SUMMARY AND CONCLUSIONS
Waste generation increases with population explosion and economic development. Improperly managed solid waste poses a risk to human health and the environment. Beside wastes, large amount of toxic substances have been introduced into the environment through human activity. These substances range in degree of toxicity and danger to environment and human health. Uncontrolled dumping and improper handling of these substances and other wastes cause a variety of problems. Improper waste management also increases greenhouse gas (GHG) emissions, which contribute to climate change. Planning for and implementing a comprehensive program for waste collection, transport, processing / treatment and disposal can minimise these problems. Processing (or) treatment of solid waste is an important step in the solid waste management programme as this step is aimed at reducing the quantity of solid waste output and to recover material or energy while processing the waste.

Number of techniques are being adopted for solid waste processing. Among these, composting and vermicomposting have been globally accepted as effective method for bioconversion of organic wastes. Earthworms, by their peculiar food, feeding and
burrowing habits are considered as the most efficient converters of wastes. Being an agricultural country, India produces huge quantities of solid wastes, which can be converted into vermicompost, a nutrient rich manure and soil conditioner.

The current agricultural practices involve extensive use of synthetic fertilizers and pesticides. Persistence of these pesticides and their residues in the soil and water affects the environment in general and the agroecosystem in particular is a serious concern. Attempts focusing on the use of biological pesticides, fertilizers and biocontrol agents are also receiving worldwide attention. The soil pollution due to the heavy metals, toxic chemicals, petroleum, diesel and crude oil is also of great concern. Bioremediation of such polluted soil is an emerging area of research. In the present work the role of earthworms in bioremediation of contaminated soils, and as a biological control agents are being explored besides using them as bioconverters of solid wastes.

The present study involves the application of vermitechnology in solving the problems of weed menace, solid waste management, control of plant parasitic nematodes and bioremediation of oil contaminated soil. The entire work done with the specific objectives are presented as five parts in the thesis viz: Part I: General introduction, Part II: Vermicomposting of different phytomass including rubber leaf litter and ayurvedic pharmaceutical waste into vermicompost, Part III: Control of plant parasitic nematodes using vermicompost and Part IV: Bioremediation of oil contaminated soil using vermitechnology and Part V: Summary and conclusion.

Part I-General introduction

A general introduction on municipal solid waste and its management aspects are presented in this part.

Part II-Waste management with earthworms

In Part II of the study, an attempt has been made to explore the possibility of using earthworms for converting different substrates such as leaf litters, aquatic invasive weeds and solid waste emerging from ayurvedic pharmaceutical industries into vermicompost. Three epigeic earthworms- well established as efficient bioconvertors, *E. fetida*, *E. eugeniae*, and *P. excavatus*, were used in this study. In order to enhance the process of vermiconversion the substrates were subjected to aerobic composting for 30
days and the resulting precomposted substrates were subjected to vermicomposting. The experiment was conducted in specially designed vermireactors, which were inoculated with chosen species of earthworms. The study was conducted for a period of three to ten months during which vermicompost output, biomass increase and increase in worm number for all the three species were recorded. The results proved that vermitechnology could be an effective method for management of solid wastes such as leaf litters, troublesome aquatic weeds and solid waste emerging from ayurvedic industry.

Part III- Studies on plant parasitic nematodes

Part III of the thesis deals with the biocontrol of plant parasitic nematode population. Root-Knot Nematodes of species *Meloidogyne incognita* is one of the most destructive of all pathogens of agricultural crops all over the world. In this part, an attempt has been made to find out the comparative efficacy of various vermicompost and vermitea in preventing infection by root knot nematodes on vegetable crops. Three fast growing vegetable crop plants *Capsicum annum* (chilli), *Lycopersicon esculantus* (tomato) and *Hibiscus esculenta* (okra) were used in these vermicomposting experiments. The experiments were carried out in denematised soils in pots. Vermicomposts obtained by using *Azadirachta indica* A. Juss (Neem leaf litter), *Cymbopogon flexuosus* (Lemon grass) and Cow dung were used in this study. This experiments have shown that among the three vermicomposts, neem and lemongrass vermicomposts have been noted to be more effective leading to less number of root galls, egg masses, soil nematodes. This study also analysed the impact of vermitea produced from three different vermicomposts in suppressing the root-knot nematode population in vegetable crops such as Chilli and Brinjal by assessing their effect on root knots formation and egg mass formation by the parasite. The result of vermitea experiment indicates that neem and lemon grass vermitea have more nematicidal activity.

