Research Article

Assessment of Earthworm Community Structure in Industrial and Non-industrial Soils

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ABSTRACT

The trend of industrialization in all over the world significantly altered the assemblages of species and their surrounding environments in the soil. In the present study, the earthworm community structures were assessed in the industrial and non-industrial soils. Total seven earthworm species i.e. *Amynthas morrisi* (Beddard), *Lampito mauritii* (Kinberg), *Metaphire posthuma* (Vaillant) and *Polypheretima elongata* (Perrier) belonging to family Megascolecidae while *Eutyphoeus incommodus* (Beddard), *Eutyphoeus waltoni* (Michaelsen) and *Octochaetona beatrix* (Beddard) belonging to family Octochaetidae were reported. It was also reported that the earthworm species, their abundance and biomass was significantly ($p < 0.05$) higher in non-industrial soils as compared to industrial soils. The *Metaphire posthuma* was reported as the most abundant earthworm species in both industrial and non-industrial soils. The diversity indices such as the Shannon-Wiener diversity index, Simpson index of diversity and species richness index were higher in non-industrial soils while the Simpson index and species evenness index were high in industrial soils. The soil properties such as pH, EC, TDS and heavy metals content were much higher in the industrial soils and significant negative correlation of above said soil properties with earthworm ecological characteristics. This study can be considered as indication that industrialization has much more negative effects on the earthworms and their community structures.

Key words: Diversity indices, Soil properties, Relative abundance, Correlation analysis, Earthworm Ecological group.

INTRODUCTION

The industrialization trend all over the world is increasing day by day. But this trend of industrialization has changed the land cover and appearance of different landscapes causes numerous problems like land insecurity, worsening water quality, excessive air pollution, noise and the problems of waste disposal etc.[1] This ever-changing industrial environment and ecosystems have significantly altered the assemblages of species and their surrounding environments.[2] The influence of industrialization on ecological communities has, therefore, become one of the major issues in ecological studies. Different species in the industrial environment have been found to respond significantly to different rates of environmental stress.[3,4] The studies related to invertebrates under industrial soil is still very rare. Xie *et al.*[2] studied the impact of urbanization and industrialization on earthworm residential areas of Beijing city (China) and reported that landscape cover types, patch density and landscape fragment significantly affected the earthworm assemblages.

Earthworms are among the most important soil organisms because of their crucial roles in the soil.[5]

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They are also known as ecosystem engineers for their important role in influencing the physical, chemical and biological properties of the soil.[6] Earthworms stimulate microbial activity, mix and aggregate the soil, water infiltration rate, soil water content, and water holding capacity, etc. They also increase litter decomposition, soil organic matter dynamics, nutrient cycles, promote plant growth, and reduce some soil-borne diseases.[7] Earthworms are functionally very important and diverse, and therefore potentially useful for the management of biodiversity and ecosystem services.[8] Many studies have also supported the beneficial role of the earthworm to the sustainable function of ecosystems.[9] Earthworms are classified into three ecological or functional groups i.e. epigeic, endogeic and anecic.[10] Epigeic earthworms are those species that live on the earth's surface and are deeply pigmented. Endogeic species are typically light pigmented or non-pigmented species that form complex horizontal burrows within the soil. Anecic species has large size with uniform pigmentation at their anterior and posterior end. They feed on the surface residue along with the soil after pulling the same into their vertical burrows.

The present study was carried out with the following objectives (a) to study the earthworm community structures in industrial and non-industrial soil; (b) to measure soil physico-chemical properties in industrial and non-industrial soils; (c) how the soil properties influence the existence of earthworm communities in industrial and non-industrial soils.

MATERIALS AND METHODS

Site description

The study was conducted in the district Ludhiana, Punjab, India (Figure 1). It lies between north latitude 30°-34' and 31°-01' and east longitude 75°-18' and 76°-20'. This district is also known as Manchester of India having different types of industries such as bicycles, textiles, chemicals etc. This district is also faced with air pollution problems and ranked 13th in the most polluted city in the world.[11]

The survey of the district was conducted to select the different sites for earthworm sampling among industrial and non-industrial soils. The industrial soils consist of industrial areas and their surrounding habitats while non-industrial soils included horticulture gardens, agricultural fields etc. Based on the survey, a total of 54 sampling sites were selected (27 sites in each category).

