TURNING GARBAGE INTO GOLD

An Introduction to Vermiculture Biotechnology

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WASTE BIOMASS – A FUEL

When we burn our garbage, garden trash or agricultural residues for quick disposal, we are literally burning our money.

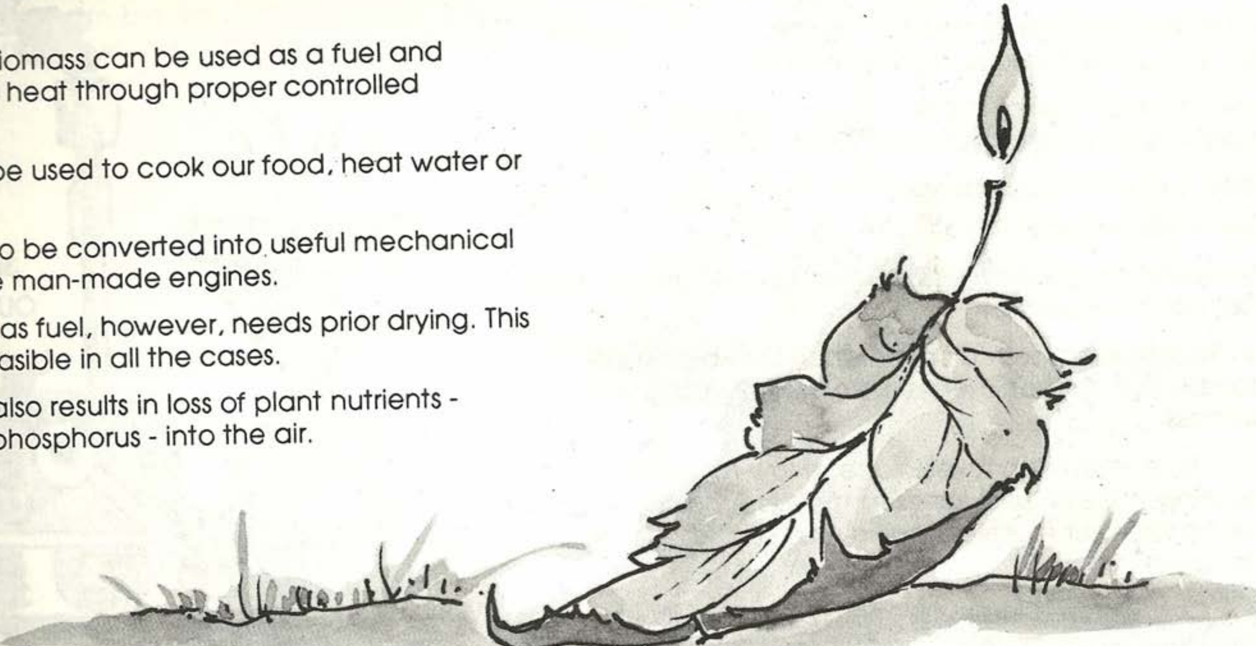
This valuable biomass can be used as a fuel and converted into heat through proper controlled combustion.

This heat can be used to cook our food, heat water or air.

Heat could also be converted into useful mechanical work - as in the man-made engines.

Using biomass as fuel, however, needs prior drying. This may not be feasible in all the cases.

Such burning also results in loss of plant nutrients - nitrogen and phosphorus - into the air.



BIO-COMBUSTION

Dry as well as wet biomass, however can be biologically 'burnt' without losing the nitrogen and phosphorus to air.

Plants fix solar energy and inorganic nutrients, from the soil and air, to produce organic matter.

Animals and most of the tiny micro-organisms, in turn, have to consume organic matter as food.

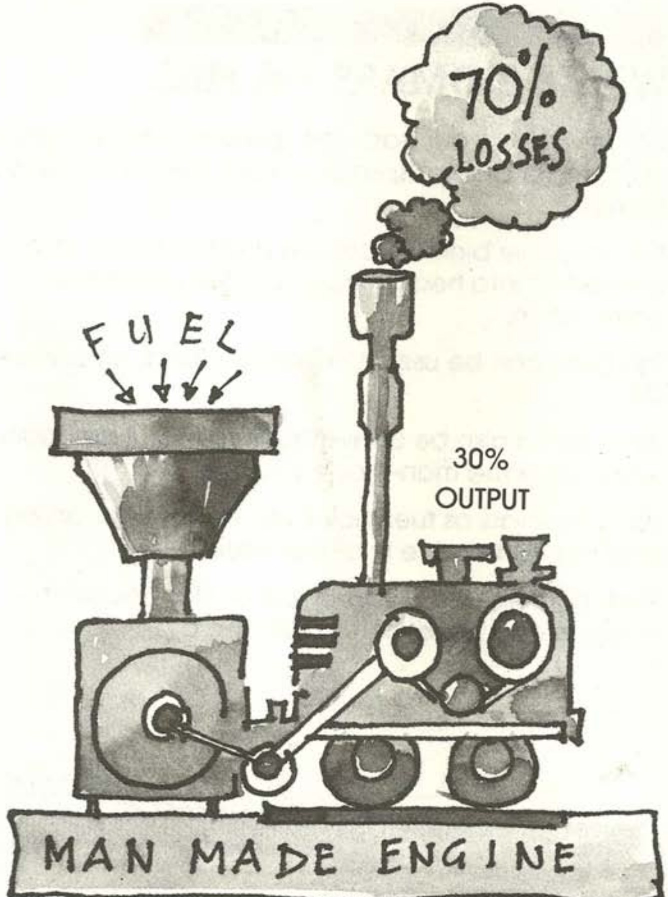
Food is burnt biologically by these creatures, liberating useful bio-energy (ATP).

Biological combustion has several advantages over the thermal combustion:

- Moisture causes no interference with biological combustion. In fact, moisture is essential during the process.

- Bio-combustion takes place at low temperature resulting in lower heat-losses to the surroundings. There are no losses of volatile organic matter, nitrogen and phosphorus.

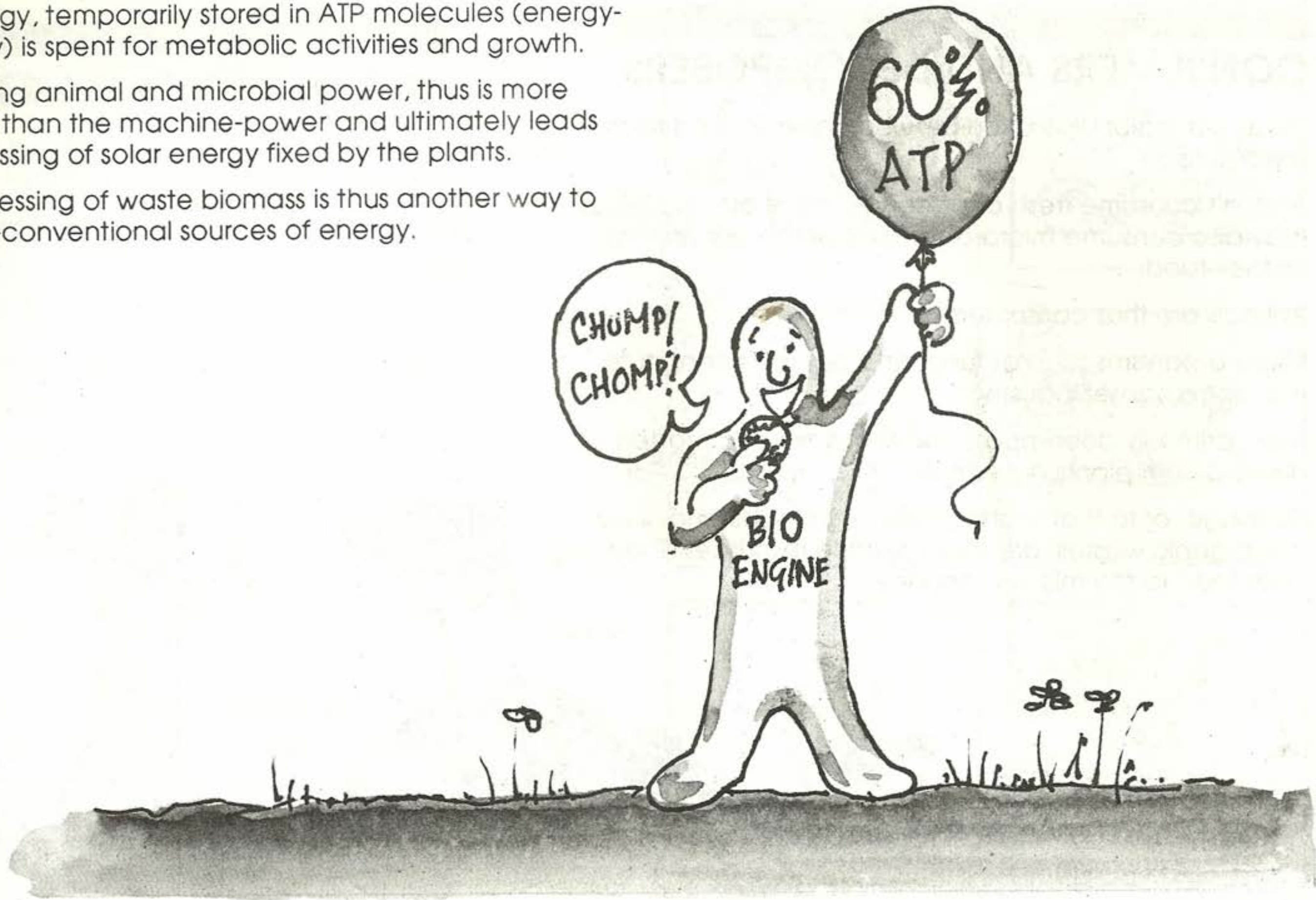
- Conversion of biomass energy into useful bio-energy (ATP) is quite efficient (about 60 per cent), at least double that of the finest man-made engine ever made.



