"The plough is one of the most ancient and most valuable of man’s inventions; but long before he existed the land was in fact regularly ploughed by earthworms. It may be doubted whether there are any other animals which have played so important a part in the history of the world, as have these lowly organized creatures" ---- Charles Darwin (1881).

Earthworms have originated about 600 million years ago during the Precambrian era and they have been the silent witness of plant and animal evolution through several millions of years (Glaessner et al., 1969). Michaelsen (1903) and Arldt (1908) estimated the origin of earthworms much earlier during the upper Jurassic and upper Triassic periods respectively. On the basis of their habitats and food and feeding habits, Stephenson (1930) believed that they appeared in the Cretaceous when dicotyledonous plants came into existence. Earthworms have been recognized as 'friends of the farmers' since thousands of years. The pharaoh of ancient Egypt, Cleopatra (69 BC to 30 BC) was acknowledged their value and she declared them sacred in 50 BC. Aristotle (384-322 BC) identified the role of earthworms in turning over soil from deeps of the earth and called them "intestines of the earth".

Earthworms are an integral component of complex soil ecosystem to play major role in nutrient recycling. Since Darwin, their tremendous role in the aeration, formation, structure, texture, water seepage and fertility of the soil has been greatly respected. Later on their importance was reduced due to advent of chemical fertilizers and pesticides, resulting destruction of earthworms fauna in the soil. Green revolution, using chemical fertilizers and pesticides and modern tools of agriculture, was need of that time to provide enough food to human populations. Exorbitant and non-judicious use of them disturbed the balance of nature and they are held responsible for environmental issues including pollution, greenhouse effect, depletion of ozone layer, global climatic changes and hazards to biodiversity and human beings. Now emphasis is given to environment friendly technologies, waste recycling and sustainable development. In recent past
interest in earthworm biology was revived due to increasing awareness towards nature oriented bio-technologies for sustainable development so as environmental quality can be improved by decreasing pollution and its consequences. The contribution and very diverse roles of earthworms in human life has been poorly recognized in modern human civilization. In fact earthworms are proving themselves to be a great ‘biological resource’ for mankind as a waste decomposer, bio-fertilizer manufacturer, landclaimer, protein producer, food source, vitamin source, natural detoxicant as bio-indicator of pollution, as bait, as industrial raw materials and above all as drug source. Earthworms can be used as bio-indicators of pollution because they are highly resistant to industrial effluents, pesticides and their residues and heavy metals. They have capacity to accumulate pesticides and heavy metals such as cadmium, cobalt, mercury, zinc and lead in their tissues. They reduce the effects of environmental and human health hazards of such toxic chemicals through mechanisms of detoxification, bio-accumulation, increasing mucus concentration, restricting their movements and increasing the reproductive potential up to certain concentration levels (Tripathi and Bhardwaj, 2003). Various earthworm species like *Lumbricus terrestris*, *L. rubellus* and *D. rubida* can bio-accumulate heavy metals in their tissues at higher concentration (Sinha et. al., 2010). World human population is increasing day by day and tremendous amount of biological residue (waste) is produced that is causing serious problems of disposal and management. Extensive land areas are required for disposal (dumping and land-filling) of waste. During or after disposal, large amount of waste reaches to the water bodies around the human population, leading to contamination of soil and groundwater. Emission of toxic and obnoxious gases and leachates from the dumping sites enhances the risk of air, soil and water pollution and hazards to human health. In majority of places in India, a large amount of waste is burned (incinerated) just to get it rid off. It is happening everyday and everywhere and no attention is being paid to check it. It is obvious that burning of biomass is not safe and burning of plastic and other synthetics is even worse. Several solutions of safe and eco-friendly waste disposal and management have been tried and recommended but each one has some or the other drawbacks.
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Vermi-biotechnology can be the right choice/approach to convert different types of organic waste into vermicompost because selected types of earthworms are able to consume them as food with the help of symbiotic microorganisms. This valuable vermicompost can be used as a major tool for sustainable agriculture, organic farming and environmental conservation programmes. Polycyclic Aromatic Hydrocarbons (PAHs) widely occur in oil, coal and tar deposits, cooked food, cooked meat and smoked fish. These recalcitrant hydrocarbons are by-products of fossil fuel or food burning. They are important class of pollutants, are detrimental to human health and are very difficult to remediate. It has been reported that earthworms like Lumbricus rubellus and Eisenia fetida can efficiently degrade such PAHs, phenanthrene, fluoranthene, anthracene, benzo(a)pyrene and phenanthrene (Contreras-Ramos et al., 2006; Ma et al., 1995). Asphaltenes, the high molecular weight hydrocarbons, found in oil contaminated soil can also be eliminated by earthworms during soil mineralization process (Tomoko et al., 2005, Martin-gil et al., 2007, Ceccanti et al., 2006). Similarly greater losses of toxic and persistent organic pollutants Polychlorinated Biphenyls (PCBs) were reported from the contaminated soil treated with earthworms as compared to the untreated soil (Singer et al., 2001).

