DISCUSSION

Heavy metals accumulate in the soil of through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Khan *et al.*, 2008; Zhang *et al.*, 2010). Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are lead (Pb), chromium (Cr), cobalt (Co), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) (GWRTAC, 1997). Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation (Kirpichtchikova *et al.*, 2006), and their total concentration in soils persists for a long time after their introduction (Adriano, 2003). Changes in their chemical forms (speciation) and bioavailability are, however, possible.

The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants (Maslin and Maier, 2000). Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plantanimalhuman), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems. The adequate protection and restoration of soil ecosystems contaminated by heavy metals require their characterization and remediation. (McLaughlin *et al.*, 2000a; McLaughlin *et al.*, 2000b).

Earthworms (especially *Eisenia foetida*) can accumulate high concentrations of metals including heavy metals in their tissues without affecting their physiology and this particularly when the metals are mostly non-bioavailable. They can readily bio-accumulate cadmium, mercury, lead, copper, manganese, calcium, iron and zinc and extremely high amounts of Zn, Pb and Cd. Cadmium levels up to 100 mg kg^{-1} and lead up to 7600 mg kg^{-1} dry weight have been found in tissues (Ireland, 1983). Contreras-Ramos *et al.* (2005) confirmed that the stabilized sludge has metal levels below the limits set by the USEPA in 60 days. The significant removal of lead and cadmium from vermicomposted sewage sludge. Some metals are protein-bound (so called metallothioneins) in earthworms, these have a very high capacity to bind metals. The chloragogen cells in earthworms appear to accumulate heavy metals specifically which are immobilized in the small spheroidal chloragosomes and debris vesicles that the cells contain (Brahmbhatt, 2006).

The concentration of cobalt in the vermicomposts of different animal dungs with municipal solid wastes with respect to initial feed mixture of vermibeds was observed. There was a significant decrease in the concentration of Co in vermicomposts of all combinations of animal dungs with municipal solid wastes. It is due to the accumulation of Co in earthworm body during vermic-activity, Selladurai *et al. (*2005) reported that the possibility for metals to be bound to ions and carbonates increases in ingested material. The metal content reduces in digested organic material due to bioaccumulations of more soluble fractions of metals in an earthworm gut or cutaneous tissues. Heavy metals found in domestic and industrial wastes are concerned with sewage sludge at high level. The heavy metals concentration in sewage sludge was higher and affects the health of people and animals (Liu *et al.*, 2005).

The comparative study of *Eisenia foetida* and *Perionyx excavatus* species of earthworms in vermicomposting of MSW and paper pulp has been suitability utilized to produce vermicompost (Kaviraj and Sharma, 2003). The municipal solid waste is suitable as feedstuffs for earthworms to produce vermicompost, because they contain major and minor nutrients in plant-available forms, enzymes, vitamins and plant growth hormones for general plant development (Garg *et al.*, 2008; Borah *et al.*, 2007). Muthukumarvel *et al.* (2008) observed that the municipal solid wastes are mainly from domestic and commercial areas that contain recyclable toxic substances, comparable organic matter and other compound. With rapid increase in population, the generation of municipal solid waste has increase in population several folds during last few years. Huge amount of heavy metals entered in environment due to the volcanic activity, erosion of rocks, forest fire and many industries as well as anthropogenic activity (Martine and Griswold, 2009). The maximum decrease in the concentration of Co in the vermicomposts obtained from the combination of buffalo dung with municipal solid wastes in ratio of 1:1 was observed 100%, from 0.017±0.007 mg/kg to below detection limit (BDL), because it may be possible that the essential nutrients for the proper metabolism were present into the buffalo dung with municipal soild wastes combination which also promotes the more accumulation of Co in earthworm body and finly decrease the level of heavy metals in vermicompost.

There was a significant decrease in the concentration of Co in vermicomposts of all combinations of animal dungs with kitchen wastes (KW). Maximum decrease in the concentration of Co in the vermicomposts obtained from the combination of buffalo dung with kitchen wastes in ratio (1:3), it may be due to the microbial activity during vermicomposting enhance the mineralization of inorganic substances and provides suitable conditions for the accumulation of heavy metals into the body of earthworm *Eisenia foetida*. The earthworm, *Eisenia foetida* is effective in lowering down the Co in different wastes during the vermicomposting (Suthar and Singh, 2008). Wijewardena and Gunaratne (2004) reported that the animal manure provide considerable amount of plant nutrient and many other beneficial effects for crop growth, however, animal manure may contain appreciable amount of toxic heavy metals added to soils through these metals could be entered to human body through food chain. The vermicomposting could be an appropriate technology for metal remediation from noxious urban sludges at low input basis (Jordao *et al.*, 2006). The ready vermicompost was not only rich in plant nutrient but also has minimum risk of environmental contamination due to lower metal availability in it. The greater metal concentration in composting earthworms clearly indicates the accumulation of metals in earthworms from inhabiting substrate (Suthar and Singh, 2008).

The concentration of Cr decreased more than 80% in the vermicomposts of different animal dungs with municipal solid wastes with respect to initial feed mixture of vermibeds. Maximum decrease in the concentration of Cr in the vermicomposts obtained from the combination of cow dung (91.27%, from 0.848 ± 0.003 to 0.074 ± 0.003 mg/kg). Rudd (1987) studied organic matter and high nutrient containt of municipal sewage sludge and promoted its application to agricultural land as an organic fertilizer. Sharma *et al.* (2008) observed that vegetable exposed to atmosphere at the market have higher level of heavy metals as compared to fresh vegetable. The vegetable grown in vicinity of brick kiln industries and near the national highway also showed higher level of heavy metals in edible crops (Sharma *et al.*, 2009). Czekała *et al.* (1996), which reveal that both in tannery sludge and composts with this sludge supplement Cr, occurred in water soluble and exchangeable fraction. Also Kabata-Pendias *et al.* (1987) found a small amount of mobile chromium forms in sewage sludge. According to Kostecka (2000) sewage sludges may provide a good medium for redworms. It might be connected with constantly increasing number of bacteria and protozoans due to sludge treatment. The obstacle to utilization of these wastes as a medium may be not only too high concentration of heavy metals but also in sufficient amount of cellulose (Hatanaka *et al.*, 1983). According to Malecki *et al.* (1982) *Eisenia foetida* tolerates relatively great contents of heavy metals in the substratum, Hartenstein *et al.* (1980) in their studies conducted on sewage sludge substrata found that chromium, even in high concentrations, is not harmful for redworm growth.

There was a significant decrease in the concentration of Cr in vermicomposts of all combinations of animal dungs with KW. The concentration of Cr was maximum decrease in the vermicomposts obtained from the combination of buffalo dung with kitchen wastes in ratio of 1:3 during final vermicompost during vermic-actity by earthworm *Eisenia foetida*. The buffalo dung is good feed material for earthworm during feeding mechanism the cobalt metal accumulate in earthworm body such as gizzard in higher comparably than posterior region of intestine. However, certain toxicants may be present in municipal sludge, which may threaten crop yield, long-term soil quality, and human health (Lee *et al.*, 1996).