Earthworm sampling

The earthworm sampling was done in the monsoon and post-monsoon season. The GPS coordinates of each sampling site were also recorded. Earthworms were sampled randomly in triplicates at each study site under industrial and non-industrial soils by the hand-sorting method up to 50 cm deep using metal quadrates (30 cm × 30 cm). The quadrate was inserted into the soil and block of the soil of the same size was excavated. The earthworm individuals were sorted from the above said block of the soil. The above said area was also dug further with the help of spade to collect the deep burrowing earthworm individuals. The extracted earthworm individuals washed with tap water, placed on filter paper for drying and finally weighed. After weighing, earthworms were killed with 70% ethanol and finally preserved in 5% formalin solution. The preserved earthworm individuals were identified to species level by using earthworm keys.[12] The soil samples were also collected from earthworm collection sites and put into a plastic bag labelled with a place name, date of sampling etc. for physico-chemical analysis.

Earthworm ecological characteristics

The earthworm individuals were identified to species levels and categorized into their ecological group i.e. anecic, epigeic and endogeic in both industrial and non-industrial sites. The relative abundance was also calculated for each earthworm species to identify the most common or rare earthworm species. The following formula was used to calculate the relative abundance of each earthworm species.

$$\text{Relative Abundance (\%)} = \frac{\text{Number of earthworm individuals in each species}}{\text{Total number of individuals}} \text{X } 100$$

The different diversity indices such as the Shannon-Wiener diversity index (H'), Simpson index (D),

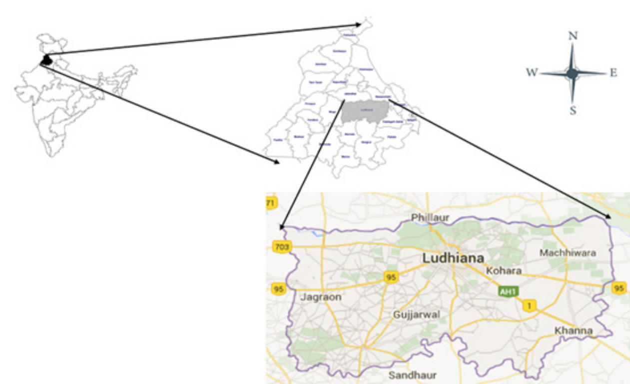

Figure 1: The map showing the location of district Ludhiana used for current study.

Simpson index of diversity ($S_{(1-D)}$), Margalef species richness index (D_{Mg}) and Species evenness index (E) were also calculated.

Soil analysis

The soil samples collected from each collection site was air dried and sieved properly before the analysis. The soil was analyzed for pH, electrical conductivity (EC), total dissolved salts (TDS), organic carbon (OC), zinc (Zn), iron (Fe), Manganese (Mn), copper (Cu), lead (Pb), cadmium (Cd), nickel (Ni), arsenic (As) and cobalt (Co). The EC, pH and TDS were measured by using a digital meter (Eutech Instruments, PCSTestr 35 series). Organic carbon was measured by using the method of Nelson and Sommers.[13] The content of heavy metals (Zn, Fe, Mn, Cu, Pb, Cd, Ni, As, and Co) were analyzed by using the atomic absorption spectrophotometer after digesting the soil samples with 1:4 of perchloric acid and nitric acid. The double distilled water was used for all the above said chemical analysis and all the glassware used for the analysis were properly washed.

Statistical analysis

The descriptive statistics of both industrial and non-industrial soils were presented in mean ± S.E. The mean of each soil variable in both sites was compared by t-test. The Pearson correlation coefficients and canonical correlation analysis (CCA) were also done to study the relationship between different soil variables and earthworm ecological characteristics. PERMANOVA (Permutation multivariate analysis of variance) was also applied to compare the groups of earthworm individuals in both industrial and non-industrial soils by using similarity matrices and the resemblance between the matrices was done by using Bray–Curtis similarity measures with 9999 random permutations. All the statistical analysis was done with the help of SPSS (version 21) and past (version 4.02) statistical software.

