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RESEARCH ARTICLE

DISTRIBUTION OF EARTHWORM SPECIES IN HIGHLY POLLUTION PRONE SURROUNDING AREAS OF PARADEEP PHOSPHATE LIMITED, PARADEEP

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ABSTRACT

It has been a long time concern raised by ecologist and environmentalist over various threats from industrialization and urbanization which influence consistently terrestrial ecosystem and its biota from last two decades. Present investigation conducted to assess the species diversity of earthworms with their inhabiting soil physicochemical analysis to ascertain the range of impact under the hammer of Paradeep Phosphate Limited PPL pollution. Investigation revealed five earthworm species, Octochaetona *surensis*, Octochaetona *barkudensis,* Lampito *mauriti*, Perionyx *excavates* and Pontoscolex *corethrurs* belongs to three families, Octichaetidae, Megascolecidae and Glossoscolecidae. Perionyx *excavates* was the new arrival for this particular region of Odisha because it was not reported previously in this particular part of the district. Physicochemical assessment of soil ascertain that soil was highly contaminated with heavy metals such as Cd, Cr, Pb, Hg, Zn and As, which directly influence the earthworm population and its inhabiting number. Concentration of heavy metals was Cr>Cd>Pb>Hg>Zn>As>Cu>Ni. Particularly the around areas of PPL shows high contamination with heavy metals and very low pH (3.4) with high electrical conductivity (0.5) which is the consequence of high metallic deposit on soil. But the soil contamination levels gradually decreases with increasing distance from the plant.

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INTRODUCTION

Soil biota includes the organisms which spend all or some part of their life below ground. Soil organisms ranges from the myriad of invisible microbes, such as bacteria, fungi and protozoa, to the macro-fauna, for example earthworms, ants and termites. Macro fauna consists of species large enough (2 mm to 20 mm wide or visible to naked eyes) to disrupt the soil by their burrowing and feeding habit and has the most direct effect on soil properties or soil dwelling organisms. The most important taxa are Isopoda (woodlice), larger Diplopoda, earthworms, Isoptera (termites), Coleoptera (beetles), Diptera (flies), ants and molluscs. Earthworms are cosmopolitan and among the most ancient fauna of terrestrial ecosystem. They play most effective role in formation and maintenance of soil fertility. Earthworms have over 600 million years of experience as 'environmental managers' in the ecosystem and scientists all over the world very much concern about the role of earthworms as soil fertility improvers, waste managers, and plant growth promoters. They are both 'protective' & 'productive' for environment and society.

They protect the environment (by remedifying the contaminated soil, degrading the solid wastes and purifying wastewater) and also produce nutritive 'protein rich feed materials' for cattle and 'organic fertilizers' for the farmers to grow safe and chemical-free organic foods for society (Lee, 1985). Earthworms harbor millions of 'nitrogen-fixing' and 'decomposer microbes' in their gut. About 3500 earthworm species are known worldwide and it is estimated that at least another 3000 species have yet to be discovered and described (Fragoso *et al*., 1997). Increasing industrialization and pollution level becomes a serious issue for terrestrial ecosystem and its biota with respect to their environment. Pollution of the environment with toxic metals has increased dramatically since the onset of the industrial revolution as reported by Voegelan *et al*. (2003). Soil pollution by heavy metals such as cadmium, lead, chromium, copper and zinc is a problem of high concern. Rashad and Shalaby (2007) presented the fact that agriculture (irrigation with polluted waters, sewage sludge and fertilizer, especially phosphates, contaminated manure and pesticide and pesticide containing heavy metals), waste incineration, combustion of fossil fuels and road traffic, long range transport of atmospheric pollutants adds to the metals in the natural environment. Paradeep Phosphate Limited (PPL), one of the premier fertilizer company manufacturing phosphatic fertilizers

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Plate 1. Phosphogypsum deposited in the campus of PPL

Plate 2. Phosphogypsum looking like a mountain in PPL campus

Table 1. Earthworms found from the study area

Family	Genus	Species
Octichaetidae	Octochaetona	*Surensis* (Michaelsen)
		Barkudensis (Stephenson)
Megascolecidae	Lmapito	*Mauriti* (Kinberg)
	Perionyx	*Excavates* (Perrier)
Glossoscolecidae	Pontoscolex	*Corethrurs* (Muler)