This energy, temporarily stored in ATP molecules (energy-currency) is spent for metabolic activities and growth.

Harnessing animal and microbial power, thus is more efficient than the machine-power and ultimately leads to harnessing of solar energy fixed by the plants.

Bio-processing of waste biomass is thus another way to tap non-conventional sources of energy.



CONSUMERS AND DECOMPOSERS

There is a major distinction between animals and micro-organisms.

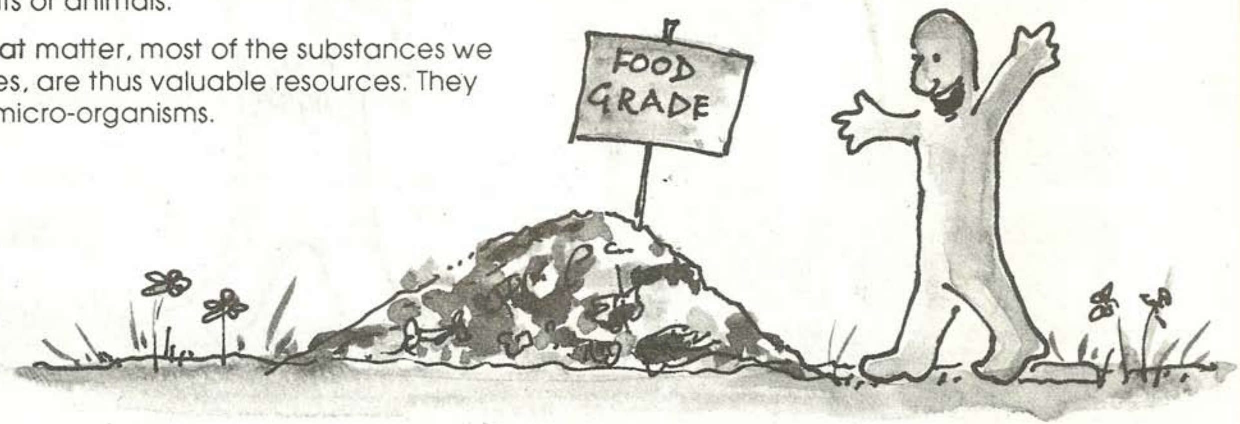
Animals consume fresh or preserved plant biomass. They may also consume micro-organisms and other animals as their food.

Animals are thus consumers.

Micro-organisms such as fungi and bacteria constitute the 'decomposer industry'.

They primarily decompose the dead organic matter, derived from plants or animals.

Garbage, or to that matter, most of the substances we call organic wastes, are thus valuable resources. They offer food to the micro-organisms.



BACTERIA ARE VORACIOUS.

The following table gives daily food consumption by 1,000 kg total biomass of different organisms :

Elephant	4 kg
Men	20 kg
Mice	200 kg
Earthworms	500 kg
Fungi	2,000 kg
Bacteria	20,000 kg

Bacteria, thus are the super-consumers of food.

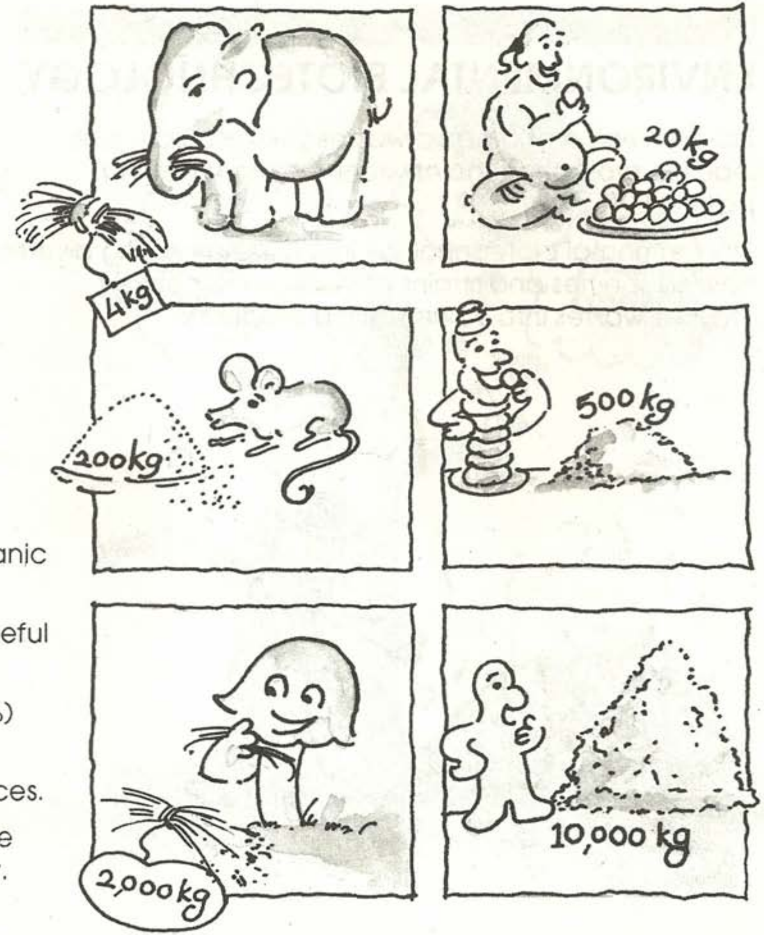
They are versatile and consume a wide range of organic molecules as their food.

Some of them produce a whole range of products useful to us.

Their own biomass, too, is full with proteins (about 70%)

Hence bacteria could be harnessed for speedy bioconversion of organic wastes into valuable resources.

No wonder, bacteria are the prime candidates in the newly developing technology - called biotechnology.



ENVIRONMENTAL BIOTECHNOLOGY

Bio-conversion of organic wastes ~~into~~ resources also leads to protecting the environment from getting polluted.

Environmental biotechnology involves harnessing diverse desired species and strains of bacteria to convert organic wastes into value-added products.

GOOD BACTERIA NEED PROPER MANAGEMENT.

Bacteria need proper supply of oxygen to match their speed of growth and food consumption.

They also need proper conditions of temperature, moisture. pH and nutrients.

They cannot maintain their speed even when a single factor becomes a limiting one.

When bacteria consume the available oxygen in garbage or sewage, the conditions become limited by oxygen and those bacteria adopted to oxygenless or anaerobic environment take over.

These anaerobic bacteria carry out incomplete combustion of food, similar to that in the car with a mistuned engine.

They are able to release only about 5 per cent of the energy in the food and thus grow very slow as compared to the aerobic bacteria.

They produce incompletely oxidised molecules such as methane (a greenhouse gas) and several obnoxious compounds which cause environmental pollution.

Anaerobic bacteria may be specifically harnessed in a bio-gas plant to produce methane, to be used as a fuel.

Incompletely oxidised slurry from the bio-gas plant can be subsequently used to grow aerobic bacteria.

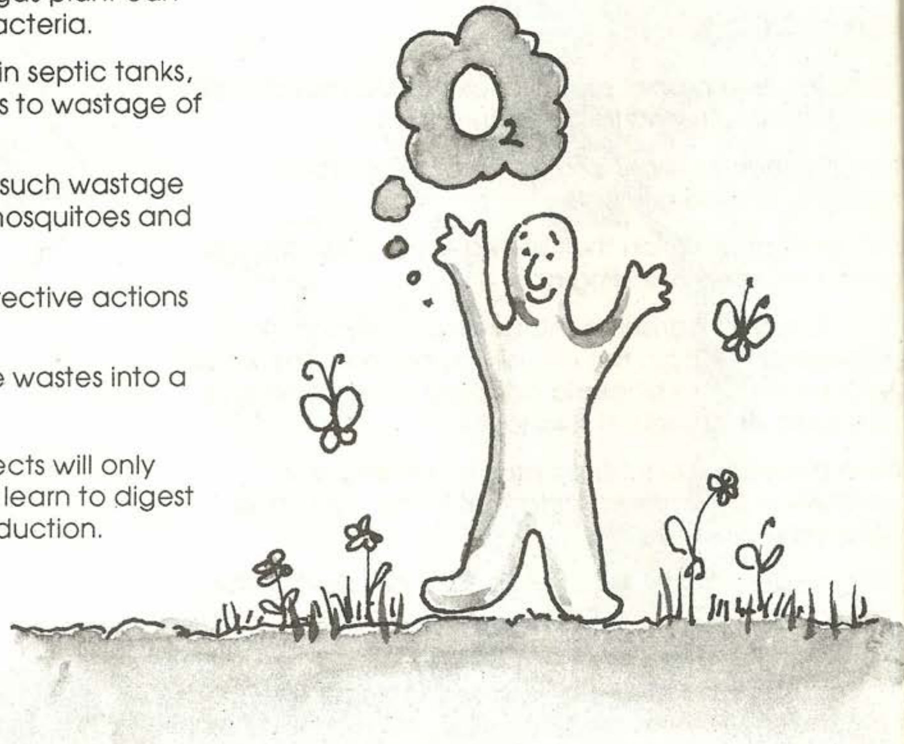
However, allowing anaerobic conditions in septic tanks, ponds, rivers and heaps of garbage leads to wastage of resources.