RESULTS

Earthworm communitie's structure

A total of 401 earthworm individuals was sampled during this study, out of which 231 individuals were belonging to non-industrial soils while 170 individuals were sampled from industrial soils. A total of seven earthworm species belonging to two families i.e. Megascolecidae and Octochaetidae were reported in this study from both industrial and non-industrial soils (Table 1). The earthworm species *Amynthas morrisi* (Beddard), *Lampito mauritii* (Kinberg), *Metaphire posthuma* (Vaillant) and *Polypheretima elongata* (Perrier) belong to family Megascolecidae while *Eutyphoeus incommodus* (Beddard), *Eutyphoeus waltoni* (Michaelsen) and *Octochaetona beatrix* (Beddard) belong to family Octochaetidae. Total six and five earthworm species were extracted from non-industrial and industrial soils respectively. The earthworm species *E. incommodus* and *P. elongata* were not reported in industrial soil while *E. waltoni* was not reported in non-industrial soil. Based on ecological category, three endogeic and four anecic earthworm species were reported in the present study. The industrial soils were reported with 3 anecic and 2 endogeic species while non-industrial soils were

Table 1: The earthworm communities, their distribution and relative abundance (%) in industrial and non-industrial soils.

Family	Earthworm species	Ecological group	Distribution		Relative abundance (%)	
			Industrial soils	non-industrial soils	Industrial soils	non-industrial soils
Megascolecidae	*Amynthas morrisi*	Anecic	+	+	2.597	1.765
	Lampito mauritii	Anecic	+	+	20.588	13.953
	Metaphire posthuma	Endogeic	+	+	74.132	79.754
	Polypheretima elongata	Endogeic	-	+	-	0.866
Octochaetidae	*Eutyphoeus incommodus*	Anecic	-	+	-	1.932
	Eutyphoeus waltoni	Anecic	+	-	0.345	-
	Octochaetona beatrix	Endogeic	+	+	2.353	1.732

+ : present; - : absent

reported with 3 and 3 species in anecic and endogeic ecological category respectively. The endogeic species *M. posthuma* was the most abundant in both industrial and non-industrial soils with a relative abundance of ~74% and ~79% respectively followed by *L. mauritii* with a relative abundance of ~20% and ~13% (Table 1). The relative abundance of anecic and endogeic earthworm species was more in industrial soils as compared to non-industrial soils except *M. posthuma*.

The abundance of earthworms was also significantly (PERMANOVA, F=2.84, $p < 0.05$) higher in non-industrial soils as compared to industrial soils. The earthworm individuals/m^2 under anecic ecological category was high in industrial soil while the endogeic species *M. posthuma* has a higher abundance (6.78 individuals/m^2) in non-industrial soils (Table 2). The other endogeic species i.e. *O. beatrix* and *P. elongata* has a lower abundance in non-industrial soils. Due to the high number of earthworm species in non-industrial soils, the diversity indices such as the Shannon-Wiener diversity index, Simpson index of diversity and species richness index was high at non-industrial soils while Simpson index and species evenness index was high in industrial soils.

Soil properties in industrial and non-industrial soils

The soil properties were significantly different in industrial and non-industrial soils (Table 3). The pH was slightly alkaline in industrial soils (7.54) and non-industrial soils ecosystem (7.46). The EC content was high in industrial soils (0.81 mS/cm) as compared to the non-industrial soils (0.78 mS/cm). The content of TDS was significantly ($p < 0.05$) different with high content reported in industrial soils (196.37 mg/l) as compared to the non-industrial soils (117.41 mg/l). The content of OC was significantly higher in non-industrial soils (0.91%) as compared to an industrial soil (0.74%). The content of heavy metals was significantly ($p < 0.05$) higher in industrial soils. The content of zinc in the industrial soils was 90.1 mg/kg which was significantly higher than non-industrial soils (45.02 mg/kg). The content of Mn, Cu and Pb were also significantly high in industrial soils with the content of 284.55 mg/kg, 50.18 mg/kg and 113.57 mg/kg respectively. The content of Cd, Ni and Co were also significantly higher in industrial soils as compared to non-industrial soils.