Table 2. Physicochemical parameters of soil of the study area

Soil Parameters	Study sites				
	Inside plant	Site - A	Site - B	Site - C	Site – D(Control)
Temperature	30.37 ± 0.21	29.16 ± 0.54	29.14 ± 0.42	29.0 ± 0.54	25.01 ± 0.05
pH	3.4 ± 0.23	5.2 ± 0.11	5.7 ± 0.47	5.2 ± 0.12	7.3 ± 0.10
EC in mmhos/cm	0.5 ± 0.01	0.1 ± 0.10	1.2 ± 0.24	0.1 ± 1.41	0.1 ± 0.11
OC in %	0.42 ± 0.41	0.57 ± 0.11	0.14 ± 0.03	0.52 ± 0.32	0.71 ± 0.05
P kg/ha	155 ± 0.11	142 ± 0.87	114 ± 0.14	84 ± 0.27	58 ± 0.11
K kg/ha	420 ± 1.05	527 ± 0.14	390 ± 0.74	310 ± 0.11	202 ± 0.04
N kg/ha	15 ± 0.43	21 ± 0.05	21 ± 0.12	22 ± 0.24	41 ± 0.01

Values are mean ± SD

Table 3. Concentration of heavy metals (mg/kg) in soil

Heavy metals	Concentration (mg/kg) in study sites				
	Inside plant	Site - A	Site - B	Site - C	Site – D(Control)
As	8.82 ± 0.21	7.24 ± 0.62	6.4 ± 0.31	6.3 ± 0.13	1.02 ± 0.01
Cd	0.09 ± 0.001	0.08 ± 0.002	0.06 ± 0.01	0.05 ± 0.01	0.01 ± 0.01
Cr	0.53 ± 0.21	0.54 ± 0.01	0.22 ± 0.33	0.10 ± 0.16	0.03 ± 0.38
Hg	0.04 ± 0.13	0.01 ± 0.011	0.01 ± 0.11	0.006 ± 0.42	0.02 ± 0.41
Pb	0.68 ± 0.36	0.43 ± 0.16	0.44 ± 0.11	0.35 ± 0.25	0.03 ± 0.11
Ni	1.5 ± 1.21	1.61 ± 1.24	071 ± 0.62	0.46 ± 0.05	0.27 ± 0.04
Zn	14.32 ± 0.21	14.54 ± 0.57	13.25 ± 0.13	16.11 ± 0.05	10.54 ± 0.24
Cu	0.81 ± 0.52	0.87 ± 0.13	0.68 ± 0.72	0.59 ± 0.21	0.58 ± 0.11

Values are mean ± SD

situated in the port town of Paradeep (A major port of India) in the district of Jagatsinghpur in Orissa, India. It is the largest DI-Ammonium Phosphate (DAP) plant in Asia and covering more than 3000 acres of area. PPL produces about 1.2 million metric tons of DAP and other complex fertilizers (Ammonia Urea complex fertilizer) annually. Besides manufactured products and as a by-product it produces Phosphogypsum (PG). Currently the main concern is the growing pile-up of gypsum (calcium sulphate) from the industry because for every tone of sulphuric acid produced, 5 tones of PG generated as by-product. Now PG deposit area spreads over 100 hectares. Through wind and rain, PG spreads all over the surrounding areas and brings the terrestrial ecosystem in an alarming situation. PPL also go through a scanner by state pollution control board regarding spreading pollution in nearby areas due to complain filed by local people. The major step and prime focus towards this investigation is to assess the species diversity of earthworms and their distribution of population in an area which is very much prone towards the hammering impact of PPL pollution and its pollutant.

MATERIALS AND METHODS

Study area

Paradeep Phosphate Limited (PPL) located in port town of Paradeep of Jagatsinghpur, Odisha and lies between latitude 20° 16' 42"N and longitude 86° 38' 40"E. PPL came into existence in the year 1982. The town experiences maximum temperature in May-June (48 º C) before the arrival of monsoon and lowest (15 - 25 º C) towards December. As this part of the district belongs to coastal belt it is very much prone towards cyclone particularly in the month of October and November and experience maximum rainfall during the year. Types of soil found in this area are coastal alluvial, sandy loamy and clay loamy soils. Local folks are very much relying on agriculture like rice, sugarcane and betel.

Earthworm sampling and identification

Earthworms were collected by using TSBF (Tropical Soil Biology and Fertility) methodology i.e. conventional digging (25cm × 25cm × 30 cm) and hand sorting method was used for each quadrate[1]. Samples were collected from nearby areas of PPL and also from the PPL campus. Various habitats chosen for sampling was garden, cow dung dumped area, swampy area, sewage water canals, poultry waste dumped area, domestic waste disbursal areas and PPL plant pollutant dump area. Digging was done up to 30 cm depth from soil surface. And earthworms were collected by removing the soil carefully. Sufficient amount of soil also collected for physicochemical analysis. Soil samples were collected from the plant, 100 m (Site - A), 200 m (Site - B), 400 m (Site - C) and 5 km (Site – D, as Control) away from the plant and each samples carry four replicates. In laboratory collected Specimens were fixed in 30% alcohol for about 2 - 4 minutes for anesthetizing and then transferred to 10% formalin solution for permanent preservation. Earthworms were identified by ZSI (Zoological Survey of India), Kolkata.

