Sindh Univ. Res. Jour. (Sci. Ser.) Vol.44 (2) 189-194 (2012)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Heavy Metal Detection in *Mystus Bleekeri* as Bioindicator and Potential Risk of Human Health

M. NAEEM, A. SALAM, N. T. NAREJO* M.Y. KHOKHAR**, R.A. YAR, A.ISHTIAQ

Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan 60800, Pakistan.

Corresponding author, , N. T. NAREJO, E-mail: dr_ntnarejo46@yahoo.com Cell No. +92 3423604831

Received 24th March 2012 and Revised 2nd April 2012

Abstract: The detection levels of five heavy metals Copper (Cu), Magnesium (Mg), Zinc (Zn) Cadmium (Cd) and Manganese (Mn) were elucidate from ninety five *Mystus bleekeri* samples to estimate water contamination and potential risk of human consumption in Sialkot region which is an important industrial area in Pakisan. The fish samples were collected from different locations of Nala Daik and were dtermined by spectrorophotometer. The metals detected cadmium exceeds the threshold limits for fish meat imposed by European and other international organizations. Magnesium was found unexpectedly in high amounts but its consumption limits are not set down yet . Copper found only in trace amounts and Zinc levels were within the threshold limits. Regressions were performed for both size and condition factor with metal concentrations. Zn shows positive allometry ($P<0.001$) for fish size (both weight and length) while Mg shows negative allometry for fish interms of length and weight, Mn was least significant in relation with body weight (wet weight, $\mu g g^{-1}$). No effect of condition factor was observed in the study on *Mystus bleekeri.* Inter-elemental regression shows only few significant correlations among metals.

Keywords: Heavy metals, Sialkot region, *Mystus bleekeri*, atomic absorption, body size, condition factor.

1. INTRODUCTION

The natural water bodies largely contaminated through inorganic and organic wastes. Most of them possess hazaradous compounds, likes heavy metals, which could accumulate in animals tissues at with high concentrations than that of present in water column and sediment (Rainbow, 2007; Beltrame *et al.*, 2010). The wastes (heavy metals) deposited in the tissues of fish which will intern hazaradous to the consumers (Sarojam, 2009). In qauatic environment fish is oftenly used as bio-indicator of heavy metalsand water pollution (Evans *et al.*, 1993; Mansour and Sidky, 2002). Metal deposition in tissues is largely attributed to differences in uptake and depuration period for different metals in various fish species (Tawari-Fufeyin and Ekaye, 2007). Multiple factors like season, physico-chemical factors of water (Kargin, 1996) could play a vital role in heavy metal deposition in different fish tissues. The metals concentaration also differs in species to species, depending upon size, age, rate of growth and other physico-chemical factors (Kagi and Schaffer, 1998). Fish is an important diet and cheap source of animal protein for the poeple of third world countries (Burger and Gochfeld, 2010) which contain omega-3 (n-3), essential amino acids that helps to reduce cholesterol levels and minimize coronary diseases (Daviglus *et al*., 2002; Patterson, 2002; Burger and Gochfeld, 2010). Sialkot has been known as Pakistan's largest support, as is known as a city full of industries such as leathers goods producing along with leather related industries, textile metallurgical and pharmaceutical industries. The surface and ground water of Sialkot has been degraded due to rapid industrialization along with urbanization and agricultural activities in its surroundings areas (Qadir *et al.*, 2008). An estimated discharge of effluent from only tanneries is approximately 1.1 million liters per day (Dawn, 2006). All the industrial units consume large amount of water which, together with dissolved toxic substances (acids, base or toxic chemical compounds and heavy metals) after processing is discharged into nearby agricultural lands, ponds, open ditches, rivers, streams and open land (Rizwan-Ullah *et al.*, 2009). The present investigations was undertaken to study the concentration levels of selected metals in wild catfish, *Mystus bleekeri* as indicator of water pollution, and correlate the concentration of metals with respect to fish size and condition factor.