In addition to the use of earthworms for bio-remediation and bio-monitoring of waste stuffs and environmental pollution, their role in alleviation in human health is also important. Vermicomposting practice has promise in improving community health due to its significance in reducing environmental pollution and suppression in population of pathogenic organisms and vectors of diseases. Vermicomposting units could also be exploited as source of useful by-products such as earthworm powder, worm meal, vermic protein to be used nutrient and medicinal resources. However, the significance of earthworms and vermiculture in improvement of human health has been poorly emphasized. The presence of a number of bio-active substances from earthworms has been demonstrated that have industrial and pharmaceutical importance. They are used as raw materials for rubber, lubricant, detergent, soaps and cosmetic industries and they are also used as animal and human food and for prevention and treatment of diseases.
Earthworms form a small but very important link in the chain of life. They are essential component of the food chain and energy cycle and are being eaten by a number of animals including invertebrates, fishes, amphibians, reptiles, birds and mammals including human beings, especially by tribal people in various parts of the world. Examples of traditional use of earthworms as human food and medicine are distributed over the globe. In New Zealand two types of earthworms, Kurekure and Whiti (known for their sweet and pleasant residual taste) were offered to elderly persons and given to dying person as the last food. Native tribes in Australia, New Zealand, Japan, China, New Guinea, Africa, South India have been cited for the use of earthworms as food (Best, 1902; Spencer and Gillen, 1904; Grottanelli, 1965; Julka, 1988; Ranganathan, 2006; Cooper et al. 2012). Lawrence and Miller (1945) were the first scientists who showed that earthworms contain sufficient amount of protein and hence are widely eaten up by animals. In USA and UK earthworms fed on sterilized filter paper are being utilized animal and even as human food (Senapati and Pani, 1984).

In Venezuela earthworms are prescribed, by the tribes, for pregnant women and mothers during first month of delivery as a primary source of proteins, fats and essential vitamins and as a gourmet food (Paoletti et al., 2003). These edible earthworm species were reported to contain significant amounts of calcium, iron, and other nutrients (Paoletti and Dufour, 2005). A number of workers have analyzed the constituents of different species of earthworms and it was found that the overall composition of earthworm tissues does not differ greatly from that of vertebrate tissues (McInroy, 1971; Schulz and Graff, 1977; Sabine, 1978; Yoshida and Hoshii, 1978; Mekada et al., 1979; Taboga, 1980; Graff, 1982). Dried earthworm powder consists of 60-70% protein, 6-11% fat, 5-21% carbohydrates, 2-3% minerals and a verity of vitamins including niacin, thiamine (B₁), riboflavin (B₂), pyridoxine (B₆), vitamin B₁₂, pantothenic acid, folic acid, biotin (Edwards, 1985). Earthworms contain special type of long chain fatty acids which cannot synthesized by non-ruminant animals in significant amounts (Edwards, 1985) and the quantity of saturated and unsaturated fatty acids was higher (32.66%) in *Eudrilus eugeniae* than in native earthworms of Philippines (26.94%) (Ang Lopez and Alis, 2005).
According to Sun et al. (1997) earthworms contain 78-79 g/L free amino acids and they contain a high concentration of important vitamins and minerals such as iron and calcium. Istiqomah et al. (2009) reported that both earthworms and earthworm meal contain a range of essential and non-essential amino acids. It fulfils Food and Agriculture organization of United Nations (FAO) and World Health Organization (WHO) standards, particularly in terms of lysine, methionine, cysteine and tyrosine, all of which are important components of human and animal feed (Singh and Rai, 1998).