Fortunately for us, nature warns us about such wastage through odour and proliferation of flies, mosquitoes and other insects.

We must note these signals and take corrective actions which will ensure supply of oxygen.

This can be simply done by spreading the wastes into a thin layer, above the soil.

Spraying toxic substances to kill these insects will only poison the environment. The insects soon learn to digest the poison due to their high rate of reproduction.



AEROBIC BACTERIA

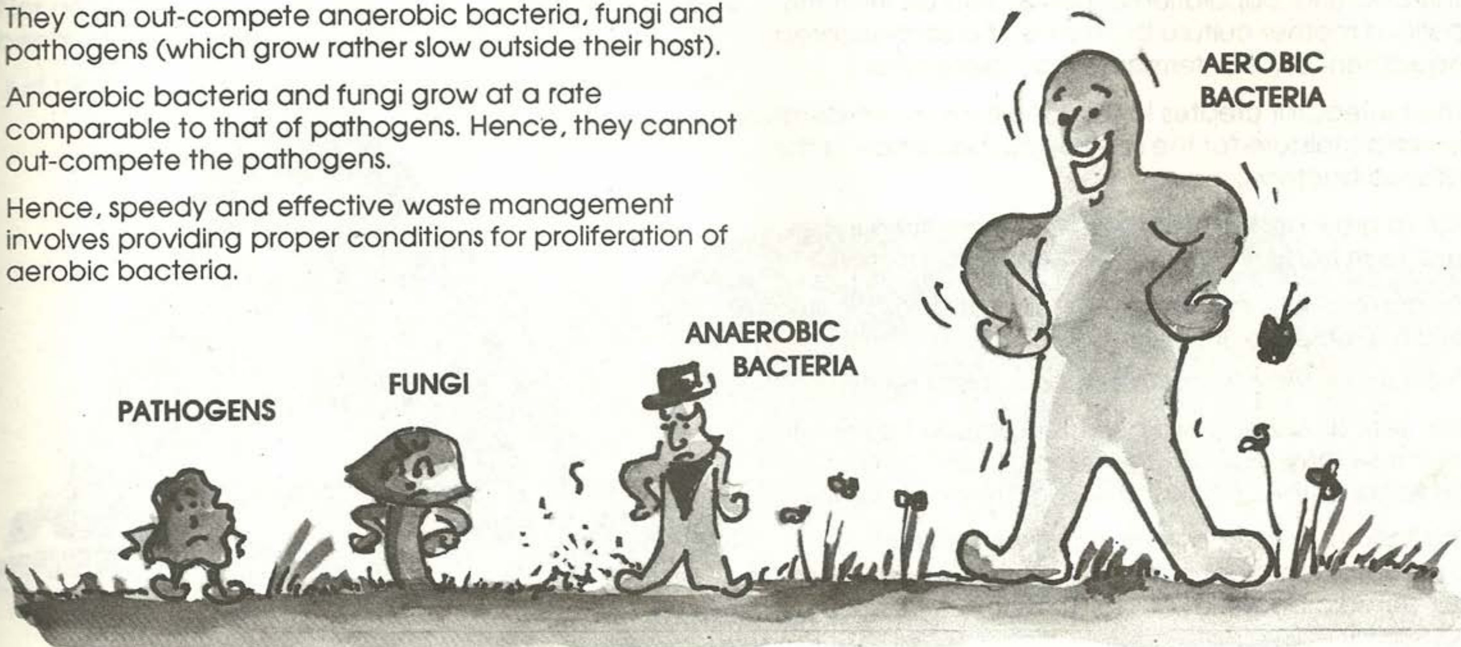
AEROBIC ENVIRONMENT SUPPRESSES PATHOGENS.

Aerobic bacteria can multiply very fast under ideal conditions, doubling even in a short period of 20 minutes.

They can out-compete anaerobic bacteria, fungi and pathogens (which grow rather slow outside their host).

Anaerobic bacteria and fungi grow at a rate comparable to that of pathogens. Hence, they cannot out-compete the pathogens.

Hence, speedy and effective waste management involves providing proper conditions for proliferation of aerobic bacteria.



BIOREACTORS

Doing this with modern industrial equipment is of course relatively straightforward.

The desired strains of bacteria are first isolated from the rest, and allowed to grow as a culture.

The bacterial population is then scaled up from this purified mother culture by means of a sophisticated equipment called "fermenter" or "bioreactor".

The bioreactor creates ideal conditions of temperature, pH and moisture for the speedy multiplication of the desired bacteria.

But to grow and sustain these same bacteria in a garbage heap is a somewhat more difficult task.

To achieve this, one would literally need to construct a similar bioreactor inside the garbage.

Though this may sound farfetched, it isn't really.

You see, all animals are also bioreactors of some kind, because they regulate the temperature, moisture and pH levels of their bodies to ensure their own survival.

The task thus boils down to finding an animal whose bioreactor functions correspond to the conditions that suit aerobic bacteria.

MAN-MADE BIOREACTOR

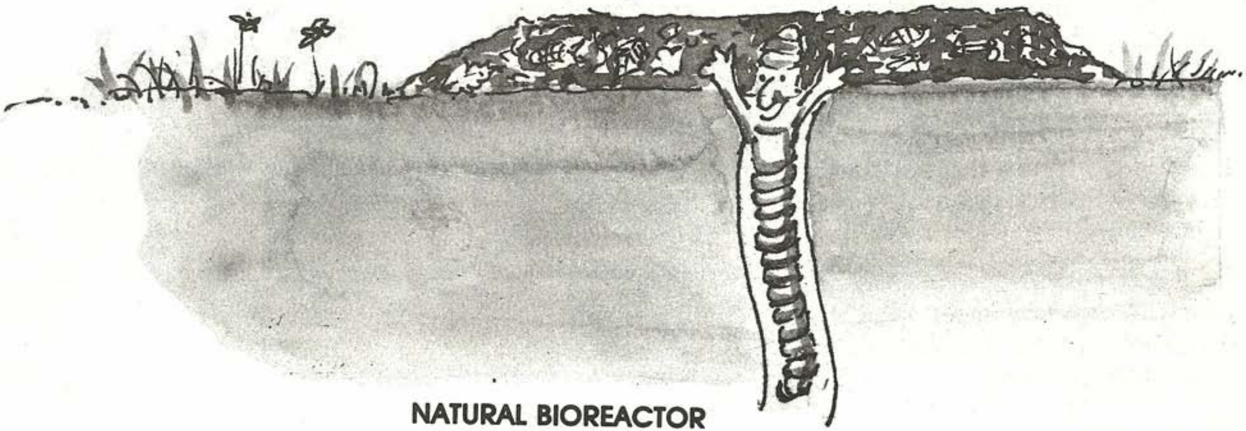
This animal shouldn't be too fussy about being surrounded by garbage, either.

Fortunately, just such an animal exists... in fact one quite well known to man - the lowly earthworm.

The gut of an earthworm is a perfect natural bioreactor which provides an ideal breeding home for aerobic bacteria.

Nor does the earthworm mind the presence of garbage, because it isn't really garbage to him...

Just highly nutritious matter which the bacteria can eat.



NATURAL BIOREACTOR

EARTHWORMS FARM BACTERIA.

But if the earthworm is so concerned about the bacteria, it isn't without a very good reason.

Actually, he's only lining up his next meal, because bacteria are what he feeds on ... and just as man cultivates wheat for his own consumption, the earthworm cultivates bacteria.

To our good fortune, the method of farming practised by the earthworm automatically promotes aerobic over anaerobic bacteria.

His own insides are already highly aerobic, because of his natural ability to inhale oxygen from the atmosphere in large amounts.

Apart from this, his constant burrowing action allows air to penetrate to a much greater depth.

Most importantly, the earthworm himself seems to realise instinctively that anaerobic bacteria, fungi and pathogens are undesirable, and so eats them preferentially, thus preventing their proliferation.

But even when only aerobic bacteria are present, consumption by the earthworm poses no threat to their continued survival.

PREDATOR CULLS THE PREY.

As ecology teaches us, the relationship between a predator and its prey, though harmful to the individual victim, is beneficial to the community at large.

The elegantly designed mechanism by which this works is well worth understanding.

It has been observed that any predator always preys first on aging and unhealthy members of the population, leaving the young and healthy members to grow.

Accordingly, the earthworm too will feed only on those bacteria that are lazy or unwanted, while sparing the useful ones.

Selective feeding of this kind, called "culling" is nature's method of family planning.

In fact, it is by far the most efficient method of population control, because it ensures that the fittest creatures survive, ultimately leading to improvement of the species.

Besides, if culling did not exist, organisms like bacteria would multiply in an entirely unregulated manner.

At first, this would lead to a virtual population explosion among them (Portion A).

However, scarcity of resources would soon result in competition among the bacteria, and the rate of multiplication would slow down until it reaches zero (Portion B).

Even then, the population would not stabilise.