*Department of Fresh Water Biology and Fisheries, University of Sindh, Jamshoro 67080, Sindh, Pakistan.
**Department of Chemistry Bahauddin Zakariya University, Multan 60800, Pakistan.

2. MATERIALS AND METHODS

Collection of Samples and condition factor measurements

The samples of experimental fish, *Mystus bleekeri* were collected from Nala Daik, of Sialkot district with the help of hand net and cast nets between February and March, 2010. The collected fish samples were packed in plastic container and transported to the B. Z. University, Multan for further studies. The fish were washed and measurements of total length and body weight was recorded with the help of measuring scale and electronic balance (MP-3000 Chyo, Japan) respectively.

Sample Preparation and Metal analyses by flame atomic absorption spectrophotometer

Sample solutions were prepared from fish powder (dried) and ashed in a muffle furnance at 500 ^{0}C for overnight. The residue ash was dissolved in 1% HNO_3, then filtered and diluted up to 25 ml with deionized water (possess 1 % HNO_3). The stock solutions were then kept in polyethylene bottles with proper labeling according to samples for metal analysis. All the digested samples were analyzed by the flame atomic absorption spectrophotometer at Instrumental Laboratory, Chemistry Department, Bahauddin Zakariya University, Multan. Two replicate analyses were carried out for each and every sample. The instrument calibration was repeated after every ten samples during experiment.

Statistical Analysis

Descriptive statistics for each trait were expressed as Mean ± Standard Error. The statistical analyses regression analysis, computation of correlation coefficients and standard error the student's *t*-test, were applied. Data presentation and plotting by using computer package Lotus 1-2-3 (Zar, 1996). For the study of the effect of condition on the element load of fish, the individual condition factor of fish samples was determined with the Fulton's Condition Factor. In order to understand inter relation among the measured elements, Pearson correlation analysis was carried out using MS-Excel for windows 7.0 software.

3. RESULTS

Ninety five samples of wild catfish *Mystus bleekeri* were analyzed for the determination of various heavy metals. The values of zinc, copper, manganese, cadmium and magnesium, in *M. bleekeri* are shown in **(Table1).** Deposition of the observed metals in the fish was as Mg > Mn > Zn > Cd >Cu.

Table -1: Grand mean and standard error values of elemental concentration in carcasses of *Mystus bleekeri* (whole fish) (n = 95)

Elements	Concentration	
	µgg^{-1} of dry weight	µgg^{-1} of wet weight
	Mean ± S.E.	Mean ± S.E.
Mg	5460.53 ± 281.8541	1201.20 ± 60.6927
Mn	100.68 ± 7.7101	22.12 ± 1.6293
Cu	0.26 ± 0.1564	0.06 ± 0.0336
Zn	76.11 ± 5.0572	16.96 ± 1.1255
Cd	29.03 ± 4.1415	6.27 ± 0.8831

Body Weight Relationship with Metal Concentrations

The values of Mg and Zn were observed highly significant with the fish weight. Mn was least significant (P<0.05) while insisignificant correlation was found in Cu and Cd with body weight. It was observed that in *Mystus bleekeri* total quantity of Mn and Zn show positive allometry (b > 1.0), while Mg exhibited negative allometric growth with increase in total weight **(Table 2).**

Table -2: Regression parameters of log wet body weight (g) versus log body burden element (µg) for Mystus bleekeri (n = 95)*[Log body burden element (µg) = a + b Log wet body weigt (g)]*

Wet body weight (g)	Elements	r	a	b	S.E (b)	t value (b = 1)
1.20 to 3.02	Mg	0.311***	3.087	0.809	0.256	-3.097**
	Mn	0.203*	1.020	1.365	0.684	-0.097 ^{ns}
	Cu	0.109 ^{ns}	0.891	-0.892	0.840	-2.082*
	Zn	0.448***	0.545	2.764	0.572	1.016 ^{ns}
	Cd	0.007 ^{ns}	0.015	-0.007	0.110	-9.098***

a = Intercept; b = Slope; S.E= Standard Error; r = Correlation Coefficient; *** = P<0.001; $^{n.s.}$ = > 0.05, S.E. Standard error

