



Review of Literature

The increasing quantity of solid waste in the modern age of development is one of the growing environmental problems in both developed and developing countries (Sexton, 2000). The use of biodegradable solid wastes as soil amendments (soil conditioners or fertilizers) or for land reclamation has reduced the volume of waste that is usually land filled, incinerated or disposed off at surface sites. In the last several years, numerous scientific, political and social factors have contributed to a growing public concern over the safety of biodegradable solid wastes. Therefore, the concept of organic matter recovery is becoming more popular. The organic portion of solid waste, however, could be utilized in a very profitable way by vermicomposting and other composting procedures (Ganesh *et al.*, 2009).

Composting as a resource recovery is becoming a more acceptable alternative for sludge treatment due to potential use for land application as biofertilizer and soil conditioner (Niwagaba *et al.*, 2009). Vermicomposting is an environment- friendly sound techniques of organic waste management by which earthworms carry out the composting process producing an economically high valuable end product named vermicast, generally called vermicompost (Simsek-Ersahin, 2011). It is an innovative technology for the treatment of wastes causing its biodegradation and stabilization to reduce the pathogenicity (Begum and Krishna, 2010).

Agricultural wastes such as sago waste has a potential to cause pollution either on land or in water. In order to reduce this problem, the effect of vermicompost in sago waste management was studied (Petrus *et al.*, 2009). In order to reduce this problem, a study was carried out to recycle tapioca solid

waste by using selected earthworms and microbes and also a combination of the two.

A review of literature relating to the present study is explored under the following headings

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2.1 POLLUTION CAUSED BY WASTE DISPOSAL

Solid waste is probably the most visible form of pollution. Every year, people dispose off billions of tonnes of solid garbage. Industrial wastes account for majority of the discarded material. Solid waste from homes and offices is called municipal solid waste. It includes paper, plastic, glass, metal cans, food scraps, and yard trimmings. Other wastes consist of junked automobiles, scrap metal, leftover materials from agricultural processes, hospitals, health care centres and mining wastes.

Disposal of these wastes damage the environment. Open dumps spoil the natural beauty of the land and provide a home for rats and other disease - carrying animals. Both open dumps and landfills may contain toxins that leak into ground water or flow into surface water bodies. The uncontrolled burning of solid waste creates smoke and ends in air pollution. Even burning waste in

incinerators can release toxic chemicals, ash, and harmful metals into the air (Eckelman and Chertow, 2009).

2.1.1 MUNICIPAL SOLID WASTES

Municipal solid waste is classified as hazardous waste because they contain large amounts of leachable heavy metals, soluble salts and trace organic pollutants (Reijnders, 2005). Soil acidification is one of the causes for rising land degradation caused by the dumping of municipal solid waste. The risk of acidification is currently being assessed as a part of agriculture productivity (Kwon *et al.*, 2009).

2.1.2 HOUSEHOLD WASTES

Household wastes comprise of kitchen waste, paper waste, grass clippings and composted materials (Nair and Okamitsu, 2010). Some of the environmental effects caused by the improper disposal of house hold wastes are pollution of surface and ground water, clogging of drains, open decomposition (rotting) that can lead to the development of unpleasant odour, breeding of vectors like flies and rats which increase the risk of diseases such as typhoid, malaria and yellow fever.

2.1.3 LIVE STOCK EXCRETA

In India, millions of tonnes of livestock excreta are produced. Air pollution studies have shown that livestock and poultry farms are responsible for the harmful gases in the environment. Cows, pigs and chicken feed produce 70 percent excretion of nitrogen -containing substances. Large number of livestock excreta causes rise in temperature, fermentation, decomposition of ammonia, emission of hydrogen sulphide and other odourous gases into the atmosphere. The production of methyl mercaptan, dimethyl disulphide, dimethyl sulphide, dimethylamine and a variety of lower fatty acids and other poisonous gases results in the decline of oxygen in the atmosphere (Amanullah *et al.*, 2010).

2.1.4 INDUSTRIAL WASTES

Disposal of wastes from the industries affects the nature of the environment. In the tanning process, large quantities of solid wastes are generated. These solid wastes consist of salt, waste hair, waste lime and waste flesh, buffing dust and trimming waste. Chrome wet shaving is carried out when skins are shaved for proper thickness. After chrome tanning, the main problem with these wastes is their high chromium content. The chrome tanned waste contains chromium in trivalent form but it was found that when the solid wastes are used in making poultry feed, the chromium is converted into a hexavalent form which is carcinogenic. The mixing of this metal in poultry feed could produce serious human health problems (Ozgunay *et al.*, 2007).