Part IV Bioremediation of contaminated soil

Part IV of the thesis report the use of earthworms and associated microorganisms together in remediating petroleum contaminated soil. The bioremediation experiments were conducted in two phases. In the first phase, petroleum contaminated soil was subjected to aerobic composting with different amendments such as cow dung,
cowdung along with vermitea etc with and without the addition of microbial inoculum. The products of the precompost were subsequently subjected to vermicomposting in the second phase using two different earthworm species, *Eisenia fetida* and *Eudrilus eugeniae*. The precompost obtained were used as bedding material for earthworms in vermireactors. The vermireactors were operated with and without additional feed of cowdung. After 30 days of vermicomposting, the percentage removal of Total petroleum hydrocarbon (TPH) in the soil samples were analysed by Soxhlet extraction followed by concentration measurement using UV spectrophotometer. The loss of TPH due to mere evaporation from the reactors operated without any amendment and without precomposting and without earthworms was also assessed. Worm biomass, mortality, survival and young ones produced during the vermicomposting of precomposted soils were recorded. Apart from using earthworms, an attempt has also been made to study the impact of different proportion of amendment such as cowdung, vermicomposts and vermitea (an extract of vermicompost using water) on the remediation of petroleum contaminated soil.

The results indicate that, reduction in total petroleum hydrocarbon (TPH) concentration was noticed in all earthworm treated reactors. Addition of additives such as cow dung and cow dung along with vermitea has resulted in better removal of total petroleum hydrocarbon from the contaminated soil during the initial period of precomposting itself. The contaminated soil precomposted with enrichment culture (microbial inoculum) irrespective of the amendments when fed in the vermireactors has shown a better removal of TPH than the precomposted soil without the inoculum (Enrichment culture). Maximum removal of TPH was obtained with 60 day precomposted samples in all three combinations such as contaminated soil, contaminated soil with cow dung amendments and vermitea addition. Also contaminated soil when amended with different additives such as cow dung, vermicompost and vermitea showed increased percentage removal than contaminated soil alone. The combination of microbes and earthworms resulted in a better- rather faster removal of TPH than the experiments reported in the literature in which remediation was done with microbes alone. Cowdung (CD) supplements either at precomposting or at vermicomposting stage increases the TPH removal rate, i.e. Addition of CD facilitates faster removal of TPH. The CD supplement also enhances the number of juveniles production as well reduces mortality.
In summary the potentials of earthworms as a good converter of degradable organic wastes, phytomass into manure has been exhibited in this study. Besides this, the role of earthworms and their casts in reducing the plant parasitic nematodes and removing the TPH content of the oil-contaminated soil has also been shown clearly.

Conclusions

Following significant conclusions are drawn from this study:

1. Different leaf litters used in this study as feed for earthworms could be successfully bio processed into nutrient rich vermicast by all the three earthworm species used in this study. Vermitechnology can be used as an effective tool for the management of aquatic weeds whereby the high productivity of this phytomass can be utilized and converted into valuable biomanure.

2. A kind of pretreatment step – washing, precomposting etc – is necessary whenever a substrate with metal / salt content need to be subjected Vermicomposting. All the three species of earthworm could successfully bioconvert Ayurvedic pharmaceutical waste (APW) into vermicompost.

3. Neem and Lemongrass derived vermicompost amendment could reduce the root gall formation by *Meloidogyne incognita* in three plants studied.

4. Neem and lemongrass derived vermitea was also very effective in the management/control of *Meloidogyne incognita* in vegetable crops.

5. Bioremediation using vermitechnology, when properly managed, is an environmentally sound and cost-effective method of treating soil contaminated with petroleum hydrocarbons. Presences of earthworm have increased the rate of bioremediation of the oil contaminated soil in terms of removal of total petroleum hydrocarbon (TPH). The combination of microbes and earthworms resulted in a better- rather faster removal of TPH than the experiments reported in the literature in which remediation was done conducted with microbes alone.
6. In polyculture and monoculture reactors tested, the polyculture vermi reactors were found to be more efficient in terms of removal of TPH as the microbial activities are better in the polyculture reactors than monoculture vermi reactors.

7. Vermicompost, cowdung and vermitea amendment with contaminated soil also resulted in better removal of TPH from contaminated soil. The addition enhances microbial degradation and can also be used as an efficient tool for bioremediation of contaminated soil.