Total Length Relationship with Metal Concentrations

Total length of *Mystus bleekeri* was found to be highly correlated with observed Zn values. Mg values was also found to be significant (P<0.01), but no correlation was observed in Mn, Cu and Cd with total length. Positive allometric (b>3.0) increase was observed in Zn concentration but negative (b < 3.0), in case of Mg concentration **(Table -3).**

Table -3: Regresstion parameters of og total length (TL, cm) versus log body burden element (µg) for Mystus bleekeri (n = 95)[Log body burden element (µg) = a + b Log total length (cm)]

Total length (cm)	Element	r	a	b	S.E (b)	t value (b = 3)
5.50 to 7.80	Mg	0.287**	1.608	2.121	0.734	-1.966 ^{ns}
	Mn	0.162 ^{ns}	-1.089	3.101	1.958	1.569 ^{ns}
	Cu	0.097 ^{ns}	0.249	-0.291	0.310	-9.968***
	Zn	0.354***	-3.671	6.212	1.700	4.447***
	Cd	0.025 ^{ns}	1.098	-0.581	2.400	-1.831 ^{ns}

a = Intercept; b = Slope; S.E= Standard Error; r = Correlation Coefficient; *** = P<0.001; $^{n.s.}$ = > 0.05

Relationship between Elemental Concentrations and Condition Factor

Regression analysis among metal concentrations (wet body weight, µgg^{-1}) and condition factor of *Mystus bleekeri* are given showed insignificant relationship with increasing condition factor **(Table-4).**

Table -4: Regresstion parameters of condition factor versus metal concentration (wet weight, µgg^{-1}) in wet body weight for *Mystus bleekeri* (n = 95)
[Body burden element (µg) = a + b condition factor]

Condition Factor	Element	r	a	b	S.E (b)	t value (b = 0)
0.6 to 1.02	Mg	0.041 ^{ns}	1436.555	-319.50	812.24	-0.393
	Mn	0.045 ^{ns}	15.157	9.46	21.80	0.434
	Cu	0.170 ^{ns}	-0.487	0.74	0.44	1.666
	Zn	0.019 ^{ns}	14.881	2.82	15.07	0.187
	Cd	0.151 ^{ns}	18.966	-17.24	11.69	-1.474

a = Intercept; b = Slope; S.E= Standard Error; r = Correlation Coefficient; *** = P<0.001,
$^{n.s.}$ = > 0.05

Multiple Regression Analysis (MRA)

The calculation of multiple regression analysis 'r' between various parameters like, wet body weight and total length, these value was observed significantly high (P<0.001) with Zn values, and significant (P<0.01) with Mg and significantly found lowest (P<0.05) in Mn. The values of Cu and Cd were not found significant in this relation **(Table -5).**

To test the degree of multicollinearity, variance-inflation factors (VIF) were determined for the multiple linear regression. The VIF values of regression coefficients in multiple regression analysis for each paramter were found to be lower than 10.

Table -5: Multiple regression analysis of wet body weight (W, g.) and total length (TL, cm) with metal concentration (wet body weight, µgg^{-1}) for *Mystus bleekeri* (n = 95)

