fertility: Fertilizers and Integrated Nutrient Management by HLS Tandon, p 13*

3.1.3 Decomposers

Decomposers (fungi, bacteria and actinomycetes) breakdown the organic material, form humus and unlock the useful nutrients (NPK, S, trace elements etc) and made them available to plants. Phosphate solubilizers (fungi and bacteria) secrete organic acids and help in solubilization of insoluble P-compound in soil. Mycorrhizal fungi have been reported to mobilized P and other nutrients in normal as well as saline soils. Some bacteria live in association with roots of cereals, e.g. rice, sugarcane and grasses, and produce phyto hormones to enhance plant growth.

Some microbes act as biological control of pathogens, due to liberation of antibiotic and other compounds. The bacteria which affect insects are broadly classified as spore-formers and non-spore-formers. The spore formers include milky disease organisms, *Bacillus popilliae, B. lentimorbus* and facultative groups such as *B. sphaericus* and *B. thuringiensis*. The non-spore-formers include *serratia, pseudomonas, aerobacter* and *streptococcus*. The spore forming bacteria are promising organisms for microbial control (*Biological approaches in soil microorganisms for sustainable crop production by K.R. Dadarwal*).

The microbial community structure / composition not only affects biological process, but most of them especially fungi and algae influence soil physical properties and help in aggregate formation and water retention in soil. The number of groups of microorganisms that commonly occur in top 0 to 15cm per ha-furrow slice (HFS) may be for bacteria 10^{17} - 10^{18} with fresh biomass 450 – 4500 Kg, for actinomycetes 10^{16} - 10^{17} with fresh biomass 450 – 4500 Kg, for fungi 10^{14} - 10^{15} with fresh bio mass 112 – 1120 Kg, for algae 10^{13} - 10^{14} with fresh biomass 56 –500 Kg and for protozoa 10^{13} - 10^{14} with fresh biomass, 17 – 170 Kg. The microflora (bacteria, actinomycetes, fungi and algae (together form 2076 to 20760 kg fresh biomass and 415 – 5190 Kg dry biomass (20 – 25 % for fresh biomass per HFS. The microbial number in the top soil (3-8 cm) may be 12 million /g, comprising live biomass of bacteria 100-4000 Kg / ha; while double of this biomass for all the microbes (bacteria, actinomycetes, algae and fungi) forming 0.02 – 0.8% of total soil biomass.

(*Reference given by A. Sikandar: effect of organic and inorganic fertilizer on the dynamics of soil microorganisms, biomass, composition and activity. Nuclear Institute for Agriculture Biology, Faisalabad, Pakistan*)

3.1.4 Biodegradation

Trials have been made to achieve biodegradation of petroleum hydrocarbons using indigenous bacteria. The bacteria mixtures of 40 to 50 different organisms utilized have shown to work effectively on petroleum hydrocarbon at many sites. The bacteria used were naturally occurring, non engineered, non pathogenic organisms and have the ability to degrade petroleum hydrocarbon to CO_2 and water. The indigenous bacteria metabolize hydrocarbons as a carbon source in the presence of an electron acceptor. There are several possible electron acceptors available for intrinsic biodegradation including dissolved oxygen, nitrates, sulfates and iron. Dissolved oxygen is the most favored electron acceptor, and is used as an indicator of biodegradation that occurs by aerobic processes. Each 1.0 mg /L of dissolved oxygen consumed by microorganisms will destroy approximately 0.32 mg/L of BETX. During aerobic bio degradation, oxygen levels in the groundwater decrease. Most or all of the degradation that takes place in aerobic conditions involves the consumption of oxygen, as anaerobic bacteria generally cannot function in dissolved oxygen concentration > about 0.5 mg/L (*Remediation of a High Priority Petroleum Site Using a Combination of Remedial Technology by Scott D. Hartsough; Contaminated Soils Volume 7*).

3.1.5 Breakdown of pesticides

The predominant means of pesticide breakdown in soils is biochemical processes carried out for the most part by microorganisms and to a smaller extent by plants (pesticides taken up by plants may be broken down by plant enzymes). Fertile soils contain millions of microorganisms per ounce of surface soil. Organic pesticides may serve as sources of nutrients and energy for microorganisms.

