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RESEARCH ARTICLE

Effects of Lead on Hematological and Biochemical Parameters in Lohi Sheep Grazing Around a Sewerage Drain

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ABSTRACT

Heavy metal toxicity is increasing day by day due to increasing trends of urbanization and industrialization in developing countries like Pakistan. The present study was aimed to unveil the status of lead and its hazardous effects on Lohi sheep (an indigenous meat breed), in a selected area of District Jhang, Punjab, Pakistan. This work was carried out to determine the Pb concentration in soil, forage, water and serum to correlate its effects on biochemical and hematological parameters in sheep grazing around sewerage drain. The Lohi sheep showed higher serum lead concentration above the permissible level without manifesting any apparent signs of illness. The range of lead concentration in soil (06.91-15.80 mg/kg), forage (1.61-4.65 mg/kg) and waste water (0.01-0.15 mg/L) was safe for agriculture cultivation. The sheep (92.22%) showed serum lead concentration above the recommended safe limit of 0.35 mg/L including the sheep (18.88%) possessed serum lead level above 2.00 mg/L. The biochemical profiles, ESR and DLC showed statistically non-significant effect of lead toxicity in Lohi sheep. Whereas, RBC count, Hb and PCV showed inverse correlation with lead concentration. This is the first study which correlates the concentration of a heavy metal (Pb) in natural environment and its dissemination to animal along with the cumulative effect on liver, kidney and blood parameters. The findings of this study suggested that the water, forage and soil have served as continuous source of lead accumulation in sheep which may pose serious health hazards for the consumers.

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INTRODUCTION

Heavy metals are poorly defined group of elements that are at least five times denser than the water. Lead is a member of heavy metal group which naturally occurs in earth's crust in small traces (Lukakova *et al*., 2014; Javed, 2015; Kousar *et al*., 2016). Lead is usually found in many products like storage batteries, alloys, solder, ceramics and plastics, ammunition and protections against atomic radiation & X-ray (Abolude *et al*., 2013). When the lead based batteries are recycled, the effluents of recycling plants are emerged as source of lead toxicity especially in developing countries (Memon *et al*., 2014; Cao *et al*., 2015). Many medicinal plants and their products have been reported to be a source of lead accumulation in animals and human tissues. The contaminated forage by industrial effluents, household wastes, fertilizers, insecticides and mineral mixtures are also common sources of lead toxicity in animals (Nergus *et al*., 2005; Hassan *et al*., 2016; Naz *et al*., 2016).

Lead is considered as the major environmental pollutant which has been reported to cause accidental poisoning in domestic animals usually in the industrial regions of the world (Lukacova *et al*., 2014; Zhai *et al*., 2015). The animal products are being a major source of lead transmission from animal to man. The deficiency of essential elements in body enhances the absorption of lead (Liu *et al*., 2015). Sheep exhibits more chances of ingestion of lead due to grazing of herbage very close to the ground surface. More likely, it can ingest contaminated forage and hence shows higher lead level in blood (Smith *et al*., 2009).

Lead poisoning has been reported in domestic animals. The ruminants showed more settling and

absorption of lead in reticulum. The absorbed lead displaces some bivalent cations like calcium and disrupts the functioning of enzymes (Liu *et al*., 2015). It reduces the flexibility of red blood cells, shortens their life span and disrupts the functions of delta-aminolevulinic acid dehydratase which lead to normocytic, hypochromic anemia (Wang *et al*., 2015).

It has been reported that the intensity of pathologic changes is directly related to the quantitative accumulation of lead in various organs of the animals (El-Hameed *et al*., 2008). The higher levels of lead in various edible tissues of animals have been reported in various studies. But the correlation of blood lead level with environment and clinico-biochemical profile were not studied in small ruminants especially in indigenous sheep of Pakistan. There is no report available which warns about the health hazards associated with long term uptake of lead in natural environment in sheep. The present work was designed to determine the Pb concentration in soil, forage, water and serum, and correlates its effects with biochemical and hematological parameters in sheep grazing around a sewerage drain in District Jhang, Pakistan.

MATERIALS AND METHODS

Sampling area: The research work was carried out in a Study Area (SA) which is located around a sewerage drain (Ganda Nala) in District Jhang Punjab, Pakistan. The sewerage drain collects house hold wastes and industrial effluents from different cities and drop into Chenab River. The selected area is irrigated with sewerage water especially during the months of water scarcity. The forage of the area is used for stall feeding and grazing of sheep. It presents a true correlation of lead transfer from natural environment to sheep. The SA was divided into six sampling points at a distance of 500 meters on both sides of drain as shown in Fig. 1.