The concentration of Pb decreased more than 96% in the vermicomposts of different animal dungs with municipal solid wastes with respect to initial feed mixture of vermibeds. The maximum decrease in the concentration of Pb in the vermicomposts obtained from the combination of buffalo dung with municipal solid waste in the ratio of (1:1) was observed (96.73%, from 1.773 ± 0.008 to 0.058 ± 0.003 mg/kg). According to Suthar (2007) in general, earthworms consume a great amount of organic waste to achieve appropriate nutrition, and during this process metals are liberated in free forms due to the enzymatic actions in their gut. Furthermore, such available forms of metals are then absorbed by the epithelial layer of gut during the transiting of wastes through it. Bioaccumulation of high concentration of metals is well documented (Hsu *et al.*, 2006). Although earthworms can transfer hazardous organic wastes into stabilized value-added vermicompost, it accumulates a certain amount of toxic metals in their tissues. The accumulation of chemicals in the tissues by these detritivorous organisms can, in principle, damage soil processes and local biodiversity indirectly if their activities and demographics are compromised, and directly if the residues are transferred via earthworms to organisms occupying different trophic levels (Morgan *et al.*, 2001). Lead exposure assessments have been based on its intake from food, water, or air. Possible routes for lead exposure are inhalation and swallowing. The four main sources of contamination of food are soil, industrial pollution, agricultural technology, and food processing. Worldwide, there are six sources that account for most cases of lead exposure: gasoline additives, food-can soldering, lead-based paints, ceramic glazes, drinking water pipe systems, and folk remedies (Markowitz, 2000). The species *Lumbricus terrestris* was found to bio-accumulate of lead (Pb) in their tissues 90-180 mg/kg of dry weight, while *L. rubellus* and *D. rubida* it was 2600 mg/kg and 7600 mg/kg of dry weight respectively (Ireland, 1983).

The concentration of Pb in the vermicomposts of all combinations of animal dungs with KW. Maximum decrease in the concentration of Pb in the vermicomposts obtained from the combination of sheep dung with kitchen wastes in the ratio of (1:2) was observed (87.25%, from 0.792 ± 0.004 to 0.101 ± 0.005 mg/kg) (Table 7). Different bio-wastes treatments (municipal solid waste, sewage sludge, manures, etc.) of a long term field experiment can change soil micro and macronutrients and their available concentrations, which in turn affects soil micronutrient levels (Kaushik *et al.*, 1993; Bole and Bell, 1978; Veeken *et al.*, 2000). Tripathi and Bhardwaj (2004), explained that the changes in C:N ratio in thermocomposting normally occurred by the loss of carbon as CO_2 while in vermicomposting of biological wastes, in addition to loss of carbon the increase in nitrogen content of the substrate due to microbial and enzymatic activity also in the reduction of C:N ratio. Vermicomposting results in the bioconversion of the waste stream into two useful products, earthworm biomass and vermicompost. The former can be used as a vermicompost is considered as an excellent product since it is homogenous, has desirable aesthetics, has reduced level of contaminates, has plant growth hormones, higher level of soil enzymes, greater microbial population and tends to hold more nutrients over a longer period without adversely impacting the environment. Earthworm while ingest organic waste and soil, consume heavy metals through their intestine as well as through their skin, wherefore concentrating heavy metals in their body (Sharma *et al.*, 2005).

There was a significant change in the concentration of Ni in the vermicomposts of different animal dungs with MSW with respect to initial feed mixture of vermibeds. There was a significant decrease in the concentration of Ni in vermicomposts of all combinations of animal dungs with MSW. It was observed that vermicomposting eliminated all the concentration of Ni from the all combination of dung's of all examined animals with MSW decrease in the concentration of Ni was observed (78.65 %, from 0.089±0.003 to 0.019±0.003 mg/kg) (Table 8 and Figure 7). The viability of using earthworms as a treatment or management technique for numerous organic waste streams has been investigated by a number of workers (Singh and Sharma, 2002). Similarly a number of industrial wastes have been vermicompost and turned into nutrient rich manure (Sundaravadivel, 1995). The ability of heavy metals removal by earthworms is of particular significance while using vermicomposts made from urban solid wastes. Urban waste may contain considerable amount of heavy metals and when processed by earthworms only that they can become free of heavy metals (Jordao *et al.*, 2006). The gut-related processes in earthworm may also increase metal availability. The earthworm chloragosomes consisting of modified epithelial cells, the eleocytes of the gut containing constituents of ion exchange compounds phosphoric acid, carboxyl, phenolic hydroxyl and sulphonic acid groups acted as a cation exchange system capable of taking up and accumulating heavy metals (Cooper, 1996).

There was observed the Ni concentration in the vermicomposts of different animal dungs with municipal solid wastes with respect to initial feed mixture of vermibeds. There was a significant decrease in the concentration of Ni in vermicomposts of all combinations of animal dungs with municipal solid wastes. It was observed that vermicomposting eliminated all the concentration of Ni from the all combination of dung's of all examined animals with municipal solid wastes decrease in the concentration of Ni was observed (78.65 %, from 0.089±0.003 to 0.019±0.003 mg/kg). Dominguez and Edwards (1997) studied the total and available content of Zn and Cu during the vermicomposting process, because these are problematic minerals in pig manure. Although as a consequences of the carbon losses by mineralization during process the total amount of heavy metals increase (between 25-30%), the amounts of bioavailability heavy metals tend to decrease by 35 – 55 % in two months. Detrivores feed at or near the soil surface on plant litter or dead roots and other plant debris or on mammalian dung. These worms are called humus makers and comprise the epigeic and anecic forms i.e. *Perionyx excavatus*, *Eisenia foetida*, *Eudrilus euginae*, *Lampito mauritii*, *Polypheretima elongata*, *Octochaetona serrata* and *Octochaetona curensis* are examples of detrivorous earthworms (Ismail, 1997). Earthworms can be cultured and put to various uses i.e. to improve and maintain soil fertility, to convert organic waste into manure (Paoletti *et al.*, 1991). Agricultural waste, horticultural waste, animal waste, silkworm litter, plant biomass (leaf litter), weeds, kitchen waste abiding, foul, acidic, spicy and spoilt food, city refuse after removing non-degradable waste material such as glass, plastic, strong rubber and metal can be vermicomposted (Kale, 1995).

There was a significant decrease in the concentration of Cd in the vermicomposts of different animal dungs with municipal solid wastes with respect to initial feed mixture of vermibeds. Maximum decrease in the concentration of Cd in the vermicomposts obtained from the combination of horse dung with municipal solid wastes in the ratio (1:3) was observed (95.88%, from 0.291 ± 0.003 mg/kg to 0.012 ± 0.006 mg/kg). The cadmium may increase in the biosphere due to emission from batteries, coating, electroplating steel and cast iron, pigments, plastic stabilizers constituent of low melting or easily fusible allows electronic, optics and solder for aluminum, reactor control rods. Moreover, it is presented as a contaminant in phosphatic fertilizer and sewage and is dispersed by meaning activity (Hu, 2002; Mahindru, 2004). Earthworms easily accumulate Cd and retain it in their body tissue (Barret, 1995; Rebanova *et al.*, 1995; Lapinski *et al.*, 2002; Li *et al.*, 2010). The accumulation of metals, especially Cd in earthworms is most probably due to the binding of metals by protein metallothioneins, which localized to the membrane of the Golgi apparatus and have the capacity to bind both physiological (such as zinc, copper, selenium) and xenobiotic (such as cadmium, mercury, silver, arsenic) heavy metals through the thiol group of its cysteine residues (Kagi and Kojima, 1987; Sigel and Sigel, 2009). Heavy metals are virtually indestructible chemicals in soils. The only way to remove them from polluted soils is to take them up into the tissues of organisms such as invertebrates as earthworms vermiremediation (Wen *et al*., 2004).