Relationship	r	a	b_1 ± S.E	b_2 ± S.E	r^2	VIF
Mg= a + b_1 W + b_2 TL	0.286**	1041	970.9 ± 655.1	-92.6 ± 566.7	0.082	1.089
Mn = a + b_1 W + b_2 TL	0.226*	35.99	23.87 ± 17.23	-6.16 ± 14.91	0.051	1.054
Cu = a + b_1 W + b_2 TL	0.161 ^{ns}	2.321	0.4235 ± 0.3569	-0.4731 ± 0.31	0.026	1.027
Zn = a + b_1 W + b_2 TL	0.480***	-20.31	31.34 ±2.30	-1.17 ± 10.64	0.230	1.299
Cd = a + b_1 W + b_2 TL	0.134 ^{ns}	-13.06	-11.229 ± 9.017	7.333 ± 7.801	0.018	1.018

r = Multiple Correlation Coefficient; a = Intercept; b_1 and b_2 = Regression Coefficient;
S.E = Standard Error; r^2 = Proportion of Variance due to Regression;
VIF = Variance Inflation Factor; *** = P < 0.001; $^{n.s}$ = > 0.05

Inter-elemental Regression

There were only few significant correlations among metals (wet body weight, µgg^{-1}) for *M. bleekeri* **(Table-6).** Magnesium was positively correlated for Cd, Zinc was negatively correlated for Cd, while Cadmium was found positively correlated for Mg and negatively correlated for Zn.

Table -6: Inter-elemental regression parameters of Cadmium (µgg^{-1}) versus different metals (µgg^{-1}) in wet body weight for *Mystus bleekeri* (n = 95).

Element	r	a	b	S.E (b)
Mg	0.391***	1032.664	26.884	6.559
Mn	0.135^{ns}	23.688	-0.250	0.190
Cu	0.129 ^{ns}	0.088	-0.005	0.004
Zn	0.218*	18.699	-0.278	0.129

a = Intercept; b = Slope; S.E= Standard Error;
r = Correlation Coefficient; ^{ns} = > 0.05;
** = P < 0.01; *** = P < 0.001

4. DISCUSSION

Influence of Size of the Fish on Metal Concentration

In the present study variations between body weight and body length were found to be related to, regression analysis. Allometric growth analysis (Weatherley and Gill, 1987; Salam and Davies, 1994) has applied to calculate values of slope b through log-log regression relationship between total heavy metal body concentaration with total body weight and length. Salam *et al.,* (2002) commented that the values of the slope used as predictor for isometric and allometric increase of these metals with increasing weight and length. The regression analysis of metal concentrations and body weight Mg showed negative allometry (b<1.0) while Mn and Zn showed positive

allometry (b > 1.0). Regression between metal concentration and total length of fish showed that zinc showed positive allometry (b > 1.0) and Mg showed negative allometry (b<1.0). It suggested that concentration of Mn is increasing only with the increase of fish length which is in general agreement with that reported by (Ansari *et al*. 2006) in *Puntius chola*. However, significant proportional increase in concentrations of Zn with increase in body weight which suggests that Zn is probably accumulated at higher rate compared to its rate of excretion as the fish grows , while Mg is probably accumulated at lesser rate compared to its rate of excretion as the fish grows in its size. Negative allometry of Mg with fish weight has also reported by Naeem and Salam. (2010), but Zn was not in general agreement with that reported by (Ansari *et al*. 2006) in *Puntius chola* and (Naeem *et al.,* 2010) in *Oncorhynchus mykiss.,* (Naeem *et al.* 2011) in *Aristichthys nobilis.,* (Naeem *et al.,* 2012) in female *Oreochromis niloticus.* These variations may be due to site-specific and species specific. Elemental composition of differents fishes given in **(Table–7)**

Table -7: Comparative data of elemental concentration (µg g^{-1}) of various freshwater fish species (Whole fish)

