In the recent times, the major environmental components like air, water, soil have been polluted due to a number of natural and human activities like dumping of municipal solid waste, discharge of wastewater into the water bodies etc. This careless practice of discarding Municipal Solid Waste without proper treatment, proper oversight and control causes severe problems like breeding of flies and could lead to infectious diseases in the community. It is estimated that 1.0 to 1.1 kilogram of solid waste gets generated daily per person in a well developed city (Karthikeyan et al., 2004).

These days the disposition of organic wastes from sources like households, farms and industries has led to a growing number of environmental and economic problems. The urban lifestyle produces organic waste materials in the form of domestic trash and food waste which is accumulating in a considerable amount around the cities. The current trend about waste management aims at recycling and the recovery of waste as new products and various other forms. Recycling of organic wastes is not only an ecological necessity but in a country like ours, it is an economical compulsion too.

Many different technologies have evolved to deal with the problem of organic waste disposal. Uncontrolled dumping is one of the most prevalent modes of waste disposal which is mainly responsible for polluting the water and soil. Landfilling is another such common method of waste disposal which is becoming increasingly expensive and unacceptable. The final disposal of solid waste can be performed by other methods such as incineration and composting other than dumping or sanitary land filling. Earthworms have been established as one of the chief agents to handle the biodegradable organic matter (Grieg-Smith et al., 1992). The use of waste materials through earthworms has given birth to the concept of vermicomposting. The vermitech approach makes use of earthworms for waste management (Satchell, 1967). The innovative practice of vermiculture biotechnology, the breeding and propagation of earthworms and the use of its castings has become an effective method of waste recycling the world over.
Vermicomposting, which takes forward the process of composting of organic wastes via earthworm action, has proven to be effective in treating sewage sludge, solids from wastewater (Neuhauser et al., 1988; Dominguez et al., 2000) wastes from breweries (Butt, 1993), paper mills (Butt, 1993; Elvira et al., 1995) urban residues, food and animal wastes (Edwards et al., 1985; Dominguez et al., 1997) as well as agricultural residues and dead plants (Edwards, 1988).

It is estimated that about 0.4 kilogram of waste is produced per person in India every day, out of which 50-60% is considered to be compostable (Aalok et al., 2008). In a temple nearly 900 kilograms of flower, leaves and coconut wastes are generated daily, and this quantity goes up to nearly 1200 kilograms per day during festivals (Singh et al., 2007). Devotees offer flowers and other Nirmalayas to Gods and Goddesses which are discarded as waste material in open spaces where its aerobic and anaerobic decomposition causes bad smell and pollution, creating an unhealthy atmosphere. Managing anaerobic composting of waste is a costly affair on the other hand aerobic composting takes longer time. Vermicomposting appears to be the most suitable and cheap biotechnological process where earthworms and microorganisms bring about degradation of waste material in 45-60 days, converting it into valuable and nutrient rich manure (Shouche et al., 2011).

The present study was conducted to manage and utilize the floral waste generated by temples of Jaipur city. The process of vermicomposting was carried out in different ratios of waste and cowdung like 50:50, 60:40, 70:30, 80:20 and 90:10 for 50 days. Earthworm species Eisenia fetida was used because of its adaptability to varied conditions. As mentioned earlier ten temples of Jaipur city were selected on the basis of their popularity and number of visitors. Regular visit to the temples was made during normal days and also on special occasions like Shrawan maas, Navratri, Janmashtami, Shivratri, Ganesh Chaturthi, etc. A Questionnaire was designed (Annexure 1) in Hindi to interview the temple authorities and Mahantas regarding the visitors, the quantity of the waste generated daily/during festive season and the method of disposal used in these temples.
Through the preliminary survey it was found that the amount of waste was more during the festivals. When asked about the method of disposal it was noted that they just throw the waste in the community waste without segregation. Pandits and Mahantas do agree that this waste can be utilized instead of throwing it recklessly.

Shouche et al. (2011) studied the variations in physical parameters during vermicomposting of flower waste. Study revealed that different parameters varied periodically and became stable at the end of the process. According to this study moisture level of composting mixture should be maintained in between 60-70% and temperature should be in the range of 25-30°C for proper activity of microorganisms and earthworms. In the present research work also, these conditions were maintained throughout the process for efficient working of earthworms and successful completion of work.

