CHAPTER 2

Literature Review
A review of the previous literature reveals that, a great attention has been paid towards physico-chemical, biological characteristics and heavy metals concentrations of municipal solid waste compost and its quality testing in various countries. A number of researchers have worked on Municipal Solid Waste (MSW).

2.1. Municipal Solid Waste (MSW):

**Chandni Kirpalani et.al., in 2005**, reported to the management of municipal solid waste in Jaipur city (Rajasthan State). They observed that, total quantity of solid waste generated in the city was around 1070 TPD (Tons Per Day) with a per capita generation rate of 0.45 kg and they said that, sanitary landfill and composting methods were suitable for Municipal Solid Waste Management (MSWM).

**Seema Jilani in 2007**, carried out the research, to assess the feasibility of composting of source separated organic matter of municipal solid waste generated at low, middle and high -income areas of Karachi city and the results revealed that, high percentage of biodegradable organic waste contained 40 to 50% of moisture content and 38 to 40% C/N ratio.

**Utpal Goswami and Sharma in 2008**, worked on the study of the generation of municipal solid wastes in Guwahati city (Assam State). The study revealed that, comparatively high percentage of organic content was present in the MSW collected from the market, temple area, hotels and restaurants. These organic wastes are subjected to aerobic composting process and produced good quality of compost. At the same time, as, MSW collected from the bus stand, railway station, school and college, recreational park which had high paper and plastic content, can be recycled and reprocessed to make it reusable.

**Yadav and Devi, in 2009**, worked on Municipal Solid Waste Management in Mysore city and observed that, the system of Municipal Solid Waste Management in Mysore city was not satisfied

**Sunil Namdeo Thitame *et al.*, in 2009,** worked on the characteristics and composition of municipal solid waste generated in Sangamner city (Maharasata State). The results revealed that, composition of solid waste had 61% of organic wastes and the remaining inorganic wastes. Further, they concluded that, it was a good source of nutrients for the agriculture application, where as, inorganic materials could be used for landfill.

**Vijay Durga Prasad in 2009,** focused the research on, the disposal and treatement of solid waste adopted by the Vijayawada Municipal Corporation (VMC) in Vijayawada city (Andhra Pradesh). Various solid waste management methods were like, Composting, Vermicomposting, Incineration, Pellatisation and Pyrolysis, were used.

**2.2. Physico-chemical and biological characteristics of Municipal Solid Waste:**

**Steven *et al.*, in 1979,** worked on the variability of temperature, pH, and moisture in an aerobic composting process. The results reveals that, the temperature and pH varied greatly from one sample site to another in each cell, whereas moisture content was less varied. A significant rise in both temperature and pH were observed at two stages of degradation.

**Rodolfo Canet and Fernando Pomares in 1995,** carried out research on changes in physico-chemical characteristics during the composting process of municipal solid wastes in two plants in Valencia city. The results revealed that, the excessive large size and height of the piles of the Fervasa plant did allow adequate oxygenation of the inner materials, gave rise to a very long process and acid compost and in Compania General de Tratamiento de Residuos (C.C.T.R) plant had a very small heap and decomposition progresses was very rapid. The
characteristics of both composts were fairly standard and similar. However, the product of Fervasa showed high moisture, slightly low pH and high content of calcium and iron, whereas the C.G.T.R plant showed high contents of organic matter and nitrogen and low levels of micronutrients.

Deportes et al., in 1998, conducted research on the Microbial disinfection capacity of Municipal solid waste, during spring and summer seasons. They observed that, the fecal coliform numbers were higher in spring compared to summer season.

