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## Correlation of macro-micro mineral status with parasitic infection in captive wild carnivores of Chhattisgarh, India

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**Abstract**

The aim of this study was to correlate macro-micro mineral status with gastrointestinal parasitic (GIP) infection in wild carnivores kept in captivity in 03 Zoos of Chhattisgarh. A total of 278 faecal samples of captive wild carnivores were collected during summer and pre-monsoon and soil, water and meat samples (n=6 each) were also collected from 03 zoos to estimate the macro-micro mineral level. Faecal samples were examined by direct examination, floatation, sedimentation and McMaster method. Soil, water and meat samples were subjected to acid digestion followed by estimation using Atomic Absorption Spectrophotometer. The zoo wise prevalence of GIP reported to be 34.78%, 15.47% and 29.05% in MBZ, NVZ&S, and KPZ respectively. The macro and micro mineral level in soil, water and meat samples of 03 zoos was observed to be lower than the normal values. It was observed that macro-micro mineral level in soil, water and meat samples had significant effect on prevalence of GIP in captive carnivores under study.

**Keywords:** macro-micro minerals, captive wild carnivores, zoos, EPG

**Introduction**

The most important hosts for a large number of parasites are canids in case of wild carnivores (Joshi, 1991) [8] and their survival can be affected directly through pathological effects and indirectly by reducing the host's immunity (Thiangtum *et al.*, 2006) [21]. Wild animals may possess resistance against parasitism naturally or may have created balanced system with their parasites in natural environment but any deviation in the environment or living conditions from free-living to captivity influences the animals' ecology and might increase its sensitivity for parasitism (Maske *et al.*, 1990; Chakraborty *et al.*, 1994) [10, 4].

Captivity creates an unnatural system for wildlife which disrupts the balance between parasite and host and creates a stressful environment due to which animals become diseased or can even die from parasitic loads that they would have survived under natural conditions (VanWyk and Boomker, 2011) [22]. Additional problem in modern era of Veterinary medicine is that even though a variety of anthelmintic drugs are commercially available for treatment of the endoparasitic infection but still it is practically difficult to completely eliminate the infective stages of the parasites from the environment as well as the host. For these reasons, it is considered very important to conduct preventive measures regularly, to control the presence of parasite infections in animals and to undertake the adequate therapy when it is required (Sahoo *et al.*, 2009) [14].

Application of existing knowledge of disease control and prevention would significantly reduce economic losses due to gastro-intestinal helminthosis (Barmon *et al.*, 2014) [2]. Minerals play important role affecting susceptibility of animal's parasitic burden and have direct anthelmintic affect by influencing host metabolism and modulate immunity of the animal. According to recent evidences, the malnutrition supported prolonged nematode survival is developed by the alterations of immune functions (Fekete and Kellems, 2007) [7]. Information on parasitic infections of wild animals is meager due to paucity of systematic investigations in our country (Varadharajan and Kandasamy, 2000) [23]. Scarcity of reports exist wherein an attempt to correlate endoparasitic infection in wild animal species with macro-micro minerals

concentration in soil, plant and water has been carried out (Mishra, 2017) <sup>[12]</sup>. Hence, present study was envisaged with an attempt of find out any correlation between GIP in captive wild carnivores in relation to macro-micro mineral content of soil water and meat.

## Materials and Methods

### Study area

The present study was carried out in 03 different zoos of Chhattisgarh *Viz.* Maitri Bagh Zoo (MBZ), Bhilai; Nandanvan Zoo and Safari (NVZ&S), Raipur and Kanan Pendari Zoo (KPZ), Bilaspur.

### Faecal sample collection

A total number of 278 faecal sample of captive wild carnivores were collected during summer and pre-monsoon (n=139 each) from 03 zoos of Chhattisgarh. A total of 278 faecal samples were collected from 03 different zoos, out of which 46 samples were collected from MBZ, 84 faecal samples from NVZ&S and 148 samples from KPZ. Fresh faecal samples were collected from the captive enclosure in clean, dry interlocked polythene bags. The samples were labeled with various details like species, age, sex and enclosure number for easy identification of the samples during laboratory investigation (Khutey *et al.*, 2020) <sup>[9]</sup>.