Elements	*O. mykiss* [a]		*Labeo rohita* [b]		*Tor putitora* [c]		*Oreochromiss niloticа* [d]		*Catla catla* [e]		*Hypophthalmichthys molitrix* [f]		*Cirrhinus mrigala* [g]		*Oncorhynchus Mykiss* [h]		*Mystus bleekeri* [i]	
	Wet wt.	Dry wt.	Wet wt.	Dry wt.	Wet wt.	Dry wt.	Wet wt.	Dry wt.	Wet wt.	Dry wt.	Wet wt.	Dry wt.	Wet wt.	Dry wt.	Wet wt.	Dry wt.	Wet wt.	Dry wt.
Mg	333.0 ±163.0	1535.61 ±282.74	446.30 ±93.44	1786.5 ±192.8	512.9 ±127.9	1351.9 ±350.0	354.6 ±57.7	2236.0 ±237.0	475.0 ±70.7	2292.0 ±474.0	611.0 ±108.0	2155.0 ±613.0	512.0 ±160.0	1779.20 ±499.87	383.23 ±72.87	5460.53 ±2747.2	1201.20 ±591.56	5460.53 ±2747.2
Mn	01.8 ±00.9	18.19 ±5.01	5.29 ±1.58	09.7 ±7.7	03.0 ±2.60	08.9 ±3.9	02.3 ±0.7	40.3 ±12.2	08.5 ±2.5	26.4 ±15.2	07.0 ±4.0	50.3 ±26.3	11.9 ±6.4	12.32±4.99	2.66±0.96	100.68±75.2	22.12±15.88	100.68±75.2
Cu	01.2 ±0.46	15.17 ±	4.41 ±1.88	09.0 ±3.4	02.5 ±1.1	15.5 ±06.5	04.1 ±1.3	45.6 ±46.9	09.5 ±9.6	NQ	NQ	24.1 ±8.5	5.7 ±02.0	9.18±4.22	1.98±0.76	0.26±1.5	0.06±0.3	0.26±1.5
Zn	25.0 ±01.6	68.19 ±	19.75 ±3.82	74.0 ±9.6	01.4 ±6.0	78.7 ±15.2	20.9 ±2.80	106.5 ±9.2	23.0 ±3.2	58.2 ±8.5	15.6 ±2.4	65.7 ±7.4	15.6 ±02.6	134.88±69.02	28.37±10.06	76.11±49.3	16.96±11.0	76.11±49.3
Cd	-	0.95 ±0.12	0.27 ±0.04	NQ	NQ	-	-	NQ	NQ	-	-	-	-	1.61 ±1.88	0.34 ±0.35	29.03 +40.4	6.27 ±8.6	29.03 +40.4

Mean ± Standard deviation; NQ = Not Quatitable; a (Shearer, 1984); b (Salam *et al.,* 1993); c (Salam *et al*., 1994); d (Salam *et al.,* 1996); e (Salam *et al.,* 1998); f (Ansari *et al.,* 2000); g (Salam *et al*.,2002); ; h (Naeem *et al*., 2010); i (Present Work);

Influence of Condition Factor of the Fish on Metal Concentrations

No effect of condition factor was observed in the study on *Mystus bleekeri* which may be due to its feeding rate and growth. Which is simlar as reported by S(herwood *et al.,* 2000 and Farkas *et al.,* 2002) that in wild fish, the growth is as much an expression of micropollutants loads of fish related to their food intake, feeding, growth and physical condition.

Multiple Regression Analysis (MRA)

Multiple regression analysis (predictive equation) was applied to calculate heavy metal concentration from fresh body weight, total length and condition factor. It aws observed that only Mg and Zn values were noticed during the present study in agreement as reported by (Naeem *et al.*, 2010).

Inter-elemental Regression

Different studies have conducted in order to understand inter relation among the measured elements (Raja *et al*., 2009; Burger and Gochfeld, 2010). There were only few significant correlations among metals (wet weight, $\mu g g^{-1}$) were observed during the present investigations. That is, knowing that, in wet body weight of fish, the values of only one metal was found to be variable (high or low) is not sufficient to predict what the other metals would be. The above findings were in general agreement with those reported (Burger and Gochfeld 2010). However, (Burger and Gochfeld 2010) suggested that inter-elemental regression is necessary to have the correlations because, for future similar studies conducted with fish, this pattern may emerge.