The earthworms showed the greater concentrations of Cd in their tissues, than that of waste substrates, whereas the concentrations of Pb, Zn, Cu and Mn were more in waste than that in their tissue at the end of the vermicomposting process. The present findings clearly showed the earthworms accumulating and remediating metals from the waste substrates. The low concentration of heavy metals in earthworm tissue at initial stage of composting and gradual increase with the progress of vermicomposting reaching higher concentrations at 60 days of composting was a consistent trend of higher metals accumulation in earthworm tissue. The metal levels in earthworm tissue being directly related to the availability of metals over different time intervals. As the time passed, earthworms consume a great amount of organic waste to acquire required nutrition, and during the process metals are liberated in free forms due to the enzymatic actions in their gut resulting in accumulation in their body tissue more metals in available forms were absorbed by the epithelial layer of gut and incorporated into the body tissue of earthworm (Suthar, 2008).

A comparative study, on the quality of organic matter and heavy metal in different mixtures of paper mill sludge and sewage sludge before and after vermicomposting by earthworm *Eisenia endrei* in the 1:6 mixture of paper mill sludge to sewage sludge was the most effective mixture for increasing the weight of *Eisenia andrei* during the vermicomposting period. The heavy metals decreased during vermicomposting implying reduced availability for plants (Elvira, 1995). In Spain, *Eisenia andrei* transformed paper pulp mill substrate by process of aerobic and mesophilic hydrolysis (Elvira, 1995). According to Elvira *et al.* (1998) on vermicomposting of pulp mill sludge mixed with garbage sludge, pig slurry and poultry slurry at different ratios showed highest growth and highest mortality of *Eisenia andrei* in all the mixtures considered. Butt (1993) utilized solid paper mill sludge and spent yeast as a feed for soil dwelling earthworms (*Lumbricus terrestris*). Zharikov *et al.* (1993) reported work on utilizing the wastes of the microbiology industry (sewage sludge, husks, and low quality bacterial preparations) by red earthworm (*Eisenia foetida*). Earthworms ingest large amount of soil and are therefore exposed to heavy metals through their intestine as well as through the skin, wherefore concentrating heavy metals from the soil in their body (Morgan and Morgan, 1999). Earthworms may serve as bioindicators of soil contaminated with pesticides i.e. polychlorinated biphenyls, polycyclic hydrocarbons (Saint-Denis *et al.*, 1999), and heavy metals (Spurgeon, 1999a). Lead, cadmium, zinc and copper are accumulated under some environmental conditions, bioconcentrated in earthworms (Cortet, 1999). It is presumed that in many cases zinc is the critical toxic metal for these organisms (Spurgeon and Hopkin, 2000).

There was a significant decrease in the concentration of Cd in the vermicomposts of all combinations of animal dungs with kitchen wastes (KW) (Table 11 and Figure 10). Maximum decrease in the concentration of Cd in the vermicomposts obtained from the combination of buffalo dung with kitchen wastes in the ratio of (1:1) was observed (85.12 %, from 0.383 ± 0.003 to 0.057 ± 0.002 mg/kg) followed by sheep dung with kitchen wastes in the ratio of (1:3) (85.04 %, 0.274 ± 0.005 to 0.041 ± 0.006 mg/kg), Sharma *et al.* (2005) studied that the vermicomposting technology involves harnessing earthworms as versatile natural bioreactors playing a vital role in the decomposition of organic matter, maintaining soil fertility and in bringing out efficient nutrient recycling and enhanced plants' growth. A variety of organic solid wastes, domestic, animal, agro-industrial, human wastes etc can be vermicomposted. The value of vermicompost is further enhanced as it has simultaneously other benefits: excess worms can be used in medicines and as protein rich animal feed provided they are not growing on polluted wastes and can be used as an anti soil pollutant .

There was a significant ($P<0.05$) decrease in the concentration of As in the vermicomposts of different animal dungs with municipal solid wastes with respect to initial feed mixture of vermibeds. There was a significant decrease in the concentration of As in vermicomposts of all combinations of animal dungs with municipal solid wastes. Maximum decrease in the concentration of As in the vermicomposts obtained from the combination of buffalo dung was observed (91.67 %, from 0.168 ± 0.005 to 0.014 ± 0.005 mg/kg). However, there was a significant decrease in the concentration of As in the vermicomposts of all combinations of animal dungs with kitchen wastes (KW) (Table 13 and Figure 12). Maximum decrease in the concentration of As in the vermicomposts obtained from the all combinations of cow and sheep dung with kitchen wastes in ratio (1:1, 1:2 and 1:3) was observed (100 %) followed by buffalo dung (81.55 %, 0.168 ± 0.005 to 0.031 ± 0.005 mg/kg). Dominguez *et al.* (1997a, b) reported that even though carbon losses, through mineralisation, increased the total amount of heavy metals in a vermicomposting system, the amounts of bioavailable heavy metals is decreased significantly. Ecotoxicology also plays a role in research engaged to determine how, and to what degree, earthworms act as bioaccumulators of pesticides and heavy metals (Edwards and Bohlen, 1996; Eijsackers, 1998). Vermicomposting is a biooxidation and stabilisation process of organic material that involves the joint action of earthworms and microorganisms. The earthworms turn, fragment and aerate the organic matter in a vermicomposting system (Dominguez *et al.*, 1997a, b).

Although heavy-metal contamination in the environment has been widely reported in India, studies on fractional distribution of heavy metals are scarce. Earlier studies performed by various investigators also mainly concentrated on water quality, total metal pollution, and pesticide pollution (Solaraj *et al.*, 2010; Dhanakumar *et al.*, 2011). The detrivorous animals are relatively efficient accumulators of certain essential and nonessential metals. As such, the limited mobility of earthworms makes them an appropriate species for monitoring the potential impact of contaminants, and changes in soil structure (Suthar *et al.*, 2008). In recent years, efforts have been made to recycle the sewage sludge using epigeic earthworms into stabilized value-added product, i.e., vermicompost (Benitez *et al.*, 1999; Gupta and Garg, 2007; Suthar, 2008).

The concentrations of arsenic (As) accumulate in the body of earthworm *Eisenia foetida* was observed to be significantly increased in after the vermicomposting of different combinations of animal dungs with municipal solid waste (MSW). The significantly higher value of As inside the *Eisenia foetida* was observed when the earthworm was kept in the vermibed containing buffalo dung with municipal solid waste in the ration of 1:3 (1.58 %, 9.450 ± 0.003 to 9.602 ± 0.005 mg/kg). Karthikeyan *et al.* (2007) revealed that cow dung was good as an inoculant in the vermicomposting of market vegetable wastes, with a cow dung/vegetable waste ratio of 1:1 yielding optimum macronutrient levels in vermicompost after 30 days. The higher bioaccumulation factor ranges for metals implied higher metal accumulation in earthworms tissue, which may affect the food chain through biomagnification. It further revealed that the accumulation of metals in worms tissue, especially uptake of metals, not only remediated the metals from the urban wastes and their vermicomposts but also improve vermicompost quality reducing the metal concentration (Pattnaik and Reddy, 2011).

The problem of toxicity and accumulation of heavy metals in earthworm bodies has been investigated many times, including even potential use of these organisms for cleaning soils contaminated with these elements. However, the assumed effect has not been reached because as each living organism, also earthworms have certain limited abilities for harmful substance storage, moreover the problem of their subsequent utilization has not been solved. Potential accumulation of excessive quantities of chromium in soil resulting from these materials application may in effect lead to its contamination (Wickliff, 1982). However, it does not exclude a necessity to seek solutions enabling these materials management. One of the possibilities is biological transformation of wastes using *Eisenia fetida* redworm (Kostecka, 1994).