The results and analysis of the present investigation in detail are presented in Chapter 5 (Results). A detailed description of findings obtained is given below:

A. Vermicomposting

Variation of process parameters:

The process parameters that were observed during the vermicomposting period include pH, temperature, EC and moisture content. The monitoring of these parameters was essential to confirm optimal processing of the flower waste into vermicompost.

Moisture Content (MC):

The moisture content in organic waste and the growth rate of earthworms are related to each other. In vermicomposting process, the optimal range of moisture contents has been recorded to be 70 to 90% (Tognetti et al., 2005). *E.foetida* can sustain in moisture content ranging from 50 to 90% (Sims and Gerard, 1985). Reinecke and Venter (1985) reported that the suitable level of moisture content for *E.foetida* was above 70% in cow manure. According to Liang et al. (2003), the MC of 60-70% was found to have maximum microbial activity while 50% MC was the minimum requirement for steep increase in microbial activity.
In the present study, data revealed that the moisture content increased as the vermicomposting period increased but it declined during thermophilic phase of composting, see Table 8.1, Figure 8.1(a) - 8.1(e). Such reduction in the moisture content percentage during the thermophilic phase of composting was also noticed by Larney and Blackshow (2003) who suggested that it was probably due to high evaporating rates. Whereas increase in MC throughout the process could have been because of the continuous production of vermiwash. This result corroborated with the findings of Liang et al. (2003) according to which the increase in MC might be due to the high absorption capacity of vermicompost and assimilation rate by microbial population indicating the higher rate of degradation of waste by earthworms.

The mean values of moisture content of all samples in this study are between 53.6%- 80.71% which falls in optimum range (Table 9). MC of compost sample was found to be higher than that of vermicompost (Groups 1, 4 & 5) except Groups 2 (69.19%) and 3 (71.01%) but it did not differ significantly among groups.

Temperature:
Earthworms react to the temperature variations in a fairly complex manner. The earthworm species used in this study was Eisenia fetida which has good temperature tolerance (Dominguez and Edwards, 2004).

During this analysis, temperature was measured every 10th day in afternoon throughout the process, at the depth of 10 cm from three different sites and their mean value was taken in centigrade. It ranged between 22.1-30.8°C in vermicompost and 22.1-32.5°C in compost sample as indicated in Table 8.2, Figure 8.2(a) - 8.2(e). Temperature increased initially but as it approached the last stage it decreased (Table 8.2). The variation in temperature could be attributed to the metabolic reactions that occur during the vermicomposting process and also to the fluctuations in the atmospheric temperature (Manyuchi et al., 2012).

Another important observation was that temperature generally increased in earlier period of composting and then it decreased (Table 8.2). Our observations are in synchronization with those of Shouche et al. (2011) and Peigne and Girardin (2004)
who suggested that the general rise in temperature in the initial phase might have been caused by rapid mineralization of organic carbon and nitrogen in the presence of sufficient aeration and moisture as needed by microbes which are responsible for the breakdown of organic compounds.

The optimum temperature for *E.foetida* is 25°C, and its temperature tolerance is between 0 to 35°C (Dominguez and Edwards, 2004). The result indicated that final temperature was higher in compost samples as compared to vermicompost samples except for Group 1(50:50) where temperature of vermicompost was higher (Table 8.2). In present research maximum temperature was recorded as 29.2°C in compost sample of Groups 3 & 4 and 29°C in vermicompost samples of Group 3 whereas minimum temperature was noted for compost sample of Group 1 and vermicompost sample of Group 4. Temperature of all the groups for both samples showed that it was maintained within the tolerance level for *E.foetida* to retain its survival (Table 9).

**pH:**

Neutral and partially alkaline pH values are usually indicators of stable vermicomposts. According to some authors, an alkaline value of pH indicates that the process is finished and the products have reached the maturity (Ranalli *et al.*, 2001).

In this study, initially mean pH value of vermicompost sample for Groups 1 to 5 was 4.9, 4.8, 4.5, 4.3 and 4.0 respectively and it moved to 8, 7.2, 5.7, 6.2, 6.2 and 7.5 at the end of the process as seen in Table 9.1, Figure 9.1(a) - 9.1(e). The pH values of composting mixtures increased from acidic to alkaline. This increase was possibly due to the decomposition of nitrogenous substrates leading to the production of ammonia which constitutes a major fraction of the nitrogenous matter excreted by earthworms. Similar observations were made by Muthukumaravel *et al.* (2008). The same trend was observed by Singh *et al.* (2005) when the pH in their study rose from 4.3 to 8.2.

