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Seasonal Variations and Effect of Radiation on Soil Fertility and Enzyme Activity in Opencast Coal Mine

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Abstract

Jharia coalfield in Jharkhand, India, is also known for the largest coalfields in India. The enzyme activities play an important role in soil fertility and productivity. It indicates extremely sensitive changes in the soil health. The need for the survey of radiation effect in these sites is important for vegetation and health assessment of those people who are staying near these areas. Monitoring and sampling of soil were done in seven sampling locations of Bastacola, Rajapura, Lodna and Kustor from August 2009 to April 2010. All sampling locations lie between latitude *23° 39' to 23° 48' N and* longitude *86° 11' to 86° 27' E. Variations of physico-chemical parameters were studied in summer and winter season. Effect of radiation on two types of enzymes activity like dehydrogenase (DHA) and catalase (CTA) were studied. A two-way analysis of variance (ANOVA) showed that twelve soil quality parameters had a significant difference ($p < 0.05$) in two seasons. Enzyme activity in fire zones was found zero in spite of having high N, P, K and organic carbon. While grassland and natural vegetation showed high enzyme activity due to lesser radiation effect. The damage of microorganisms was increased due to the increase of Gamma rays. Available N, P, K and organic carbon found maximum with respect to Bastacola. Effect of Gamma radiation was found to be strongly negatively correlated with dehydrogenase activity (DHA) and catalase activity (CTA).*

Keywords: Dehydrogenase, catalase, gamma radiation, radon concentration, soil fertility.

Introduction

Open cast coal mine fires in the Jharia coalfield create a serious threat to natural resources and environmental degradation. In India, out of about 0.7 million miners, nearly 0.5 million persons are directly engaged in coal operations[1,2]. In order to improve the environmental conditions, plantation and human health it is required to detect the areas affected by coal-mine fires and also to monitor enzyme activity and soil fertility conditions.

Enzyme activity and soil fertility conditions depend upon soil physico-chemical characters, microbial community structure, and vegetation[3-5]. Monitoring of physico-chemical parameters is necessary because of the development grassland and forest land[6-11]. The pH is required for the growth of plants, but at very low and very high pH, vegetation will damage. The electrical conductivity (EC) of the soil-water system rises according to the content of soluble salts. EC is directly correlated to the concentration of soluble salts present in the soil at any temperature. High organic matter content lowers the bulk density, whereas compaction increases the bulk density. In addition, the seasonal effect also plays an important role in soil quality.

Enzyme activity of dehydrogenase (DHA) and catalase (CTA) in the soil plays a significant role in vegetation[12]. It is important for soil health, number of aerobic microorganisms and soil fertility. Both help in the cycling and transformation of potassium (K), organic carbon (OC), nitrogen (N), and other Nutrients and particles size[13]. Hoffmann and Seegerer recommended enzyme content as an indicator of soil fertility[14]. DHA indicates the potential intracellular enzyme activity of the total microbial biomass and found to be highly correlated with the CO_2 release, photolytic activity, and nitrification potential[15]. CTA of soil is another microbe that is also considered as a reproductive system in the plant. It only occurs within living cells, unlike other enzymes, which can only occur in an extracellular state[16-18].

Radioactive material is found throughout nature. The major radiation elements with low-abundance radioactive isotopes are potassium and carbon, etc[19]. But intensely radioactive elements are uranium, thorium, radium, and radon. Gamma radiation strongly affects soil moisture content, porosity, bulk density, etc. Diffusion of radon through soil shows decrease of concentration exponentially with the increase in soil thickness[20]. The diffusion coefficient of radon through soil is found to decrease with the increase of the moisture content. The survey of radon concentration level and gamma radiation is important for human health risks assessment. Radon gas and gamma radiation are easily absorbed into the soil and water[21]. The source of radiation includes burning of fossil fuels such as coal, large-scale use of phosphate fertilizers and tetraethyl lead. The radionuclide enters the human body mainly by two routes namely: inhalation and ingestion and into the plant by photosynthesis and respiration [22]. It damages the plant tissue and reduces the growth of the plant. The current research emphasises on the areas affected by subsidence that are related to subsurface coal-mine fire in the Jharia coal fields. However, due to seasonal variation in soil quality, a monitoring program is essential for a consistent estimation of the quality of soil in mine fire area. The assessment of the soil fertility can be performed by the monitored data categorization, modelling, and elucidation. Statistical analysis helps for a better understanding of the behaviour of seasonal effect on physico-chemical properties of soil.