In Philippines special dish, meatball is prepared with earthworms alone or with pork (Guerrero and Guerrero, 2006). It has also been stated that a food supplement “Eugeton” prepared from African night crawler Eudrilus eugeniae, has anticoagulant property. In African continent some people eat earthworms by knotting them on a stick and roasting over open fire (Cooper et al., 2012).

Live earthworms can be used as fish bait because of the easy availability in every climatic conditions of tropical, subtropical and temperate regions and they are easy to rear and culture at wide scale. Different species of earthworms, viz Dendrobaena veneta (Fayolle et al., 1997), Pheritima elongata (Bhawalkar, 1995, Singh, 1997), Megascolex megascolex (Munnoli, 2007) are used as fish bait. Earthworms can be converted into worm meal and vermicprotein for use as concentrated feed for fish poultry, cattle and pets. Eudrilus eugeniae has been successfully used for cattle feeding purpose in India and abroad. Edwards and Neiderer, (1988) and Kale, (1998) described the methods of preparation of worm meal. It has tremendous market in aquaculture systems for shrimps, carps, catfishes and tilapias. Earthworms and worm meal can become a replacement or supplement of traditional food and can also be given to protein deficient humans. Live earthworms, taken from vermicomposting units and enclosed in a porous plastic container, can be provided as healthy food to a variety of aquarium fishes (Agrawal, Unpublished).

Medicinal value of earthworms is known since thousand years as it is evident from history of ancient medicine from various parts of the world. In ancient Burma and Laos, smallpox victims were given bath with earthworms-soaked water for quick healing.
An earthworm broth (worms boiled with salt and onions and then filtered) had been prescribed to women who were very weak and had difficulty in nursing. In Iran, baked earthworms were eaten with bread to reduce bladder stones which were expelled after the meal. Earthworm powder was used to treat jaundice (Stephenson, 1930). According to historical records earthworms are useful in curing rheumatism also (Reynolds and Reynolds, 1972).

In Japan four kinds of drugs, antibiose, aphrodisiacs, antipyretics and antidotes are prepared from earthworms. In Indonesia an indigenous traditional medicine “Jamu” is used by low income people for treatment of dysmenorrhea (severe pain during menstruation) and post natal care of pregnant women. This medicine is prepared either by combining plant and animals components including earthworms. Rural population of Indonesia also use earthworms in blended, dried and fried form to treat typhoid fever, breast tumours, nose polyps, headaches, hypertension and as diuretics (Handayani et al., 2001).

From 1700s, earthworms were commonly used in European medical practice and regarded as highly diuretic, diaphoretic and analgesic (Dale, 1693; Rota, 2011). Earthworms were prescribed to treat apoplexy, convulsions, jaundice, dropsy and colic, and also to ease gout and pains in joints, ears and teeth. As an emollient, they were believed to increase milk production and to have wound healing properties. They were also prescribed against pneumonia and cystitis and were used to treat the bites of snakes and scorpions.

The famous ancient roman doctor ‘Pliny’ (AD 23 to AD 79) described the role of earthworms in his book Naturalis Historia. It was suggested dropping of dried earthworm oil into the ear provides considerable relief from toothache on the same side (Rufus Myer, 1994).