Data of the present study showed that the pH was significantly higher in vermicompost (p<0.05) than the compost (Table 13-17, Figure 39). The mean pH value of vermicompost and compost samples of all the groups was neutral to partially
alkaline ranging from 6 to 8. pH values in this range might be due to the decomposition of organic matter which leads to the formation of ammonium ions and humic acids, these two components have completely inverse effects on the pH. Presence of carboxylic and phenolic groups in humic acids might have caused lowering of pH while ammonium ions increased the pH of the system (Bisen et al., 2011).

Our results are in consistency with Fares et al. (2005) and Pramanik et al. (2007) who said that the joined effect of these two oppositely charged ions actually regulated the pH of vermicompost leading to a deviation of pH towards neutrality. Earthworm’s calciferous glands contain an enzyme, called carbonic anhydrase that features notably in acid-base reactions. The carbon dioxide produced by metabolic processes contributes to the acidic nature of the coelomic fluid. This effect is possibly negated by carbonic anhydrase which catalyses the conversion of this carbon dioxide into calcium carbonate, hence the calciferous glands help to regulate the pH (Edwards and Bohlen, 1996).

It was also noticed that the pH eventually decreased at the final stage (Table 9.1). This was probably due to the vermiwash released in the process. This vermiwash might have lead to the rise in moisture content which neutralised the pH of the vermicompost (Ansari and Rajpersaud, 2012). Another reason could be the production of CO$_2$ and organic acids by microbial metabolism during decomposition of different substrates in the feed mixtures (Albanell et al, 1988; Chan and Griffiths 1988; Haimi and Hutha, 1986; Elvira et al., 1998). Similar results on vermicomposting of cattle manure, fruit and vegetable wastes have been reported by Mitchell (1997) and Gunadi and Edwards (2003).

**Electrical Conductivity (EC):**

The electrical conductivity of vermicompost depends on the raw materials used in vermicomposting and their ion concentration (Atiyeh et al., 2002). EC can be related to the vermicompost’s water holding capacity, cation exchange capacity (CEC), porosity, texture and particle size. Higher particle water holding capacity, CEC and porosity will result in a higher EC (Grisso et al., 2009). The affect of EC
on the quality of compost and vermicompost is substantial because it indicates their salinity and suitability for crop growth. Mengel and Kirkby (2001) observed that too much salinity in compost could directly cause phyto toxicity, depending upon the salt tolerance of the plant species.

In this research, with the increase in time, EC was observed to be reduced as shown in Table 9.2, Figure 9.2(a) - 9.2(e). Karmegam and Daniel (2009) reported a similar decreasing trend in the level of electrical conductivity. This trend was probably due to the conversion of available salts into insoluble salts. This finding is also in concomitance with Jayakumar and Natarajan (2012) according to which slight generation of soluble metabolites such as ammonium and precipitation of dissolved salts during vermicomposting led to lower EC values.

As per the present investigation, EC of vermicompost sample was more than compost sample in all the groups (Table 9). This might be due to the loss of organic matter which most likely led to a higher concentration of ions which would have increased EC (Kiefer and Rivin, 2012). It was found insignificantly higher in vermicompost than the compost except in Group 3 (Table 15). The Values of EC were found higher but inspite of that, it was not so high as found in other wastes like agriculture waste (3.44 dS/m), food waste (16.9dS/m), etc. (Arancon et al., 2004; Mane and Raskar, 2012).

In the current study, out of all five groups; Groups 2 and 3 have lower EC as compared to others (Table 9). The reduction in EC reveals the reduction in salinity considerably. This is in concomitance with earlier studies made by Karthikeyan et al (2007) and Ansari and Rajpersaud (2012) which explains that the lower level of salinity is the essential character of good biocompost which is better for crop growth as it favours maximum nutrient absorption by plants.