Impact of soil properties on earthworm abundance and their diversity indices

The Pearson correlation coefficients between earthworm diversity indices and soil variables were given in Table 4. The soil pH was significantly negatively correlated with abundance, biomass, Simpson index, and evenness index while the TDS was significantly negatively correlated with abundance and biomass. On the other hand, OC has a significant positive correlation with abundance, biomass, Shannon-Wiener diversity index and species

Table 2: The earthworm abundance (individuals/m^2) and their diversity indices at industrial and non-industrial soils.

Family	Earthworm species	Industrial soils	Non-industrial soils
Megascolecidae	*Amynthas morrisi*	0.23±0.16	0.11±0
	Lampito mauritii	1.29±0.56	1.18±0.39
	Metaphire posthuma	4.71±0.74	6.78±0.81
	Polypheretima elongata	-	0.07±0
Octochaetidae	*Eutyphoeus incommodus*	-	0.14±0
	Eutyphoeus waltoni	0.03±0	-
	Octochaetona beatrix	0.26±0.14	0.15±0.08
Total individuals		173	231
Abundance (Individuals/m^2)		6.52±0.95	8.43±1.04
Biomass (g/m^2)		6.06±0.98	9.65±1.01
Simpson index (D)		0.85±0.04	0.84±0.02
Simpson index of diversity (S_{1-D})		0.14±0.03	0.16±0.04
Shannon-Wiener diversity index (H′)		0.23±0.06	0.26±0.06
Species Evenness (E)		0.95±0.01	0.94±0.01
Margalef species richness (D_{Mg})		0.19±0.05	0.22±0.05

richness index. The heavy metals are also negatively correlated with earthworm abundance and their diversity indices. Zinc has a significantly negative correlation to abundance, biomass, Shannon-Wiener diversity index and species richness index while Mn was significantly negatively correlated with Simpson index and Evenness index. Cu has a significant negative correlation with abundance and biomass of the earthworms while Cd has a significant negative correlation with abundance, biomass, Simpson index and evenness index. The Co also showed significantly negatively correlated with abundance, biomass and evenness index. On the other hand, no significant correlation of earthworm ecological characteristics was observed with As and Ni. The canonical correlation analysis (CCA) plot also showing similar trends with negative correlations of soil variables with earthworm's abundance and their diversity indices (Figure 2).

DISCUSSION

The difference in the earthworm species, their abundance, and biomass among the industrial soils and non-industrial soils showed the impact of land use systems on the earthworm distribution. A total of 6 and 5 species of earthworms were reported from non-industrial soils and industrial soils respectively. Similarly, the abundance of earthworms and their biomass was also high in non-industrial soils. As the number of species was more in non-industrial soils, the diversity indices were also high in non-industrial soils. The *M. posthuma* was the only most abundant earthworm species which was reported in both industrial soils and non-industrial soils but the abundance of the same was high in non-industrial soils. The sampling sites in the industrial soils were the industrial areas and their surrounding vegetation's while the sampling sites in non-industrial soils were horticulture gardens, agricultural fields etc. It was also reported that the abundance of anecic and endogeic earthworm species was high in industrial soils and non-industrial soils respectively. The agricultural management practices in non-industrial soils like ploughing, application of chemical fertilizers and pesticides disturbed the anecic earthworm species in the soil[14] which might be the reason for less abundance of anecic species in non-industrial soils. The ploughing damages the burrows of earthworm in the soil which directly disturbs anecic earthworm species as compared to species with the endogeic ecological category.[15] The anecic earthworm species do not undergo aestivation during the adverse condition caused by agricultural management practices which caused mortality in the anecic species.[16] On the other hand, endogeic species remain deep in the soil with little or negligible effect of agricultural management practices[14] which may be the reason for more abundance of endogeic species in the non-industrial soils. Kanianska *et al*.[17] and Mariotte *et al*.[18] also reported more abundance of endogeic species in the cultivated fields as compared to epigeic and anecic earthworm species. Among the endogeic species, a high abundance of *M. posthuma* was reported in both industrial soils and non-industrial soils with a relative abundance of ~74% and ~79% respectively. On the other hand, the abundance of other endogeic species i.e. *O. beatrix* and *P. elongata* was much lower. This high

Table 3: The physico-chemical properties of soil samples of industrial and non-industrial areas.