Sample collection (soil, forage, water and sheep blood): The soil and forage (*Trifolium alexandrinum* and *Aedicago sativa*) samples (n=140) were collected from all the points of study area. For this, each sampling point was divided into 20 parts by walking a distance of 25 meters to collect a sample. And a total of (n=20) soil and (n=20) forage samples were collected from each sampling point. Similarly, twenty soil and forage samples (n=20) were also collected from cultivated area near a tube-well located at College of Veterinary and Animal Sciences (CVAS), Jhang, which served as a control area.

A total of 36 water samples were collected from SA as six samples from each sampling point were collected by dividing it into equal parts. The water samples were collected in a polyethylene-acid-resistant bottle which were washed, rinsed with deionized water and dried. Concentrated nitric acid 5 ml was added as preservative to adjust the pH to <2.0 to maintain heavy metal concentrations (Liu *et al*., 2015). Samples were transported to Pathology Laboratory. Similarly, six water samples were also collected from CVAS, Jhang area which served as control.

Adult Lohi sheep (40 female & 20 male) of age 1-2 years, weighing 40-50 kg were randomly selected from each of the six sampling points. A total of (n=12) sheep (8 female & 4 male) were reared at CVAS, Jhang for ninety days under optimum conditions which served as control. The control sheep were offered feed and water which contained Pb concentration below the permissible limits. Total 5 ml blood was collected in a vacutainer with EDTA for hematological studies. Total 5 ml blood was collected to harvest serum for lead detection and biochemical studies. The blood samples were kept in an ice-pack and immediately transported to pathology laboratory.

Laboratory test (Lead concentration, Biochemical and Hematological analysis): All the samples including water, soil, forage and serum were subjected to wet digestion (Twyman, 2005) to obtain the transparent and clean solution for lead analysis. The analysis was done using Flame Atomic Absorption Spectrometry (Hitachi Polarized Zeeman AAS, Z-8200, Japan) at Central Hi-Tech Laboratory, University of Agriculture, Faisalabad.

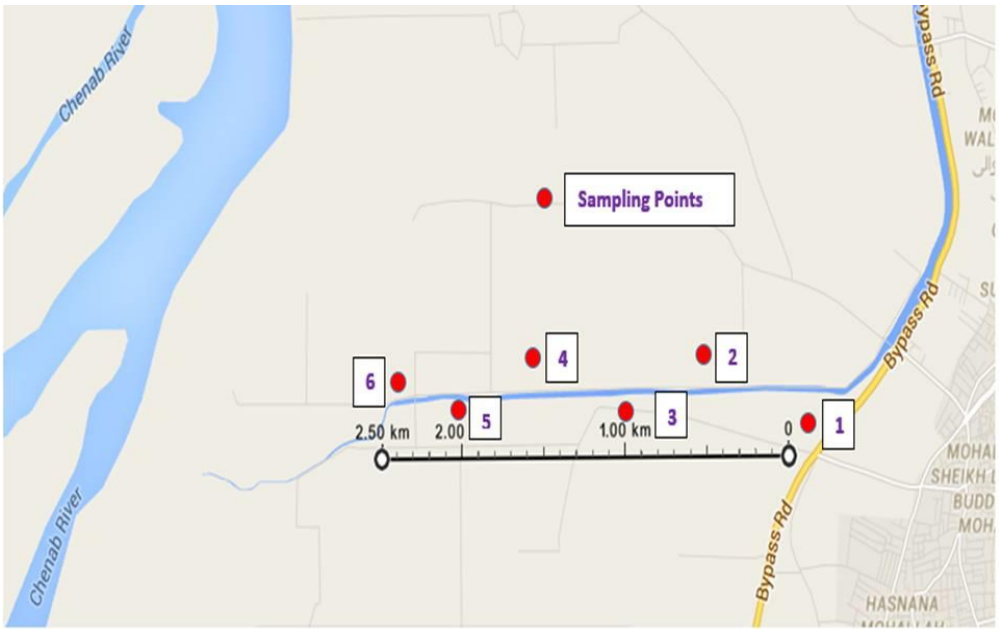

Fig. 1: Map of study area showing six sampling points around the sewerage drain, Jhang, Pakistan.