In Ayurvedic and Unani systems of medicine, the paste of dried worms has been recommended for treatment of wounds, chronic boils, piles, chronic cough, sore throat, teeth diseases, hernia, impotency, small pox, smooth delivery, gall bladder stone, hair
growth, diphtheria, jaundice, fevers, rheumatic pains, tuberculosis, bronchitis, facial paralysis, scorpion and snake bite etc. Some traditional Indian physicians (Vaidyas) prepare medicines using ashes and extracts (Bhasma and Kalpa) of earthworms for treatment of a number of diseases such as asthma, jaundice, infertility, cardio-protection and aphrodisiac. Medicinal properties of earthworms have been mentioned in several books and literature but, only few scientific investigations have actually been made (Agrawal, 2009).

In China earthworms have been used as drugs under the name “Jiryu” for thousands of years. Dried powders of earthworms have been given for the treatment of fevers, particularly related with lungs, as an antidote for poisons, for breathing difficulties, coughs and for excess water retention. In famous Chinese medical text “Ben Cao Gang Mu” (Compendium of Medicine), earthworms (Di-Lung) are described as "salty in taste, cold in property, efficacious in clearing the heart, invigorating blood circulation, dissolving stasis, opening up channels, curing stroke, hemiplegia and infantile convulsion". According to this ancient medical book “Compendium of Materia Medica” (1552-1593), Shen (2010) described that earthworm can be used for medicinal purpose in three different ways: (1) As powder by grinding the dry earthworms (2) As decoction and (3) As ash. In China, two kinds of earthworm viz. *Pheretima asiatica* and *Aporrectodea caliginosa trapezoids* are used for medicine. Chinese Pharmacology (1978) described earthworm medicinal preparation, in which earthworms are suffocated by grass ash, the ash is cleaned off, inner and outer parts of the earthworm are cleaned and then sun-dried. The recommended dose of dried earthworm is 9-18 grams. For fresh earthworms, the dose is 15-30 grams. The ointments and extracts prepared from earthworm tissues have also been used for the treatment of numerous diseases in Chinese culture (Shen, 2010).

The traditional use of earthworm formulations in treatment of cardiovascular disorders in China has been experimentally tested by Prof. Shen Homgran (1970) and a successful attempt has been made to demonstrate the possibility for development of an earthworm based medicine. In subsequent studies it was confirmed in other parts of the world and development of an orally effective, earthworm-based drug could be made.
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A strong fibrinolytic enzyme complex was isolated and purified from earthworm, *Lumbricus rubellus* (Mihara *et al*., 1983, 1989, 1991, 1992, 1993; Lu *et al*., 1988; Nakajima *et al*., 1993, 2000; Cong *et al*., 2000; Lin *et al*., 2000; Cho *et al*., 2004). Earthworm fibrinolytic enzyme (EFE) was demonstrated to include six proteolytic enzymes collectively named as lumbrokinase (LK). The enzyme(s) were reported to be fibrin specific, showing high activity in the presence or absence of plasminogen and are potentially very useful in treating thrombosis and dissolving intra vascular fibrin clots. As compared to other thrombolytic drugs, EFE is cheaper, easy to store (high stability) and effective through oral route (Mihara *et al*., 1991; Hahn *et al*., 1997; Nakajima *et al*., 2000). Therapeutic and preventive effects, of the drug, for thrombosis related diseases have been confirmed clinically (Jin *et al*., 2000). It was suggested that LKs might be used for prevention of cerebral infarction and in patients with a previous cerebrovascular ischemic event.

Successful attempts have been made to isolate, purify, characterize and crystallize EFE from other species of earthworms, *Eisenia fetida* (Yang and Ru, 1997; Wang *et al*., 2003), *E. andrei* (Lee *et al*., 2007). Instead of 6 enzymatic components, at least 7 have been found in these EFE and some differences in isoelectric points and their hydrolytic activity have also been demonstrated.