Material and Methods

Study Area: 70 *mine fires* in *Jharia* Coalfields, Jharkhand, India, spread over an *area* of 17.32 Km^2 at latitude 23°39' to 23°48' N 86°11' and longitude 86° 27' E (figure-1). The samples were collected from four sampling sites as Bastacola, Rajapura, Lodna and Kustor from August 2009 to April 2010. In Bastacola sampling location samples were collected from overburden dump (BC_1), grassland (BC_2) and forest land (BC_3). At Rajapura, sampling location samples were collected from the outer zone of active mine fire area (RP_4) and at the active fire zone (RP_5). Samples were also collected from Lodna (L_6) and Kustore active fire zone (K_7) at a depth of 10 to 15cm. The surface temperature (^{0}C) was measured simultaneously using a thermometer in every sampling site. The soil samples were packed in air tight packets to avoid atmospheric contaminants and transported to the laboratory.

Characterization and Analysis of Sample: Soil samples collected from the sampling locations and were dried in an oven at temperature of 115°C. Mechanical sieve shaker was used for the sieving. Sieved soil samples of 75 µ were used for the analysis of different parameters. The physico-chemical parameters and extractable metals were measured as per the standard method[23,24]. The concentration of metals were measured by Atomic Absorption Spectrometry (AAS) was used. DHA and CTA of soil were measured by the standard methodologies[25,26]. A two-way analysis of variance (ANOVA) was executed to estimate the seasonal variation of soil quality. Gamma radiation in sampling location was measured by using Micro R Surveyor Meter (UR 705) at a level of one meter height[1]. Radon gas was collected in Lucas cells at various sampling locations at 1 meter height from the surface of a sampling site. The concentration of radon was calculated through Radon Counting Detector (PSI-RCD 1).