The olive mill waste consists mainly of water and the solid waste. It is the residue of olive stone and pulp milling. Production of olive oil generates around 75 percent solid waste from olive and about 30 million tonnes of waste water each year. This waste is polluted by fats and harmful substances, and poses an environmental challenge (Morillo *et al.*, 2009).

2.1.5 BIOMEDICAL WASTES

Biomedical waste is the infectious waste generated from hospitals. The waste generated in hospitals and health care centres consist of solid and liquid wastes which may be hazardous, infectious and non-infectious. It has been estimated that upto 85 to 90 percent of the waste generated in hospitals is non-infectious (free from microbes and has not been in contact with any body fluids and similar to domestic waste). About 10 to 20 percent of the waste is hazardous and infectious.

Hospital waste still finds its way to road side heaps where it mixes with municipal solid waste rendering it hazardous to the environment and the public. Even the animals are not spared. Stray cattle near dumpsters ingest polythene

packets and die from internal haemorrhage. Many of the stray animals are taken to the municipality animal house and they die due to intestinal obstructions and haemorrhages as revealed by postmortem reports. Toxic emissions like dioxin, furan gases, carbon and sulphur particles from defective or inefficient incineration of chlorinated plastics of medical waste cause modulation and disruption of growth factors, hormones, enzymes and developmental processes in the body.

Biomedical waste is not only hazardous and pollutes the environment but it is also dangerous to human beings, animals and plants in other ways also. Every day, the country's numerous hospitals and other medical institutions release millions of tonnes of waste into the environment. Hence, it is necessary to take precautionary measures, so that hazardous components in the waste are rendered harmless through proper treatment by technology and safe disposal methods (Hegde *et al.*, 2007).

2.2 TAPIOCA

Tapioca starch is a fine, white powder extracted from pulped Tapioca (*Manihot Esculenta Crantz*) roots. Its main use includes substitution for potato and corn starch.