Soil Variables	Industrial soils	Non-industrial soils
pH	7.54±0.05 ^{a}	7.46±0.03 ^{a}
EC (mS/cm)	0.81±0.02 ^{a}	0.78±0.03 ^{a}
TDS (mg/l)	196.37±36.74 ^{a}	117.41±10.37 ^{b}
OC (%)	0.74±0.07 ^{a}	0.91±0.05 ^{b}
Zn (mg/kg)	90.1±18.46 ^{a}	45.02±4 ^{b}
Fe (mg/kg)	1294.84±12.07 ^{a}	1291.94±5.99 ^{a}
Mn (mg/kg)	284.55±13.03 ^{a}	256.65±11.32 ^{b}
Cu (mg/kg)	50.18±9.19 ^{a}	37.98±3.95 ^{b}
Pb (mg/kg)	113.57±7.78 ^{a}	95.95±9.13 ^{b}
Cd (mg/kg)	3.33±0.2 ^{a}	2.61±0.12 ^{b}
Ni (mg/kg)	76.49±19.57 ^{a}	48.37±16.61 ^{b}
As (mg/kg)	219.99±40.05 ^{a}	204.77±30.35 ^{a}
Co (mg/kg)	17.53±0.96 ^{a}	14.96±0.7 ^{b}

t-test was applied, the mean followed by different letters were significantly different at 5% significance level.

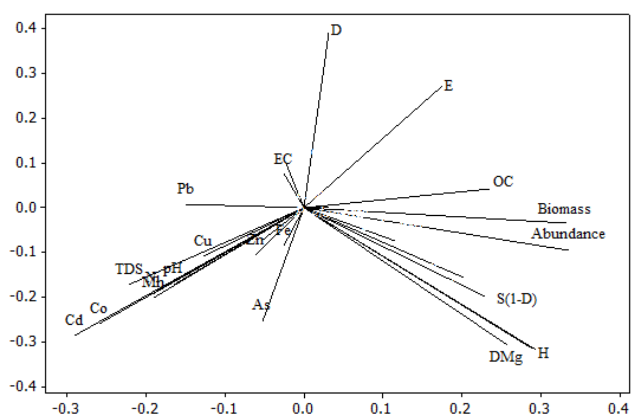

Figure 2: The canonical correlation analysis (CCA) plot for the soil variables and earthworm ecological characteristics. The axes showing the correlation coefficients of soil physico-chemical properties with earthworm's abundance and their diversity indices.

Table 4: The Pearson correlation coefficients between soil variables and earthworm ecological characteristics.

Soil variables	Abundance	Biomass	D	$S_{(1-D)}$	H′	E	D_{Mg}
pH	-0.275*	-0.464**	-0.292*	-0.070	-0.070	-0.327*	-0.060
EC	-0.001	-0.007	0.173	-0.089	-0.113	0.161	-0.125
TDS	-0.309*	-0.293*	-0.227	-0.149	-0.144	-0.319	-0.111
OC	0.413**	0.391**	0.012	0.064	0.269*	0.059	0.289*
Zn	-0.275*	-0.289*	-0.059	-0.074	-0.298*	-0.213	0.288*
Fe	0.07	0.036	-0.074	0.030	0.022	-0.047	-0.011
Mn	-0.248	-0.197	-0.361**	-0.114	-0.129	-0.433**	-0.150
Cu	-0.288*	-0.252*	0.031	-0.002	-0.010	-0.008	0.078
Pb	-0.146	-0.133	-0.102	-0.301*	-0.292*	-0.240	-0.302*
Cd	-0.398**	-0.447**	-0.372**	-0.172	-0.177	-0.488**	-0.128
Ni	-0.161	-0.223	-0.139	-0.085	-0.085	-0.200	-0.103
As	0.098	0.016	-0.225	0.151	0.143	-0.136	0.102
Co	-0.302*	-0.325*	-0.191	-0.158	-0.165	-0.310*	-0.133

*Significant at 0.05; ** Significant at 0.01

abundance of *M. posthuma* shows that all the sampling sites were dominated by one earthworm species. The high abundance of the *M. posthuma* in agricultural fields also showed that this speciesis more adapted and well stable in the study area. The high abundance of *M. posthuma* at cultivated sites might be due to their endogeic ecological nature and during adverse conditions or agricultural practices, it can go upto 20-30 cm deep into the soil.[19] Dhar and Chaudhuri[20] also observed the higher existence of endogeic earthworm species in the paddy cultivated fields of West Tripura. The various researcher also reported that agricultural management practices have negative effects on the earthworms but this study showed that industrialization has a much higher impact on the earthworm distribution as compared to agricultural management practices.