Hematology was performed to determine total erythrocyte count (TEC x 10^6/µL), total leukocyte count (TLC x 10^3/µL), differential leukocyte count (DLC%), hemoglobin estimation (Hb g/dL), pack cell volume (PCV%) and erythrocyte sedimentation rate (ESR mm/hr). All the hematological studies were performed using digital Hematology Analyzer of (Exigo Vet., Sweden, standardized for 12 pre-installed species profiles and 17 parameters). Whereas the erythrocyte sedimentation rate and differential leukocyte count were performed manually according to the procedure described by Benjamin (1985). The serum samples were analyzed for estimation of alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), urea and creatinine concentrations by using the commercially available kits (DiaSys, Germany).

Statistical analysis: The data were analyzed using IBM SPSS Statistics Version 21 and groups were compared by Kruskal-Wallis test.

RESULTS

The soil, forage, water and serum lead concentrations from six sampling points of SA and CVAS (as control) are shown in Table 1. All of six sampling points of SA showed significantly higher ($P<0.05$) lead concentration as compared to control. On individual point comparisons, the variation in lead concentration was observed among different points. All the sampling points showed variation in water lead concentration and point 2 showed the highest lead concentration (0.15 mg/L) concentration in forage, water and serum.

The ALT, AST, ALP, urea and creatinine values are described in Table 2. The ALT, AST and ALP values of SA were showing significantly higher ($P<0.05$) concentration as compared with control whereas, urea and creatinine showed non-significant difference ($P>0.05$) compared with control. On individual point comparison, the ALP showed non-significant differences ($P>0.05$) from all the sampling points of SA, whereas the AST and ALT showed non-significant differences on most of the sampling points.

The values of RBC count, TLC, Hb, PCV and ESR obtained from different sampling points are given in Table 3. The RBC, TLC, Hb and PCV values of study were found significantly lower as compared with control, but ESR values showed non-significant difference as compared to control. On individual point comparison, the Hb concentration showed non-significant differences among different sampling points of SA. The neutrophils from the SA showed significantly higher values while eosinophils and monocytes showed significantly lower values compared with the control group as shown in Table 4.

DISCUSSION

The present work was focused to determine the Pb concentration in soil, forage, water and serum of sheep to correlate its effects on biochemical and hematological parameters. The soil was irrigated by sewerage water which was the possible source of Pb in the study area. The soil lead concentration in the present study was ranging from 06.91-15.80 mg/kg in District Jhang, Punjab, Pakistan which was found below the already reported concentration of 59.90-135.70 mg/kg in Dist. Sargodha, Punjab, Pakistan (Khan *et al*., 2015). This is in agreement with the findings of Khan *et al*. (2013) who reported the soil Pb concentration below the safe limits in urban and peri-urban areas of Punjab, Pakistan. The soil lead concentration in present work was also falling below the cut-off values of 50 mg/kg which was declared suitable for forage cultivation by Kabata-Pendias (2000).

In this study, the soil lead concentration of point 1 was found higher as it was located at the start of flow of drain and hence exposed by highly saturated water with lead as compared to other points. This may be correlated with the continuous transfer and accumulation of lead or the factors that can affect the adsorption and retention of metal in soil (Khan *et al*., 2013; Butt *et al*., 2005).

Table 1: Lead concentration in soil, forage, water and serum from different sampling points of study area around the sewerage drain

Sampling Point	Soil (mg/kg)	Forage (mg/kg)	Water (mg/L)	Serum (mg/L)
Point 1	15.80±0.289a	2.51±0.046a	0.08±0.003a	0.98±0.100a
Point 2	10.79±0.117b	4.00±0.124b	0.15±0.049ab	1.84±0.436b
Point 3	12.67±0.499abc	4.65±0.159bc	0.02±0.003c	1.34±0.171ac
Point 4	10.39±0.278bd	2.73±0.062ad	0.04±0.004cd	1.54±0.105bcd
Point 5	11.34±0.249bcde	2.99±0.075ade	0.02±0.003cde	1.51±0.092bcde
Point 6	11.25±0.221bcdef	2.44±0.061adef	0.07±0.003abf	1.52±0.127bcdef
CVAS	6.91±0.327g	1.61±0.227g	0.01±0.002g	0.65±0.071g

Values are mean±SE, Minimum and maximum values, Means in the column bearing different letters (a, b, c, d, e, f, g) are statistically significantly different at $P<0.05$.