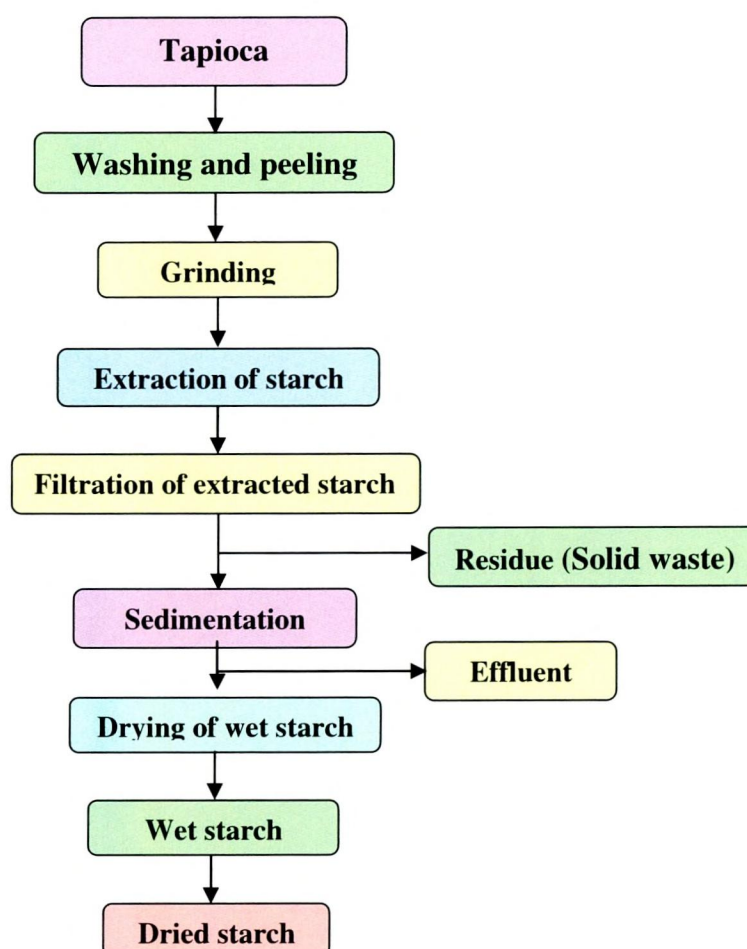
2.2.1 CHARACTERISTIC FEATURES OF TAPIOCA

Tapioca is essentially a flavourless starchy ingredient produced from treated and dried tapioca. It is similar to sago and is commonly used to make a milky pudding similar to rice pudding. Purchased tapioca comprises of many small white spheres each about 2 mm in diameter (although larger grain sizes are available). These are not seeds, but rather reconstituted processed roots. It is an important raw material used in manufacturing monosodium glutamate, fructose, glucose and dextrose (Aro, 2008).

2.2.2 PROCESSING OF TAPIOCA

The production of starch from tapioca root involves eight major stages. These are root washing, chopping, grinding, fibrous residue separation, dewatering, protein separation, dehydration, drying, and packaging. The growth of the tapioca starch industry has resulted in heavy water pollution as it generates large amounts of solid waste and waste water with high organic content (Chavalparit and Ongwandee, 2009). The flow diagram of starch production from tapioca or tapioca can be seen in the Figure 1

FIGURE 1
STARCH PRODUCTION FROM TAPIOCA



From this process, both liquid and solid wastes are generated.

2.2.3 TAPIOCA SOLID WASTE

In starch processing, the pulp waste (fibrous residues) is the main problem, especially for the big factories which produce them in massive quantities. Accumulation of this waste pollutes the environment as it is not easily dried, due to its high moisture and starch contents (Sriroth *et al.*, 2000). A small portion of this waste is used as animal fodder because of the high starch concentration. For a factory processing 400 tonnes of fresh tapioca roots releases around 80 tonnes of solid waste every day.

The generation of noxious odours during the drying and storing phases is related to the occurrence of fermentation in cases when the process is badly managed and exposed to rain, especially during the wet season. A portion of the solid waste is dumped and may become a local source of offensive odours and environmental pollution. Until now, the use of fibrous residues for recovering starch and for producing food has been investigated. An extraction of starch from the tapioca pulp by enzyme hydrolysis has been reported by Sriroth *et al.* (2000a). The human consumption of partially hydrolyzed tapioca solid waste presents digestive function problems. Hence, alternative steps should be taken in the tapioca solid waste management to reduce its pollution effects in the environment (Raupp *et al.*, 2004).

2.2.4 TAPIOCA WASTE WATER

The extraction of starch from tapioca tuber requires large quantities of water, resulting in the release of significant quantities of waste water. Moreover, the tapioca production plants discharge waste water of high biodegradable organic matter content, the average content of BOD being in the range of 13000 to 14000 mg per litre (Balagopalan, 2002). Hence waste water treatment should be done to remove substantial BOD concentration for discharging it into the water bodies.

2.3 VERMICOMPOSTING

Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. The process is faster than other methods of composting, because, the material passing through the earthworm gut undergoes a significant yet not completely understood transformation, whereby the resulting earthworm castings (worm manure) become rich in microorganisms and plant growth regulators. In short, an earthworm, through a type of biological process, is capable of transforming garbage into gold (Pattnaik and Reddy, 2010).

2.3.1 PRINCIPLE OF VERMICOMPOSTING

The earthworms consume large quantities of organic wastes rapidly and process them in their gizzards and finally excrete the material as vermicasts. The nutrients present in the vermicasts are readily soluble in water and are rich sources of macro and micro elements, vitamins, enzymes, antibiotics, growth hormones and immobilized microflora. For organic waste degradation, the earthworms act as aerators, grinders, crushers, chemical degraders and biological stimulators. They secrete enzymes like proteases, lipases, amylases, cellulases and chitinases which bring about rapid biochemical conversion of the cellulosic and proteinaceous materials in a variety of organic wastes (Sinha *et al.*, 2010).

2.3.2 METHODS OF VERMICOMPOSTING

Pit method

Vermicomposting in pits is carried out by digging a large hole in the earth in which earthworms and organic waste materials are buried. Before this, the pit is lined to prevent worms from escaping into the surrounding soil. Canvas material can be used to make a good lining, preventing worm passage yet still allowing suitable water drainage. The lined pit is filled with the organic material to be composted and then covered with soil. The pit is watered to maintain

moisture. The earthworms when added immediately burrow into the pit to compost the organic material (Nagavallemma *et al.*, 2006).