The rate of microbiological breakdown of pesticides varies with their chemical structure and climatic conditions. In a summary of 12 studies, Tinsley (1979) noted that the 50% decomposition times for certain pesticides increased in the order malathion, 2,4-D, diazinon, atrazine, diuron, DDT. The 50% decomposition time for DDT was

240 days in a tropical environment, 3840 days in a temperate environment (*Agriculture and groundwater quality, Council for Agricultural Science and Technology, Report # 103*).

3.1.6 Phytoremediation

Phytoremediation has emerged as an innovative strategy for various environmental applications. Including hydraulic control of shallow groundwater impacted by petroleum hydrocarbon. A phytoremediation barrier (phytobarrier) at an active petroleum retail station in Ohio in Spring 1997 was installed by planting hybrid poplar trees within a trench along the Western site border, downgradient of the source area. After the third growing season tree roots were observed to a depth of 10 feet. Based on ground water elevation data of the third year the hydraulic gradient across the phyto barrier had decreased more than 3 feet as compared to control, this indicated the aerobic degradation of petroleum hydrocarbon (*Phytoremediation for Hydraulic Control of Shallow Groundwater Impacted by Petroleum Hydrocarbons by William M. Golla and James J. Reid, ARCADIS Geraghty & Miller, Contaminated Soils Volume 6*).

3.2 Disadvantages / harmful effects

Of course, microorganisms also had harmed humus and disrupted society since the beginning of recorded history. Microbial diseases undoubtedly played a major role in historical events such as the decline of the Roman Empire and the conquest of the New World. In the year 1347, plague or Black Death stuck Europe with brutal force. By 1351 the plague had killed 1/3 of the population (about 25 million people). Over the next 80 years, the disease stuck again and again, eventually wiping out 75% of the European population. Some historians believe that this disaster changed European culture and prepared the way for the Renaissance. Today, the struggle by microbiologists and others against killers like AIDS, HEPATITIS and malaria continues (*Microbiology 2nd edition by Lansing. M. Prescott John P. Harley and Donald A. Klein*).

The pollution caused by solid city wastes, sewage water and industrial effluent and sludge (solid waste) have played havoc in the developed countries where it is being continuously controlled and the pollution is said to be to a lesser extent and to the largest extent in the developing countries where the problem has multiplied and it is beyond their financial as well as technical resources to control it.

In Pakistan all the drainage system ends into the riverbeds, which are presently polluted enormously. The situation is at an alarming stage because under the Indus Water treaty 1958 the rivers Sutlej, Ravi, Chenab and Jehlum have been almost abandoned. For example the untreated sewage water of Lahore city and adjoining municipalities, villages and abbadies, and untreated industrial effluents inclusive of Leather Industry from the cluster of industries of Kala Shah Kaku, Lahore and Sheikhupura, etc are discharged into the Ravi River at an average flow of > 650 cusecs / day. The flow is expected to be above 2000 cusecs by the year 2025. Present BOD load is 470 tons / day and there is a loss of more than 5000 tons / day of fish catch. The untreated heavily polluted sewage and industrial effluent is not only being used for growing agricultural crops especially vegetables as these bring higher prices in the vicinity of Lahore city, but also animals are forced to drink this very effluent. This means that most of the inhabitants of Lahore city are eating vegetables grown with polluted water and are drinking milk of animals taking this polluted effluent. This is the reason that diseases like Hepatitis, Dysentery, Gastroenteritis, Jaundice, Cancer, etc have increase tremendously. The same is true farm other big cities like Karachi, Hydrabad, Multan, Faisalabad and Sargodha (*Environmental Degradation by Eng. Col. Mumtaz Huassain*).