Faecal samples were collected from different species of wild carnivores *Viz.* Asiatic lion (*Panthera leo persica*) (n=24), Royal Bengal Tiger (*Panthera tigris tigris*) (n=35), Leopard (*Panthera pardus*) (n=21), Jackal (*Canis aureus*) (n=24), Hyaena (*Hyaena hyaena*) (n=11), Fox (*Vulpes bengalensis*) (n=19) and Jungle Cat (*Felis chaus*) (n=05) during both season (Chandrakar *et al.*, 2020) <sup>[5]</sup>.

### Soil sample collection

Soil samples (n=6 from each zoo) were collected from different areas of enclosure of 03 zoos for the estimation of macro and micro minerals. Soil surface was dug to about 15 cm depth in the 'V' shape and the sides of the dugged area were scooped for sample collection. About 100 grams of soil sample was stored in clean interlocked polythene bags and were labeled accordingly (Mishra, 2017) <sup>[12]</sup>.

### Water sample collection

Water samples were collected in polypropylene bottle of 100ml capacity, from the enclosures inside different zoos.

### Meat sample collection

The meat samples were collected from the different zoos in a clean, dry and individually labeled plastic container in ice box.

### Faecal sample examination

All faecal samples were subjected to routine coproscopical examination comprising of floatation and sedimentation technique followed by EPG count by MC Mater method as per routine protocol (Skerman and Hillard, 1966; Soulsby, 1982) <sup>[18,19]</sup>.

### Macro-micro mineral estimation

#### Mineral estimation of soil samples

The collected soil samples were dried in shade under fan at room temperature for 48 hours and sieved through a 2 mm sieve to remove debris, pebbles, stones etc. About 1 gram of dried and ground soil sample was taken into a 250 ml conical

flask and subjected to acid digestion for 12 hrs. Then it was placed into block digester and heated at 125°C for 5 hours. The digested analyte was washed with distilled water making a volume of 50ml in a volumetric flask. The solution was analyzed for estimation minerals *Viz.* calcium, phosphorus, magnesium, iron, selenium, zinc and copper were estimated using Atomic Absorption Spectrophotometer (Piper, 1942) <sup>[13]</sup>.

#### Mineral estimation of water samples

Water sample was filtered through a 0.45mm filter paper and then acidified by 1 ml of concentrated HNO<sub>3</sub> and the collected samples were stored in a dark place at room temperature until further analysis. The stored water samples were analyzed for macro and micro minerals *Viz.* calcium, phosphorus, magnesium, iron, selenium, zinc and copper by Atomic Absorption Spectrophotometer (APHA, 1998) <sup>[11]</sup>.

#### Mineral estimation of meat samples

Meat samples for mineral analysis were digested with 1:4 v/v mixture of perchloric acid (60 percent) and nitric acid (70 percent). The dilution was made with deionized water. Macro and micro nutrient elements *Viz.* calcium, phosphorus, magnesium, iron, selenium, zinc and copper were determined by using Atomic Absorption Spectrophotometer (Siddiqi *et al.*, 1994) <sup>[15]</sup>.

## Results and Discussion

### Zoo wise prevalence of GIP

The zoo wise prevalence in our study was reported to be 34.78% (16/46), 15.47% (13/84) and 29.05% (43/148) in MBZ, NVZ&S, and KPZ respectively. Comparison between different zoos revealed that significantly (p<0.05) higher prevalence of gastrointestinal nematodiasis in captive wild animals of MBZ as compared to KPZ and NVZ&S.

Thawait *et al.* (2014) <sup>[20]</sup> have also reported prevalence of helminthic infection in carnivores to be 28.33% in KPZ which is nearly similar to our findings. However, in same study, much higher prevalence (45.2%) of helminthic infection was reported in captive carnivores of Nandanvan Zoo, Raipur.

### Mineral level of soil samples

The macro and micro mineral content of soil samples collected from 03 different zoos is presented in table no. 1.

The findings of our study revealed that calcium content of soil in MBZ, Bhilai was significantly (p<0.05) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The findings of our study are in concordance with those reported by Mishra (2017) <sup>[12]</sup> who has reported mean calcium level in soil samples to be 1127.26±1.03, 1130.43±0.87 and 1126.59±1.27 mg/kg in winter, summer and rainy season respectively. However, the calcium level in soil samples of our study is above the critical value of 71 mg/kg as outlined by McDowell *et al.*, (1984) <sup>[11]</sup>.