Heap method

During rainy seasons or in regions with heavy rainfall, composting can be done in heaps above the ground and protected by a shed. A small bund is sometimes built around the pile to protect it from wind, which tends to dry the heap. The heap is usually layered first with carbonaceous materials such as leaves, hay, straw, sawdust, wood chips and chopped corn stalks. It is then covered with nitrogenous materials such as fresh grass, weeds or garden plant residues, fresh or dry manure or digested waste. The bedding with carbonaceous material and nitrogenous material is repeated. The material is normally wetted until damp but not soggy. The pile is sometimes covered with soil or hay to retain heat. All these materials can be mixed together. Proper proportions can also be maintained. Shredding the material speeds up the decomposition process considerably. If sufficient nitrogenous material is not available, a green manure or leguminous plant is grown on the fermenting heap by sowing seeds after the first turning. The green matter is then turned in at the time of the second mixing (Saini *et al.*, 2008).

2.3.3 EARTHWORMS

Earthworms have been studied during the last few years due to their importance in areas such as biotechnology, ecotoxicology, morphology, ecology, taxonomy, soil physics and soil fertility (Amador and Gorres, 2007).

Earthworms have been classified under the Phylum: *Annelida*, Order: *Oligochaeta* and Class: *Clitella*. The order *Oligochaeta* consists of 12 families: *Moniligastridae*, *egascoleidae*, *Ocnerodrilidae*, *Acanthodrilidae*, *Octochaetidae*, *Eudrilidae*, *lossoscolecidae*, *Sparganophilidae*, *Microchactidae*,

Hormogastridae, *Criodrilidae* and *Lumbricidae* (Edwards and Lofty, 1977). From an agricultural point of view, the most important family of earthworms is *Lumbricidae* that includes the genuses *Lumbricus*, *Aporrectodea*, *Allolophora*, *Dendrobaena*, *Eisenia*, *Helodrilus*, *Octalasion* and *Eophila* (Edward, 2004). The family *glossoscolecidae* includes two genuses, *Periscolex* and *Pontoscolex*, which are of agricultural importance in tropical zones (Garcia and Fragoso, 2003).

2.3.3.1 Types of earthworms

From an ecological point of view, earthworms can be classified into three categories:

- (1) ***Epigeic*** (Greek word meaning ‘upon the earth’) which live within the soil and interact with edaphic microbiota and modify soil profile with their underground galleries and excrements.
- (2) ***Endogeic*** (Greek word meaning ‘within the earth’) which transform dead fallen leaves and is soil consumers. They are subdivided into *Poli*, *Meso* and *Oligohumics*, with reduced interaction with microbiota.
- (3) ***Anecic*** (Greek word meaning ‘up from the earth’, ‘out of the earth’) consumes mainly leaf litter (Curry and Schmidt, 2007)

Earthworms affect processes within the soil in a direct manner like incorporation and redistribution of several organic and inorganic materials, aeration, moisture distribution, infiltration or in an indirect manner such as formation of microbial communities, transportation of propagules and inhibition of pathogens (Byzov *et al.*, 2007).

2.3.3.2 Biology of earthworms

An earthworm is a long, narrow, cylindrical, bilaterally symmetrical, segmented animal without bones. The body is generally dark brown, glistening and covered with a delicate cuticle. It weighs about 700–1400 mg after 10 weeks and has a muscular gizzard which finely grinds the food fresh and also the decaying plant debris, living or dead larvae, small animals, bacteria and protozoa mixed with earth to a size of 2–4 microns.

The gut of the earthworm is inhabited by millions of decomposer microorganisms. They are bisexual in nature and cross-fertilization occurs as a rule. Earthworms continue to grow throughout their lives and the numbers of segments continuously proliferate from a ‘growing zone’ just in front of the anus. Earthworms contain 70–80 percent high quality lysine rich protein on a dry weight basis. They can be used as animal feed. Usually the life span of an earthworm is about 3 to 7 years depending upon the type of species and the ecological situation. Instead of teeth, earthworms have a gizzard like a chicken that grinds the soil and organic matter that they consume. Their main purpose is to eat the soil microorganisms that live in and on the soil and organic matter.