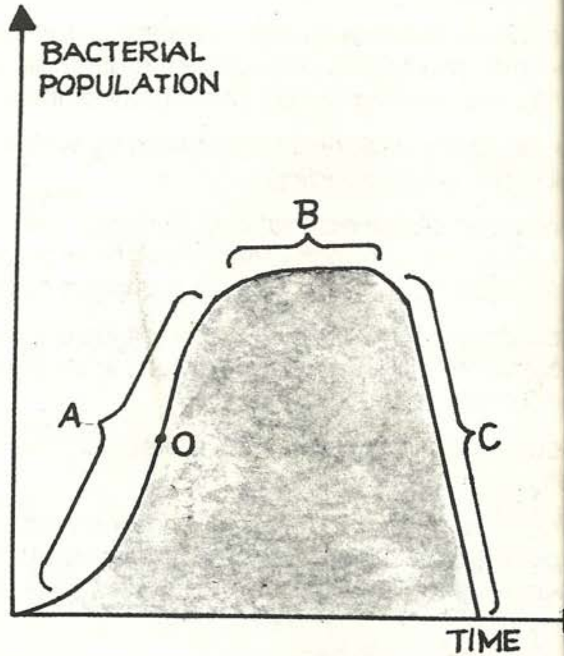
Instead, because of continued competition among the bacteria, it would actually start declining until all of them are finally wiped out (Portion C).

What is very fascinating to note is that the culling of bacteria by the earthworm always operates around that particular point (O) at which rate of multiplication is highest.

This ensures that at any given time, the bacterial population is multiplying as fast as it possibly can.

So ironical though it may sound, bacteria should actually be very grateful to the earthworms for feeding on them.

Not only do more of them grow as a result, but succeeding generations are better adapted for survival.



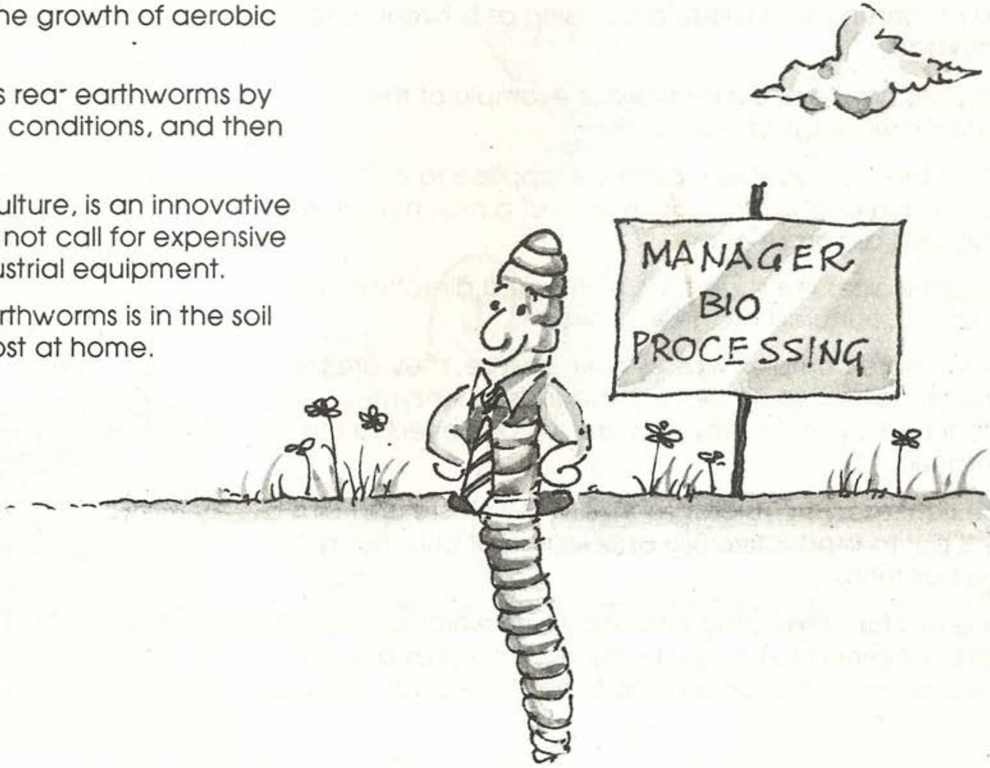
VERMICULTURE

Earthworms are thus ideal managers whom man can effectively employ to maximize the growth of aerobic bacteria for waste processing.

To achieve this, all he has to do is rear earthworms by providing them with proper living conditions, and then feeding them his organic wastes.

This technique, known as Vermiculture, is an innovative type of biotechnology that does not call for expensive laboratories or sophisticated industrial equipment.

In fact, the best place to rear earthworms is in the soil itself, which is where they feel most at home.



SOIL PROCESSING

Vermiculture's most attractive feature is that it combines soil processing with waste processing as a two-in-one package.

How this happens is a marvellous example of the intricate workings of nature.

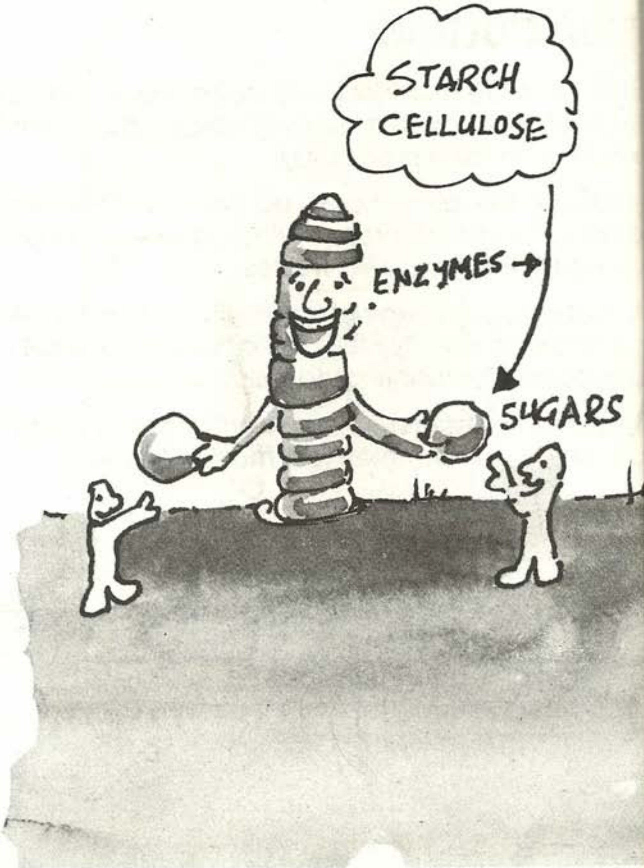
When bio-degradable wastes are applied to a soil containing earthworms in the form of a mulch, action is triggered almost at once.

Simple wastes like sugars are consumed directly by the bacteria, nurtured by the earthworm.

As for more complex wastes like cellulose, they are first broken down into simpler compounds by enzymes produced by the earthworm, before being fed to the bacteria.

The rich reserve of bio-carbon that the waste contains is thus put to productive use as a source of bio-energy for the bacteria.

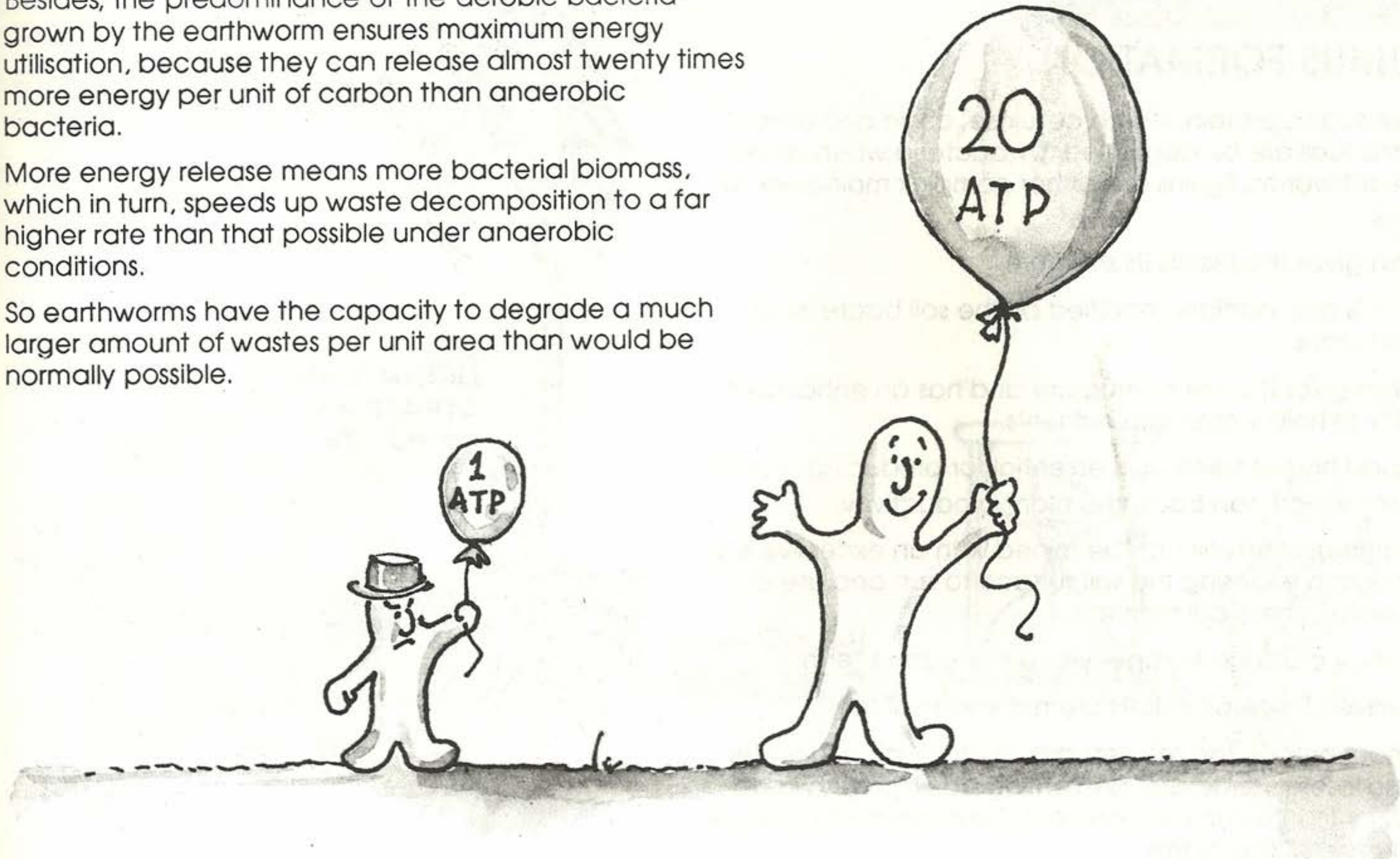
As a matter of fact, the efficiency with which carbon gets converted to useful energy is as much as double the amount achievable in the finest man-made engines.