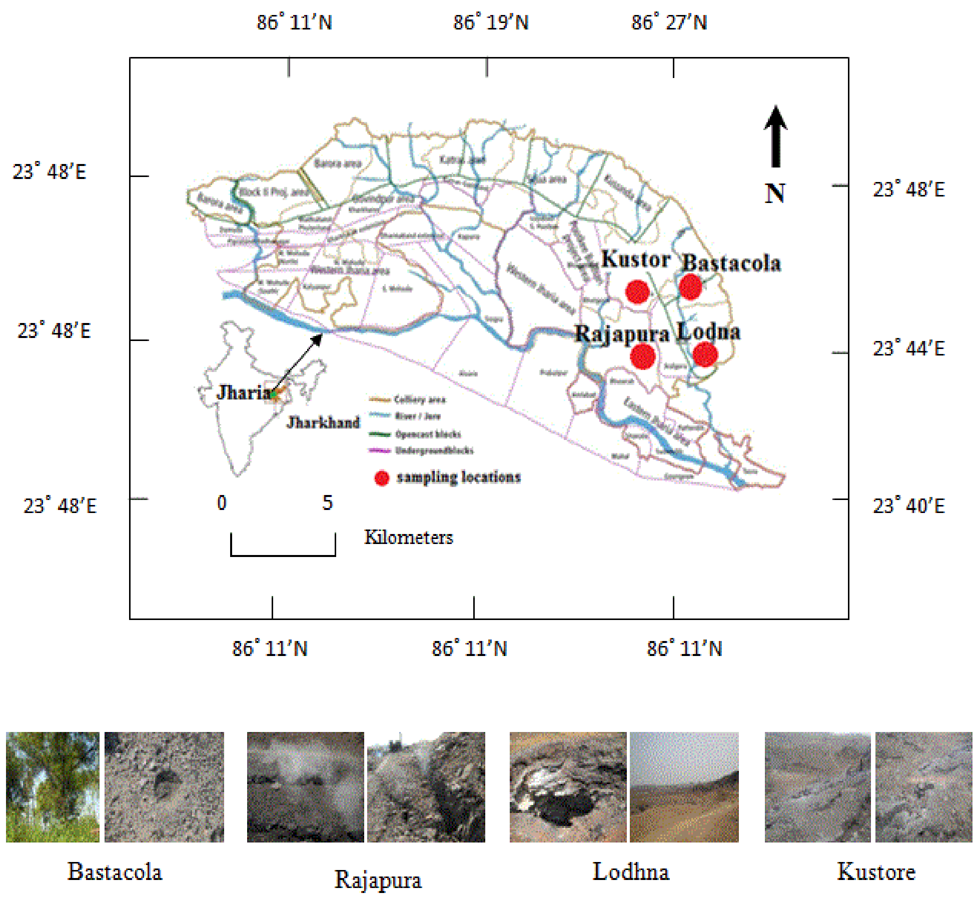

Figure-1
Map of sampling location of Jharia Coal field, Jharkhand

Results and Discussion

Seasonal variation of physico-chemical parameters of soil samples: Mean and standard deviation (SD) of soil quality parameters of seven sampling locations are reported in table-1. Two-Way ANOVA analysis of twelve parameters in two seasons is also tabulated. A significant degree of variations in the soil quality parameters was observed in summer and winter season (< 0.05). Soil temperature (T˚C) at the time of sampling was recorded and found maximum in fire zones RP_4 and RP_5, L_6 and K_7. Soil fertility was observed more in mine fire zone than other sampling locations (BC_1, BC_2, BC_3, and RP_4). It was observed that soil fertility is found to be varying inversely with electrical conductivity (EC) and bulk density (BD). High bulk density indicates the presence of rocks, and coarser soil particles that were found in Bastacola overburden dumps (BC1). On the other hand, a low value of bulk density indicates more of an organic matter, finer clay particles and silts. The electrical conductivity and bulk density found the maximum in Bastacola soil (BC_2 and BC_3) with respect to other sites. Grassland and forestland were found in these sampling sites due to high organic matter content and water holding capacity and also low bulk density.

Table-1
Results of the mean ± standard error and ANOVA of the physicochemical parameters in soil samples