Abdennaceur Hassen et al., in 2001, investigated the prevailing physico-chemical conditions and microbial community (mesophilic bacteria, yeasts and filamentous fungi bacterial spores, Salmonella and Shigella as fecal indicator bacteria: total coliforms, fecal coliforms and fecal Streptococci present in a compost of municipal solid waste. The results revealed that: (i) high temperatures significantly alter the bacterial communities. For instance, Escherichia coli, fecal Streptococci, Yeast, filamentous fungi and mesophilic bacteria were reduced by Waste Dry Weight (WDW). On the other hand, the number of bacterial spores increased at the beginning of the composting process, but after the third week their number decreased notably: (ii) Salmonella disappeared completely from compost by the 25th day, as soon as the temperature reached 60°C and (iii) the bacterial population increased gradually during the cooling phase.

Chaudhuri et al., 2000, reported on physico-chemical changes of composted kitchen waste with and without earthworms at different time intervals. The results revealed that, the earthworm compost method was found to be most beneficial and enriched with nutrients.

Jann M. Ichida et al., in 2001, carried out research on bacterial inoculum for enhancing keratin degradation and biofilm formation in
poultry feather waste and found that, application of inoculum could rapidly degrade the feather waste.

**Khalil et.al., in 2001,** worked on seasonal changes in microbial populations and their cellulolytic enzyme activities during the composting of municipal solid wastes at Damietta compost plant, Egypt. The changes in temperature, pH and C/N ratio were considered. The results obtained showed that, the temperatures of the windrows in all seasons reached a maximum, after 3 weeks of composting and then decreased by the end of the composting period (35 days), but did not reach ambient temperature. Remarkable changes in pH values of the composts in all the seasons were found, but generally, the pH was found near neutrality. The microbes and cellulolytic activities concerned with microbial population and activities of cellulose were also higher in the autumn and spring seasons, than in the summer and winter seasons. It was evident that, the degradation of organic matter increased the microflora and its celulolytic activities.

**Slomezynska et.al., in 2004,** worked on physico-chemical and toxicological characteristics of leachates from MSW landfills and reported that, parameters like BOD, COD and TOC of the leachates were found to be significantly high.

**Carboo and Fobil in 2005,** carried out research on physico-chemical analysis of municipal solid waste in the Accra Metropolis. They observed that, the MSW in the city had average moisture content of 60% by weight of fresh waste, calorific value ranging from 14 to 19.5 MJ/Kg and C/N ratios of the waste from 27:1 to 100:1. These physico-chemical characteristics were variable amongst the various waste components and the waste zones. The results concluded that, the MSW in the metropolis might be a good source for the composting program by incineration which might not be economically viable.
Sharma and Gupta in 2006, carried out research on physico-chemical characteristics of municipal solid waste generated in residential and commercial areas of the Bhopal city (Madhya Pradesh State). The results revealed that, average density, moisture content, C/N ratio, the organic matter of MSW were 329 kg/m$^3$, 42.19%, 25.62 and 38.64% respectively. The determination of energy content showed an average LCV as 633 Kcal/kg. Physical composition analysis was done and found that, MSW contained large quantity of inorganic matter as high as 61.36% (on dry weight basis), 56.125% materials was found suitable for composting (on a wet weight basis) which indicates that sanitary landfilling and composting may be the most suitable disposal methods.

Jeyapriya and Saseetharan in 2007, carried out the research, to study the municipal solid waste and leachate characteristics of Coimbatore city of Tamil Nadu. The results showed that, the biodegradable fractions of MSW was high with an average value of 68.94% and physico-chemical leachate characteristics showed varying concentrations for samples 1 to 2. pH of both the samples were near neutral and all other physico-chemical characteristics showed wide variations.

Mohammed Anis EI Hammadi et.al., in 2007, conducted the experiments to study the physico-chemical characteristics and toxicants in the composting site and the relationship between them. The results showed that, there was a clear positive relationship between organic matter and several characteristics such as C/N ratio and a clear negative correlation between organic matter and heavy metals.