Humans Health risk effects

Manganese, is an important metal (element), for which standards in fish were not found. Copper although found in a very few of samples but the mean concentration was below than the permissible limits **(Table-8).**

Table -8: Permissible limits ($\mu g g^{-1}$) for metals recommended by various organizations

Mg	Mn	Cu	Zn	Cd	Source
-	Not Listed	-	40 - 100	0.05 – 2	International Standard Range*
-	-	30	40	0.05	FAO (1983)
		20		0.05	TFC (2002)
-	-	-	-	0.05	EC (2005)
-	-	2	-	0.005	TSE-266 (2005)

***cited in:** Burger and Gochfeld (2010)

Zinc concentration was also considerably lower than the maximum level set by law. Cadmium is classified in fish as lethal and hazaradous chemical its residual levels have been prescribed for human by various organizations (FAO, 1983; EC, 2005; TSE-266, 2005). In this study, Cd contents in the samples were much more than the permitted level.

5. CONCLUSION

In the present investigations, the equations obtained could be usud as reliable tool to calculate the whole body elemental concentrations at various sizes of *Mystus bleekeri* within the range used. Elevated concentration of Cadmium is a threat to freshwater biota. The toxic element contamination observed results undoubtedly from a high anthropogenic input into the study area. However, more work is required to understand the relative importance of the various sources and to assess fully the extent of the problem.

REFERENCES:

Abbas, S.T., S. M. Mehdi, M. Sarfraz and G. Hassan (2006). Accumulation and bioavailability of heavy Metals in soils and rice plants polluted with Industrial waste water. Caderno de Pesquisa Sér. Bio., Santa Cruz do Su., 18 **(1):** 29-48.

Ansari, T. M., M. A. Saeed, A. Raza, M. Naeem and A. Salam (2006). Effect of body size on metal concentration in wild Puntius chola. Pak. J. Anal. Environ. Chem., **(2):** 116-119.

Beltrame, M. O., S. G. De Marco and J. E. Marcovecchio (2010). Effects of zinc on molting and body weight of the estuarine crab *Neohelice granulate* (Brachyura: Varunidae). Sci. Total Environ., **(408):** 531–536.

Burger, J. and M. Gochfeld (2010) Heavy metals in commercial fish in New Jersey. Environ. Res., 99 **(3):** 403–412.

Daily Dawn, 2006. No step taken to check tanneries' pollution. March 26. Retrieved from www.DAWN.com.

Daviglus, M., J. Sheeshka and E. Murkin (2002) Health benefits from eating fish. Comments Toxicol., (8): 345–374.

EC European Commission, (2005) Commission Regulation (EC) No 78/2005 of 19 January 2005 amending Regulation (EC) No 466/2001 as regards heavy metals, L 16/43–45.

Evans, D. W., D. K. Dodoo and P. J. Hanson (1993) Trace elements concentrations in fish livers Implications of variations with fish size in pollution monitoring. Mar. pollut. Bull., 26(6): 29 – 34.

FAO, (1983) Compilation of legal limits for hazardous substances in fish and fishery products. FAO Fishery Circular, No. **(464)**: 5-100.

Farkas, A., J. Salanki and A. Specziar (2002) Relation between growth and the heavy metal concentration in organs of bream Abramis brama L. Populating Lake Balaton. Arch. Environ. Contam. Toxicol., **(43):** 236–243.

Gao, Y., Q. Feng, D. Ren, Li. Qiao and S. Li (2010) The relationship between trace elements in fish otoliths of wild carp and hydrochemical conditions. Fish Physiol. Biochem., **(36):** 91–100.

Johnson, J. H. (2003) Egg-to-fry survival of two strains of Atlantic salmon (*Salmo salar*) in stream incubators under laboratory conditions. J. Freshw. Ecol., 18 **(3):**499–500.

Kagi, J.H. and A. Schaffer (1998) Biochemistry of metallothionein. Biochemistry., **(27):** 8509–8515.