Parameters	BC_1		BC_2		BC_3		RP_4		RP_5		L_6		K_7		P
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	
Temperature (T˚C)	32 ± 5	35 ± 7	36 ± 4	40 ± 5	34 ± 6	37 ± 4	46 ± 8	80 ± 6	85 ± 6	90 ± 3	85 ± 5	85 ± 4	80 ± 7	85 ± 4	0.006
pH	6.85 ± 0.6	6.8 ± 0.3	6.5 ± 0.8	6.47 ± 0.7	6.64 ± 0.4	6.61 ± 0.4	6.15 ± 0.5	7.62 ± 0.9	7.45 ± 0.3	7.45 ± 0.6	5.4 ± 0.2	5.72 ± 0.5	6.47 ± 0.4	6.39 ± 0.6	0.004
EC(µMho/cm)	0.05 ± 0.05	0.07 ± 0.3	0.02 ± 0.1	0.02 ± 0.06	0.022 ± 0.08	0.03 ± 0.06	0.22 ± 0.05	0.34 ± 0.02	0.48 ± 0.2	0.7 ± 0.3	0.458 ± 0.2	0.62 ± 0.6	0.33 ± 0.4	0.44 ± 0.3	0.000
BD (%)	1.49 ± 0.2	1.48 ± 0.5	1.29 ± 0.4	1.29 ± 0.2	1.15 ± 0.5	1.14 ± 0.9	0.99 ± 0.07	0.91 ± 0.04	0.96 ± 0.02	0.90 ± 0.07	0.94 ± 0.03	0.87 ± 0.06	0.96 ± 0.05	0.81 ± 0.04	0.000
MC (%)	1.58 ± 1.2	1.42 ± 1.8	2.42 ± 3.2	2.32 ± 1.5	3.7 ± 1.4	3.51 ± 1.3	2.76 ± 1.5	1.83 ± 1.2	0.89 ± 0.5	0.77 ± 0.2	1.2 ± 0.6	1.12 ± 0.2	1.3 ± 0.7	1.28 ± 1.2	0.001
OC (%)	3.9 ± 0.8	4.1 ± 1.8	5.9 ± 2.1	5.67 ± 2.1	2.6 ± 0.8	3.72 ± 1.8	4.5 ± 2.1	5.83 ± 3.1	6.9 ± 2.4	7.92 ± 1.8	6.0 ± 3.6	8.21 ± 1.5	6.2 ± 3.1	8.9 ± 4.7	0.008
N (ppm)	28 ± 12	58 ± 17	39.2 ± 23	88.6 ± 44	176 ± 95	287. ± 112	106 ± 47.8	561 ± 105	843 ± 336	994 ± 412	840 ± 126	945 ± 366	837± 267	981.3 ± 436	0.034
P (ppm)	2.5 ± 1.8	2.4 ± 1.3	3.3 ± 1.7	3.33 ± 2.8	13.1 ± 4.8	14.4 ± 5.7	8.1 ± 4.8	40.3 ± 13.8	60.8 ± 35.4	83.4 ± 45.7	50.6 ± 34.1	60.8 ± 52.4	59 ± 24.7	77.1 ± 42.6	0.058
K (ppm)	11.3 ± 5.6	11.2 ± 6.2	10.8 ± 3.8	12.3 ± 6.4	40.4 ± 20	59.7 ± 35	34.2 ± 25.8	79.3 ± 53.3	10.0 ± 5.2	63.4 ± 45.4	9.75 ± 3.8	50.8 ± 25.7	25.1 ± 12.3	87.7 ± 62.7	0.007
Ca (ppm)	73 ± 45	74.1 ± 56	54 ± 35.7	55 ± 27.3	42 ± 13.3	43.8 ± 25	50 ± 31.5	53.4 ± 23.7	49 ± 28.3	50.3 ± 33.7	62 ± 42.8	75.3 ± 53.2	41 ± 23.1	42.7 ± 23	0.004
Na (ppm)	14.2 ± 3.5	16.2 ± 7.6	131 ± 87	157 ± 67	88.7 ± 37.2	112.3 ± 82	89.0 ± 37.1	96.4 ± 47.2	17.6 ± 6.8	57.5 ± 27.8	39.5 ± 18.3	37.2 ± 27.3	131.5 ± 57.6	129.7 ± 64	0.025
CEC (meq//100g)	17.6 ± 5.8	14.3 ± 2.7	18.5 ± 7.1	16.3 ± 5.8	24.3 ± 4	17.4 ± 3.6	11.3 ± 2.7	10.7 ± 2.1	12.6 ± 1.4	12.2 ± 2.8	13.3 ± 3.1	10.3 ± 3.2	14.39 ± 5	12.2 ± 3.1	0.089

EC; electrical conductivity; BD: bulk density; MC: moisture content; OC: organic carbon; N: available nitrogen; P: available phosphorus; K: potassium; Ca: calcium; Na: sodium; CEC: cation exchange capacity; W: winter; S: summer; p<0.05; significant

Effect of seasonal variation in enzyme activity and soil fertility: In Bastacola forest land (BC_3) sample, the extractable metals were found larger than the fire zones and overburden dump (BC_1) which are the nutrients for the vegetation (figure-2 a). In this sampling location, DHA and CTA were found maximum than other sampling locations, whereas organic carbon content (OC) was found less (figure-2b). Taking into account the case of sampling sites RP_5, L_6 and K_7 low catalase activity is associated with high organic carbon content (OC), which reflects a considerably low microbial activity. The results obtained from the above analysis were found that there is no enzyme activity and vegetation as the concentration of soil fertility parameters like nitrogen (N), phosphorus (P) and potassium (K) were found maximum in mine fire area (figure 3a, b). The range of N, P and K was found a significant variation in the mine fire areas. This may be due to an anaerobic condition as evident from high electrical conductivity (EC). In case of sampling sites BC_2 and BC_3, the high value of catalase activity complied with low OC indicating high substrate utilization by the microorganisms, which in turn indicates the significant microbial activity. A significantly higher amount of N and P was found in fire zone as compared to overburden dumps and forestland. Soil fertility found the maximum in fire zones. It was found no radiation effect on soil fertility.

Effect of radiation on enzyme activity: Effect of radiation was analyzed in the summer season. Less radiation effect found in overburden dumps and forestlands and found maximum in fire zones (figure-4 a). By the analysis of soil samples in seven, sampling sites, the highest rate of radon at L_6 is due to mine fire, which leads to conversion of solid minerals into a gaseous form. It was found as the radon concentration increases the gamma radiation also increased and was moderately correlated with each other (figure-4b).