Besides, the predominance of the aerobic bacteria grown by the earthworm ensures maximum energy utilisation, because they can release almost twenty times more energy per unit of carbon than anaerobic bacteria.

More energy release means more bacterial biomass, which in turn, speeds up waste decomposition to a far higher rate than that possible under anaerobic conditions.

So earthworms have the capacity to degrade a much larger amount of wastes per unit area than would be normally possible.



HUMUS FORMATION

While sugar, protein, starch,cellulose, chitin and other substances are biodegraded by bacteria when aided by earthworms, lignins are rather complex molecules to crack.

Lignin gives the plants its structure.

Lignin is only partially modified by the soil bacteria to form humus.

Humus gives the soil its structure and has an enhanced ability to hold water and nutrients.

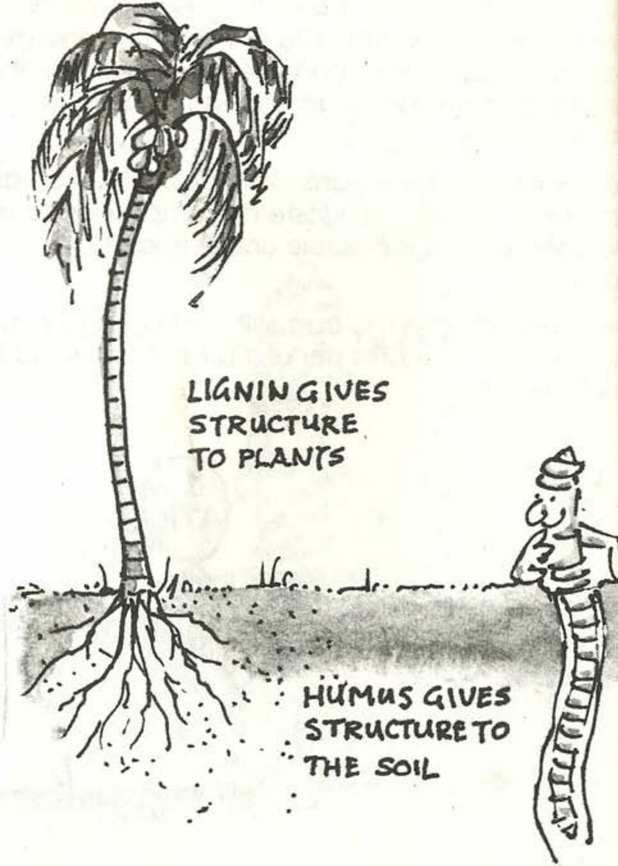
A good humus reservoir is essential for producing a fertile topsoil which can boost the plant productivity.

This humus reservoir can be mined with an excessive soil cultivation exposing the soil surface to sun and use of excessive chemical fertilisers.

This may produce bumper yields in the short term.

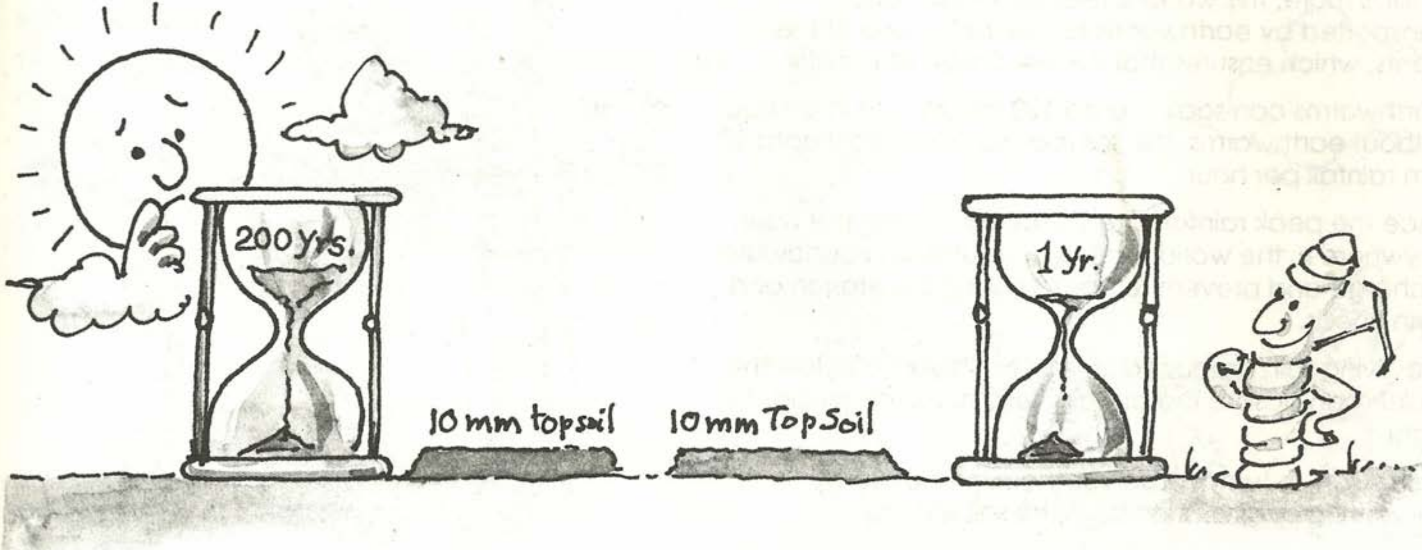
However, these practices are not sustainable.

Without humus, the soil gets blown off by air and water. It also loses its structure, preventing passage of air and water into it. This in turn, prevents development of proper root-zone of the plants.



Nature takes as much as 200 years to build up a 10 mm layer of humus-rich soil.

Given a proper supply of wastes, earthworms can achieve the same result in a single year.



WATER CONSERVATION

A valuable by-product of waste decomposition by the earthworms is water, which is produced to the extent of 60% of weight of (dry) organic wastes.

What is more, this water is released slowly and transported by earthworms to the root - zone of the plants, which ensures that it is used most efficiently.

Earthworms can soak in upto 120 mm rainfall in an hour. Without earthworms, the soil may soak in hardly upto 10 mm rainfall per hour.

Since the peak rainfall rarely exceeds 75 mm per hour, anywhere in the world, earthworms ensure groundwater recharge and prevent run-offs causing soil erosion and flash floods.

The 'living soil' produced by the earthworms below the mulch can adsorb the atmospheric moisture during the night.

The mulch, in turn, conserves the soil moisture by preventing evaporation from the soil surface.

All these mechanisms can dramatically reduce irrigation requirements, and ensure bumper crops in spite of limiting irrigation.

PLANT NUTRITION

Apart from water and humus, a healthy soil must also contain a ready supply of the various nutrients needed by plants such as nitrogen, phosphorus, potassium and several others, in balanced proportions.

Though waste cannot supply these nutrients fully, they are available elsewhere in nature in amounts quite adequate for plants needs...

Nitrogen from the atmosphere, and all others from the rock.

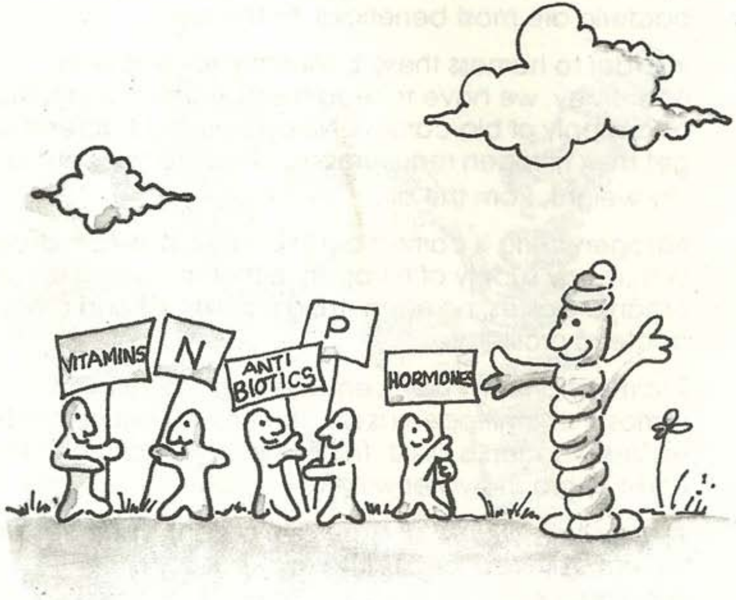
The only problem of course, is that they must first be converted to forms that plants can assimilate.