Table 2: Serum biochemical parameters of Lohi sheep from different sampling points of study area around the sewerage drain

Sampling Point	ALT U/L	ASTU/L	ALP U/L	Urea mg/dL	Creatinine mg/dL
Point 1	41.9±1.739a	36.0±1.381a	264.3±13.153a	32.0±1.318a	0.81±0.050a
Point 2	39.5±2.212ab	30.1±1.883b	243.3±15.398a	31.3±1.438a	0.78±0.023a
Point 3	31.8±1.229b	25.4±0.726bc	220.9±13.961a	36.8±1.340a	0.81±0.030a
Point 4	44.2±4.020ab	33.3±3.064abcd	224.0±15.786a	35.6±1.341a	0.79±0.023a
Point 5	36.8±1.343ab	33.5±0.857abde	240.9±10.240a	32.9±0.757a	0.76±0.016a
Point 6	40.4±3.263ab	34.4±2.400abde	277.9±12.936a	33.6±1.871a	0.82±0.027a
CVAS	26.8±0.666c	29.2±2.833bf	203.0±2.955b	30.8±0.600a	0.86±0.042a

Values are mean±SE, Minimum and maximum values, Means in the column bearing different letters (a, b, c, d, e, f) are statistically significantly different at $P<0.05$.

Table 3: The hematological parameters of blood of Lohi sheep from different sampling points in study area

Sampling Point	RBC 10^6/µL	TLC 10^3/µL	Hb g/dL	PCV %	ESR mm/hr
Point 1	7.92±0.102a	1.47±0.119a	8.64±0.078a	19.40±0.191a	1.21±0.030a
Point 2	7.55±0.209ab	2.35±0.210ab	8.48±0.219a	19.33±0.560a	1.22±0.029a
Point 3	7.28±0.215abc	1.60±0.114abc	8.13±0.169a	18.48±0.383ab	1.22±0.031a
Point 4	8.30±0.190abd	1.25±0.097acd	8.77±0.200a	21.01±0.483ac	1.25±0.040a
Point 5	7.25±0.267abce	0.96±0.079de	8.08±0.280a	18.44±0.608ab	1.21±0.030a
Point 6	8.01±0.172abcde	1.10±0.104ade	8.87±0.214a	19.72±0.496abc	1.24±0.033a
CVAS	10.58±0.604f	5.41±0.205f	12.01±0.771b	32.14±2.566d	1.35±0.061a

Values are mean±SE, Minimum and maximum values, Means in the column bearing different letters (a, b, c, d, e, f) are statistically significantly different at P<0.05.

Table 4: Differential leukocyte count (DLC) of blood of Lohi sheep from different sampling points in study area

Sampling Point	Neutrophil %	Eosinophil %	Monocyte %	Lymphocyte %
Point 1	38.79±1.708a	1.22±0.093a	3.36±0.141a	56.61±1.698a
Point 2	39.41±1.142a	1.07±0.097a	3.63±0.082ab	56.04±1.123a
Point 3	39.99±1.373a	1.12±0.114a	3.52±0.052abc	55.35±1.324a
Point 4	38.27±1.783a	1.16±0.069a	3.58±0.074abcd	56.98±1.771a
Point 5	30.36±1.825b	1.28±0.119a	3.46±0.063abcd	64.89±1.857c
Point 6	29.50±1.900bc	1.20±0.074a	3.18±0.028ad	66.10±1.931c
CVAS	23.61±0.947d	5.16±0.563b	4.35±0.203e	66.87±1.310c

Values are mean±SE, Minimum and maximum values, Means in the column bearing different letters (a, b, c, d, e, f) are statistically significantly different at P<0.05.

In the present study, the forage lead concentration was ranging from 1.61-4.65 mg/kg which were found below the maximum tolerable level of lead (30 mg/Kg) to develop toxic effects in animals (Khan *et al*., 2015). The forage lead concentration of point 2 and 3 was higher than maximum acceptable limit (3.0 mg/Kg) for plants (Butt *et al*., 2005; Ahmad *et al*., 2009).

In present study, the lead concentration in sewerage water was found to be below the permissible limits of 5.0 mg/L (WHO, 2007) which were similar to the findings of Khan *et al*. (2013). According to reports, water containing Pb concentration even below the permissible limits when continuously used for irrigation for longer periods, might cause build-up of metal in forage and ultimately in animals (Kirkham, 1983).

In present study, the higher serum lead concentration above the reference range of 0.01-0.20 mg/L (Abdou *et al*., 2015) were in agreement with the findings of (Rodriguez-Estival *et al*., 2012; Abdou *et al*., 2015) who also reported the higher lead concentrations in blood of different animals. It was the first study which determined the Pb levels in irrigating water, forage and serum of sheep reared in a selected area of Jhang, Punjab, Pakistan.