Soil analysis

Collected soil samples analyzed for different physicochemical parameters. Soil temperature was measured by thermometer. Soil pH was measured by Digital pH meter (Misra, 1968). Organic carbon (OC) was determined after modification in Walkley and Black Method (Baker, 1976; Walkley and Black, 1934) and soil total nitrogen (N) by acid digestion Kjeldahl procedure as given by Anderson and Ingram (1993). Available phosphorus (P) by ammonium molybdate stannous chloride method (Sparling *et al*., 1985) and potassium (K) by atomic absorption spectrophotometer model Perkin-Elmer 200. Heavy metallic content analysis of sampled soil was done by using atomic absorption spectrophotometer Model Perkin-Elmer 403.

RESULTS

Table 4. Concentration wise heavy metal availability in soils

Metals	Availability in soil
	Cr>Cd>Pb>Hg>Zn>As>Cu>Ni

Results of the present study absolutely provokes the environmental ethics which is not going to entertain the environmentalist and farmers particularly resource limited smallholder farmers. Present investigation founds five species of earthworms (Octochaetona *surensis*, Octochaetona *barkudensis,* Lampito *mauriti*, Perionyx *excavates* and Pontoscolex *corethrurs*) belonging three families (Octichaetidae, Megascolecidae and Glossoscolecidae) but very much informal in population point of view although number and population varies season to season. It was advent of Perionyx *excavates* which was not previously noticed among the nine species reported in this part of Odisha by Julka and Senapati (1987). This species may call as an exotic one for this particular region and also for the district. Perionyx availability may be a consequence of evolution due to industrialization and rapidly changing environment or any logical or possible factors.

Soil physicochemical analysis may very much responsible for this new arrival. As it already reported that earthworms very much capable of bearing a wide range of soil physiochemical fluctuation and can accumulating large amount of toxic and heavy metals which may consequence arrival of new species as well as genus too. From pH to heavy metal availability, every physicochemical factors of soil putting a question how far soil health and its ecosystem sustain in such a pollution prone area. As the study sites an industrial area, the temperature recorded was 25 – 30 º C. Inside the factory highest temperature noticed while moving away from the plant temperature gradually decreases. pH recorded was acidic (3.4) inside the plant and it is considerably increases towards basic pH from site – A to D (Control). pH results were almost opposite when it compared to Stanly *et al*. (2014). This because of phosphate fertilizers are very much responsible for acidic soil as it easily leach to soil and then to water. Potash (K) and phosphorous (P) was high inside the plant and around areas of the plant i. e in site – A, B and C but soil K and P availability was observed moderate in site – D (Control). Maximum availability of P and K due to DAP fertilizer production with other fertilizers like ammonia and urea in the plant which amass in the soil. Soil nitrogen availability was not up to the mark in all sites including site – D (Control). It may due to climatic and industrial factors which may technically responsible. Soil electrical conductivity (EC) was very much towards lethal concentration inside factory while organic carbon (OC) percent was near about moderate but in site – D (Control) normal OC and EC observed. Industry and its surrounding areas are always been in a keen observation under SPCB (State pollution control board) as its impact level on soil and terrestrial ecosystem was many and major which going to hammer on biotic organism including humans also directly or indirectly. Heavy metals and its concentration level is always prone to soil and its physicochemical parameters. In this particular observation, eight heavy metals analyzed and it was observed that cadmium (Cd), chromium (Cr) and lead (Pb) concentration found higher than normal limit where arsenic (As), zinc (Zn) and mercury (Hg) was almost exceeding the par level but in Control or site – D, the concentration level was up to the mark according to world health organization (WHO) permissible standard around areas of PPL. Anyakora *et al*. (2013) revealed same concentration range of heavy metals except As in their stydy. High phosphate deposit also elevates the concentration of Arsenic as it is an anionic compounds.