This wonder drug, in fact, is a serine protease enzyme complex (lumbrokinase) that acts as a potent thrombolytic agent. As compared to other chemical based fibrinolytic medicines, lumbrokinase is safer, stable, easy to store and is effective through oral rather than injectable route. This product is patented in several countries under different trade names; Plasmin Plus, Vermivit, Bolouake, LR-Zyme and is recommended to be used as a dietary supplement for those who require to improve their blood circulation, who suffer from acute and chronic cardiovascular difficulties, such as cerebral thrombus, cerebral embolism, pulmonary embolism, angitis, myocardial infarction, hyperplasminemia, platelet hypercoagulability, deep vein thrombosis, traveller's thrombosis, blood clots, tendency to develop thrombus. It is nontoxic, good for long term use without any side
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effects. This is an excellent example of successful development of an effective drug formulation with state of the art of bio-engineering technology.

Hori et al. (1974) have reported significant anti-pyretic activity in the tissue extracts of earthworms, *Lumbricus spencer* and *Perichaeta communissuina* in experimental rabbits and it was concluded that the effect might be due to monoamines. Nagasawa et al. (1991) have demonstrated inhibition of the growth of mammary tumours in mice by lombricine obtained from earthworms. The findings also indicate that the drug may also be of some importance for diabetic patients. Anti-tumor and anti-cancer properties of EFE and some other earthworm based bioactive molecules have been demonstrated using experimental animals and cultured cell lines (Chen, 2001; Chen et al., 2007; Lee et al., 2007). Further studies are required in this direction.

Earthworm-based drugs are not yet available in India and there are several complications and difficulties, including very high expenses, in their import. In India, Vermicomposting practice is slowly getting popularity and a variety of epigeic species of earthworms are being used for this purpose. A lot of research work has been carried out in Vermicomposting Centre of Department of Zoology, Jiwaji University, Gwalior since 2005 till today. Four species of epigeic earthworms (*Eudrilus eugeniae*, *Eisenia fetida*, *Perionyx excavates* and *Perionyx cressiseptatus*) are available in the Centre for Vermicomposting of different waste material including cattle dung, animal house waste, pea waste, paper waste, kitchen and food waste, temple waste, sewage sludge, garden waste. On the basis of research work done by Ph.D. and M.Phil. Research Scholars, it can be concluded that out of the four species, the performance of *Eudrilus eugeniae* is the best with regards of bio-number, biomass and vermicompost production at eco-climatic conditions of Gwalior. Only few studies have been done by Indian workers dealing with medicinal aspects of earthworms. Significant anti-inflammatory activity of crude and fractioned earthworm extracts has clearly been demonstrated in experimental rats in which paw oedema was induced by carageenan injection and cotton pellets implantation (Yegnanarayan et al., 1987, 1998; Ismail et al., 1992; Balamurugan et al., 2007).
Therefore the present study was planned to demonstrate pharmacologically significant biological activities of Nigerian composting worm, *Eudrilus eugeniae*. The main aim of the study was to explore pharmaceutical importance of *Eudrilus eugeniae*, which can serve as renewable source of resource from the vermicomposting units. Following are the objectives of the study:

1. To maintain a stock culture of the experimental earthworm, *Eudrilus eugeniae*.
2. To standardize the techniques for preparation of earthworm based samples (earthworm powder, extract, earthworm exudates).
3. To evaluate *in-vitro* anti-oxidant activity of earthworm samples.
4. To evaluate anti-inflammatory activity of earthworm samples.
5. To evaluate *in-vivo* anti-oxidant activity of earthworm samples.
6. To evaluate antipyretic activity of earthworm samples.
7. To evaluate anti-bacterial activity of earthworm samples.
8. To evaluate wound healing activity of earthworm samples.
9. To evaluate fibrinolytic, proteolytic and fibrinogenolytic activities of earthworm samples.