Bastacola area (BC_3) showed relatively less terrestrial gamma radiation as well as atmospheric radon concentrations due to vegetation. It was found DHA and CTA were highest in BC_3 (forest land) comparison to BC_1 and BC_2 (overburden dumps and grassland) respectively. In mine fire area RP_4, RP_5, L_6 and K_7 there was no enzyme activity as there soil fertility was good. Moreover, the high temperature might be responsible for increased natural radiation. Figure-5a, b and Figure 6a, b described the radiation rate inversely correlated with enzyme activity.

Conclusion

The investigation of Jharia coalfield reveals the impact of mine fire on the microbial activity and soil fertility. It is noted that the plantation is also possible in mining area as well as over bourdon dumps. A preliminary investigation on radiation rate was successfully done and found less effect on soil fertility but a large effect on enzyme activity. This study also emphasizes the environmental significance of the vegetation to minimize the temperature rise, consequently low emission of radiation. In case of catalase and dehydrogenase, it is also found that radiation and enzyme activity are strongly negatively correlated whereas the enzyme activities are moderately correlated with each other. Hence, it is concluded that radiations have deleterious effects on soil microbes and enzymes.

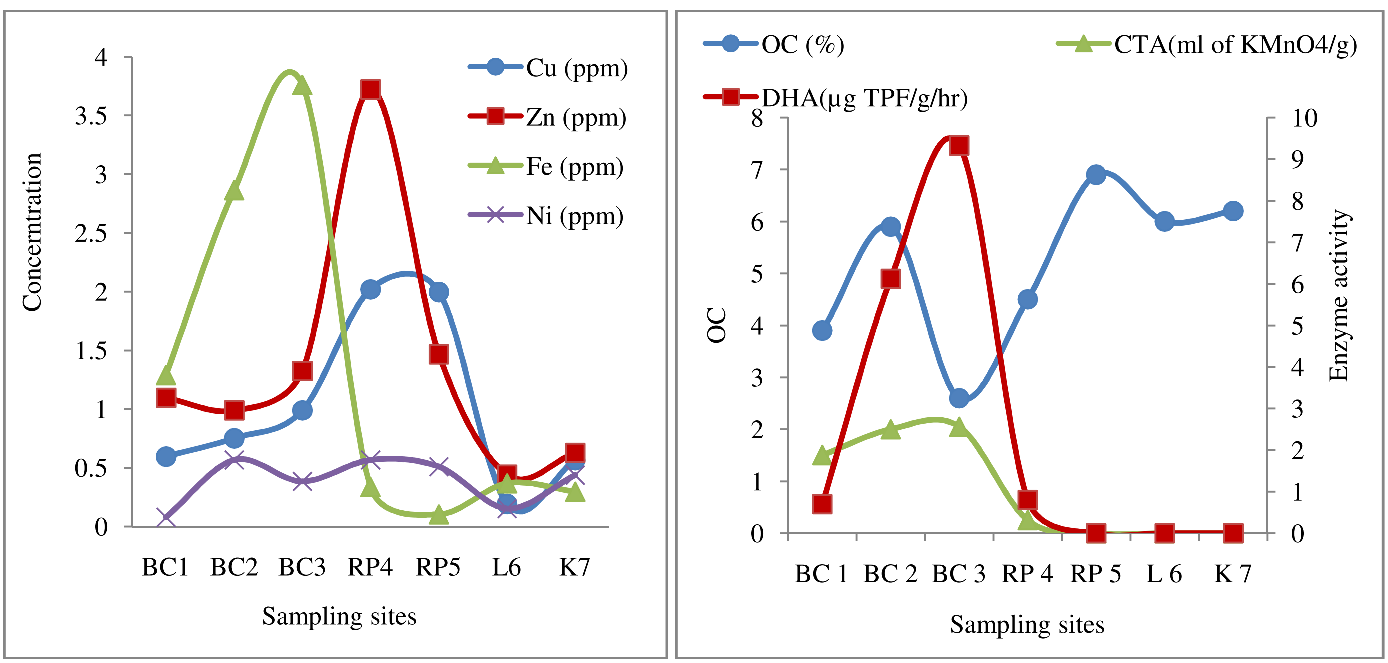

Figure-2(a, b)
Variation of different metal concentration and enzyme activity vs. organic carbon in different sampling location