**Organic Carbon (OC):**

Vermicomposting process involves the feeding of earthworm on organic matter and microbial degradation. The combined process brings about carbon loss from substrates in the form of carbon dioxide.
In the present study, organic carbon content of vermicompost sample (Group 1: 3%, Group 2: 3%, Group 3: 3.1%, Group 4: 3.1%, Group 5: 3%) was found to be higher than compost (Group 1: 2.7%, Group 2: 2.7%, Group 3: 2.8%, Group 4: 2.8%, Group 5: 2.7%) in all the groups (Table 9, Figure 41). This could be attributed to the involvement of three factors namely microbial activity, enzymatic activity and worm cast in vermicompost sample than compost sample which lack worm cast. Earthworm accelerates the mineralisation rate and converts the waste into casting with higher nutritional value and degree of humification (Albanel et al., 1988). Worm casts are clumps of digested organic matter excreted out by earthworms, which are rich in carbon. The carbon content of the cast tend to be due to the addition of intestinal mucus (Blair et al., 1994). They typically have higher amount of total and available nitrogen, organic carbon, total and exchangeable calcium, magnesium, potassium and available phosphorus compared to surface soils (Lavelle, 1994). Due to the continuous addition of worm cast, the carbon content in vermicompost samples was found to be more. But this value of vermicompost was found much lesser as compared to other wastes like sheep manure (Azarni et al., 2009), agricultural waste (Mane and Raskar, 2012), food waste (Arancon et al., 2004) etc. The present findings corroborated to those of Karthikeyan et al. (2007) who suggested that the carbon content of the waste was utilized as energy by the earthworms and this could have been the reason of lower concentration of OC as compared to other wastes.

In another study Bhor et al. (2013) also reported the decrease in OC that might be due to oxidation of carbon to carbon dioxide during decomposition process. This result is also supported by Bernel et al. (2009) who stated that vermicomposting involves a partial mineralization of the organic substrate leading to carbon losses during the process. It was found significantly higher as compared to compost sample see Table 13-17.

**Total Nitrogen (N):**

Gunadi et al. (2002) exhibited that the nitrogen profile of vermicompost was enhanced by earthworm activity through nitrogen transformation by microbial action, accumulation of mucus and nitrogenous wastes secreted by earthworms (Bisen et al., 2011). The final nitrogen content in vermicompost depends upon the initial nitrogen present in the waste and the extent of decomposition.
In the present research work, no significant difference was seen amongst groups (Table 12). Compost samples showed significantly higher Nitrogen Content in Groups 4 and 5 (Table 16 and 17). Total Nitrogen (TN) Content of vermicompost sample was noted lower than the compost sample except for Group 3 (Table 9, Figure 42). This loss of nitrogen might have been due to leaching through vermibed wash during composting. Total Nitrogen percent noted in this study are in agreement with the findings of Iyer et al. (2012) who also observed decrease in nitrogen content in vermicompost and revealed that this decrease in the nutrient component was probably due to the utilization of nutrients by enhanced microbial population in the vermicompost. Result confirms the findings of several workers who reported that the earthworms promote microbial growth as well as microbial activity (Edward and Bohlen, 1996). Higher microbial activity in the earthworm cast was also reported by Teotia et al. (1950) and Kollmannsperger (1956).

The higher total Nitrogen content in vermicompost sample of Group 3 could be attributed to appropriate mineralization of nitrogen. The amount of waste and cow dung varies amongst the groups; in Group 1; 500 grams of cow dung was taken and in subsequent groups it was reduced by 100 grams each (Table 3). It might be assumed that neither a higher quantity of cow dung, as in Groups 1 (50:50) and 2 (60:40), nor a lower quantity (Groups 4 and 5) is suitable for the appropriate mineralization. Hence, the combination of flower waste and cow dung (70:30) in Group 3 could be considered suitable for the appropriate mineralization of nitrogen.

**Phosphorus (P):**

The waste materials ingested by the earthworms undergo physical decomposition and biochemical changes assisted by the enzymatic and enteric microbial activities. While passing through the earthworm gut, nutrients are discharged in the form of microbial metabolites that enrich the feed residue with plant nutrients and growth promoting substances in an assimilated form (Senapati, 1992; Kitturmath et al., 2007).