Raut et.al., in 2008, studied the microbial dynamics and enzyme activities during rapid composting of municipal solid waste (MSW). Various treatments such as aeration (A), the addition of chemical agents [glucose (G) and acetic acid (AA)] and the application of
cellulolytic microbial (M) inoculum (*Phanerochaete chrysosporium* and *Trichoderma ressei*) were used to facilitate the decomposition of MSW. The results revealed that, changes in various physical, chemical and biological (microbial biomass and enzyme activities) characteristics and the degradation of organic substrates were quick (within 9 to 12 days) in case of rapid composting as indicated by the reduction in C/N ratio was below 20, whereas, normal composting took more than 20 days to attain C/N ratio below 20.

Rebollido *et al.*, in 2008, did the research on succession of microbial populations during the composting process of organic fraction of MSW and some physico-chemical characteristics were followed during the process. The moisture content was maintained at 50 to 60% and temperature monitored daily, in order to study the effects of important environmental factors on microbial communities. The results showed that, the substrate was colonized in major proportion by bacteria (44.6%), actinomycetes (32.3%) and in lower numbers of fungi (23.1%). The following dominant genera were present such as *Bacillus*, *Streptomyces*, *Actinomyces*, *Pseudomonas* and *Azospirillum*. After multiple regression analysis, results shown that, the environmental conditions have the major influence on microbial groups found.

Saidi *et al.*, in 2008, carried out research, to evaluate biochemical characteristics during composting of various composts. The obtained results indicated that, the biochemical properties vary widely in accordance with the type and range of biodegradable material characteristics.

Zaved *et al.*, in 2008, conducted research on the effective bacterium strains using solid waste degradation to produce good quality compost. Three different microorganism sample strains named as NAIUL, BCDump and BCSS (2) were isolated and grown on Czapek Dox Agar (CDA) media. In this study, changes in color, odor, weight loss, volume loss, temperature and pH scale of garbage were
considered to identify the foremost effective strain. The best decomposition activity in terms of weight and volume loss was shown by suspension of BCDump strain. They confirmed that, useful bacterium may be isolated from the encircling surrounding for friendly bioconversion of solid organic waste.

**Raut et.al., in 2008,** carried out research, on microbial and enzymatic activities during rapid composting of municipal solid waste using various treatments such as chemical agents and bio-inoculums. The results obtained showed that, degradation of organic materials was quick in case of rapid composting than normal composting. This was apparent through the studies on microbial dynamics and enzyme activities. On the other hand, different physico-chemical characteristics including C/N ratio could not provide a clear understanding about the degradation profiles of various organic substrates through microbial dynamics and enzymatic activities.

**Farrell and Jones in 2009,** conducted the experiments to study the critical evaluation of municipal solid waste composting and potential compost markets, the results revealed that, the best option for using the organic resource was in land remediation and restoration schemes.

**Gabriele Alfano et.al., in 2009,** carried out research on physico-chemical, microbiological, agrochemical and phytopathological aspects in the recycling of olive waste composted residues. The results confirmed that, olive waste composting was very much suitable for agriculture with no phytotoxicity, free of pathogens and the ability to improve soil fertility for plant production.

**Gautam et.al., in 2009,** worked on degradation and recycling of urban solid waste in Jabalpur city (Madhya Pradesh State). The results revealed that, 47% of degradable waste and 53% non-degradable solid waste were present in the urban solid waste. The
initial compositions of urban waste were indicating an organic carbon status of 38%. This paper concluded that, the recycling of solid urban waste can be transformed from municipal solid waste to enriched composts.

**Gautham and Bundela in 2010,** carried out research on feasibility of composting of source separated organic matter of municipal solid waste generated at low, middle and high income areas of Jabalpur city (Madhya Pradesh State). The results revealed that, the presence of a high percentage of biodegradable materials and physico-chemical characteristics from the point of view of organic matter, moisture content and the C/N ratio in the compost samples were found to be within the acceptable limits, set by international standards.

**Farhan Zamrer et.al., in 2010,** carried out research on dynamic activities for microbial characteristics during composting (1\textsuperscript{st}, 15\textsuperscript{th} and 60\textsuperscript{th} days) of herbal pharmaceutical industrial waste. The results obtained from this study showed that, the beneficial microbial load initially was less and very high at the last stages of decomposition and 60\textsuperscript{th} days old compost sample was free from phytotoxicity.