The level of phosphorus content of soil in MBZ, Bhilai was significantly (p<0.05) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The phosphorus level in soil samples collected from plain regions of Chhattisgarh has been reported to be 0.018 mg% (Singh *et al.*, 2018) <sup>[17]</sup> which is similar to the values obtained in our study.

The concentration of magnesium content of soil in MBZ, Bhilai was significantly (p<0.05) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ,

Bilaspur. The mean magnesium level in soil samples of our study are similar to those documented by Mishra (2017) <sup>[12]</sup> where magnesium level in soil was reported to be 249.12±0.11, 250.79±0.22 and 248.79±0.22 mg/kg in winter, summer and rainy season respectively. Contrastingly higher values of magnesium content in soil samples during our study have been observed as compared to the critical value of 9.1 mg/kg (McDowell *et al.*, 1984) <sup>[11]</sup>.

The findings of our study revealed that copper content of soil in MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean copper level in soil samples in our study are in congruity with those stated by Mishra (2017) <sup>[12]</sup> wherein the mean values were reported to be 1.38±0.07, 1.32±0.03 and 1.37±0.09 mg/kg in winter, summer and rainy season respectively. However, the copper content in soil is above the critical value of 1 mg/kg for soil of subtropics and tropics (McDowell *et al.*, 1984) <sup>[11]</sup>.

The concentration of iron content of soil in MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean iron level in soil samples of our study are in close proximity to those stated by Mishra (2017) <sup>[12]</sup> wherein iron content of soil samples was reported to be 42.17±0.86, 38.83±2.02 and 40.5±1.61 mg/kg in winter, summer and rainy season respectively. However, the iron content in soil samples of our study is much higher than the critical value of 20 mg/kg as reported by McDowell *et al.* (1984) <sup>[11]</sup>.

The level of zinc content in soil samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The values of zinc in soil samples during our study are almost similar to those stated by Mishra (2017) <sup>[12]</sup> where zinc level in soil was reported to be 1.45±0.19, 1.26±0.19 and 1.42±0.2 mg/kg in winter, summer and rainy season respectively. However, the zinc content in soil samples of our study is little below the critical value of 1.5 mg/kg as reported by McDowell *et al.* (1984) <sup>[11]</sup>.

The concentration of selenium content in soil samples of all zoos were non-significantly ( $p>0.05$ ) different in summer and pre-monsoon season. A similar kind of selenium level in soil samples has been reported as 0.01±0.01, 0.01±0.01 and 0.01±0.01 mg/kg in winter, summer and rainy season respectively (Mishra, 2017) <sup>[12]</sup>. Similarly, the selenium content in soil is in close proximity to the critical value of 0.01 mg/kg as reported for soil of subtropics and tropical region (McDowell *et al.*, 1984) <sup>[11]</sup>.

#### Mineral level of water samples

The macro and micro mineral content of water samples collected from 03 different zoos is presented in table no. 2.

The level of calcium content in water samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean calcium level in water samples of our study are similar to those stated by Mishra (2017) <sup>[12]</sup> wherein calcium level in water was reported to be 41.54±0.35, 42.03 ±0.06 and 40.65±0.26 ppm in winter, summer and rainy season respectively. The calcium content of water samples in our study is within the permissible limit of WHO (2002) <sup>[24]</sup> guidelines (75 ppm).

The phosphorus content in water samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur.

Almost similar value of mean phosphorus level (0.103±0.009 ppm) in water samples has been reported by Davis (2017) <sup>[6]</sup>.

The level of magnesium content in water samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean magnesium level in water samples of our study are similar to those stated by Mishra (2017) <sup>[12]</sup> where magnesium level in water was reported to be 1.5±0.19, 1.51±0.01 and 1.41±0.03 ppm in winter, summer and rainy season respectively. The magnesium content of water samples in our study is within the permissible limit (50 ppm) of WHO (2002) <sup>[24]</sup> guidelines.

The copper content in water samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean copper level in water samples of our study are in concordance with those stated by Mishra (2017) <sup>[12]</sup> where copper level in water was reported to be 0.3±0.01, 0.31±0.01 and 0.3±0.01 ppm in winter, summer and rainy season respectively. However, the copper content in water samples of our study is much higher than the permissible limit of 0.05 ppm as stated by WHO (2002) <sup>[24]</sup> guidelines.