In the present research, vermicompost samples had higher P content (Group 1: 2%, Group 2: 1.9%, Group 3: 1.6%, Group 4: 1.2% and Group 5: 1.1%) as
compared to compost samples (Group 1: 0.8%, Group 2: 1.7%, Group 3: 0.9%, Group 4: 0.7% and Group 5: 0.8%) see Table 9. It was found significantly higher in the vermicompost as compared to compost harvested at the end of the experiment (Table 13-17, Figure 43). Higher P content in vermicompost was also recorded by Orozco et al. (1996). This might be due to the higher population of P-solubilizers (Chowdappa et al., 1999) or probably due to mineralization and mobilization of phosphorus as a result of bacterial and faecal phosphatase activity of earthworms (Garg et al., 2006). The worms during vermicomposting converted the insoluble P into soluble forms with the help of P-solubilizing microorganisms through phosphatases present in the earthworm gut, making it more available to plants (Ghosh et al., 1999; Suthar and Singh, 2008).

This finding is also supported by Padmavathiamma et al. (2008) who suggested that the status of P content in vermicompost depends on acid formation during organic matter decomposition process by the microorganisms and is the major mechanism for solubilisation of insoluble phosphorus. Among all groups; Group 1(50:50) showed maximum P percent see Table 9. The enhanced P level in this group suggests more phosphorous mineralization during the process. Satchell and Martein (1984); Sangwan et al. (2010) also found an increase in P. They attributed this increase to direct action of worm gut enzymes. Le Bayon and Binet (2006) have reported that some amount of phosphorus is converted to more available forms partly by earthworm gut enzymes, i.e. acid phosphatases and alkaline phosphatases.

Bisen et al. (2011) revealed that the presence of large number of micro flora in the gut of earthworm might have played an important role in increasing P content in the process of vermicomposting.

**Potassium (K):**

Vermicomposting has been established as an effective process for recovering higher K from organic waste (Manna et al., 2003; Suthar, 2007). The generation of acid during decomposition of organic matter by the microorganisms is the crucial process for solubilization of insoluble potassium (Adi and Noor, 2009).
During this analysis, K content was found higher in vermicompost samples to that of compost sample. It was recorded 0.09% for Group 1, 0.07% for Group 2, 0.1% for Group 3, 0.04% for Group 4 and 0.03% for Group 5 in vermicompost samples (Table 9). The results showed that potassium was significantly higher in vermicompost than compost except for Group 5 where it was insignificantly lower than vermicompost (Table 17, Figure 44). The higher potassium content in vermicompost sample as compared to compost could be corroborated by the findings of Delgado et al. (1995) who also recorded higher K concentration in the end product prepared from sewage sludge. This result is also found similar to the findings reported by Rao et al. (1996) who suggested that the increase in K of the vermicompost in relation to that of the compost was probably because of physical decomposition of organic matter of waste due to biological grinding during passage through the gut, coupled with enzymatic activity in worm’s gut.

Our results are well supported by Kaviraj and Sharma (2003) who stated that the microorganisms present in the worm’s gut probably converted insoluble K into the soluble form by producing microbial enzymes.

Suthar (2007) in his study also noticed that earthworm processed waste material contains high concentration of exchangeable potassium due to enhanced microbial activity during vermicomposting process which consequently enhanced the rate of mineralization.

**Calcium (Ca):**

The earthworms control the mineralization process and transform a part of calcium from binding form to free forms, leading to its enhancement in worm casts.

In this analysis, the mean value of Ca was noted higher in vermicompost samples for Groups 3 (0.008%) and Group 5 (0.005%) as compared to compost (Table 9, Figure 45) whereas in rest of the groups there was either none or insignificant difference between vermicompost and compost samples. The increase in Ca content of vermicompost is well supported by Piearce (1972) who stated that the chemistry of faecal material of earthworms is most likely responsible for this.
Earthworms have specialized glands that encapsulate the faecal material in calciferous deposits as it leaves the worms after passing through the worm gut. It is suggested that gut process associated with calcium metabolism is primarily responsible for enhanced content of inorganic calcium content in worm cast. However the similar pattern of calcium enhancement is well documented in available literature (Heartenstin and Heartenstin, 1981; Garg et al., 2006).

Similar result was also observed by Spiers et al. (1986) who reported that earthworms convert calcium oxalate crystals in ingested fungal hyphae to calcium bicarbonate which is then egested in cast material, which increases calcium availability in the final vermicompost.