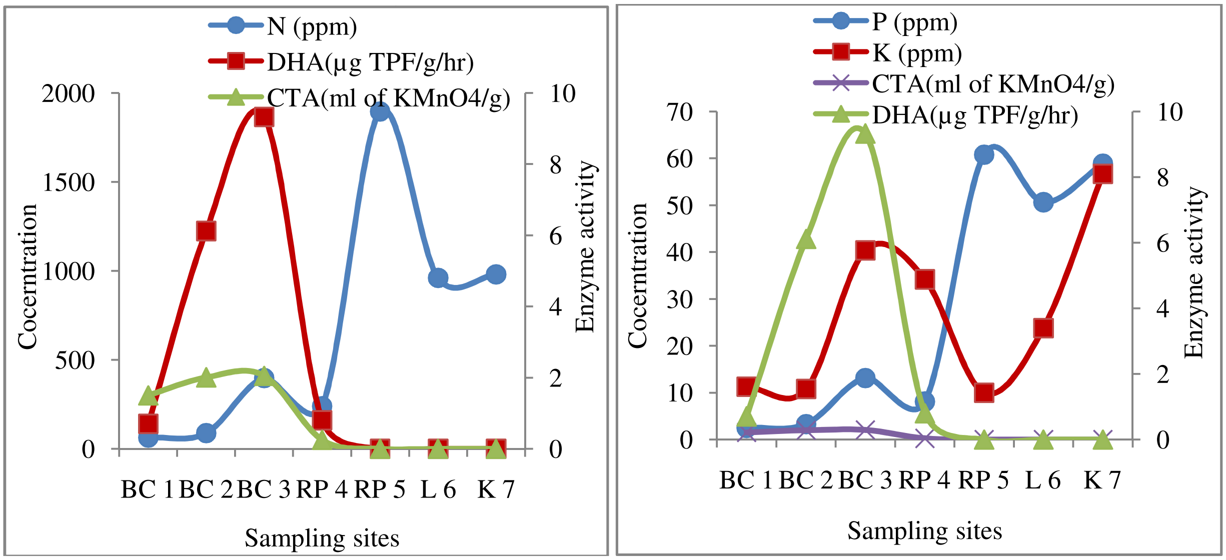

Figure-3 (a, b)
Variation of N, P and K vs. enzyme activity organic carbon in different sampling location

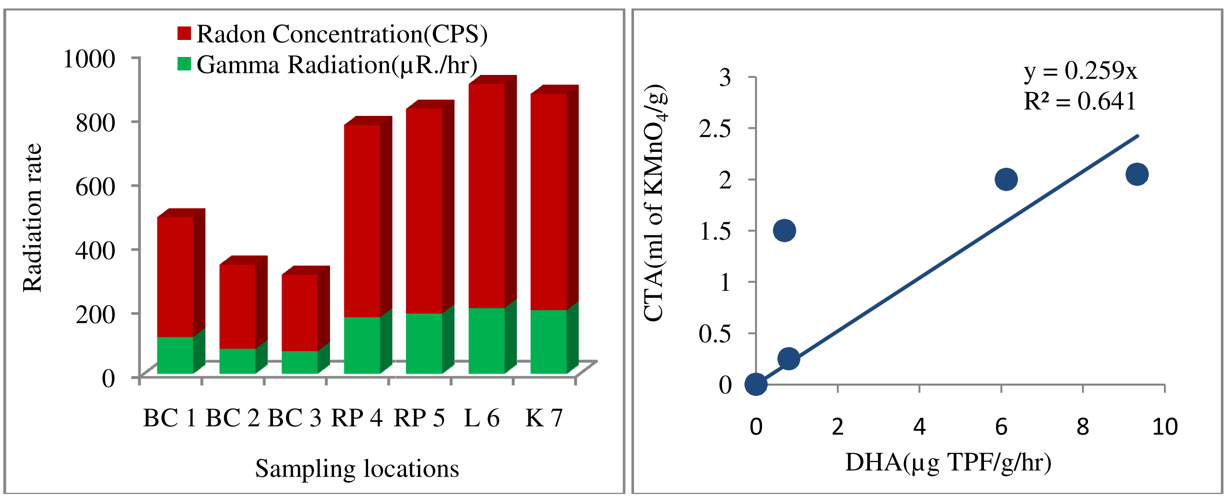

Figure-4 (a, b)
Variation of radiation rate and correlation between enzyme activities in different sampling location