4. INVENTION OF EM TECHNOLOGY

Prof. Dr. Teruo Higa, University of Ryukyus, Okinawa, Japan developed the first batch of Effective Microorganism, which eventually called EM in 1980. It is available in the liquid form. It is produced through a natural process of fermentation and not chemically synthesized or genetically engineered. EM is a combination of various beneficial, naturally occurring microorganisms mostly used for or found in food. EM is a liquid concentrate. It is produced in vats from cultivations of over 80 varieties of microorganisms. The microorganisms are drawn from 10 genera belonging to 5 different families. The most outstanding characteristic of EM is this that it includes both aerobic and anaerobic species coexisting symbiotically in a most beneficially productive manner. EM contains beneficial tiny anabiotic microorganisms form 3 main genera: phototrophic bacteria, lactic acid bacteria and yeast.

Photosynthetic bacteria (Rhodopseudomonas):
The photosynthetic or phototrophic bacteria are a group of independent, self-supporting microbes. These bacteria synthesize useful substances from secretions of roots, organic matter and / or harmful gases (hydrogen sulphide), by using sunlight and the heat of soil as source of energy. The useful substances developed by these microbes include amino acids, nucleic acid, bioactive substance and sugars, all of which promote plant growth and development. The metabolites developed by these microorganisms are absorbed directly by the plants and act as substrates for increasing beneficial microbial populations. For example, Vesicular Arbuscular (VA) mycorrhizae in the rhizosphere are increased due to the availability of nitrogenous compounds (amino acid) which are secreted by the phototrophic bacteria. The VA mycorrhizae in turn enhance the solubility of phosphates in soils, thereby supplying unavailable phosphorus to plants. VA mycorrhizae can also coexist with Azotobactor and Rhizobium, thereby increasing the capacity of plants to fix atmospheric nitrogen.

Lactic acid bacteria (Lactobacillus):
Lactic acid bacteria produce lactic acid from sugars and other carbohydrates, developed by photosynthetic bacteria and yeast. Lactic acid is a strong sterilizing compound and suppresses harmful microorganisms and enhances decomposition of organic matter. Moreover, Lactic acid bacteria promote the fermentation and decomposition of material such as lignin and cellulose, thereby removing undesirable effects of undecomposed organic matter. Lactic acid bacteria have the ability to suppress disease-inducing microorganisms such as Fusarium, which occurring continuous cropping programs. Under normal circumstances, species such as Fusarium weakens crop plants, thereby exposing them to diseases and increased pest population such as nematodes. The use of lactic acid bacteria reduces nematode populations and controls propagation and spread of Fusarium, thereby inducing a better environment for crop growth.

Yeast (Saccharomyces):
Yeasts synthesize ant microbial and other useful substances required for plant growth from amino acid and sugars secreted by photosynthetic bacteria, organic matter and plant roots. The bioactive substances such as hormones and enzymes produced by yeasts promote active cell and root division. These secretions are also useful substrates for Effective Microorganisms such as Lactic acid bacteria and Actinomycetes.

EM as "co existence and co prosperity"
The difference species of Effective Microorganism (Photosynthetic and lactic acid bacteria and yeast) have their respective function. However, photosynthetic bacteria could be considered the pivot of EM activity. Photosynthetic bacteria support the activities of other microorganisms in EM. However, the photosynthetic bacteria also utilize substances produced by other microbes. This phenomenon is termed "Co existence and Co prosperity". The enhancement of population of EM in soils by application promotes the development of existing beneficial soil microorganisms. Thus, the micro flora of the soil becomes abundant; thereby the soil develops a well-balanced microbial system. In this process soil specific microbes (especially harmful species) are suppressed, thereby reducing microbial diseases that cause soil borne diseases. In contrast, in these developed soil, the

Effective Microorganisms maintain a symbiotic process with the roots of plants within the rhizosphere.

Plant roots also secrete substances such as carbohydrates, amino and organic acids and active enzymes. Effective microorganisms use these secretions for growth. During this process, they also secrete and provide amino and nucleic acids, a variety of vitamins and hormones to plants. Further more, EM in the rhizosphere co exist with plants. Therefore, plants grow exceptionally well in soils, which are dominated by Effective Microorganisms.

EM is a living entity containing active microbes. Manufacturing of EM requires good quality water free of pollutants or chemicals. EM can be stored in a closed container for a period up to 6 months if kept in a dark cool place (Refrigeration is not required). EM always has a sweet sour smell. One may notice a white film on the surface of EM solution when it is stored. This is yeast and does not cause any harm to the EM.