**Cecilia Sundberg et.al., in 2011,** worked on the characterisation of source separated household waste, intended for composting. The results revealed that, with low pH, high organic acid content and lactic acid bacteria with a wide variety of pathogens were found, which indicated the need for high temperature hygienisation during the process. For efficient composting, it was recommended that, food waste could be mixed with ample amounts of recycled bulk material and compost, provided that pH was well over 6. This helps to buffer the pH, as well as to increase the number of bacteria needed for a good composting process.

**Janakiram and Sridevi in 2011,** carried out research on physico-chemical characteristics analysis at different degradation stages (zero,
30th and 60th days) for aerobic composting of vegetable and fruit wastes which were being taken for investigation. The results confirm that, the physical and chemical characteristics an increase as days of composting increased, except for pH and C/N ratio.

**Jukka M. Kurola et.al. in 2011**, carried out research on wood ash for application in municipal bio-waste composting. The results revealed that, the addition of low doses (4 to 8%) of wood ash raised process pH and enhanced heat production and microbial activity in bio-waste degradation. Wood ash avoids the potential odor annoyance and minimizes the environmental risk for heavy metals contamination and meets the criteria for the limit values of the impurities in the ashes.

**Gautam in 2012**, conducted the research on the diversity of cellulolytic microbes and the biodegradation of municipal solid waste by potential strain. The obtained results confirmed that, 250 different microbes were identified, out of which 165 belonged to fungi and 85 bacteria. The *Trichoderma viride* was found to be a potential strain in the secondary screening and also resulted in the greater bioconversion of the original materials. pH and temperatures were found to be the most excellent indicators for the end of the bioconversion of municipal solid waste. Good quality compost was obtained in 60 days.

**Piyush Chandna et.al., in 2013**, studied the bacterial diversity during composting of agricultural waste. The predominant bacteria was characterized biochemically, followed by 16S rRNA gene sequencing. The isolated strains, both gram positive and gram negative groups and some new species of *Bacillus* were also identified from the compost sample.

**2.3. Heavy metals concentrations:**

**Olajire and Ayodele, in 1998**, carried out research on heavy metals analysis of municipal solid wastes. Waste samples were collected from
waste dumping sites at various locations (urban and suburban areas) of the western part of Nigeria. The physico-chemical characteristics like moisture content, dry weight, organic matter, pH, total nitrogen and total phosphorous and heavy metal concentrations (Nickel, Chromium, Cadmium, Lead, Sodium, Potassium, Iron, Copper, Manganese, Zinc, Cadmium Mercury and Arsenic) were analysed using Atomic Absorption Spectrophotometer. The obtained results confirm that, many metals, especially Cadmium, Copper, Lead and Zinc disperse into the environment in leachates from landfills, which pollute soils and ground water and in the fumes from incinerators.

Gillian M Greenway and Qi Jun Song, in 2002, worked on heavy metals speciation of the composting process. The results revealed that, in general, metals become less available for the first extraction step, as the composting process proceeds.

Parvaresh et.al., in 2004, carried out the research to determine C/N ratio and heavy metals in bulking agent cloud for sewage composting. The results showed that, concentrations of Chromium and Cadmium in the mixture of dewatered sewage sludge and bulking agents were lower than the standard level.

Hogarh et.al., in 2008, worked on the assessment of heavy metals contamination and the macro nutrient content of compost for environmental pollution control board in Ghana. It was observed that, the overall NPK concentration was low in different compost samples. While, total nitrogen and potassium contents were greater in agricultural waste composts compared to municipal solid waste composts. The heavy metals concentrations were found to vary with the seasons.

Utpal Goswami and Sarma, in 2008, carried out research, to assess the heavy metals concentrations in the biodegradable solid waste of Guwahati city. The heavy metals concentrations in the biodegradable
solid waste samples were found in negligible concentrations for Cadmium and maximum with Zinc.