The earthworm excrement is commonly called worm casts or castings. These soil clusters are glued together when excreted by the earthworm and are quite resistant to erosive forces. Their castings contain many more microorganisms than the food sources because their intestines enrich the casts with microorganisms (Sinha *et al.*, 2002).

2.3.3.3 Reproduction of earthworms

Although earthworms have both female and male sex organs, they still need to mate in order to reproduce. They cannot fertilize themselves. Unlike the human race, earthworms go about finding a mate randomly. They sort of just

stumble into their mate, relying on their extreme sensitivity. Worms cannot see or hear, but can detect ground vibrations. They actually feel the ground vibrate or the grass move when another worm is moving through it. When the worm knows a potential mate is nearby, it will start searching in that area with the tip of its body until it runs into the other worm. Then they slide up next to each other and roll over on their sides one facing left and the other right.

Each earthworm has four pairs of setae. These are like bristles on a hairbrush and can be extended out or retracted into the earthworm body. The third set of setae is used in the mating process. They are used to hold the earthworms together while mating. Once they are in position, sperms from each worm passes to the other and is collected and stored in special sacs. The process lasts 2 to 3 hours.

In the second part of the reproductive process, a special slimy substance is produced by the clitellum. Fertilization takes place outside the body, but within the protection of the slime tube. Once free in the soil, the slime tube dries, shrinks and forms a protective covering over the eggs. It is now called a cocoon. Eggs will remain in the cocoon almost forever. They will only hatch if the conditions are right for their survival. The bacteria itself decays the outer part of the cocoon allowing it to release the worms (Plisko, 2010).

2.3.3.4 Benefits of earthworms and earthworm compost

2.3.3.4.1 Physical effects of earthworms on soil

Vermicompost has a fine particulate structure, good moisture - holding capacity and contains nutrients such as nitrogen, potassium, and calcium in forms that are readily taken up by plants (Arancon *et al.*, 2005b). By their burrowing activities, earthworms create a gallery of channels in the soil, even in harpan and compacted soil. This in turn leads to good aeration of the soil and consequently, good root respiration and ultimately good crop performance. Good water

absorption resulting from earthworm activities results in less water runoff that could leach nutrients or wash off top soil. With the facilitating effect of earthworm - burrowing activities, roots can grow much faster as much as seven inches per day.

The polysaccharide produced by earthworms binds sandy soil into good aggregates that resist rapid drainage. On the other hand, clayey soils are broken into adequate soil aggregates that improve their drainage and aeration. By a combination of these processes, earthworms improve the performance of various crops (Owa *et al.*, 2010). They also increase the quality, fertility and mineral content of the soil. They enhance soil aeration and texture and thereby reduce soil compaction. They build up the water retention capacity of soil, because of their high organic matter content and promotes better root growth and nutrient absorption (Nourbakhsh, 2007).

2.3.3.4.2 Enhancement of soil fertility

Vermiremediation leads to total improvement in the quality of soil and land where the earthworms inhabit and make them highly productive. Earthworms significantly contribute to soil conditioning to improve its physical, chemical as well as the biological properties and also its nutritive value. Earthworms swallow large amounts of soil every day, grind them in their gizzard and digest them in their intestines with the aid of enzymes. Only 5-10 percent of the digested and ingested material is absorbed into the body and the rest is excreted out in soil in the form of fine mucus - coated granular aggregates called vermicastings which are rich in nitrates, phosphates, potassium, micronutrients and beneficial soil microbes including nitrogen fixers and mycorrhizal fungi.

The considerable economic and environmental significance is the earthworm feed which is used in vermiremediation processes. Vermicomposting can be employed to reuse and recycle the vast amounts of organic wastes which

end up in landfills for disposal at high costs. It can also be said that vermicomposting not only cleans up polluted land but also improves its quality. The soil becomes lighter, porous and rich in biological activities. The productivity is increased to several times. During the vermiremediation process of soil, populations of earthworms increase significantly benefiting the soil in several ways. A ‘wasteland’ gets transformed into a ‘wonderland’ by vermicomposting. Earthworms are in fact regarded as biological indicators of good fertile soil and land.

Studies indicate that earthworms like *Eisenia fetida* can tolerate soils nearly half as salty as seawater. Application of live earthworms to sugarcane crops grown on saline soils irrigated with saline ground water gives a yield of 125 tonnes of sugarcane per hectare with marked improvement in soil chemistry (Sinha *et al.*, 2010a).