The level of iron content in water samples of MBZ, Bhilai was significantly ( $p<0.05$ ) higher in pre-monsoon season as compared to KPZ, Bilaspur. The mean iron level in water samples of our study are similar to those stated by Mishra (2017) <sup>[12]</sup> where iron level in water was reported to be 1.51±0.01, 1.52±0.01 and 1.5±0.01 ppm in winter, summer and rainy season respectively. The iron content in water samples of our study exceeds the permissible limit (0.3 ppm) of WHO (2003) <sup>[24]</sup> guidelines.

The zinc content in water samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean zinc level in water samples of our study are in concordance with those stated by Mishra (2017) <sup>[12]</sup> where zinc level in water was reported to be 2.9±0.41, 3.18±0.15 and 2.3±0.47 ppm in winter, summer and rainy season respectively. The zinc content in water samples of 03 different zoos is within the permissible limit (5 ppm) as per standards of WHO (2002) <sup>[24]</sup>. The level of selenium content in water samples in 03 different zoos under study was non-significantly ( $p>0.05$ ) different from each other. However, the mean selenium level in water samples of our study are similar to those stated by Mishra (2017) where selenium level in water was reported to be 0.01 ± 0.00, 0.01 ± 0.00 and 0.01 ± 0.00 ppm in winter, summer and rainy season respectively. The selenium content in water samples of our study is within the permissible limit of WHO (2002) <sup>[24]</sup> guidelines (0.01 ppm).

#### Mineral level of meat samples

The macro and micro mineral content of meat samples collected from 03 different zoos is presented in table no. 3.

The calcium content in meat samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The findings of our study are in accordance with the mean calcium level of 11.21±0.35 mg/ 100gm in meat samples reported by Siham *et al.* (2013) <sup>[16]</sup> and 11 mg/100gm by Casey (1992) <sup>[3]</sup>.

The mean phosphorus content in meat samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean phosphorus level in meat samples

recorded by Siham *et al.* (2013) <sup>[16]</sup> was 154.5±3.82 mg/100gm while Casey (1992) <sup>[3]</sup> reported phosphorus content of meat samples to be 155.5 mg per 100 gm which is in accordance with the findings of our study.

The magnesium content in meat samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The findings of our study are in agreement with the findings of Siham *et al.* (2013) <sup>[16]</sup> who have reported mean phosphorus level in meat samples to be 27.31±4.57 mg/100gm. Similarly, Casey (1992) <sup>[3]</sup> has also reported mean phosphorus level of meat samples to be 19.7 mg/100 gm which is in congruity with our findings.

The level of copper in meat samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean copper level in meat samples recorded by Casey (1992) <sup>[3]</sup> was 0.30 mg per 100 gm which is similar to the findings of our study.

The mean iron content in meat samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to NVZ&S, Raipur and KPZ, Bilaspur. The mean iron level in meat samples of our study are in close proximity to those stated by Siham *et al.* (2013) <sup>[16]</sup> as 3.50±0.45 mg/100gm as well as Casey (1992) <sup>[3]</sup> who has reported

4.37mg/100 gm level of iron in meat samples.

The level of zinc in meat samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer season as compared to NVZ&S, Raipur. However, the mean zinc content of meat samples of MBZ, Bhilai was significantly ( $p<0.05$ ) lower in summer and pre-monsoon season as compared to KPZ, Bilaspur. The mean zinc level in meat samples recorded by Casey (1992) <sup>[3]</sup> was 3.51 mg per 100 gm which is similar to our observations.

The macro and micro mineral content of soil, water and meat samples of 03 selected zoos during this study was recorded to be comparatively lower than the normal recommended values. The decreased content of these minerals could have led to increased prevalence of gastrointestinal parasites in captive wild carnivores under study (Mishra, 2017) <sup>[12]</sup>.

It has been assumed that minerals play an important role in affecting susceptibility of animals to parasitic load and exert direct anthelmintic affect by influencing host metabolism and modulating immunity of the animal. Additionally, gastrointestinal parasites have been proposed to alter the utilization of calcium, phosphorus and magnesium in affected animals. Immunocompromised status arising due to deficiency of macro and micro minerals also leads to prolonged nematode survival (Fekete and Kellems, 2007) <sup>[7]</sup>.