In the present study, the values of ALT, AST and ALP were observed within range of reference values. This disagreed with the findings of Badiei *et al*. (2009) who observed the higher ALT and AST concentration in experimentally lead intoxicated Iranian male sheep. Similar findings were also reported by Zaki *et al*. (2010) in Merino sheep. The possible reason for this disagreement could be a sheep breed variation or variable uptake of lead from forage and water.

In the present study, the urea and creatinine concentration were observed within the normal reference range. The values for urea in our study were in agreement with the findings of Zaki *et al*. (2010). Whereas, Zaki *et al*. (2010), reported higher creatinine values in Merino sheep as compared to our study. This variation might be due to different breed of sheep or uptake of Pb in natural environment.

In present study, the reason for the low RBC count, TLC, Hb and PCV might be the exposure of Pb in natural environment at low dose for a longer period. Similar, low RBC count (5.4±1.24 10^6/µL), Hb (8.13±0.14 g/dL) and PCV (32.0±1.4%) values were also reported by Zaki *et al*. (2010) in Merino sheep and Sellaoui *et al*. (2016) in Ouled Djellal ewes which were intoxicated with Pb. However, Zaki *et al*. (2010) reported an increase in TLC values in contrast to our findings.

The ESR values of present research were found in normal reference range which differs with the finding of Zaki *et al*. (2010) who reported higher ESR in Merino sheep of 6 months of age. This difference might be due to age, breed and variable Pb concentrations present in polluted area.

The variable mean values of differential Leukocyte count (DLC) in the present work were similar to the findings of Farkhondeh *et al*. (2014) who observed higher neutrophils and Alabbassi *et al*. (2017) who observed higher neutrophils and lower eosinophils in Pb toxicity in different studies. However, the possible reason of difference in monocyte count in our study might be due to different animal breed or dose of Pb by Alabbassi *et al*. (2017).

Conclusions: In summary, the Pb concentration in soil, forage, water and serum was determined and its effects were correlated with biochemical and hematological parameters in Lohi sheep (as indigenous mutton breed), grazing around sewerage drain in Jhang, Punjab, Pakistan. The Lohi sheep showed higher serum lead concentration above the permissible level without manifesting any apparent signs of illness. The findings of this study suggest that the water, forage and soil served as continuous source of lead accumulation in sheep. The findings are also indicative for the threats of Pb toxicity in Lohi sheep as a local meat breed. Further studies are required to evaluate the threshold level of lead in other indigenous animals and their products. This will contribute towards safeguard of animal and public health in the country.

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Authors contribution: MS and MY conceived and designed the experiment. MS and SE executed the experiment and AA analyzed the sera. MS, MK and MA processed the samples by wet digestion. MS and AK conducted the hematology. All authors interpreted the data, critically revised the manuscript and improved the final version.

REFERENCES

Abdou SA, Mohamed FF and Mohamed EF, 2015. Estimation of some heavy metal residues in blood serum and tissues of camels. Assiut Vet Med J 61:221-9.

Abolude DS, Barak Z, Tanimu Y, *et al*., 2013. Assessment of the concentration of metals in a sewage treatment pond of the Ahmadu Bello University Zaria, Nigeria. J Aquat Sci 28:24-34.

Ahmad K, Khan ZI, Ashraf M, *et al*., 2009. Determination of forage concentrations of lead, nickel and chromium in relation to the requirements of grazing ruminants in the salt range, Pakistan. Pak J Bot 41:61-5.

Alabbassi MG, Hussain SA and Ali SH, 2017. Therapeutic effects of melatonin in lead-induced toxicity in rats. Iraqi J Pharm Sci 17:47-54.

Badiei K, Nikghadam P, Mostaghni K, *et al*., 2009. Effect of lead on thyroid function in sheep. Iran J Vet Res 10:223-7.

Benjamin MM, 1985. Outlines of veterinary clinical pathology. 3rdEd, The Iwoa State Uni. Press, Ames, Iwoa, USA, pp:7-8.

Butt MS, Sharif K, Bajwa BE, *et al*., 2005. Hazardous effect of sewage water on the environment; focus on heavy metals and chemical composition of soil and vegetables. Manag Environ Qual Int J 16:338-46.

Cao S, Duan X, Zhao X, *et al*., 2015. Health risk assessment of various metal (loid) s via multiple exposure pathways on children living near a typical lead-acid battery plant, China. Environ Pollut 200:16-23.