Due to its non - toxic nature, it is ecofriendly and has beneficial effects on the biochemical activities of the soil (Alam *et al.*, 2007). Application of vermicompost decreases soil bulk density and increases the water holding capacity. This is however significant and proportional to the rate of compost application (Civeira, 2010).

There is a close relationship between the nutrient status of soil and organic matter content. The addition of farmyard manure raises soil fertility and yields to levels greater than those under synthetic fertilizer treatments (Chong, 2005). Incorporation of vermicompost into growing media has shown to significantly improve plant growth, since it constitutes a slow-release source of nutrients (Hidalgo *et al.*, 2006). The process of vermicomposting tends to result in higher levels of plant availability of most of the nutrients than does the conventional composting process. (Sallaku *et al.*, 2009).

2.3.3.4.3 Effect of vermicompost on plant growth

Plant responses to vermicompost application may be due to the production of plant growth regulators such as indole acetic acid, kinetin or gibberellins associated with humic and fulvic acids which also act as plant growth regulators. The plant hormones which are produced become adsorbed on to the humates and fulvates and are released slowly into soils to promote plant growth over the whole growing season or even during several growing seasons (Arancon *et al.*, 2005a).

Earthworm castings contain abundant essential elements that plants need for healthy growth. Analysis of earthworm castings reveal that they are richer in nutrients than the surrounding soils, contain high concentrations of organic material, silt and clay often having three times more calcium and several times more nitrogen, phosphorus and potassium (Kalantari *et al.*, 2010).

2.3.3.4.4 Inhibitory effects of vermicompost on plant pathogens

Benefits of compost application in agriculture mainly results from its property of inhibiting root pathogens and soil-borne plant diseases (Perner *et al.*, 2006). Vermicompost is rich in growth hormones and vitamins and thus acts as a powerful biocide against pathogens (Kalantari *et al.*, 2010). The application of aqueous compost extracts has been shown to reduce diseases by necrotrophs as well as biotrophs (Al-Dahmani *et al.*, 2003). The aqueous extracts of vermicompost are also shown to depress soil - borne pathogens and pests (Rodriguez *et al.*, 2000).

Vermicomposts have been shown to suppress attacks by soil and foliar transmitted plant diseases, such as *Pythium*, *Rhizoctonia*, *Plectosporium* and *Verticillium*, significantly in both the field and greenhouse. Vermicomposts can also suppress arthropod pests such as caterpillars, including cabbage white caterpillars, tomato hornworms, and cucumber beetles as well as sucking

arthropods such as scale insects, mealy bugs, aphids and spider mites (Arancon *et al.*, 2005b).

Earthworms are both plant growth promoters and protectors. There has been considerable evidence in recent years regarding the ability of earthworms and their vermicomposts to protect plants against various pests and diseases by suppressing or repelling them, inducing biological resistance to fight them or by killing them through in-built pesticidal action (Edwards *et al.*, 2007).

2.3.3.4.5 Destructive effects on environmental pathogens

In the intestines of earthworms, some bacteria and fungus (*Pencillium* and *Aspergillus*) have also been found (Singleton *et al.*, 2003).

The earthworms produce antibiotics and kill the pathogenic organisms in the waste and soil where they inhabit and render it virtually sterile. It was reported that the removal of pathogens like *faecal coliforms*, *Salmonella species*, enteric viruses and helminth ova from sewage and sludge appears to be much more rapid when they are processed by *Eisenia fetida* (Bajsa *et al.*, 2003). Other studies also confirmed significant human pathogen reduction in biosolids vermicomposted by earthworms. Pathogens like enteric viruses, parasitic eggs and *escherichia coli* are known to be reduced to safe levels in sludge vermicasts (Eastman *et al.*, 2001).

2.3.3.4.6 Earthworms in environmental monitoring

Earthworms have been found to bioaccumulate heavy metals, pesticides and lipophilic organic micropollutants like the polycyclic aromatic hydrocarbons (PAH) from the soil. *Eisenia fetida* can be used as test organisms for different soil contaminants and several reports indicate that *Eisenia fetida* can tolerate 1.5 percent crude oil containing several toxic organic pollutants (Coker, 2006). Earthworms can degrade fly-ash from coal power plants which is considered to

be a hazardous waste and poses serious disposal problems due to the heavy metal content. Earthworms ingest heavy metals from fly-ash while converting them into vermicompost. They can even degrade human excreta into a odourless porous product with good texture and safe pathogen quality (Bajsa *et al.*, 2004).