The soils having a high population of disease causing microbes (Fusarium) are called Disease inducing soils. These are generally hard and physical characteristics are not conducive for crop growth. The soils having organisms such as Pencillium, Trichaderma, Aspergillus and Sterptomyces, which produce antibiotics, are called disease suppressive soils. These soils have very good physical characteristics. The soils containing zymogenic organisms such as Lactic acid bacteria and yeast are called zymogenic soils. When raw organic matter with high nitrogen contents is applied, the soil develops an aromatic smell, the population of fermenting fungi such as Aspergillus and Rhizopus increases. These soils have very good physical characteristics with a high water holding capacity.

EM is a versatile product that uses microorganisms found in all ecosystems. 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.

[*An Earth Saving Revolution: A means to resolve our world's problems through Effective Microorganisms (EM) by Dr. Teruo Higa*]

5. Benefits of EM Technology

The effective microorganisms secrete beneficial substances such as vitamins, organic acids, chelated minerals and antioxidant when in contact with organic matter. EM is being used successfully in the field of agriculture, fisheries, poultry, animal husbandry and for the preparation of compost and Bokashi. Now its application has spread in controlling the environmental pollution caused by city solid waste, sewage water, industrial solid wastes and effluent. EM application has helped to eliminate obnoxious odor at leather and starch industry, livestock farms and zoo etc. Its application has been extended to health sectors with the invention of EM-X, research is being conducted in various countries to see the effect of EM-X as antioxidant in patients suffering from cancer, aids, diabetes and skin diseases.

Today, EM Technology has extended its activities to over 116 countries, where it is being used in the field of agriculture, fisheries, poultry, animal husbandry and environments such as recycling of sewage water, city wastes and kitchen garbage. Of 116 countries EM is being manufactured in 45 countries.

5.1 Agriculture

EM Technology has brought a major revolution in a number of seemingly diverse areas. EM Technology is effecting significant and on going changes in agriculture. It has increased not only the yield but also improved the quality of the produce. In Japan the average yield of rice has been increased from 540 kg to 840-9000 kg / 1000 m^2. The cucumber plant grown with EM produced 4 – 5 cucumber per node instead of one only. In South America, Brazil has been enthusiastically focusing on EM as a way of breaking free from the destructive slash-and-burn farming methods which have grown up there, and of simultaneously protecting the natural environment of the Amazon Basin. As a result Brazil is currently the world's largest consumer of EM. Brazil's monthly production capacity of EM is over 700 tons. USA, Canada, China France, Russia, Germany, Holland, Japan, Australia, Spain, Argentina, Malaysia, Kenya, Syria, Egypt, Pakistan, India, Sri Lanka, Colombia, Vietnam, Taiwan, Korea, Philippines, Denmark, Poland, South Africa, Sudan, Lebanon, Indonesia, Thailand, New Zealand, Peru are producing and using EM in various fields. On the other hand in 71 countries EM is being used but not manufactured, among these are Chili, Cambodia, Cuba, Sweden, Namibia, Angola, Mali, Portugal, Greece, Yugoslavia, Saudi Arabia, Nigeria, Afghanistan, Zimbabwe, UAE, Mexico, Hungary, Finland, Congo, Ghana, Morocco, Turkey, Iran, Qatar, Italy, Austria, Israel, and Venezuela, etc.

In Hawaii EM (1: 500) was sprayed on Macadamia Nuts trees at Cordoza farm weekly and EM Bokashi was applied around the base of each tree along with EM extended application. EM application improved the health of the trees. EM treatment increased not only the size of the flowers but also caused the formation of clusters of macadamia nuts on the branch instead of only single nut.

In Waliua, Oahu U.S.A. the Dole Food Corporation applied EM Bokashi around the base of 2 years old grape fruit trees and EM (1: 1000) was sprayed over the entire plants weekly. EM increased the quality and quantity of grape fruits. It also prevented the insect attack.