Human health is greatly affected by exposure to arsenic through drinking water. Arsenic is a carcinogen and its consumption can negatively affect the gastrointestinal tract, cardio-vascular and central nervous systems. Elemental arsenic is a metalloids found ubiquitously in nature. Humans are exposed to arsenic through medicinal, environmental, and occupational sources. Both organic and inorganic arsenic are present in various amounts in food-like marine fish. Organic forms are arsenobetaine, arsenic analog of trimethylglycine, commonly known as betaine which account for 90% or more of the total arsenic in marine fish, and arsenocholine, in smaller amounts. However, inorganic forms of arsenic are much more toxic than the organic forms. World Health Organisation (WHO) and US Environmental Protection Agency have set the maximum acceptable level of arsenic in drinking water as 10μg/L (Agrawal and Shukla, 2012). Arsenic occurs in ground water primarily as a result of natural weathering of arsenic containing rocks, although in certain areas high arsenic concentration are caused due to industrial waste discharges and application of arsenical herbicides/pesticides (Smedley and Kinniburgh, 2002).

According to Suthar *et al.* (2008) earthworms accumulate aconsiderable content of metal in their tissues and could serve as useful biological indicator of contamination because of the fairly consistent relationships between the concentrations of certain contaminants in earthworms and soils. Few studies, however, suggested that accumulation of metals depends largely on the interaction of the earthworm with local edaphic factors, such as pH, organic matter content. Lukkari *et al.* (2006) stated that bound of metals to organic matter (more tightly bound fractions) partly reduced the availability of metals for earthworms. In this study, the organic matter fractions in substrate seem to be of primary importance. Edwards (1988) reported the life cycles and optimal conditions for growth and survival of *Eisenia foetida, Dendrobaena veneta, Eudrilus eugeniae,* and *Perionyx excavatus* in animal and vegetable wastes during vermicomposting.

There was significant increased concentration of different heavy metals, namely, cobalt (Co), chromium (Cr), lead (Pb), nickel (Ni), cadmium (Cd) and arsenic (As) observed inside the body of *Eisenia foetida* before and after vermicomposting of different combinations of animal (buffalo, cow, goat, horse and sheep) dungs with municipal solid (MSW) wastes and kitchen waste (KW) and in the ratio of 1:1, 1:2 and 1:3. Jordao *et al.* (2006) reported that the ability of heavy metals removal by earthworms is of particular significance while using vermicomposts made from urban solid wastes. Urban waste may contain considerable heavy metals and when processed by earthworms only that they can become free of heavy metals. Vermicomposting, which involves the use of earthworms to convert biodegradable solid waste into a useful product (vermicompost or vermicast), has a unique position in the domain of environmental engineering, as it is the only pollution control that uses a multicellular animal as the main bioagent (Abbasi *et al.*, 2009). The bioaccumulation of metals in earthworms is their ability to eliminate the excess of metals in their tissues during the process of vermicomposting (Dia *et al.*, 2004; Gupta *et al.*, 2005; Suthar *et al.*, 2008). The significantly increased cobalt concentration was observed inside the body of earthworm *Eisenia foetida* after the vermicomposting of different combinations of animal dungs with MSW

(Table 16) because Co was more significantly decreased by the *E. fetida* from municipal sludge during vermicomposting in comparison to *E. eugeniae* (Selladurai *et al.* 2009). Wen *et al.* (2004) also demonstrated that earthworm activity increases the mobility and bioavailability of heavy metals (Zn, Cu, Cr, Cd, Co, Ni, and Pb) in the soils.

The concentration of Cr inside the tissues of *Eisenia foetida* significantly increased after the vermicomposting of different combinations of animal dungs with MSW. The maximum concentration of Cr increased in the body of *Eisenia foetida* during vermicomposting was observed when the earthworms were kept in the vermibeds containing goat dung with MSW in the ratio 1:2 (0.69 %, 114.515± 0.006 to 115.316 ± 0.003 mg/kg. The earthworms species have been identified and quite a few of them are versatile waste eaters and bio-degraders and several of them are bio-accumulators and bio-transformers of toxic chemicals from contaminated soils rendering the land fit for productive uses (Reinecke *et al.*, 1992; Sudha and Kapoor, 2000; Sinha *et al.*, 2002; Dynes, 2003). The worms secrete enzymes proteases, lipases, amylases, cellulases and chitinases in their gizzard and intestine which bring about rapid biochemical conversion of the cellulosic and the proteinaceous materials in the waste organics. Earthworms convert cellulose into its food value faster than proteins and other carbohydrates. They ingest the cellulose, pass it through its intestine, adjust the pH of the digested (degraded) materials, cull the unwanted microorganisms and then deposit the processed cellulosic materials mixed with minerals and microbes as aggregates called 'vermicasts' in the soil (Dash, 1978).

The concentration of Cr accumulated inside the body tissue of *Eisenia foetida* significantly increased when put inside the vermibed consisted of different animal dungs with KW in different ratios of 1:1, 1:2 and 1:3 after vermicomposting. The presence of significantly higher level of Cr inside *Eisenia foetida* was observed in the combination of buffalo dung (0.58 %, 114.515 ± 0.006 to 115.187 ± 0.002 mg/kg). Under favorable conditions, earthworms and microorganisms act 'symbiotically and synergistically' to accelerate and enhance the decomposition of the organic matter in the waste. It is the microorganisms which break down the cellulose in the food waste, grass clippings and the leaves from garden wastes (Morgan and Burrows, 1982). Several studies have found that earthworms effectively bio-accumulate or biodegrade several organic and inorganic chemicals including 'heavy metals', 'organochlorine pesticide' and the lipophilic organic micropollutants like 'polycyclic aromatic hydrocarbons' residues in the medium in which it inhabits. No farmlands in the world today where heavy use of agrochemicals were made in the wake of 'green revolution' are free of organic pesticides. Several studies have found definite relationship between 'organochlorine pesticide' residues in the soil and their amount in earthworms, with an average concentration factor (in earthworm tissues) of about 9 for all compounds and doses tested (Ireland, 1983). Earthworms are found in wide range of soils representing 60-80% of the total soil biomass. Significantly, the worms lead to total improvement in the quality of soil and land where they inhabit and also enhance total plant growth and crop productivity (Bonkowski and Schaefer, 1997; Devliegher and Verstraete, 1997; Lavelle and Martin, 1992; Winding *et al.*, 1997; Yvan *et al.*, 2009).

The concentration of Pb inside the tissues of *Eisenia foetida* was observed to be significantly increased after the vermicomposting of different combinations of animal dungs with MSW. Maximum value of Pb inside the body of *Eisenia foetida* was observed when it was inoculated in the vermibed containing buffalo dung with municipal solid waste in the ratio of 1:1 (14.25 %, 9.438 ± 0.005 to 11.007 ± 0.002 mg/kg). The earthworm species *Lumbricus terrestris* was found to bio-accumulate in their tissues 90-180 mg lead (Pb)/kg of dry weight, while *Lumbricus rubellus* and *Dendrobaena rubida* it was 2600 mg/kg and 7600 mg/kg of dry weight respectively (Ireland, 1983). Earthworms act as 'Ecosystem Engineer' converting a product of 'negative' economic and environmental value i.e. 'waste' into a product of 'highly positive' economic and environmental values i.e. 'highly nutritive organic fertilizer' (brown gold) and 'safe food' (green gold). Vermiculture can maintain the global 'human sustainability cycle' producing food back from food & farm wastes (Ismail, 2005; Jensen, 1998; Singh, 1993). Vermicomposting offers excellent potential to promote safe, hygienic and sustainable management of biodegradable MSW. It has been demonstrated that, through vermicomposting, MSW such as city garbage, household and kitchen wastes, vegetable wastes, paper wastes, human faeces and others could be sustainably transformed into organic fertiliser or vermicompost that provides great benefits to agricultural soil and plants. Generally, earthworms are sensitive to their environment and require temperature, moisture content, pH and sometimes ventilation at proper levels for the optimum vermicomposting process (Sim and Wu, 2010).