Kargin, F. (1996) Seasonal changes in levels of heavy metals in tissues of *Mullus barbatus* and *Sparus aurata* collected from Iskenderum Gulf (Turkey). Water, Air Soil Pollut., **(90):** 557-562.

Mansour, S. A. and M. M. Sidky (2002). Ecotoxicological studies. 3: Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. Food Chem., **(78):** 15-22.

Naeem, M. and A. Salam (2010) Proximate composition of fresh water bighead carp, *Aristichthys nobilis*, in relation to body size and condition factor from Islamabad, Pakistan. Afr. J. Biotechnol., 9 **(50):** 8687-8692.

Naeem, M., A. Salam, S. S. Tahir and N. Rauf (2010) Assessment of the essential element and toxic heavy metals in hatchery reared *Oncorhynchus mykiss*. Int. J. Agric. Biol., **(12):** 935–938.

Naeem, M., A. Salam, S. S. Tahir and N. Rauf (2011) The effect of fish size and condition on the contents of twelve essential and non essential elements in *ristichthys nobilis* from Pakistan. Pak. Vet. J., 31**(2):** 109- 112.

Naeem, M., A. Salam, M. Y. Khokhar, M. F. Nasir, M. F. Nouman, A. Ishtiaq and R. A. Yar (2012).Evaluation of metal contents in female *Oreochromis niloticus* with emphasis on potential risk of consumption and relation to some biological aspects. Afri. J. Biotec., 10 **(53):** 11054-11057.

Patterson, J. (2002) Introduction-comparative dietary risk: balance the risks and benefits offish consumption. Comments Toxicol., **(8):** 337–344.

Qadir, A., R. N. Malik and S. Z. Hussain (2008) Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, Pakistan. Environ. Monit. Assess., **(140):** 43-59.

Rainbow, P. S. (2007) Trace metal bioaccumulation: models, metabolic availability and toxicity. Environ. Int., **(33):** 576–82.

Raja, P., S. Veerasingam, G. Suresh, G. Marichamy and R. Venkatachalapathy (2009) Heavy Metals Concentration in Four Commercially Valuable Marine Edible Fish Species from Parangipettai Coast, South East Coast of India. Int. J. Anim. Veter. Adv., 1**(1):** 10-14.

Rizwan-Ullah, R. M. Malik and A. Qadir (2009) Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan. Afr. J. Environ. Sci. Technol., 3 **(12):** 429-446.

Salam, A. and P. M. C. Davies (1994) Body composition of northern pike (*Esox lucius* L.) in relation to body size and condition factor. Fish. Res., **(19):** 193-204.

Salam, A., T. M. Ansari, N. Tariq and Q. A. Akhtar (2002) Effect of body size on Metal concentrations in farmed *Cirrhinus mrigala*. Asian Fish Sci., **(15):** 329-334.

Sarojam, P. (2009) Atomic Absorptiona: Application Note, Analysis of Fish and Seafoods with AAnalyst 800 Atomic Absorption Spectrophotometer for Trace Metal Contamination, in Accordance with AOAC Methods 999.10 and 999.11, PerkinElmer, Inc. Shelton, USA.

Sherwood, G. D., D. J. Rasmussen and D. J. Rowan (2000) Bioenergetic costs of heavy metal exposure in yellow perch (Perca flavescens): In situ estimates with a radiotracer (137Cs) technique. Can. J. Fish. Aquat. Sci., (**57):** 441–50.

Tawari-Fufeyin, P. and S. A. Ekaye (2007) Fish species diversity as indicator of pollution in Ikpoba river, Benin City, Nigeria. Rev. Fish Biol. Fisheries., **(17):** 21-30.

TSE–266 (Turkish Standars) (2005). Insani tüketim amaçlı sular hakkında yönetmelik. Türk Standartları, Ankara.(In Turkish).

Weatherley, A. H. and H. S. Gill (1987) The biology of fish growth. Academic Press, London. 1-44.