Here again, it is the earthworm who comes to the rescue.

Amazingly enough, scientists have discovered that the bacteria he grows are just the right varieties for the job : nitrogen fixers, phosphorus solubilisers, vitamin, antibiotic and hormone producers, and many others still unknown to man.

You may wonder at this happy coincidence, which sounds almost too good to be true.

Actually, it is no coincidence at all.



After, all, the soil is the earthworm's natural habitat.

So like anyone with common sense, he keeps his house in proper order by growing those bacteria which the soil needs.

Besides, he's been staying there for about 600 million years, so he's had more than enough time to learn which bacteria are most beneficial to the soil.

In order to harness these beneficial soil bacteria effectivley, we have to feed them waste organic matter as a supply of bio-carbon. Nitrogen-fixing bacteria can get their nitrogen requirement, about 10 per cent of their dry weight, from the air.

Nitrogen-fixing is carried out in a need-based manner. With ready supply of nitrogen, either through urea or organic wastes, nitrogen-fixing is inhibited and other bacteria proliferate.

This mechanism, in turn, ensures that the soil fixes atmospheric nitrogen as per the crops' requirements. No excess nitrogen is fixed. This prevents poisoning of food and the groundwater with free nitrates.

Application of urea or excessive organic manures inhibits this natural mechanism and may cause nutrient imbalances.

Such crop is severely attacked by the pests.

Earthworms, however, monitor these soil processes so that the crops are healthy due to balanced plant nutrition.

Healthy crops offer balanced nutrition to the animals, contributing, in turn, to their health.

In order to boost these soil processes, we should feed the organic wastes, solid or liquid, to the soil.

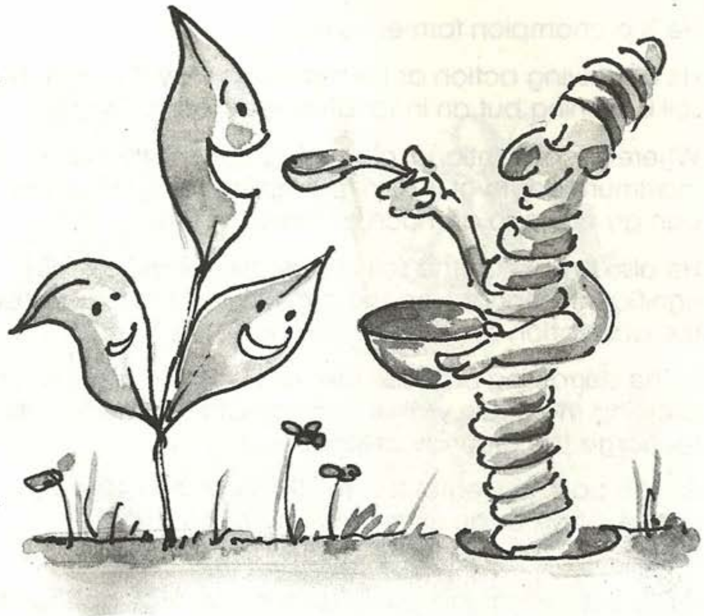
External processing , such as composting reduce the supply of bio-carbon very much needed for carrying out these soil processes.

One may process organic wastes in well monitored biogas plants to generate fuel. However we are reducing the supply of bio-carbon required by the soil processes.

Sewage treatment through the septic tanks is totally wasteful. The methane generated goes to the atmosphere, causing the greenhouse effect.

Conventional aerobic processes for wastewater treatment focus on growing assorted bacteria to burn the bio-carbon, termed as BOD and COD in the trade.

Earthworms, however, ensure proper utilisation of bio-carbon to produce balanced nutrition for the plants.



EARTHWORMS - THE MOST EXPERIENCED FARMER

The earthworm's talents do not stop at waste processing and soil enrichment, either.

He is a champion farmer as well.

His burrowing action as he makes his way through the soil is nothing but an innovative method of tillage.

Whereas conventional ploughing upturns the soil to a maximum depth of 30 cm, ploughing by earthworms can go down to as much as three meters.

He also breaks up the soil into smaller particles, thus significantly enhancing the surface area available for the adsorption of moisture and nutrients.

In the burrowing process, the soil's porosity increases too allowing more rain water to percolate downwards and recharge the groundwater table.

Air too can now enter the soil through the burrows, where it acts as an excellent insulator against temperature fluctuations on the soil's surface.

While burrowing, the earthworm is also busy acting as a round-the-clock mini fertilizer factory.

Soil entering his mouth is constantly being processed by the inoculation of a mixed bacterial culture, and the grinding of rock particles to the size of a single micron.

This processed soil is then excreted through the anus in the form of a manure that is known as "vermicastings".

Vermicastings are a highly enriched kind of biofertiliser, which boast of a microbial density that is almost one thousand times that of the surrounding soil.

What is more, nestling among the vermicastings are scores of tiny earthworm cocoons which will hatch within a month, adding still further to the earthworm population already in the soil.

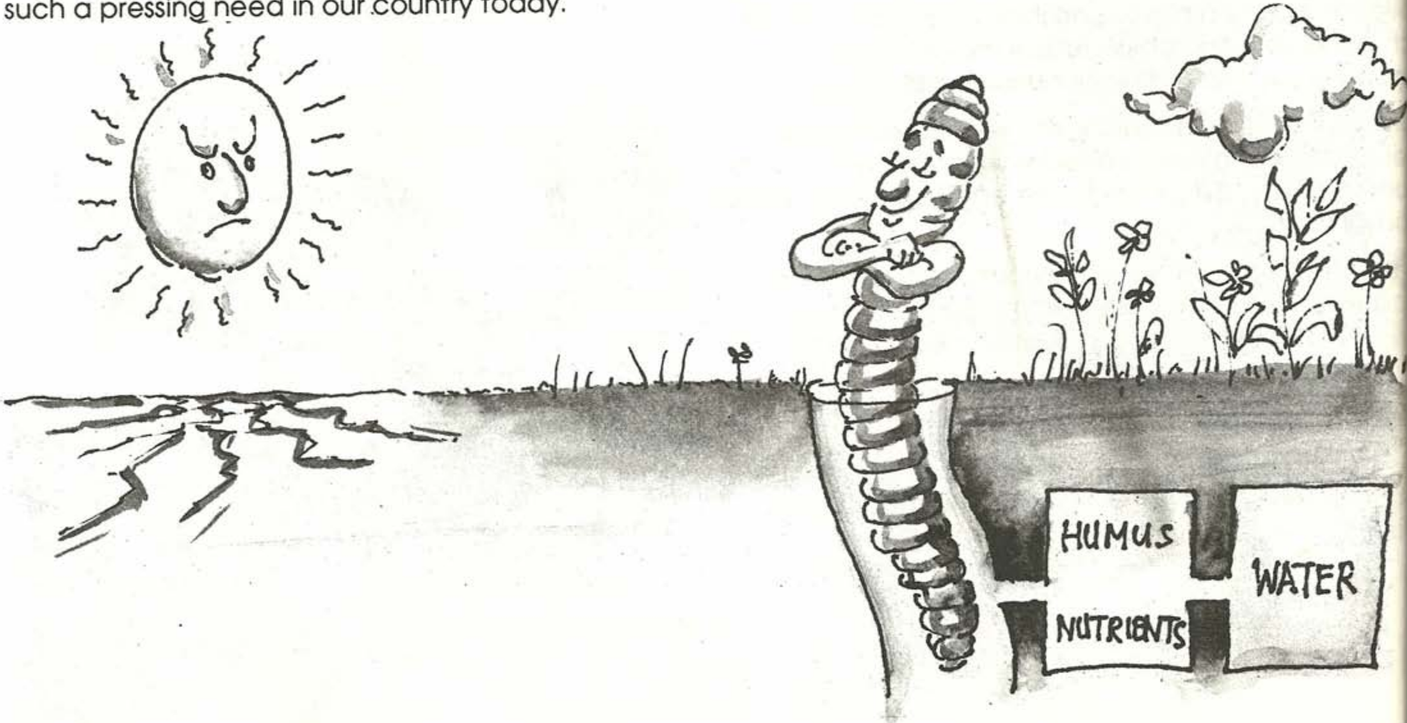
Thus the efforts of a single earthworm can be quickly replicated several times over, with a cumulative effect on plant growth that is quite phenomenal.

Of course, if the earthworm is taking such pains to see that plants grow well, it isn't merely as a hobby.

He is far-sighted enough to realise that the greater the plant biomass produced, the greater the quantity of residues that will find their way back to the soil.

All he's really doing, therefore, is making sure that the soil's reservoir of humus and nutrients is being adequately replenished.

Earthworms can thus be used very effectively to restore the fertility of degraded soils and wastelands, which is such a pressing need in our country today.