The concentration of Pb accumulated inside the body tissue of *Eisenia foetida* significantly increased in combination of different animal dung with kitchen wastes in different ratios of 1:1, 1:2 and 1:3 after vermicomposting. The presence of significantly higher level of Pb inside *Eisenia foetida* was observed in the combination of sheep dung with kitchen waste in the ratio of 1:3 (6.20 %, 9.438 ± 0.005 to 10.062 ± 0.003 mg/kg). According to Kalamdhad *et al.* (2009) found that vermicomposting using *Eisenia foetida* was more suitable than the windrow method to transform pre-composted vegetable waste, dry tree leaves and cow dung into finer and better-quality compost within 20 days. The presence of high moisture content in kitchen waste may also decrease the number and weight of earthworms, because the movement of air through the available pore spaces in the substrate is restricted by the presence of excess water (Adi and Noor, 2009; Singh *et al.*, 2004). According to Bico *et al.* (2009) in general, epigeic species are normally used in vermicomposting as opposed to anecic and endogeic species. This is due to the predominantly humus consuming and surface dwelling nature of epigeic species. Earthworms can contribute to the physical structure and nutritive value of the soil by burrowing and feeding but they can also be a potential pollution hazard. Suthar and Singh (2008) reported considerable amounts of metals in tissues of earthworms inoculated in distillery sludge for long periods. They correlated the metal loss from substrate with the metal level in earthworm tissues.

The concentration of cadmium inside the body of *Eisenia foetida* was observed to be significantly increased in after the vermicomposting of different combinations of animal dungs with municipal solid waste (MSW) in the ratio of 1:1, 1:2 and 1:3. The significantly higher value of cadmium inside *Eisenia foetida* was observed in the earthworm body in the combination of cow dung with municipal solid waste in the ration of 1:2 (1.12 %, 61.645 ± 0.004 to 62.346 ±0.004 mg/kg) because Lead (Pb), cadmium (Cd), zinc (Zn) and copper (Cu) are accumulated in earthworms body under some environmental conditions (Cortet, 1999). It is presumed that in many cases zinc is the critical toxic metal for these organisms (Spurgeon and Hopkin, 2000). According to Gheisari *et al.* (2010), found that, if MSW was properly pretreated for a period of 21 days through conventional composting, the pretreated waste could then be readily used by *Eisenia fetida* in vermicomposting without any addition of additives such as cow dung. Lodha (2007), reported that a better quality of compost from MSW could be generated using the vermicomposting technique. Tognetti *et al.* (2007) also studied that the quality improvement of municipal organic waste with biosolids by vermicomposting was limited, because it did not affect the concentrations of organic matter and total nitrogen as compared with traditional composting. Vermicomposting is a viable andcompletely feasible option foruse at household level, provided it is acceptable to family members to handle the worms and subsequently remove wormcasts (Ravi *et al.*, 2009).

The concentration of nickel (Ni) accumulated inside the body tissue of *Eisenia foetida* significantly increased when put inside the vermibed consisted of different animal dungs with kitchen wastes in different rations (1:1, 1:2 and 1:3) after vermicomposting. The presence of significantly higher level of Ni was observed in the combination of buffalo dung with kitchen waste in the ratio of (1:1) (11.04 %, 6.339 ± 0.002 to 7.126 ± 0.004 mg/kg). The absence of feeding and casting activity of earthworm in kitchen waste during the first 10 days of vermicomposting was reported by some researchers (Chaudhuri *et al.*, 2000; Chaudhuri and Bhattacharjee, 2002). According to Kalamdhad *et al.* (2009) found that vermicomposting using *Eisenia foetida* was more suitable than the windrow method to transform pre-composted vegetable waste, dry tree leaves and cow dung into finer and better-quality compost within 20 days. The presence of high moisture content in kitchen waste may also decrease the number and weight of earthworms, because the movement of air through the available pore spaces in the substrate is restricted by the presence of excess water

(Singh *et al.*, 2004; Adi and Noor, 2009). The organic waste (market, municipal, household) are dumped indiscriminately or littered on the streets causing environmental deterioration. Biological processes such as composting followed by vermicomposting to convert vegetables waste (as valuable nutrient source) in agriculturally useful organic fertilizer would be of great benefit. The vermicompost have comparatively high value of nutrients such as calcium, sodium, magnesium, iron, zinc, manganese and copper which can serve as a natural fertilizer giving high yield of plants. The vermicomposting has proved very effective and efficient for developing compost from vegetable waste (Jadia and Fulekar, 2008).

The concentration of cadmium inside the tissues of *Eisenia foetida* was observed to be significantly increased in after the vermicomposting of different combinations of animal dungs with municipal solid waste (MSW) in the ratio of 1:1, 1:2 and 1:3. The significantly higher value of cadmium inside *Eisenia foetida* was observed when the earthworm was kept in the vermibed containing cow dung with municipal solid waste in the ration of 1:2 (1.12 %, 61.645 ± 0.004 to 62.346 ±0.004 mg/kg) whereas, the concentration of Cd accumulated inside the body tissue of *Eisenia foetida* significantly increased when put inside the vermibed consisted of different animal dungs with kitchen wastes in different ratios 1:1, 1:2 and 1:3 after vermicomposting. The presence of significantly higher level of Ni was observed in the combination of horse dung 1:1 (0.48 %, 61.645 ± 0.004

to 61.945 ± 0.003 mg/kg). Beyer (1981) reported that earthworms can take up and accumulate in their tissues heavy metals such as cadmium, mercury and gold, when living both in non- contaminated and contaminated environments (Helmke *et al.*, 1979). The accumulation of heavy metals in the body tissue of earthworm *Eisenia foetida* significant increase in the metals concentration in their body tissue during vermic-activity after final vermicompost. However, earthworms can function more effectively in vermicomposting when the ventilation is good and the material they are living in is relatively porous and well aerated. The proper aeration in vermicomposting systems could be achieved by periodic turning or mechanical mixing of the substrate biomass (Garg and Gupta, 2009). Selladurai *et al.* (2009) studied that the municipal solid waste and its stern pollution are an alarming problem that needs immediate attention. Efforts were made to explore the potential of epigenic earthworms *Eudrilus eugeniae* and *Eisenia foetida* in biological management of municipal sludge collected from various parts of study area using vermitechnology. Observed data suggest considerable decrease in toxic metals compared with the initial levels, the concentrations of heavy metals including Zn, Fe, Cu, Pb, Mn, Cr, Ni and Co has decreased noticeably in *E. eugeniae* treated municipal sludge. Similar effect was also observed in *E. fetida* as well, when compared to *E. fetida* and *E. eugeniae* latter was found to more effective in reducing the metal toxicity of the sludge; in addition, the earthworm enriches the sludge with various nutrients essential for plant and microbial growth.