2.3.3.4.7 Role of earthworms in human health

Lumbrokinase is a group of six proteolytic enzymes. Recent studies suggest that it may be effective in the treatment and prevention of ischemic heart diseases as well as myocardial infarction, thrombosis of central vein of retina, embolism of peripheral veins and pulmonary embolism. It is now being used in the treatment of cerebral infarction also. Researchers showed that cancer cannot be induced in earthworms inferring that there are some bioactive compounds and genetic defense mechanisms in the earthworms that protect them from the disease. Lumbrokinase also promises to wage war against cancer (Hwang *et al.*, 2002).

2.3.3.4.8 Earthworms as protein feed

Earthworms are rich in high quality protein (65%) with all essential amino acids. There is 70-80% high quality lysine, methionine, glutamic acid and leucine, lysine and arginine levels are higher than those in fish meals. Earthworms are also rich in vitamins A and B. There is 0.25 mg of vitamin B₁ and 2.3 mg of vitamin B₂ per 100 gm of earthworms. Vitamin D accounts for 0.04-0.073 percent of earthworms wet weight. Thus, earthworms are wonderful probiotic feed for fish, cattle and poultry. As earthworm protein is complete with essential amino acids especially with the tasty glutamic acid, it is ideal for human consumption (Sinha *et al.*, 2010).

2.3.3.5 Enzymes in earthworm gut

Earthworm gizzards have an in-house supply of various enzymes which act upon the complex biomelecules and thereby metabolise the phosphate and

nitrogen present in the organic waste. The activity of amylase, cellulase, xylanase, cellobioase endoglucanase, acid phosphatase, alkaline phosphatase and nitrate reductase action can be observed in the gut of the earthworms. The activity of earthworms is regionally specialized and influenced by physiological state. The enzymes in association with the gut flora break down the food containing plant matter and decompose the remains of small animals. The digestion of complex organic molecules and humification of soil organic matter is carried out through a mutualism between earthworm microflora and digestion system (Praba *et al.*, 2007a).

2.3.3.6 Organic wastes degraded by earthworms

Earthworms feed on nitrogen - rich organic wastes. They feed easily on partially degraded materials like cattle dung, primarily acted upon by microbes.

The following categories of wastes are very effectively degraded and managed by earthworms. Kitchen wastes like vegetable and fruit waste, both raw and cooked rice and pulses, remains of bread and chapattis, raw and cooked meat, crushed bones, egg shells tea and coffee rejects. Garden wastes such as fresh and dead leaves, weeds and grasses and flower petals, farm wastes like crop residues, rice and wheat straw, bran and husks rejected fruits, seeds, sugarcane trash, banana stems, coir wastes and weeds can also be used. Dairy farm wastes like cattle dung (fresh dung should be avoided as it releases methane which may be injurious to earthworms). About a week old dung is a very suitable feed. Sugar mill residues such as pressed mud-cake, spoiled bagasse and trash, slaughter house wastes such as residues like flesh, feathers, bones and blood are other sources. Distillery and hatchery wastes, municipal wastes which include all organic residues such as garbage and sewage sludge. Earthworms are particularly effective in sewage sludge management. In sludge, they increase oxygen consumption, decrease anaerobic decomposition and increase mineralization (Sinha *et al.*, 2002).

2.3.4 MICROORGANISMS

Microorganisms are very tiny one-celled organisms, viruses, fungi, and bacteria, which are found everywhere in the world. They are found in all living things, plants and animals. They can live in the air, on land, and in fresh or salt water environments. Some of them cause harmful diseases, but some microorganisms are needed for the survival of living things. Microorganisms are also responsible for building fertile soil for plants to grow by sticking to the roots of plants and decomposing dead organic matter into food for the plant to absorb (DeLong and Pace, 2001).

2.3.4.1 Types of microorganisms

The composting process is dependent on microorganisms to break down organic matter into compost. There are many types of microorganisms found in active compost of which the most common are: bacteria - the most numerous of all the microorganisms found in compost, actinomycetes - important for breaking down paper product like newspaper and bark, fungi - molds and yeast which help break down materials that bacteria cannot, especially lignin in woody materials, protozoa - consume bacteria, fungi and microorganic particulates and rotifers - help to control populations of bacteria and small protozoans (Smith, 2006).