Garg and Kaushik (2005) have also reported an increase in calcium content during the vermicomposting of industrial wastes. Likewise, Raphel and Velmourougane (2010) also found an increase in calcium content in their study.

**Magnesium (Mg):**

Data of the present study showed no significant difference in magnesium content amongst groups except in Group 1 (Table 13). In the two extreme Groups; 1(0.008%) and 5(0.006%), vermicompost sample showed higher magnesium content which was significantly higher in vermicompost sample of Group 1, whereas in rest of the groups the value was higher for compost (Table 13-17, Figure 46). Deficiency of Mg in vermicompost samples of these groups can be rectified by adding Magnesium Sulphate (Sherman, n.d., para.2). Our result is in concomitance with that of Garg et al. (2006) and Yasir et al. (2009) who showed increase in Mg content of vermicompost indicating the conversion of nutrients to plant-available forms during passage through the earthworm gut.

Results are supported by Chowdappa et al. (1999) who also revealed that the composition of the micronutrient was higher in vermicompost than compost. The higher concentration of Mg in vermicompost samples reported in present study was also in consistence with the findings of earlier workers (Tiwari et al., 1989; Orozco et al., 1996; Padmavathiamma et al., 2008; Raphel and Velmourougane, 2010).
In this study, the bioconversion ratio was also calculated. The total weight of the vermicompost obtained from vermicomposting of floral waste was 755.0 g (50:50), 775.5 g (60:40), 685.5 g (70:30), 654.0 g (80:20) and 620.0 g (90:10). The percent conversion of vermicompost was 62.9% (50:50), 64.6% (60:40), 57.1% (70:30), 54.5% (80:20) and 51.6% (90:10) (Table 10). The highest rate of bioconversion was observed in 60:40 ratio. The relatively higher growth of earthworms led to the higher bioconversion rates. Similar results were also reported by Ndegwa et al. (2000).

From above explanation of all parameters it was clear that the amount of Organic Carbon, Potassium and Phosphorus was more in vermicompost samples for all the groups as compared to compost samples. Different ratios were taken to find out the one that was better in terms of nutrient level and shows the best rate of conversion. The floral waste with cow dung at 50:50, 60:40 and 70:30 ratios could be bioconverted into a nutrient rich vermicompost. The remaining two ratios i.e. 80:20 and 90:10 can be ruled out because the values of NPK were not significant as compared to other ratios. Hence, it may be recommended that marigold at concentrations viz., 50:50, 60:40 and 70:30 may be bioconverted into a nutrient rich vermicompost which can be used as a bioorganic fertilizer for crops.

**B. HANDMADE PAPER MAKING**

In the present research work, the potential of the flowers collected from temples, was also assessed for handmade papermaking. Various types of flowers are offered to the deities in temples of India, therefore, large amount of floral waste is generated from these temples. Generally, this waste is dumped unattended for natural degradation, which causes generation of obnoxious odour with consequent environmental pollution. Lot of work has been done by various researchers/Non Government Organizations to address this issue and some reports are also available in literature to use this biodegradable waste for a range of applications viz. industrial dyeing of textile fibers (Vankar et al., 2009) production of vermicompost (Sailaja et al., 2013; Gurav and Pathade, 2011), sacharification (Ray and Karmakar, 2011), anaerobic hydrolysis of flower waste (Zhang and Shao, 2008) etc. besides its
common use in handmade paper industry for mottling. In this study handmade paper was prepared in Kumarappa National Handmade Paper Industry (KNHPI) and was analysed for strength properties.

These properties of paper reveal the inherent chemistry, morphology, and arrangement of the individual fibres as well as structure of the paper. They also exhibit the chemical changes that make the paper lose its permanence with time. Hence strength properties can act as indicators of the durability of paper, even when the nature of the chemical changes which can deteriorate the paper remain unknown (Caulfield and Gunderson, 1988). Strength properties if carefully monitored can be used for assessing the efficiency of treatments for ageing of paper. This requires test methods and procedures that have been proven to be reliable. Technical Association of the Paper and Pulp Industry (TAPPI) test methods have been used in this study for evaluating the fundamental characteristics of paper such as tensile index, burst index, tear index and folding endurance.