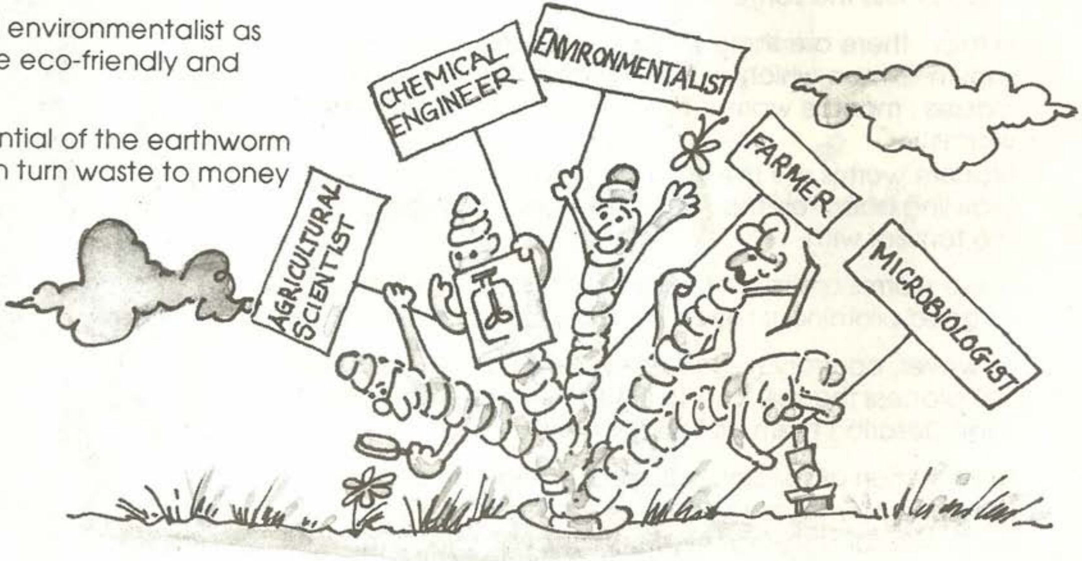
THE VERSATILE EARTHWORM

All in all, the range of an earthworm's skills quite takes one's breath away.

He is a chemical engineer, a microbiologist, agricultural scientist and a farmer, all rolled into one.

What is more, he is a committed environmentalist as well, because all his methods are eco-friendly and sustainable.

It is precisely this incredible potential of the earthworm which, if harnessed properly, can turn waste to money



EARTHWORM SPECIES

Of course, it is very important to choose the right species of earthworm for the task.

A very common fallacy is that all earthworms behave in more or less the same way.

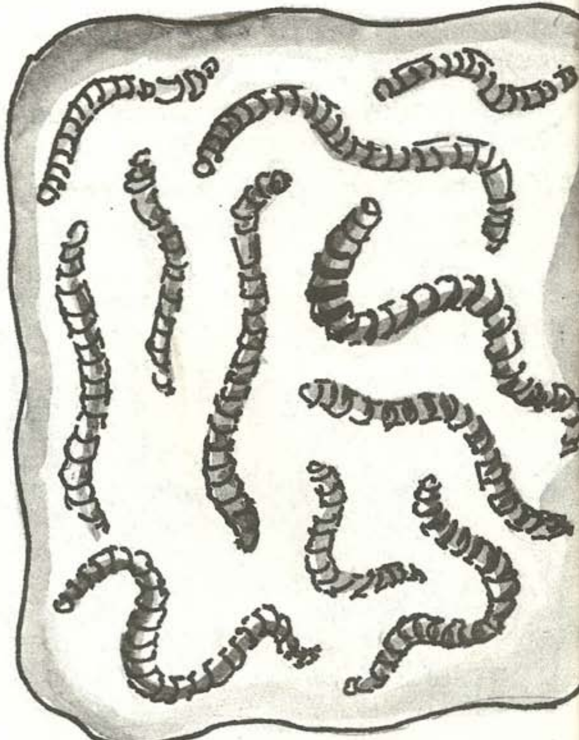
In fact, there are three thousand different species known to man which can be divided into two main classes : manure worms (red worms) and soil processing worms.

Manure worms are the reddish brown creatures seen crawling about on the soil's surface, whom most of us are familiar with.

These worms are rapid multipliers, and can thus be used as good proteinous feed for poultry and other livestock.

However, contrary to general belief, manure worms do not process the soil, and so it is somewhat inaccurate to even describe them as "earthworms".

The function of soil and rock processing can only be performed by those varieties of earthworms that burrow inside the soil, making the nutrients available to the plants, in a gradual manner.



It has also been found that these earthworms can survive better in harsh field conditions.

The fact that they live beneath the soil surface automatically renders them less susceptible to predation by birds.

What is more, because of their well trained bacterial workforce, burrowing earthworms are capable of breaking down the toughest of wastes like surgarcane trash, feathers or bones.

Burrowing varieties of earthworms are thus the most appropriate choice for vermiculture. The vermiculture technology developed by the Bhawalkar Earthworm Research Institute, or BERI, is based on one such species of burrowing earthworms called Pheretima elongata, who has been found especially efficient.

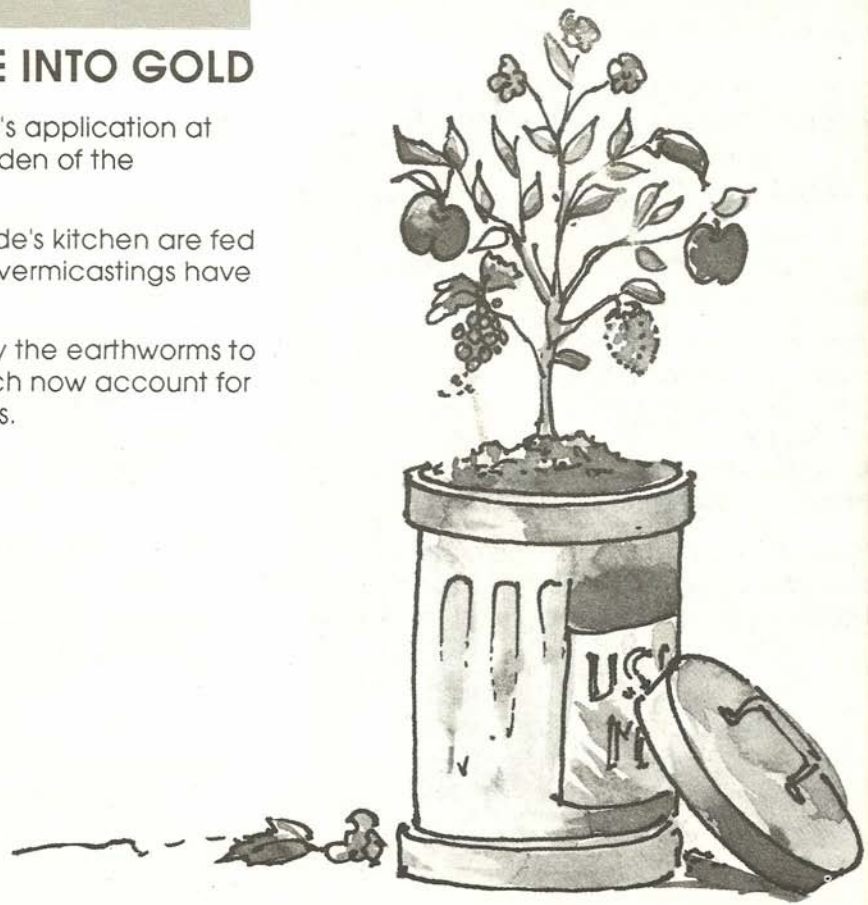
A whole series of custom made vermiculture packages have been designed by the BERI to suit different scales of field application, and different kinds of wastes.

CONVERTING GARBAGE INTO GOLD

An excellent example of vermiculture's application at the household level is the terrace garden of the Shrikhande family.

All the daily wastes from the Shrikhande's kitchen are fed to the soil in the garden beds, where vermicastings have already been applied.

The wastes are quickly transformed by the earthworms to large fleshy fruit and vegetables, which now account for much of the Shrikhande family's needs.



COMMERCIAL FARMING

Chandrakant Gaekwad is a small farmer who has been using the same technique on his one acre plot of pomegranate trees.

The base of each tree was treated with vermicastings about a year ago.

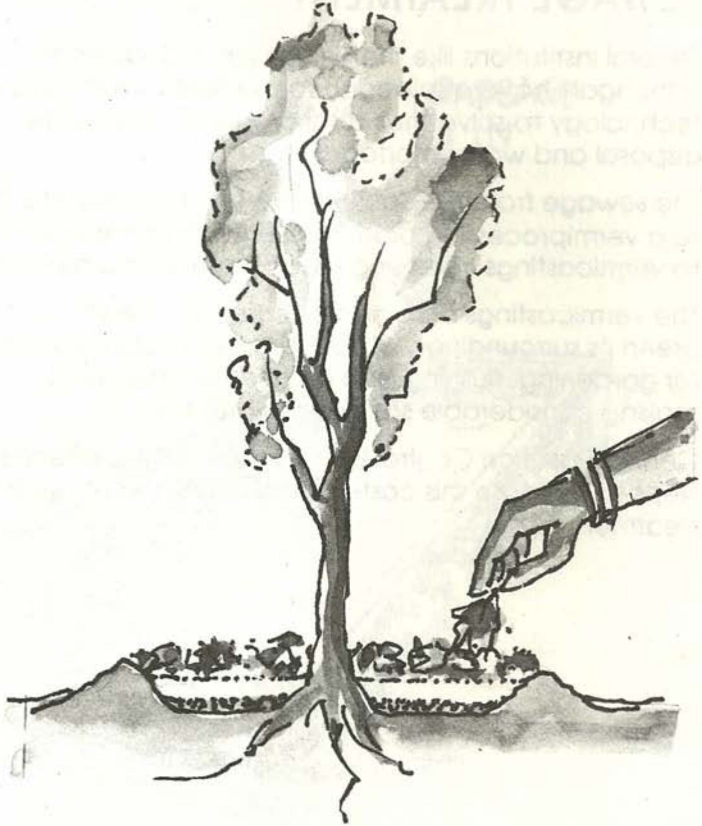
Of course, instead of household wastes, Gaekwad just recycles the weeds that grow in the plantation itself, by spreading them as mulch over the soil.