El-Hameed AR, Shalaby SI, Mohamed AH, *et al*., 2008. Effect of oral administration of lead acetate on some biochemical and hormonal parameters during pregnancy in Baladi Goats. Glob Vet 2:301-7.

Farkhondeh T, Boskabady MH, Kohi MK, *et al*., 2014. Lead exposure effects inflammatory mediators, total and differential white blood cells in sensitized guinea pigs during and after sensitization. Drug Chem Toxicol 37:329-35.

Hassan W, Abdullah S, Abbas K, *et al*., 2015. The effect of sub-lethal level of dietary copper and cadmium on the growth performance and oxidative stress in *Cirrhina mrigala*. Pak J Agric Sci 52:789-94.

Javed M, 2015. Growth and metals depuration in Zn plus Pb plus Ni mixture stressed fish grown under composite pond culture conditions. Int J Agric Biol 17:631-6.

Kabata-Pendias A and Pendias H, 2000. Trace elements in soil and plants. 3rd Ed, CRC Press, Inc. Boca Raton, USA, pp:221-33.

Khan A, Javid S, Muhmood A, *et al*., 2013. Heavy metal status of soil and vegetables grown on peri-urban area of Lahore District. Soil Environ 32:49-54.

Khan ZI, Ahmad K, Akram NA, *et al*., 2015. Heavy metals concentration in soil-plant-animal continuum under semi-arid conditions of Punjab, Pakistan. Pak J Zool 47:377-82.

Kirkham MB, 1983. Study on accumulation of heavy metals in soils receiving sewage water. Agri Ecosys Environ 9:251-255.

Kousar S, Javed M and Ilyas R, 2016. Assessment of acute toxicity of aluminum to the four freshwater fish species (*Labeo rohita*, *Cirrhina mrigala*, *Catla catla* and *Ctenopharyngodon idella*). Pak J Agric Sci 53:491-5.

Liu KS, Mao XD, Shi J, *et al*., 2015. Towards bio monitoring of toxic (lead) and essential elements in whole blood from 1-to72-month old children: a cross-sectional study. Afr Health Sci 15:634-40.

Lukacova A, Golian J, Massanyi P, *et al*., 2014. Lead concentration in meat an meat products of different origin. Potravinarstvo Slovak J Food Sc 8:43-7.

Memon F, Narejo NT, Abbasi A, *et al*., 2014. Blood and offal tissue lead levels of goats, sheep and chickens farmed near battery recycling smelters of Hyderabad Pakistan. Sindh Univ Res J 46:407-12.

Naz S, Anjum MA and Akhtar S, 2016. Monitoring of growth, yield, biomass and heavy metals accumulation in spinach grown under different irrigation sources. Int J Agric Biol 18:689-97.

Nergus Y, Ahmed SI and Sharif M, 2005. Impact of contaminated vegetables, fruits and fodders on human health by Malir River farms Karachi. J Chem Soc Pak 27:561-71.

Rodriguez-Estival J, Barasona JA and Mateo R, 2012. Blood Pb and δ-ALAD inhibition in cattle and sheep from a Pb-polluted area. Environ Pollut 160:118-24.

Sellaoui S, Soufedda N, Boudaoud A, *et al*., 2016. Effects of repeated oral administration of lead combined with cadmium in non-lactating ewes. Pak Vet J 36:440-4.

Smith KM, Abrahams PW, Dagleish MP, *et al*., 2009. The intake of lead and associated metals by sheep grazing mining-contaminated floodplain pastures in mid-Wales, UK: I. Soil ingestion, soil–metal partitioning and potential availability to pasture herbage and livestock. Sci Total Environ, 407:3731-9.

Twyman RM, 2005. Sample dissolution for elemental analysis: Wet Digestion. In: Encyclopedia of Analytical Science. 2nd Ed. Elsevier Science, London, UK, pp:146-153.

Wang X, Wang L and Liu S, 2014. Heme-Regulated eIF2α kinase plays a crucial role in protecting erythroid cells against Pb-induced hemolytic stress. Chem Res Toxicol 28:460-9.

World Health Organization (WHO), 2007. Joint FAO/WHO expert standards program codex alimentation commission, Geneva, Switzerland, Series 67.

Zaki MS, Mustafa S and Awad I, 2010. Some studies on lead toxicity in Marino sheep. J Am Sci 6:128-31.

Zhai Q, Narbad A and Chen W, 2015. Dietary strategies for the treatment of cadmium and lead toxicity. Nutrients, 7:552-71.