**Tear Index:**

The degree of inter fibre bonding in the sheet influence the tearing process. In sheets which have a low degree of inter fibre bonding, the fibres can easily be ripped out of the structure. Apart from this the tearing resistance also depends on fibre length and on the number of places where the fibres bind. A higher degree of bonding signifies that the fibres are properly fixed in the sheet and the pressure applied during the tear test leads to the breaking of individual fibres (Karlsson, 2007).

In the present study, tear index of alkaline treated flower pulp was found to be 7 Nm/g in Set A1 with 10% NaOH and 5 Nm/g in Set A2 with 5% NaOH (Table 19, Figure 47). The tear index of flower pulp was recorded to be higher than other alkaline treated pulps like currency pulp (Chauhan et al., 2009), Banana, Ankara and Pineapple pulp (Kumar et al., 2013). This result is supported by Van den Akker et al. (1958) who stated that short fibres are evidently easier to rip out as compared to long fibres, therefore papers made of long fibres exhibit much better tearing resistance than those made with shorter fibres. This finding is also supported by Seth (1990 a) who showed that tearing resistance increased with increasing fibre length,
specifically when the degree of bonding is low. Lee et al (1991) also observed that the tear index depends on fibre length. The present finding (higher tear index in alkaline pulp) also corroborated to those of Seth and Page (1988) who showed that coarser fibres gave sheets a higher tear index than finer fibres.

It was also observed that flower pulp treated with 1.0% enzyme dose had slightly higher tear index as 8 Nm/g compared to that of 0.5% enzyme dose, where it was found as 7 Nm/g (Table 21, Figure 48). The lower values of tear index in Set B2 might be due to the reduction in the bonding strength in spite of the increase in the number of inter-fibre bonds during beating (Bhat et al., 1991). Paper making processes that enhance inter fibre bonding, improve tensile and bursting strength, but tend to decrease tearing resistance (Caulfield and Gunderson, 1988).

**Tensile Index:**

Tensile test results indicate the intricate structure of paper and the characteristics of its individual fibres. The dimensions and strength of the individual fibres, their arrangement and the degree to which they are bonded to each other are all essential factors that contribute to the test results (Fagbemigun et al., 2014). The tensile strength is determined by the bonded area, thus collapsibility, external fibrillation and especially wet fibre flexibility (Paavilainen, 1993b).

In the present research work, Tensile Index of Alkaline treated flower pulp was noted to be higher (20 mN.m²/g) in Set A1 as compared to Set A2 (16 mN.m²/g) as given in Table 19 and Figure 47. This decrease in tensile index could be accredited to the decrease in fibre strength as described by Seth (1990a) who suggested that tensile strength increases with density and decreases with decreasing fibre strength. However, the decrease in tensile strength could also be attributed to increasing coarseness. According to Paavilainen (1993a) “good bonding ability and intrinsic fibre strength are the most important factors for high tensile strength”. On the other hand, for the enzyme treated flower pulp Tensile Index was noted to be 19 mN.m²/g in both the Sets (B1 and B2) as shown in Table 21 and Figure 48. For two papers of equal tensile strength, however, the one with the greater stretch will consequently exhibit the higher bursting strength. Stretch is the amount of distortion which paper
undergoes under tensile stress. (Caulfield and Gunderson, 1988). This accounts for the higher value of burst index recorded for Set B1 (1.3 Kpa.m$^2$/g).

**Burst Index:**

Burst index and tensile strength display a good correlation between them. Those fibre properties and papermaking practices that improve tensile strength also tend to improve bursting strength (Scribner and Carson, 1953).

The value of Burst Index for Alkaline treated flower pulp was observed to be 1.2 Kpa.m$^2$/g in both the Sets (A1 and A2), see Table 19 and Figure 47, whereas enzyme treated flower pulp showed Burst index of 1.3 Kpa.m$^2$/g and 1.1 Kpa.m$^2$/g with 1.0% and 0.5% enzyme dose respectively (Table 21, Figure 48). The value of Burst index for enzyme treated flower pulp was found to be higher than alkaline treated pulp. The higher value of burst index could be assigned to fibre bonding. The results are also supported by Dutt et al. (2009); Jahan and Rawshan (2009) according to whom the burst index depends on fibre bonding as beating improves fibre bonding which in turn increase the burst index of the pulp.