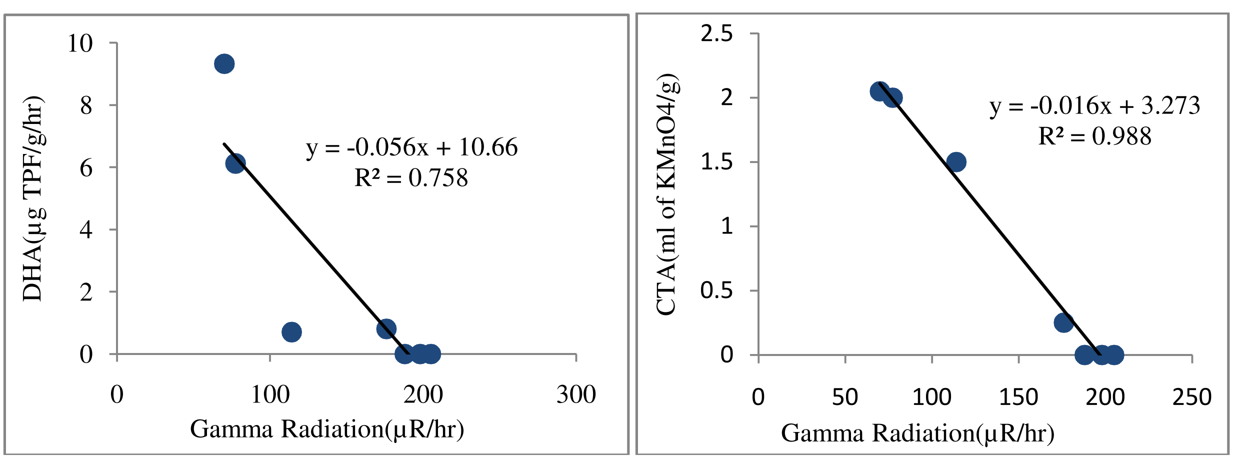

Figure-5 (a, b)
Correlation between Gamma radiation rate vs. enzyme activities in different sampling location

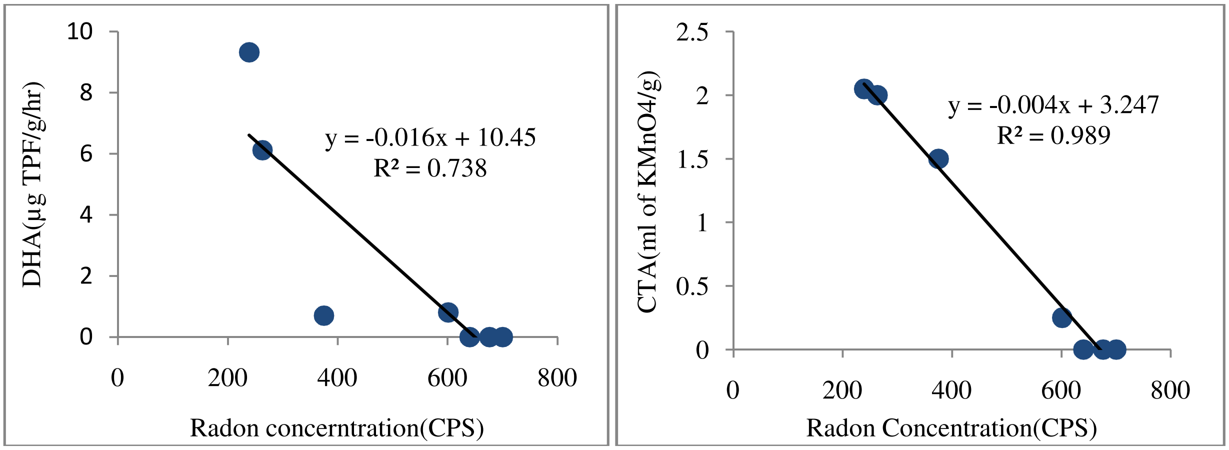

Figure 6 (a, b)
correlation between radon concentration vs. enzyme activities in different sampling location

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