Being cationic metals Cd, Cr, Pb, Zn, Hg etc. have the tendency to soluble with water in low pH which may consequence high metallic concentration in soil. Although, Cr is an essential element for humans, the hexavalent form is toxic, mutagenic and carcinogenic and Pb can lead mental lapse with elevated levels in soil and environment (National research council (1974)). This observation is also very much relevant with Stanly *et al*. (2014). Concentration of nickel and copper was very much normal level than others. According to Reilly (1991), heavy metals such as Cd, Cu, Pb, Ni and Zn can cause deleterious health effects in humans if exposed openly in soil and environment for a longer duration. The concentration levels of Cd recorded almost same compared with Madejon *et al*. (2002), Sezgin *et al*. (2003) and Oviasogie and Ofomaja (Oviasogie and Ofomaja, 2007). The high concentration of Zn is expected since it readily hydrates and combines with other metals to form its ores. Similar concentration level of Zn as observed in this study has been reported by Eddy *et al*. (2006). Previous investigations also reported that heavy metals like Zn and Cu are the main elements which inhibit the use of sludge for agricultural purpose (Su and Wong, 2003; Udon *et al*., 2004; Dai *et al*., 2007). The concentration of heavy metals decreases gradually with increase the distance from the factory and it was clearly reflex in site – D (control). Present investigation report was very much related with Olafisoye *et al.* (2013). Elevated levels of frequently noticed most heavy metals are always been observed in the soil, water and environment along side of industrial areas only because of their cationic nature. This cationic nature also solely responsible for maximum EC which can disturb the ionic balance in soil as well as in plants too.

DISCUSSION

Highest concentration of heavy metals (Cr>Cd>Pb>Hg>Zn> As>Cu>Ni) can be hazardous because of bioaccumulation in soil biota and increase biomagnifications in food chain. It hinders the health of soil dwelling organisms in a great extent. Even the low concentration of Cd in foods can affect and damage many organs like kidney, liver etc. of human and kidneys and liver can act as cadmium store house and release gradually to all body parts (Anyakora *et al*., 2013). It was also reported environmental exposure to cadmium can result cancer through inhalation (Nawrot *et al*., 2006). Once metals particularly heavy metals are introduced to the environment, they will remain for a longer duration because metals do not degrade like organic molecules. Mercury and selenium are only two metals which can be degraded due to transformation and volatized by soil micro organisms. However, in general it is very difficult to eliminate metals from the environment. Therefore we must be very keen, enthusiastic and abide about the industrial production of different materials including fertilizers and disposal of byproducts or pollutants. It was previously well documented about physicochemical composition of soil around cement and fertilizer companies and reported very high levels of Cr, Cd, Fe, Ca etc. and contamination levels decreasing dramatically with distance from the respective sites (Asubojo *et al*., 1991; Mandre *et al*., 1998). Behera and Patnaik (2016) revealed the lethality level of DAP fertilizer by-product (phosphogypsum) over earthworms and the impact of phosphogypsum considerably increases with increase in dose concentration and exposure period on earthworms and the phosphogypsum exposure consequence all the earthworm population dead in 30 days.

Influence of soil macro fauna particularly earthworm on soil properties plays a major, vital and deciding factor for resource-limited smallholder farmers, who depend on the soil natural fertility which directly relates biological productivity of the soil for their livelihoods. But high impact of industrialization hampers the relationship among soil, plant and human by exerting toxic materials on terrestrial ecosystem. However, relatively few of the comparative studies done on the effects of industrialization and its pollutants on soil biota specifically earthworm which really support and act as a friend for smallholder farmers and traditional agriculture. Agriculture and organic fertilizers must be allied with each other naturally to maintain an amity with environment and this harmony shouldn’t be abdicate due to anthropogenic interference. Civilized humans must agile from this situation as soon as possible because there is no doubt that human race running towards an ail situation. To develop a friendly environment for terrestrial ecosystem and farmers, we must not interfere the harmony. Because soil contamination with metals by anthropogenic activities not only adversely affect soil biota and its ecosystem but also a major setback for the poor and resource limited farmers. Providing economical resources and fertilizers never be an ultimatum for those resource-limited smallholder farmers who live along side of the different industries and suffering from pollution hazards particularly in their agriculture. As an example, the peoples living in the surrounding areas of PPL plant suffers and faces many problem starting from soil to water contamination and water to environmental pollution. Macro faunal distribution and its population particularly earthworms affected mainly by physicochemical properties and quality of soil. Earthworms role and its importance for soil fertility and farmers is always been immense but main threats towards earthworm diversity and its population from human itself who hampers their habitat continuously in the sake of civilization, urbanization and industrialization. We need to improvise our environmental acts properly and strictly for the sake of soil ecosystem, farmers, healthy environment and for the future generation to live in this earth.

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