The TDS, OC, and heavy metals (Zn, Mn, Cu, Pb, Cd, Ni and Co) content in industrial soils were significantly ($p < 0.05$) higher as compared to non-industrial soils. This high content of heavy metals in the industrial soils showed that soil sample from industrial area was more polluted as compared to non-industrial soils. The Ludhiana district is the hub of industries which discharged their wastes in the open dumps, fill in the soil or into the water bodies. Secondly, the population in the industrial area is high which generates a large amount of solid waste. On the other hand, soil collected from non-industrial areas were mainly from agricultural fields. The agricultural fields were also surrounded by various types of vegetation which can remediate the soil by accumulating the toxic metals from the soil. While the level of vegetation in industrial soils is less as compared to non-industrial soils and hence the toxic metals retained within the soil which cause an increase in the content of various kinds of impurities in the soil. The results of Pearson correlation and CCA between earthworm ecological characteristics and soil variables also showed the dependence of earthworm on soil properties. The earthworm ecological characteristics showed a significant negative correlation with pH and TDS. The pH is an important factor for earthworm distribution as earthworms can survive only in neutral but also in slightly acidic to slightly alkaline soil conditions. In the present study, the pH of both industrial soils and non-industrial soils was slightly alkaline in nature i.e. 7.5 and 7.4 respectively. According to Curry and Schmidt,[21] earthworm species prefer to live in soil having pH between 5 to 7.4 but as the pH shifts from this range, the species richness tends to decrease. A similar result was reported in this study, as non-industrial soils have pH 7.4 and also has high species number and their abundance as compared to industrial soils. The variation in pH from above said range also affects other variables i.e. calcium which is necessary for earthworm survival and cocoon production.[2] The TDS content in the soil also affects earthworm distribution and survival. The industrial soils have high pH content as compared to non-industrial soils which are also supported by the negative correlation of TDS with earthworm abundance and biomass. Similarly, the content of OC was high in the non-industrial soils as compared to industrial soil. The OC is the critical factor for the earthworm distribution as it helps in determines the type and nature of food for an earthworm.[14] The non-industrial soils were mostly the agricultural fields with high OC content which might be due to ploughing of crop straw and waste along with the soil after crop harvesting. This type of strategy increased the availability of organic matter to earthworms.[18,22] Dhar and Chaudhuri[20] and Bartz *et al*.[23] also observed a significant positive relationship between soil OC and earthworm abundance i.e. high earthworm abundance in soil having high OC content and vice versa. The significant negative correlation was reported between earthworm ecological characteristics and soil heavy metal contents in this study. These heavy metal concentration in the soil is an important component for earthworm distribution and abundance.[24] This high content of heavy metals was observed in the soils of industrial area as compared to non-industrial areas which resulted in less abundance or earthworm species in the industrial soils and vice versa. Ahangar and Keshtehgar[25] also reported less earthworm diversity and abundance due to the high content of heavy metal in the soil. Rybak *et al*.[26] also reported the negative effects of heavy metals on the genetic diversity of earthworm *Aporrectodea caliginosa*. The Zn, Pb, and Cd in the soil directly affect earthworm biomass and species richness.[27] But the effects of the heavy metals in the soil are also dependent on their concentration.[23,28] The earthworm can bioaccumulate heavy metals in their tissues and as the concentration of heavy metals increases, these heavy metals cause toxicity in the earthworm and hence cause mortality.[23] The various researcher also reported high content of heavy metals in the agricultural fields but this study showed that industrial soils ecosystem has a much higher content of heavy metals as compared to cultivated fields.