**Table 1:** Mean ± S.E.values of micro and macro mineral level in soil samples of different zoos

Mineral	Season	MBZ (n=6)	NVZ (n=6)	KPZ (n=6)
		Mean ± S.E.	Mean ± S.E.	Mean ± S.E.
Ca	Summer	1094.93 ± 1.39 <sup>b</sup>	1128.43 ± 1.90 <sup>a</sup>	1129.76 ± 2.10 <sup>a</sup>
	Pre-monsoon	1089.6 ± 2.16 <sup>b</sup>	1128.15 ± 0.60 <sup>a</sup>	1126.48 ± 1.02 <sup>a</sup>
P	Summer	0.06 ± 0.00 <sup>b</sup>	0.08 ± 0.00 <sup>a</sup>	0.08 ± 0.00 <sup>a</sup>
	Pre-monsoon	0.06 ± 0.00 <sup>b</sup>	0.08 ± 0.00 <sup>a</sup>	0.08 ± 0.00 <sup>a</sup>
Mg	Summer	226.75 ± 3.81 <sup>b</sup>	246.10 ± 3.06 <sup>a</sup>	247.52 ± 3.45 <sup>a</sup>
	Pre-monsoon	213.78 ± 2.08 <sup>b</sup>	240.83 ± 1.22 <sup>a</sup>	244.03 ± 3.68 <sup>a</sup>
Cu	Summer	1.12 ± 0.01 <sup>b</sup>	1.37 ± 0.01 <sup>a</sup>	1.35 ± 0.01 <sup>a</sup>
	Pre-monsoon	1.12 ± 0.01 <sup>b</sup>	1.36 ± 0.02 <sup>a</sup>	1.36 ± 0.01 <sup>a</sup>
Fe	Summer	30.43 ± 0.08 <sup>c</sup>	39.26 ± 0.37 <sup>b</sup>	41.54 ± 0.42 <sup>a</sup>
	Pre-monsoon	30.44 ± 0.08 <sup>c</sup>	36.73 ± 0.86 <sup>b</sup>	39.26 ± 0.37 <sup>a</sup>
Zn	Summer	1.12 ± 0.01 <sup>b</sup>	1.39 ± 0.36 <sup>a</sup>	1.43 ± 0.02 <sup>a</sup>
	Pre-monsoon	1.03 ± 0.00 <sup>b</sup>	1.35 ± 0.01 <sup>a</sup>	1.37 ± 0.01 <sup>a</sup>
Se	Summer	0.00± 0.00	0.00± 0.00	0.01 ± 0.00
	Pre-monsoon	0.00± 0.00	0.00± 0.00	0.00± 0.00

a, b and c = Means within the same row with different superscripts differ significantly ( $p<0.05$ )

**Table 2:** Mean ± S.E.values of micro and macro mineral level in water samples of different zoos

Mineral	Season	MBZ (n=6)	NVZ (n=6)	KPZ (n=6)
		Mean ± S.E.	Mean ± S.E.	Mean ± S.E.
Ca	Summer	37.05± 0.74 <sup>b</sup>	42.67± 0.09 <sup>a</sup>	43.66± 0.49 <sup>a</sup>
	Pre-monsoon	34.46± 0.39 <sup>b</sup>	40.67± 0.24 <sup>a</sup>	40.28± 0.29 <sup>a</sup>
P	Summer	0.10± 0.00 <sup>b</sup>	0.10± 0.00 <sup>a</sup>	0.10± 0.00 <sup>a</sup>
	Pre-monsoon	0.08± 0.00 <sup>b</sup>	0.10± 0.00 <sup>a</sup>	0.10± 0.00 <sup>a</sup>
Mg	Summer	1.51± 0.01 <sup>b</sup>	1.54± 0.01 <sup>ab</sup>	1.56± 0.01 <sup>a</sup>
	Pre-monsoon	1.23± 0.22	1.46± 0.01	1.50± 0.02
Cu	Summer	0.18± 0.04 <sup>b</sup>	0.30± 0.03 <sup>a</sup>	0.28± 0.03 <sup>a</sup>
	Pre-monsoon	0.15± 0.03	0.23± 0.04	0.23± 0.04
Fe	Summer	1.56± 0.01	1.56± 0.01	1.57± 0.01
	Pre-monsoon	1.50± 0.01	1.48± 0.01	1.48± 0.01
Zn	Summer	1.38± 0.05 <sup>b</sup>	3.11± 0.20 <sup>a</sup>	3.13± 0.22 <sup>a</sup>
	Pre-monsoon	1.07± 0.01 <sup>c</sup>	2.53± 0.04 <sup>a</sup>	1.38± 0.05 <sup>b</sup>
Se	Summer	0.01± 0.00	0.01± 0.00	0.01± 0.00
	Pre-monsoon	0.01± 0.00	0.01± 0.00	0.01± 0.00