The concentration of arsenic accumulates in the body of earthworm *Eisenia foetida* was observed to be significantly increased in after the vermicomposting of different combinations of animal dungs with municipal solid waste (MSW). The significantly higher value of As inside the *Eisenia foetida* was observed when the earthworm was kept in the vermibed containing buffalo dung with municipal solid waste in the ration of 1:3 (1.58 %, 9.450 ± 0.003 to 9.602 ± 0.005 mg/kg). According to Singh *et al.* (2004) stated that the 90% moisture content led to anaerobic conditions on the 12th day of vermicomposting of hostel kitchen waste. According to Nair *et al.* (2006) a combination of thermocomposting and vermicomposting of kitchen waste will improve the efficiency of treatment, they found that thermocomposting for 9 days prior to vermicomposting for 75 days was helpful in waste and moisture stabilisation as well as mass and pathogen reduction. Kaviraj and Sharma (2003) also found that the earthworms were able to vermicompost local MSW, with the maximum carbon reduction being achieved by *E. fetida* (44.3%) and *Lampito mauritii* (44.1%) after 42 days of vermicomposting. Also, vermicomposting (for up to 80 days) of previously composted and shredded municipal organic waste by *E. fetida* led to products with higher organic matter, total nitrogen and available nutrient concentrations, probably owing to the joint effect of earthworm activity and a shorter thermophilic phase (Tognetti *et al.*, 2007).

The concentration of arsenic accumulated in the body of *Eisenia foetida* significantly increased when put inside the vermibed consisted of different animal dungs with kitchen wastes in different rations 1:1, 1:2 and 1:3 after vermicomposting. The presence of significantly higher level of arsenic was observed in the combination of buffalo dung with kitchen wastes in the ratio of 1:3 (2.05%, 9.450 ± 0.003 to 9.648 ± 0.002 mg/kg). A similar phenomenon was reported by Kristiana *et al.* (2005) observed that a mixture of earthworms (*Lumbricus rubellus, Eisenia foetida* and *Perionyx excavatus*) produced the best vermicompost during vermicomposting of kitchen waste that was mixed with coffee grounds and cow dung. Adi and Noor (2009), studied that the quality of vermicompost could be enhanced when kitchen waste was vermicomposted via *Lumbricus rubellus* together with coffee grounds. Suthar and Singh (2008) used two epigeic earthworms, *Perionyx excavates* and *Perionyx sansibaricus*, to break down household waste under laboratory conditions. On the other hand, Tripathi and Bhardwaj (2004) reported that the use both epigeic earthworm *Eisenia foetida* and anecic *L. mauritii* to decompose kitchen waste that was amended with cow manure. They found that *Eisenia foetida* produced moderate mineralisation and higher decomposition rates with moderate breeding. In many western temperate countries, *Eisenia foetida* is a favourable species for vermicomposting, and it is also preferred by Indian researchers for vermicomposting, together with *Eudrilus eugeniae* (Kale, 1997). Although epigeic earthworms such as *Eisenia foetida* are capable of converting all biodegradable MSW into manure, they are of no significant value in modifying the structure of soil, whereas anecic earthworms such as *Lampito mauritti* are capable of both consuming organic waste and modifying the soil structure (Kaviraj and Sharma, 2003). The total metals was not accumulating by the earthworm *Eisenia foetida* after vermicomposting with respect initial feed mixture to prepared vermicompost due to the heavy metals.

There was significantly decreased heavy metals (Co, Cr, Pb, Ni, Cd and As) concentration observed in the soil and in the soil with vermicompost of different animal dungs (buffalo, cow, goat, horse and sheep) as well as after inoculation of the earthworm *Eisenia foetida* before sowing and after harvesting the crops. Simultaneously, the heavy metals were estimated in the seeds of crop before sowing and in the grains of crop after its harvesting. The earthworm *Eisenia foetida* was responsible for the accumulation of heavy metals from different combination of soil with vermicompost of different animal dungs. It implies that the earthworm *Eisenia foetida* is a suitable species for vermicomposting that accumulates the heavy metals from the soil. Wen *et al.* (2004) reported that the water extractible Cu, Pb and Zn increased in soil inoculated with *Eisenia foetida* in uncontaminated soil. In fact, soils treated with vermicomposts (from paper waste or food waste) show significant increases in microbial biomass nitrogen, dehydrogenase activity and orthophosphates in comparison with soils treated with inorganic fertilizer, where the former may have influenced plant growth indirectly (Arancon *et al.*, 2005). The maximum amount of Co was observed to decrease in the combination of soil with cow dung vermicompost inoculated with earthworm *Eisenia foetida* (48.21 % decreased, conc. 4.352±0.002 to 2.254±0.006 mg/kg) (Table 20). Arancon *et al.* (2004) reported that the use of earthworms in MSW processing and application of vermicomposts in soil have raised concerns over the concentration of heavy metals in MSW. Edwards and Bohlen (1996) reported that during vermicomposting, they are capable of degrading organic matter into fine particulate material or vermicompost that is rich in nutrients and can be used commercially as a plant growth medium and soil amender.

The concentration of cobalt was also observed in maize (*Zea mays*) grain before sowing and after harvesting grown in different combinations of soil with different animal dungs inoculated with earthworms. The maximum decrease in the concentration of Co was 100 % concentration from 0.068±0.003 mg/kg to below detection limit (BDL). Ruiz *et al.* (2009) studied that the earthworm *Eisenia fetida* on the uptake of Pb, Zn, Cd and Cu from soils polluted by mining activities using maize (*Zea mays*) and barley (*Hordeum vulgare*). Arancon *et al.* (2003) studied that the vermicomposts, produced commercially from cattle manure, market food waste and recycled paper waste, were applied to small replicated field plots planted with tomatoes

(*Lycopersicon esculentum*) and bell peppers (*Capsicum anuum grossum*) at rates of 10 tonnes/hectare to 20 tonnes/hectare in 1999 and at rates of 5 tonnes/hectare to 10 tonnes/hectare in 2000. The earthworm *Eisenia foetida* was responsible for the accumulation of heavy metals from different combination of soil with vermicompost of animal dungs.

Wen *et al.* (2004) observed that the earthworm treatments significantly ($P<0.1$) increased the yield of wheat shoots and roots by 1.5–1.9 and 1.2–1.5 times, respectively, in the five soils. The heavy metal content of roots increased in the presence of earthworms by 40%, 60%, 50%, 30%, 50%, 100%, and 120% for Cr, Co, Ni, Zn, Cu, Cd, and Pb, respectively, in respect to the values without earthworms. Significant increases were also found for the Zn, Cu, and Cr concentrations ($P <0.05$), and for the Ni and Pb concentrations ($P <0.1$) of wheat shoots. Earthworm treatments increase heavy metal contents of wheat to a different extent for different soil types.

The maximum concentration of Co was significantly 35.3 % increased in inoculated earthworm body when the combinations of soil with horse dung vermicompost. The observed difference in metal contents in vermicomposted material for different treatments should be related to the different rates of metabolic physiology for metals. Organic matter ingested by earthworms undergoes chemical and microbial changes when it passes through the gut part of the organic matter is digested, and pH and microbial activity of the gut contents increases (Edwards and Bohlen, 1996).

The concentration of Cr significantly decreased in the soil and soil with vermicompost of different animal dungs and inoculated with earthworm *Eisenia foetida* in its different combinations after harvesting maize crop. The maximum amount of Cr was observed to 37.61 % decrease in the combination of soil with goat dung vermicompost inoculated with earthworm *Eisenia foetida*. According to Suthar (2009) the actual process of stabilisation of organic material through the joint action of earthworms and micro-organisms. Microbes are responsible for the biochemical degradation of organic matter, while earthworms are the important drivers to condition the substrate and alter the biological activity. The vermicompost is a rich source of beneficial micro-organisms and nutrients (Paul, 2000) and is used as a soil conditioner or fertilizer (Rock and Martnes, 1995; Hattenschwile and Gaser, 2005). Increase in crop yield, soil nutrients status and nutrients uptake was reported due to application of vermicompost (Singh and Sharma, 2003; Roberts *et al.*, 2007).