CONCLUSION

This study was focused to assess the earthworm communities and their relation to soil properties in industrial and non-industrial soils. This study showed that earthworm communities, their abundance, and biomass were high in the non-industrial soils as compared to industrial soils. Various studies proved that agricultural management practices have negative effects on the earthworm communities but this research showed that industrialization has much more negative effects on the earthworms. The soil properties such as pH, EC, TDS and heavy metals content were much high in the industrial soils as compared to non-industrial soils which have a significant negative effect on the earthworm. This industrialization is changing the world day by day but this industrialization also destroying the earthworm communities and other soil organisms. These results can be considered as a hypothetical indication for the effect of industrialization on earthworm communities structures.

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Author Contribution

The paper was conceived and designed by: JS and CP. The sampling of earthworms and analysis of soil samples were done by FV. SSD assisted in analysis of the soil sample. The data and articles were analyzed by JS and SS. The manuscript's first draft was written by FV and SS. The critical revisions and the final version were done by CP and JS. All authors have read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

Cm: Centimeter; **Cu:** Copper; **Co:** Cobalt; **Cd:** Cadmium; **CCA:** Canonical Correlation Analysis; **D:** Simpson index; **DMg:** Margalef species richness index; **E:** Species evenness index; **EC:** Electrical conductivity; **Fe:** Iron; **mg/Kg:** milligram per kilogram; **GPS:** Global positioning system; **H':** Shannon-Wiener diversity index; **mg/L:** milligram per liter; **Mn:** Manganese; **Ni:** Nickel; **As:** Arsenic; **OC:** Organic carbon; **Pb:** Lead; **PERMANOVA:** Permutational multivariate analysis of variance; **SPSS:** Statistical Package for the Social Sciences; **S(1-D):** Simpson index of diversity; **TDS:** Total dissolved salts; **Zn:** Zinc; **mS/cm:** milli siemens per centimeter.

SUMMARY

The trend of industrialization in all over the world significantly altered the assemblages of species and their surrounding environments in the soil. It was also reported that the earthworm species, their abundance and biomass was significantly ($p < 0.05$) higher in non-industrial soils as compared to industrial soils. The *Metaphire posthuma* was reported as the most abundant earthworm species in both industrial and non-industrial soils. The soil properties such as pH, EC, TDS and heavy metals content were much higher in the industrial soils and significant negative correlation of above said soil properties with earthworm ecological characteristics.