2.3.4.2 *Trichoderma viridae* and *Bacillus polymyxa*

Trichoderma viridae is a fungus and a bio-fungicide. It is used for seed and soil treatment for suppression of various diseases caused by fungal pathogens. It is also a pathogen in its own right, causing green mould rot of onion.

Composting of municipal solid waste by efficient decomposing microorganisms is carried out by introducing *Trichoderma viridae* (Gautam *et al.*, 2010). To avoid phosphorus deficiency, phosphate-solubilizing microorganisms like *Bacillus polymyxa* play an important role in supplying

phosphate to plants in a more environment-friendly and sustainable manner (khan *et al.*, 2007).

2.3.4.3 Microorganisms in vermicomposting

Biofertilizers are used as inoculums for seed treatment of several plants. Both bacterial *Azospirillum* (nitrogen fixing bacteria) and *Bacillus polymyxa* (phosphate dissolving bacteria) inoculants and their mixtures can increase growth parameters, nutrient content and yield when compared to the control with full dose of nitrate phosphate and potash chemical fertilizer (Mostafa and Abo-baker, 2010). Apart from setting the optimum operational conditions for the vermicomposting process, other approaches such as pre-composting, inoculating microorganisms into municipal solid waste and redesigning the conventional vermireactor could be introduced to further enhance the vermicomposting of municipal solid waste (Sim and Wu, 2010). Inoculation of microbial strains alongwith the earthworm promotes enzyme action and humic acid levels in the substrate during composting (Pramanik *et al.*, 2009).

2.3.4.4 Interaction of earthworms with microorganisms

Vermicomposts can be produced through interactions between earthworms and microorganisms in a mesophilic process (upto 35°C). It forms a fully stabilized material with low carbon to nitrogen ratios. They have high and diverse enzymatic and microbial activities and nutrient contents (Arancon *et al.*, 2005a). The intestines of earthworms are known to lodge different microorganisms and enzymes, which get mixed with the digested food and help the essential minerals to decompose rapidly to form vermicompost (Kaushik and Garg, 2003).

Vermicompost is an excellent base for the establishment of beneficial non-symbiotic and symbiotic microbes. Application of vermicompost increases the total microbial population of nitrogen fixing bacteriae and actinomycetes. The increased microbial activity improves the availability of soil phosphorus and

nitrogen (Reddy and Ohkura, 2004). It is known to be a product rich in microorganisms that help the plants to mobilize and acquire nutrients (Postma *et al.*, 2003).

The earthworms increase nitrogen fixation by both nodular and free living nitrogen fixing bacteria and thus enhance plant growth. Vermicompost has been proved to be the cheapest source of nitrogen and other essential elements for better nodulation and yield particularly in legumes. Such plants can meet their nitrogen needs through both biological nitrogen fixation (symbiosis) and native nitrogen in the soil (Parthasarathi and Ranganathan, 2002).

2.3.5 Cow dung

Increasing cattle production not only increases meat production but also increases faecal production. Various kinds of pathogenic bacteria derived from the intestinal tract of animals exist in compost materials like cow dung. In order to sterilize the pathogenic bacteria completely in compost material, the cow dung can be put into a heat treatment. Pathogenic indicator bacteria such as coliform bacteria, fecal coliform, *Escherichia coli* and *Salmonella* may die rapidly when cow dung temperature rose to above 50⁰ C. During heat treatment, the mesophiles decreased rapidly and the thermophiles stabilized or increased, and most of the composting microbes in cow dung were *bacillus*. It indicated that *bacillus* was the dominator microbe in composting process (Gong, 2007).

The lower C:N ratio in cow dung manure (high nitrogen content) is an indication of a good source of protein for the microbes involved in the decomposition of organic materials. The cow dung facilitates early maturity of the compost and also contributes to its nutritional content (Adegunloye *et al.*, 2007). In order to avoid the negative environmental impact, cattle dung can be converted into valuable organic fertilizer by vermicomposting.

With this background information, the present study was undertaken to study the efficacy of composting by using earthworms, microbes and a combination of both as a means of depolluting the non - toxic tapioca solid waste.

The layout of the study and the methodology employed are described in the following chapter.