The concentration of Cr was also observed in maize (*Zea mays*) grain before sowing and after harvesting grown in different combination of soil with different animal dungs inoculated with earthworms. The Cr was 50.70 % decrease in the maize grain in the combination of soil with vermicompost of horse dung inoculated with earthworm. The amount of chromium was accumulated by maize plant when sown in the soil 14.70

% decreased as compared to the soil with horse dung vermicompost along with earthworm *Eisenia foetida*. High rate of Cd accumulation was typical for such plants as *Cirsium arvense*, *Trifolium pratense*, *Atriplex hastata*, *Tussilago farfara*, *Capsella bursapastoris*, *Artemisia vulgarus* and *Rumex confertus*. Cadmium maximum content was registered among *Cirsium arvense* in test plot No. 4 and amounted 3.09 mg/kg of dry mass (Tatyana *et al.*, 2012).

The maximum concentration of Cr was significantly increased in inoculated earthworm body when the combinations of soil with cow dung vermicompost (2.51 %, 101.517±0.003 to 104.134±0.005 mg/kg) after the harvesting of maize crop. In general, mechanical turning of solid wastes at periodic intervals is not essential during the process of vermicomposting. This is due to the movement of earthworms through the solid wastes that assists in breaking down and aerating the materials, providing ideal conditions for microbes to flourish, which in turn accelerates the conversion rate of organic matter to vermicompost (Kwon *et al.*, 2009). Hopkin (1989) suggested that the earthworms have specific capacity to regulate metals, particularly trace metals, in their bodies, and accumulation and regulation mechanisms could be species-specific. There is great possibility of entering of toxicants via earthworms to organisms occupying different trophic levels, if proper management of inoculated worms, Earthworms caused significant impacts on contents of plant nutrients in sludge during vermicomposting process. The vermicomposted sludge showed a considerable amount of some important plant nutrients. The nutrient profile of ready product suggests its potential use in land restoration practices. Earlier studies have revealed that vermicomposting could be an appropriate technology to convert negligible community wastes into value-added products. In general, the vermicomposting process refers to feeding of earthworms on organic matter and microbial degradation; therefore, both earthworms and microorganisms play an important role in vermicomposting system. This biological mutuality accelerates the organic matter mineralization process. Vermicomposted material showed a considerable increase in content of important plant nutrients: total N, available P, and exchangeable cations . Data suggested that mineralization rate was higher in bedding those that contained lower proportion of sludge. It is concluded that the rate of mineralization could be decreased due to increasing concentration of metals in higher treatments (those treatments that contained more proportions of sludge). It is concluded that higher concentrations of sludge in vermibed affected theproduction rate of microbial enzymes, closely associated with sludge mineralization process (Suthar and Singh, 2008).

The maximum amount of Pb was observed to 57.58 % decrease in the combination of soil with sheep dung vermicompost inoculated with earthworm *Eisenia foetida* (7.791±0.003 to 3.305±0.006 mg/kg). Vermicomposting of sewage sludge using spent mushroom compost from Pleurotus sajor-caju as feed material was conducted to determine the effect on the concentration of heavy metals, namely Cr, Cd, Pb, Cu, and Zn. Previous studies have reported the feasibility of brandling worms, *Eisenia foetida*, for vermicomposting SS, whereas we conducted vermicomposting by employing red worms, Lumbricus rubellus, with a combination of different percentages of SS and spent mushroom compost (SMC) for 70 days subsequent to 21 days of precomposting. The vermicompost produced in treatments with a low percentage of SS were fine in texture, dark incolour and odourless in contrast to the initial physicalcharacteristics. Results indicate that growth in earthworm numbers and biomass gain was maximum at 25:75 (TD) of SS: SMC compared to other treatments with 5 and 8- fold increases, respectively. The heavy metals contained in vermicompost were 0.25 ~ 11.57-fold higher than the initial concentration due to mineralization and excretion of non-accumulated heavy metals existent in the earthworms' gut, which were present prior to treatments. Even so, the concentration was below the limits set by EU and US biosolid compost standards and safe to be utilized as a biofertilizer and soil conditioner (Bakar *et al.*, 2011; Nair *et al.*, 2006).

The maximum amount of Ni was observed to decrease in the combination of soil with goat dung vermicompost inoculated with earthworm *Eisenia foetida* (74.9 % decreased, conc. 3.191±0.004 to 0.801±0.003 mg/kg), followed by soil with sheep dung vermicompost inoculated with the earthworm (73.9 % decrease, conc. 3.196±0.002 to 0.835±0.003 mg/kg). Chhotu *et al.* (2008) reported that the vermicompost can be used to remediate metals contaminated sites because it binds metals and increase uptake by providing nut rients such as sodium, magnesium, iron, zinc, manganese and copper which can serve as a natural fertilizer giving high yield of biomass and microbial consortium helped the overall growth of the sunflower plant. The use of vermicompost amended soil would be effective to remediate the heavy metals from contaminated environment. There was a substantial accumulation of Ni by the earthworms *Eisenia foetida*, suggesting that vermicomposting is an efficient method for reducing metals pollution in the soil (Macki *et al.*, 2009).

The concentration of Cd significantly decreased in the soil and soil with vermicompost of different animal dungs and inoculated with earthworm *Eisenia foetida* in its different combinations after harvesting maize crop. The maximum amount of Cd was observed to 63.21% decrease in the combination of soil with sheep dung vermicompost inoculated with earthworm *Eisenia foetida*, whereas the concentration of Cd was also observed in maize (*Zea mays*) grain before sowing and after harvesting grown in different combination of soil with different animal dungs inoculated with earthworms. The maximum decrease in the concentration of Cd 86.43 % (conc. from 0.140±0.003 to 0.019±0.003 mg/kg) was observed in the combination of soil with vermicompost of sheep dung inoculated with earthworm. Cadmium is not a vital element for plants functioning it ranks among extremely toxic elements. Having equal concentrations with other HM it produces 2 - 20 times more serious negative impact on the living organisms (Bityutsky, 2005). The earthworm *Eisenia foetida* was suitable species for the decreased concentration of Cd metals from the soil and have ability to accumulate in their body tissue.

The concentration of cobalt was also observed in pea (*Pisum sativum*) grain before sowing and after harvesting grown in different combination of soil with different animal dungs inoculated with earthworms. The maximum decrease in the concentration of Co 100 % decreased, conc. 0.538 ± 0.004 mg/kg to BDL (below detection limit) was observed in the combination of soil with vermicompost of sheep dung inoculated with earthworm. Heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, and Zn are plant essential metals, and most plants have the ability to accumulate them (Jadia and Fulekar, 2009). According to Pączka and Kostecka (2013) studied that the possibility of using the vermicompost produced from kitchen waste by earthworms *Eisenia fetida* which benificial to growth and productivity of peas (*Pisum sativum*) crop. The earthworm is a potentially important agent, either directly or indirectly, modulating the transfer of inorganic and organic toxicants through community's resident on contaminated soils (Cooke *et al.*, 1992), and for many years it has been considered as an interesting biological indicator of many metals in soils (Gish and Christepnsen, 1973; Udovic *et al.*, 2007; Suthar *et al.*, 2008).