REFERENCES

1. Soni P, Salokhe VM. Strategic Analysis of Industrial soils and Peri-industrial soils Agriculture in Asia: Issues, Potential and Challenges. In Sustainable Landscape Planning in Selected Industrial soils Regions Springer, Tokyo; 2017;73-83.
2. Xie T, Wang M, Chen W, Uwizeyimana H. Impacts of industrial soilsization and landscape patterns on the earthworm communities in residential areas in Beijing. Sci Total Environ. 2018;626:1261-9.
3. Teets NM, Denlinger DL. Surviving in a frozen desert: Environmental stress physiology of terrestrial Antarctic arthropods. J Exp Biol. 2014;217(1):84-93.
4. Savage AM, Hackett B, Guénard B, Youngsteadt EK, Dunn RR. Fine-scale heterogeneity across Manhattan's industrial soils habitat mosaic is associated with variation in ant composition and richness. Insect Conserv Divers. 2015;8:216-28.
5. Ebewore SO, Ovharhe OJ. Crop farmers' perception of the role of earthworm in soil improvement in delta state, Nigeria. Sch J Agric Vet Sci. 2016;3(1):72-8.
6. Singh S, Singh J, Vig AP. Earthworm as ecological engineers to change the physico-chemical properties of soil: soil vs vermicast. Ecol Eng. 2016;90:1-5.
7. Chandran MS, Sujatha S, Mohan M, Julka JM, Ramasamy EV. Earthworm diversity at Nilgiri biosphere reserve, Western Ghats, India. Biodivers Conserv. 2012;21(13):3343-53.
8. Blouin M, Hodson ME, Delgado EA, Baker G, Brussaard L, Butt KR, et al. A review of earthworm impact on soil function and ecosystem services. Eur J Soil Sci. 2013;64(2):161-82.
9. Barrios E. Soil biota, ecosystem services and land productivity. Ecol Econ. 2007;64(2):269-85.
10. Bouche MB. Lombriciens de France. Ecologie et systematique. Annales de Zoologie Ecologie Animale. Numero Spec. 1972;72.
11. Majeed R. Effect of chemical treatments on storage life and fruit quality of plum (*Prunus salicina*Lindl.) cv. Satluj purple. Doctoral dissertation, Punjab Agricultural University, Ludhiana; 2014.
12. Julka JM. Know your Earthworms.Rashtriya Vigyan Evam Prodyogiki Sanchar Parishad (RVPSP) Solan (HP, India). 2008.
13. Nelson DW, Sommers LE. Total carbon, organic carbon, and organic matter. Methods of soil analysis: Part 3 Chemical methods. 1996;5:961-1010.
14. Singh S, Sharma A, Khajuria K, Singh J, Vig AP. Soil properties changes earthworm diversity indices in different agro-ecosystem. BMC Ecol. 2020;20:1-14.
15. Ghanem-Nadra K, Mohammed K, Mohammed EH. Interaction between Soil Physicochemical Parameters and Earthworm Communities in Irrigated Areas with Natural Water and Wastewaters. Appl Environ Soil Sci. 2017;11. https://doi.org/10.1155/2017/5808945.
16. Lagerlöf J, Pålsson O, Arvidsson J. Earthworms influenced by reduced tillage, conventional tillage and energy forest in Swedish agricultural field experiments. Acta Agric Scand Sect B. 2012;62(3):235-44.
17. Kanianska R, Jaďuďová J, Makovníková J, Kizeková M. Assessment of relationships between earthworms and soil abiotic and biotic factors as a tool in sustainable agricultural. Sustainability. 2016;8(9):906. https://doi.org/10.3390/su8090906.
18. Mariotte P, Bayon LRC, Eisenhauer N, Guenat C, Buttler A. Subordinate plant species moderate drought effects on earthworm communities in grasslands. Soil Biol Biochem. 2016;96:119-27.
19. Singh S, Singh J, Vig AP. Effect of abiotic factors on the distribution of earthworms in different land use patterns. J Basic Appl Zool. 2016;74:41-50.
20. Dhar S, Chaudhuri PS. Earthworm Communities in Paddy (*Oryza sativa*) fields of West Tripura (India). Proc Zool Soc. 2020;1-12. https://doi.org/10.1007/s12595-019-00313-6.
21. Curry JP, Schmidt O. The feeding ecology of earthworms: A review. Pedobiologia. 2007;50(6):463-77.
22. Ernst G, Emmerling C. Impact of five different tillage systems on soil organic carbon content and the density, biomass, and community composition of earthworms after a ten year period. Eur J Soil Biol. 2009;45(3):247-51.
23. Bartz MLC, Pasini A, Brown GG. Earthworms as soil quality indicators in Brazilian no-tillage systems. Appl Soil Ecol. 2013;69:39-48.
24. Singh S, Singh J, Vig AP. Diversity and abundance of earthworms in different landuse patterns: Relation with soil properties. Asian J Biol Life Sci. 2020;9(2):111-8.
25. Ahangar AG, Keshtehgar A. Influence of heavy metals on earthworms, soil microbial community and mammals. J Nov Appl Sci. 2015;4:125-34.
26. Rybak AV, Belykh ES, Maystrenko TA, Shadrin DM, Pylina YI, Chadin IF, *et al*. Genetic analysis in earthworm population from area contaminated with radionuclides and heavy metals. Sci Total Environ. 2020;137920. https://doi.org/10.1016/j.scitotenv.2020.137920.
27. Wang K, Qiao Y, Li H, Zhang H, Yue S, Ji X, *et al*. Structural equation model of the relationship between metals in contaminated soil and in earthworm (*Metaphire californica*) in Hunan Province, subtropical China. Ecotoxicol Environ Saf. 2018;156:443-51.
28. Shi Y, Shi Y, Zheng L. Individual and cellular responses of earthworms (*Eisenia fetida*) to endosulfan at environmentally related concentrations. Environ Toxicol Pharmacol. 2020;74:103299. https://doi.org/10.1016/j.etap.2019.103299.

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