a, b and c = Means within the same row with different superscripts differ significantly ( $p<0.05$ )

**Table 3:** Mean  $\pm$  S.E. values of micro and macro mineral level in meat samples of different zoos

Mineral	Season	MBZ (n=6)	NVZ (n=6)	KPZ (n=6)
		Mean $\pm$ S.E.	Mean $\pm$ S.E.	Mean $\pm$ S.E.
Ca	Summer	80.17 $\pm$ 1.01 <sup>c</sup>	110 $\pm$ 0.58 <sup>a</sup>	106.17 $\pm$ 0.87 <sup>b</sup>
	Pre-monsoon	82.83 $\pm$ 0.95 <sup>b</sup>	105.5 $\pm$ 1.45 <sup>a</sup>	104.67 $\pm$ 0.80 <sup>a</sup>
P	Summer	1174.17 $\pm$ 14.88 <sup>b</sup>	1487.5 $\pm$ 15.83 <sup>a</sup>	1477.33 $\pm$ 10.86 <sup>a</sup>
	Pre-monsoon	1153 $\pm$ 12.23 <sup>b</sup>	1473.67 $\pm$ 10.55 <sup>a</sup>	1471.33 $\pm$ 9.32 <sup>a</sup>
Mg	Summer	154.33 $\pm$ 1.20 <sup>b</sup>	186.5 $\pm$ 2.43 <sup>a</sup>	185.33 $\pm$ 1.76 <sup>a</sup>
	Pre-monsoon	155.83 $\pm$ 1.74 <sup>c</sup>	188.83 $\pm$ 1.54 <sup>a</sup>	184.17 $\pm$ 1.19 <sup>b</sup>
Cu	Summer	1.58 $\pm$ 0.10 <sup>b</sup>	2.8 $\pm$ 0.06 <sup>a</sup>	2.63 $\pm$ 0.08 <sup>a</sup>
	Pre-monsoon	1.65 $\pm$ 0.07 <sup>b</sup>	2.7 $\pm$ 0.1 <sup>a</sup>	2.63 $\pm$ 0.16 <sup>a</sup>
Fe	Summer	34.13 $\pm$ 1.73 <sup>b</sup>	42.91 $\pm$ 0.30 <sup>a</sup>	42.63 $\pm$ 0.09 <sup>a</sup>
	Pre-monsoon	32.28 $\pm$ 1.10 <sup>b</sup>	42.6 $\pm$ 0.19 <sup>a</sup>	42.68 $\pm$ 0.15 <sup>a</sup>
Zn	Summer	29.03 $\pm$ 0.56 <sup>c</sup>	34.57 $\pm$ 0.28 <sup>a</sup>	33 $\pm$ 0.17 <sup>b</sup>
	Pre-monsoon	31.87 $\pm$ 0.79 <sup>b</sup>	34.7 $\pm$ 0.13 <sup>a</sup>	34.3 $\pm$ 0.34 <sup>a</sup>
Se	Summer	1061.17 $\pm$ 10.64 <sup>b</sup>	1175.83 $\pm$ 17.21 <sup>a</sup>	1201.17 $\pm$ 12.58 <sup>a</sup>
	Pre-monsoon	1034.5 $\pm$ 11.25 <sup>b</sup>	1232.67 $\pm$ 19.87 <sup>a</sup>	1225.83 $\pm$ 21.43 <sup>a</sup>

a, b and c = Means within the same row with different superscripts differ significantly ( $p < 0.05$ )

### Conclusion

The macro and micro mineral level in soil, water and meat samples were found to be lower in all 03 zoos which could have resulted in higher incidence of gastrointestinal parasites in captive wild carnivores of 03 zoos.

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