He also adds a dash of cowdung to make the weeds more palatable to the bacteria.

Though Gaekwad uses no chemical fertilisers, his yields today are among the highest in the area.

What is more, his produce, being organically grown, fetches a price almost twenty per cent higher than chemically grown pomegranates.

Another farmer, Rajendra Patil applied vermicastings to his 5.5 acre pomegranate plot 3 years back. While he has maintained his per plant income at Rs.250 per year, his annual costs have reduced from Rs. 110 to Rs. 55 to Rs. 30 to Rs. 20 per plant in successive years.



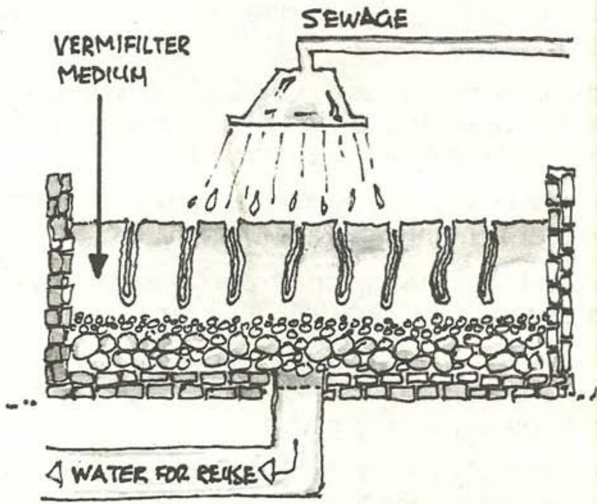
SEWAGE TREATMENT

Several institutions like the Sanjeevan Vidyalaya at Panchgani have also begun to use BERI's vermiculture technology to solve their dual problems of sewage disposal and water shortage.

The sewage from the Sanjeevan Vidyalaya hostel is fed to a vermiprocessing plant where earthworms convert it to vermicastings, releasing clean water in the process.

The vermicastings obtained are used by the school to green its surroundings, while the water produced suffices for gardening, flushing and other such operations, making considerable savings in water bill.

Central Pollution Control Board is now taking effective steps to promote this cost-effective method of sewage treatment.



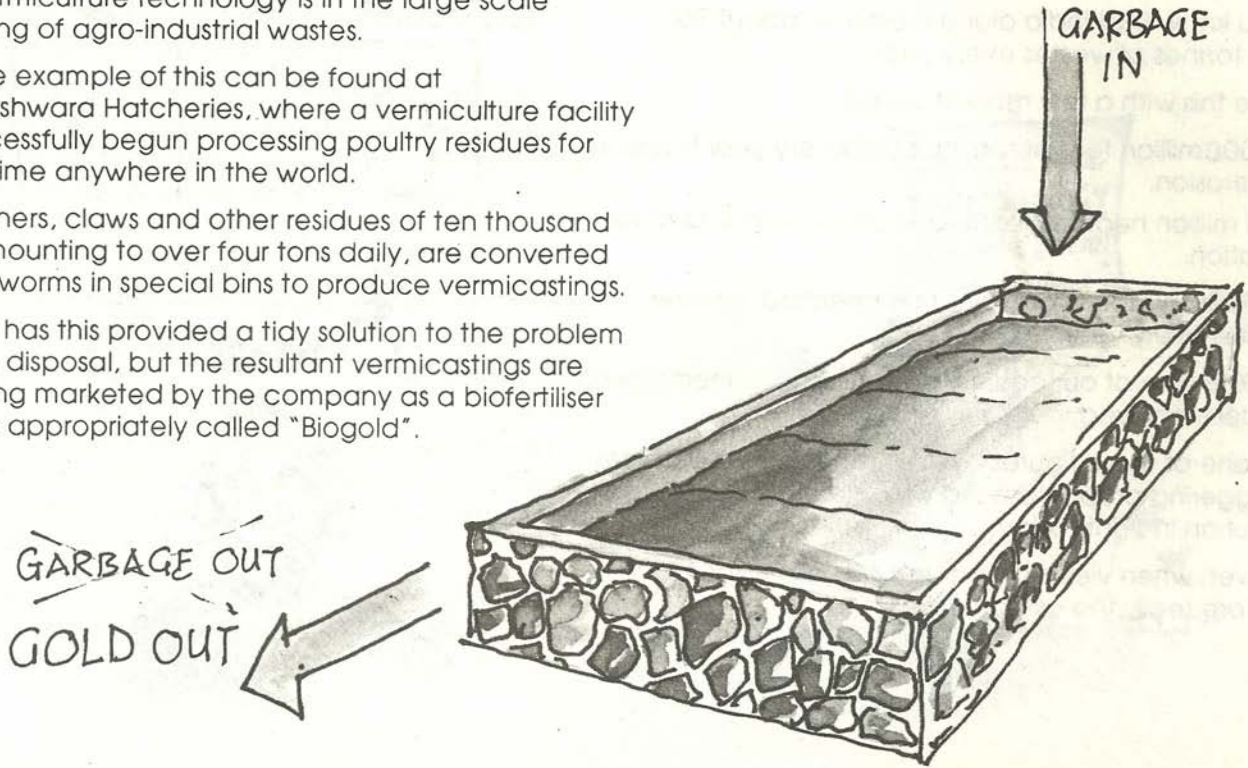
AGRO-INDUSTRIAL WASTES

But perhaps the most significant area of application of BERI's vermiculture technology is in the large scale processing of agro-industrial wastes.

A unique example of this can be found at Venkateshwara Hatcheries, where a vermiculture facility has successfully begun processing poultry residues for the first time anywhere in the world.

The feathers, claws and other residues of ten thousand birds, amounting to over four tons daily, are converted by earthworms in special bins to produce vermicastings.

Not only has this provided a tidy solution to the problem of waste disposal, but the resultant vermicastings are now being marketed by the company as a biofertiliser produce appropriately called "Biogold".



CONVERTING PROBLEMS INTO OPPORTUNITIES

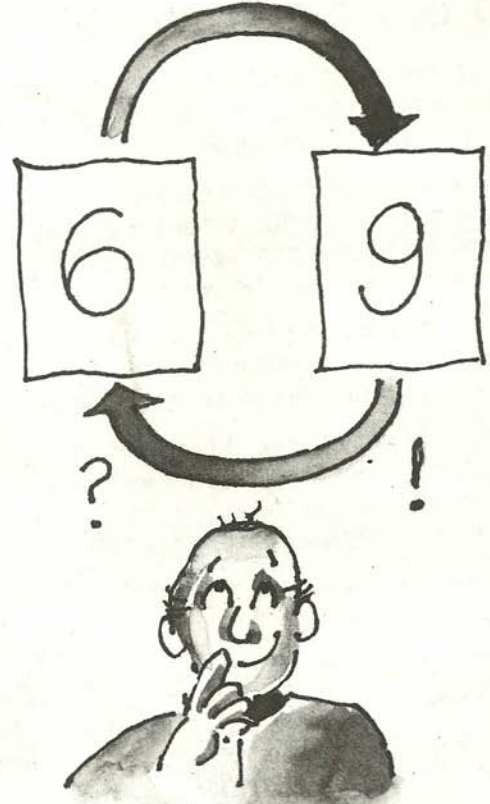
Do you know that India alone produces about 750 million tonnes of wastes every year?

Couple this with a few more statistics :

- 6,000 million tons of topsoil is lost every year because of soil erosion.
- 90 million hectares of land in our country is unfit for cultivation.
- 40 billion rupees are spent on chemical fertilizer subsidies every year.
- 400 million of our country's population is unemployed or underemployed.

Each one of these figures by itself represents a problem of staggering proportions., to which there appears to be no solution in sight today.

However, when viewed with an integrated approach, these are really the opportunities.



THE SOLUTION

There is one very simple and inexpensive method by which all these challenges can be tackled at one stroke... vermiculture biotechnology.

Indeed , if vermiculture were to be adopted on a countrywide scale, we could provide employment to millions of youth, eliminate dependence on chemicals, bring our wastelands under cultivation, feed our hungry citizens, and make the entire country green and prosperous in the span of just a few years.

Over a hundred years ago, the great biologist Charles Darwin wrote "Of all animals, few have contributed so much to the development of the world, as we know it, as earthworms".

Today, it is time we took note of Darwin's words and began using the vast untapped potential of this modest and unassuming creature to build a better future for ourselves and our children.

After all, through vermiculture biotechnology, the earthworm has given to man the almost unbelievable power of turning his garbage into gold...