**Antonis Zarpas et.al., in 2010,** carried out research on compost quality and application from the sewage sludge, which was organic fraction of municipal solid waste using natural Zeolite- Clinoptilolite. The obtained results confirmed 25% of clinoptilolite ability to bind 100% Cadmium, 27% Copper, 13% of Chromium, 20% of Iron, 37% of Nickel, 50% of Lead and 55% of Zinc, whereas Zeolite can retain the heavy metals and not let them pass on the ground water.

**Manju Rawat et.al., 2013,** carried out research work on heavy metals concentrations of municipal solid wastes in three highly populated cities of India, like, Delhi (Capital of India), Ahmedabad (Gujarat) and Bangalore (Karnataka). The results reveal that, for all the heavy metals concentrations within the prescribed limits of India standards. The MSW compost from Delhi was found with slightly high in metals concentrations then other cities. The results were concluded that, MSW compost samples can used for agricultural field as soil fortification.

**2.4. Compost Stability and Maturity:**

**Bernal et.al., in 1998** carried out research to assess the physico-chemical, stability and maturity tests of the organic waste mixtures at different composting periods. The values for mature compost depends on the wastes from which the composts were made.

**Sanchez-Monedro et.al., in 2002,** carried out research to assess the stability and maturity of compost using different maturity tests of compost like, Germination index, (based on percentage of seed germination), SOUR (specific oxygen uptake rate, respirometric method based on oxygen consumption by the microorganisms), Self heating test, (reflecting the energy output from the aerobic process); and Solvita (a commercial maturity test based on CO₂ and NH₃
The results revealed that, the temperature and volatile solids were found to reduce during maturity stage and the Germination Index Test (GIT), which confirms that phytotoxicity got reduced with maturity.

Dimitris et.al., in 2004, worked on emission of volatile organic compounds during composting of municipal solid wastes. The results revealed that, MSW composting can be a source of hazardous volatile organic compounds and various xenobiotic volatile organic compounds which were identified in the gaseous emissions of all principal organic MSW components and they suggested that, proper optimization of the composting process, in addition to gas treatment units, such as bio-filtration, can aid in the reduction of volatile organic carbon emissions and odors, commonly encountered in MSW composting facilities.

Steger et.al., in 2006, studied the physico-chemical characteristics of compost, maturity and Actinobacteria populations during full-scale composting of organic kitchen wastes. The Actinobacteria species identification with a PCR-denaturing gradient gel electrophoresis method and fatty acids with the phospholipid fatty acid and ester-linked methods were carried out. These results showed that, compost quality, particularly maturity, is linked to the composition of the microbial community structure. However, Actinobacteria populations were a potential indicator of compost maturity.

Kavitha and Subramanian, in 2006, conducted the research on application of municipal solid waste compost in paddy fields using different treatments and to study the plant nutrient uptake and yield of the rice in different compositions. The highest grain and straw yields were observed in the treatment combination of 25% enriched compost and 75% recommended dose of inorganic fertilizers with a value of 5.22 and 8.65 tons/hectare respectively. The lowest grain
yield was recorded in treatments where the 100 % compost was applied alone.

**Daniel Said-Pullicino et.al., in 2007,** carried out the assessment of the changes in the chemical characteristics of organic matter during composting and their influence on compost stability and maturity. Compost stability and maturity test method, such as respirometric and bioassays (Lepidium Sativum L. Seeds) method, together with an analysis of non-cellulosic polysaccharides, phenolic compounds and organic nitrogen within the water extracts were carried out. The results confirmed that, the influence of solubilisation, mineralization and organic matter transformation was noted in the quality of the final compost.

**María Gomez-Brandon et.al., in 2008,** carried out the research work to study the stability and maturity during the composting process of cattle manure and compost samples drawn after 15 days in the trenches and at different maturation phases (i.e. 80th, 180th and 270th days). The results obtained showed, 80th days old samples had a high content of ammonia, high level of phytotoxicity and the low degree of organic matter stability. However, 180th day compost sample was free from phytotoxicity and safe agriculture purpose.