[--*An Earth Saving Revolution: A means to resolve our world's problems through Effective Microorganisms (EM) by Dr. Teruo Higa, p 14 – 15;*

--*EM World Network Map indicating countries manufacturing and using EM / not producing EM but using EM in various field by EM Research Organization, Okinawa, Japan;*

--*EM Research Organization, Inc., 417 Ehako Place Honolulu, Hawaii 96817, January 3, 2000, Report # 10362*].

5.2 Reclamation of saline-sodic soils in Pakistan

Saline sodic soils can be reclaimed with the application of EM Technology comprising of composting of FYM + PM with EM, preparation of Bokashi from rice bran with EM, seed treatment with EM, EM irrigations and EM sprays in the 1st year with good yields. The reclamation with EM involves no soil amendments as needed for reclaiming sodic soils. The Na^+ of the exchange complex is replace with H, NH_4, and Ca released during the decomposition of composted material added to the soil. The microbial activity is increased to such an extent that a saline-sodic soil becomes normal agricultural land. The microorganisms which increased their population with the application of EM with all its products and helped to achieve reclamation are given in table –3.

(*Mechanisms of effective microorganisms (EM) in removing salt from saline soils by A. Syed, N. Satou & T. Higa: 13th Annual West Coast Conference on Contaminated Soils, Sediments and Water: March 17 – 20, 2003 San Diego, CA, USA*)

Table –3. **Beneficial microorganisms developed with EM application in the saline-sodic soil.**

Sr. No	Salt affected soil (control)	Sr. No	EM treated soil
1	Bacillus-sp	1	Azotobacter-sp
2	Entrobacter-sp	2	Bacillus -sp1
3	E. coli group	3	Bacillus-subtile
4	Fungi	4	Clostridium-treponema
5	Pseudomonas-sp	5	Corymebacerium-sp
6	Streptococcus-sp	6	Furabacterum
7	Seratia-sp	7	Gluconobacter-sp
		8	Lactobacillus- cassei
		9	Lactobacillus-sake
		10	Lactobacillus-sp
		11	Lactobacillus-sp1
		12	Lactobacillus-sp2
		13	Micrococcus-sp
		14	Micrococcus-sp1
		15	Micrococcus-sp2
		16	Pseudomonas- aeruginosa
		17	Pseudomonas- fluorescens
		18	Pseudomonas- putida
		19	Pseudomonas- Q1
		20	Pseudomonas- type –1
		21	Pseudomonas- type –2
		22	Pseudomonas-sp
		23	Rhodobacter-capsulatus
		24	Rhodoseubodomonas-sp
		25	Rhodospirillum-sp
		26	Streptococcus-sp
		27	Treponema-sp

(*Mechanisms of effective microorganisms (EM) in removing salt from saline soils by A. Syed, N. Satou & T. Higa: 13th Annual West Coast Conference on Contaminated Soils, Sediments and Water: March 17 – 20, 2003 Mission Valley Marriott San Diego, CA, USA*)

5.3 Animal husbandry

A ranch in America experienced a high incidence of deformity among its cattle. Investigations showed that the deformities were related to the underground water supply on the ranch. The cattle were drinking this underground water, which was found to be loaded with heavy minerals. EM was introduced to the wells containing this very groundwater. In a short space of time it was noticed that the birth of deformed young dropped away surprisingly.

[*An Earth Saving Revolution: A means to resolve our world's problems through Effective Microorganisms (EM) by Dr. Teruo Higa, p 168*]

5.4 Environmental pollution

EM resolves problems of environmental pollutions with two types of microorganisms. Zymogenic EM produces antioxidants and certain synthesizing strains of anaerobic microorganisms love to consume contaminants and pollutants. The photosynthetic bacteria, which play central role in EM, are able to tolerate extremely high temperature, in certain cases temperatures in excess of 700^{o}C. The use of EM has purified the wastewater in the public library in Gushikawa, a city in Okinawa, Japan. The effluent has been treated with EM, which has purified it to such a degree that it can safely be used for drinking purposes. The use of EM has caused a lot of savings. EM Technology is being used to banish odors in bathrooms and showers as well as to remove the contaminated and malodorous build-up inside pipes.