The concentration of Cr significantly decreased in the soil and soil with vermicompost of different animal dungs and inoculated with earthworm *Eisenia foetida* in its different combinations after harvesting rice (*Oryza sativa*) crop. The maximum amount of Cr was observed to decrease in the combination of soil with horse dung vermicompost inoculated with earthworm *Eisenia foetida* (17.20 % decreased, conc. 10.324 ± 0.005 to 8.548 ± 0.008 mg/kg) as well as the concentration of Cr was also observed in rice (*Oryza sativa*) grain before sowing and after harvesting grown in different combination of soil with different animal dungs inoculated with earthworms. The maximum decrease in the concentration of Cr 92.35 % was observed in the combination of soil with vermicompost of horse dung inoculated with earthworm. Mishra *et al.* (2005) stated that vermicomposted MSW (up to 250 kg ha^{-1}) caused a significant increase in growth parameters, germination of seeds and chlorophyll content of rice (*Oryza sativa*).

According to Kumar *et al.* (2008) the heavy metals may enter the MSW stream from a variety of sources such as industrial discharges, pharmaceutical waste, insecticides, batteries, motor oils, paint chips, electrical and electronic consumables, house dust, lead foils, vehicular emissions and other urban activities. Vermi-composting and Vermi-agroproduction is self-promoted, self-regulated, self-improved and selfenhanced, low or no-energy requiring zero-waste technology, easy to construct, operate and maintain. It excels all ‘bio-conversion’, ‘bio-degradation’ and ‘bio-production’ technologies by the fact that it can utilize organics that otherwise cannot be utilized by others. It excels all ‘bio-treatment’ technologies because it achieves greater utilization than the rate of destruction achieved by other technologies. It involves about

100-1000 times higher 'value addition' than other biological technologies (Appelhof, 1997, 2003). Arancon *et al.* (2005) also observed that the vermicompost from food waste or paper waste increased the growth and yield of peppers significantly, including increased leaf area, plant shoot biomass and marketable fruit weight and decreased yield of non-marketable fruit. vermicomposts. The developed vermicompost from this technology has high nutrient values (offer a whole range of socio- economic benefits such as saving time, electricity, man power for farmers of the developing country). Composting and vermicomposting are bioxidative processes that stabilize the organic matter. Composting includes a thermophilic phase during which labile organic matter degradation occurs and pathogens are effectively reduced. Vermicomposting includes coupled activities of earthworms and microorganisms, stabilizing the organic matter and does not involve a thermophilic phase (Tognetti *et al.*, 2005).

The concentration of lead significantly decreased in the soil and soil with vermicompost of different animal dungs and inoculated with earthworm *Eisenia foetida* in its different combinations after harvesting maize crop. The maximum amount of Pb was observed to 32.72 % decreased in the combination of soil with goat dung vermicompost inoculated with earthworm *Eisenia foetida* (conc. 4.966 ± 0.012 to 3.341 ± 0.008 mg/kg) (Table 28). The difference among different metals could be related to the difference in specific metal regulating mechanism in earthworms. Recent studies revealed that accumulation of metals, especially Cd, Cu and Zn, in earthworms is mainly due to the binding of metals by metallothioneins (Kagi and Kojima, 1987).

The concentration of lead was also observed in rice (*Oryza sativa*) grain before sowing and after harvesting grown in different combination of soil with different animal dungs inoculated with earthworms. The maximum decrease in the concentration of Pb 89.80 % was observed in the combination of soil with vermicompost of goat dung inoculated with earthworm *Eisenia foetida*. However, there was a consistent trend of higher metals in tissues of earthworms. Disposal of municipal solid wastes and household hazardous wastes including batteries, paint residue, ash, treated woods and electronic fire wastes increase the heavy metals in soil (Pare *et al*., 1999; Macki *et al*., 2009).

According to Morgan and Morgan (1992) difference species can show a considerable difference for tissue's metal contents mainly due to difference in their food selectivity and metabolic physiology. Earthworms play a major role in the organic litter transit from the surface to inner layer of the soil; they pulverize the organic matter with soil particles and depart their castings throughout the soil profile. Burrowing activities of earthworms increase the water holding capacity along with providing optimum aerobic growth conditions for bacteria and plant roots (Wurst *et al*., 2003). Earthworms are burrowing detritivores that function as primary decomposers and that play an important role in the formation of soils, and mixing of their organic and inorganic fractions (Laskowski *et al*., 1998; Grelle and Descamps, 2000). In addition to chloragogenous tissue, the intestinal epithelium also exhibits a great ability for metal accumulation as Morgan *et al.* (2002) found for another oligochaete species, *Dendrodrilus rubidus*.

In conclusion, it can be stated that *Eisenia foetida* is a suitable species which can decreased the heavy metal contents present in soil and different waste materials by accumulating in their body tissue. In the present study cobalt (Co) was observed significantly ($P<0.05$) decrease in the combination of buffalo dung with municipal solid wastes (1:1) and also observed in cow dung with municipal solid wastes in ratio (1:3). The concentration of chromium (Cr) was observed in the combination of buffalo dung with municipal solid wastes (1:3). The nickel (Ni) was decreased in the all combination of different animal dung with municipal solid wastes in the level of BDL (below detectible limit) during vermic-activity which the preparation of vermicompost by earthworm *Eisenia foetida*. There was decreased concentration of cadmium (Cd) obtained from buffalo dung with municipal solid wastes (1:3). The arsenic (As) concentration was observed significantly ($P<0.05$) decreased in the combination of horse dung with municipal solid wastes (1:3). The chromium (Cr) and nickel (Ni) were significantly ($P<0.05$) decreased in the combination of soil with goat dung. The lead (Pb) concentration was observed in the combination of soil with buffalo dung and cadmium (Cd) was also observed in the combination of soil with sheep dung. The cobalt (Co) and arsenic (As) were significantly decreased in soil before sowing the maize grain of soil in the combination of soil with cow dung in soil due to inoculation of earthworm *Eisenia foetida* in maize (*Zea maize*) crop field. The heavy metals (Co, Cd and Pb) were observed significantly decreased in the combination of soil with cow dung in soil due to inoculation of earthworm *E. foetida activity* in pea (*Pisum sativum*) crop field. The heavy metals (Co, Cr, Pb, Ni, Cd and As) concentration were significantly ($P<0.05$) decreased in different plant seed of maize (*Zea maize*), wheat (*Triticum aestivum*), rice (*Oryza sativa*) and also observed in pea (*Pisum sativum*) crop. The cobalt (Co) was observed significantly decreased in the combination of soil with cow dung. The chromium (Cr) was observed significantly decreased in the combination of soil with horse dung. The lead (Pb) was decreased in maize grain after harvesting from the combination of soil with buffalo dung whereas, the nickel (Ni) and cadmium (Cd) were significantly decreased the metals concentration in maize grain after harvesting from the combination of soil with goat dung. The heavy metals (Co, Cr, Pb, Ni, Cd and As) concentration were significantly ($P<0.05$) increased in earthworm *E. foetida* body from agricultural field of maize (*Zea maize*), wheat (*Triticum aestivum*), rice (*Oryza sativa*) and also observed in pea (*Pisum sativum*) due to the accumulation of these metals in their body tissue. These toxic metals were remediated from preparation of vermicompost as well as the cultivated field soil due to the accumulation of metals in their earthworm (*E. foetida*) body. Through vermicomposting different wastes can be converted into rich organic manures. The use of vermicomposts in crop field enhanced the plant growth and productivity. The inoculation of earthworm *E. foetida* in crop fields can decompose the different wastes and plough the soil. So we can say that the vermibiotechnology is a useful process for the management of the heavy metals from soil and different wastes thus protecting the human health and environment.