**Mokhtari et.al., in 2011,** conducted the experiments to study the stability test of in-vessel composting of municipal solid waste. The results revealed that, the characteristics like temperature, nitrate-nitrogen ratio, dehydrogenase enzyme activity (DA), Specific Oxygen Uptake Rate (SOUR) got decreased during successive level composting process and pH were found to be acidic during the last stage. SOUR had shown the different stages of microbial decomposition and a numerical value for compost stability also, SOUR value less than 2 mg O₂/g can show the full stability of compost.
Amalia Carmen mitelut and Mona Elena popa, in 2011, carried out research work on seed germination bioassay (radish seeds) for toxicity test of six different biodegradable materials. The compost extract 25%, 50%, 75% and 100% were compared with control (100% distilled water) for each type of material. The results revealed that, all the 25, 50, 75 and 100% of compost samples showed photoxicity nature.

Kutsanedzie et.al., in 2012, worked on the assessment of physico-chemical, biological characteristics and germination index of composting in Horizontal-Vertical Aeration Technology (HV) and Force Aeration Technology (FA) systems at Volta River Estate Limited Farms (VREL). Results showed that, temperature and pH were not significantly different in both systems and at the same time, some members of the microbial community were identified, while, higher stable germination index was recorded early in the FA system and at the end of the week, both systems had a high germination index.

Ahsanur Rahman et.al., in 2012, studied the effects of bicompost, cow dung composts and NPK fertilizers on growth, yield and yield components of Chilli plants. The experiment was conducted randomized block design with three replications at the Botanical Garden of Rajshahi University Campus, Bangladesh during August 2008 to February 2009. The results showed that, inorganic fertilizers (NPK) with biocompost (3 kg/pot) was suitable for larger production of Chilli, which may increase soil fertility.

Monireh Majlessi et.al., in 2012, carried out the research work to assess the stability and maturity of the vermicomposting of cooking wastes. The chemical characteristics (EC, pH, carbon to nitrogen contents (C/N)) and germination bioassay (Cress seeds) were carriedout. The results revealed that, stability test alone, was not able to make sure high vermicompost quality. Therefore, the high vermicompost quality required a simultaneous use of maturity and stability tests.
Tanmoy Karak et. al., 2013, carried out research work on physico-chemical characteristics, heavy metals concentrations and germination index for six modes of composting mixtures and these samples were analysed according to the Indian composting standard protocol. The obtained results reveal that, all the prepared mixtures compost samples were found to be suitable in Indian standards. However, for M2 compost sample mixtures (cow dung / municipal solid waste / tea pruning litter / pond sediment / tea waste / water hyacinth, 1:1.5:1.5:2.5:2.5:1) mode was found to be better to others as it contains comparatively superior nutrient status.

Soughir et. al., 2013, carried out the research on effects of NaCl priming on the emergence and seedling growth of Tunisian fenugreek (Trigonella foenum-graecum L.) under different salinity conditions (0, 4, 6, 8 and 10 g/L). Seeds of fenugreek were primed with NaCl (4 g/L) for 36 h in continuous 25°C. Primed (P) and non-primed (NP) seeds were sown in plastic pots and placed in greenhouse for 4 months. The obtained results show that, roots length, plant height, leaf area and yields of plants was greater in primed seeds than non-prime seeds. These results confirms that, NaCl priming of fenugreek seeds increased salt tolerance of seedlings by reducing sodium and promoting potassium and calcium accumulation.

From the literature survey, it appears that, considerable work was carried out on solid waste management, the physico-chemical and biological characteristics, studies on maturity stages of compost and heavy metal concentrations were carried out in different parts of the country. However, in Mysore city, limited work was carried out on management aspects of solid waste and its quantity generated from various sources, but not much work was carried out on physico-chemical, biological characteristics during composting processes and lack of compost quality test using stability and maturity test. With this concept, the present work is undertaken.