[*An Earth Saving Revolution: A means to resolve our world's problems through Effective Microorganisms (EM) by Dr. Teruo Higa, P 148 - 149*]

5.5 Deodorization at a waste treatment plant

In Switzerland, the Olfar Technology of Switzerland developed a plant with finer system for handling 5 - 20 tons of waste per hour. It is capable of disposing of discarded and waste items. This recycling operation was capable of dealing with a huge miscellany of items ranging from scrap metals like aluminum, iron and steel as well as plastics and vinyl's, waste paper and textiles of all kinds to kitchen waste, food scraps and other organic substances. The entire accumulated mishmash of waste was finely pulverized and then separated for recycling by means of a most advanced sorting and processing procedure. There was, however, one serious drawback to all of this: the sorted and processed waste gave off the most pungent and awful stench. Despite the fact that ozone sterilization was being used midway through the process to counteract the smell. The stench itself was bad enough, but the ozone used in the sterilization process was downright dangerous. Ozone is a virulent carcinogen and as such potentially life-threatening. EM was introduced into the system at one of the earliest stages of the operation. EM was sprinkled on to the waste materials right at the start of the pulverization process before entry into the crusher. EM acted as a very powerful deodorant and eradicated the terrible stench completely as if by magic. EM further enabled the Swiss recycling operation to do away with the dangerous process of ozone sterilization and improved the running efficiency of the machinery.

[*An Earth Saving Revolution: A means to resolve our world's problems through Effective Microorganisms (EM) by Dr. Teruo Higa, P 120 -121*]

5.6 Deodorization from kitchen garbage processing

Kani City, central western part of mainland Japan, has been exceptionally successful in its use of EM Technology to process kitchen garbage since 1992.The associated unpleasant smell produced by the saprogenic or putrefactive bacteria has been completely eliminated by the use of EM.

[*An Earth Saving Revolution: A means to resolve our world's problems through Effective Microorganisms (EM) by Dr. Teruo Higa, P 124 -125*]

5.7 Deodorization at a zoo

The use of EM has banished the unpleasant odor coming from animals kept at Honolulu zoo, Oahu U.S.A. Offensive odor is generally caused by admixture of among other things ammonia, hydrogen sulfide, trim ethylamine and methylmercapton. These substances just happened to provide substrate for the microorganisms in EM, who go to it and gobble them up, thereby effectively eradicating them.

(*EM Research Organization, Inc., 417 Ehako Place Honolulu, Hawaii 96817, January 3, 2000, Report # 10362*)

5.8 Safe disposal of tannery's sludge and its conversion into biofertilizer

EM experts has completed research trial on effluent and sludge treatment with EM products in collaboration with Pakistan Tanner Association Lahore. The tannery sludge of Eastern Leather Company was changed to a powdery farm material, was named as bio sludge / bio fertilizer because of its richness in macro and micronutrients. It is worth mentioning that Cr was reduced from 50 000 ppm to 312 ppm in the sludge. The sludge of Siddiq Leather Works (SLW) was also treated and it changed into a powdery material. Cr was reduced to nil to 1.054% as per analysis of Soil and Water Laboratory, Agriculture Department, Government of Punjab and Environmental Sciences Laboratory, PTA, Lahore respectively. At ELC premises rice crop was grown with the application of bio sludge and EM irrigation and EM spraying. The results were satisfactory.

(*Pilot Study on Safe Disposal of Effluent and Sludge through Bioremediation using EM Technology at Siddiq Leather Works by EMRO / PTA Collaboration, March 2003*).

5.9 Safe disposal of petroleum sludge and its conversion into biofertilizer

EM experts has carried out research in collaboration with NCPC on the bio remediation of oily sludge of Attock Refinery Ltd in October 2002. The oily sludge was converted to bio sludge with the use of various EM products and finally by mixing with equal quantity of dried soil it was converted to a bio fertilizer. Agricultural trials are under progress. The heavy metals in the sludge were diminished to a certain extent. Treatment of 600 tons of oily sludge at large scale with EM Technology is under consideration by the ARL dignitaries.

[*Final Report on Attock Refinery Limited, Oily Sludge Bioremediation (anaerobic), phase-1: treatment of sludge using EM Technology by EM & NCPC Collaboration, 6th February 2003*].