This could also be due to the inverse correlation between tearing resistance and burst index (Seth and Page, 1988). This concurred with our earlier observation where tear index of enzyme treated (Set B1 and Set B2) flower pulp was found higher as compared to alkaline treated (Set A1 and Set A2) and the current investigation where the burst index observed is lower for enzyme treated flower pulp, thus establishing the inverse correlation.

**Folding Endurance (Double Folds):**

Folding endurance can be contemplated as a modified tensile strength test because the test specimen is subjected to stress that ultimately leads to breaking. This test resembles the repeated action of paper folding which is important in determining the deterioration of paper with age (Luner, 1969). In the early stages of beating, during the paper making process, folding endurance increases and so does the tensile strength. However, as the beating progresses, folding endurance decreases with time because of the increase in brittleness of the paper.
In the present study, Double Fold, number of Alkaline treated flower pulp, Set A1 and Set A2 was measured to be 70 (10% NaOH) and 27 (5% NaOH) respectively (Table 19, Figure 47). However in the enzyme treated flower pulp Double Fold, number was 30 in Set B1 and 56 in Set B2 as given in Table 21 and Figure 48. Alkaline treated flower pulp in Set A1 and enzyme treated pulp in Set B2 showed higher double fold, number. The higher value of Double fold, number, could possibly be dependent on fibre length and sheet density. Seth (1990a) also showed an increase in double fold, number, with increasing fibre length and increasing sheet density.

Data revealed that enzyme treated pulp had lower value of Double fold no. which might be due to inadequate fibre bonding or brittleness (Caulfield and Gunderson, 1988).

The two types of handmade papers produced from enzymatically processed floral waste (Figure 50) and from the chemically processed floral waste (Figure 49) were evaluated for their physical strength properties (Table 18 and 20). From Table 18, it can be seen that the handmade paper produced in Set A1 with 10% NaOH was better as compared to that produced in Set A2 with 5% NaOH in terms of tensile index, tear index and burst index. Double fold was reported to be same in both the cases. While in the case of handmade papers produced from enzymatically processed waste, Set B2 with 0.5% enzyme dose showed better results as compared to the Set B1 with 1.0% enzyme (Table 20). So, an enzyme dose of 0.5% was sufficient enough to suitably process the flower waste.

When chemically processed handmade paper was compared with the enzymatically processed paper of floral waste, the later one was found to be slightly better in terms of physical strength properties as compared to that obtained from chemically processed floral waste. Thus the floral waste from temples can be recycled for making handmade paper.

With the preliminary studies done as a part of this research, we got an idea to use temple waste for making handmade paper however a detailed and systematic
study is required before establishing its actual use. Optimization of enzyme and pulping chemical doses can also be conducted for getting better results.

In this study, the production of vermicompost and handmade paper from temple waste are methods of sustainable waste management which adhere to the concept of Zero waste. The raw material used for these processes was waste procured from temples, i.e. flowers, so there was no extra cost involved from the raw material perspective. The waste which is generally burnt or buried or disposed off into water bodies was recycled and recovered in line with the philosophy of Zero Waste. Zero waste is a concept for 21st century which includes recycling but goes beyond that to eliminate all discharges to land, water and air that are a threat to the environment. It is a principle that focuses on avoiding and eliminating the volume of waste materials to conserve and recover all resources in the process and can be applied to industrial, agricultural as well as civic waste.

Large temples generate huge amount of waste which, if converted into vermicompost, can be used by temples in their gardens or can be sold out. The income generated out of it could be used for beautification and maintenance of temples. Disposables made from Handmade Paper can be used instead of baskets and plastic bags in the temples for carrying garlands, ‘Prasad’ and other puja items. Temples can set up their own small scale industry to manufacture Paper made ‘Pattal Donas’ which could be used in city like Jaipur where practices like Savamani and Goth are very common.

This sustainable waste technique can be implemented on a larger scale and eventually other temples can participate, this will eliminate their waste products which have adverse environmental impacts and would help to promote the concept of “Green Temples” (Figure 52). These temples would not only ease the burden on the environment that is caused by the volume of waste that they produce and the uninspiring methods of its disposal but would rather create value in terms of vermicompost, which enriches the soil; and paper products, which would eventually cut down deforestation, hence benefitting the environment.
Figure 52: Zero waste management in temples