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THE PATTERNS OF HEAVY METAL RETENTIONS IN THE KIDNEY AND URINARY METAL ELIMINATION IN MALLARD (*ANAS PLATYRHYNCHOS - DOMESTICUS*) EXPOSED TO IRON ORE REJECT RUNOFFS

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ABSTRACT

Goa, India has several active mining belts, majority being iron ore mines. As a result, large stock piles of the rejects are dumped around. The runoffs from such piles contaminate the surrounding waterbodies during monsoon. Birds from such areas are likely to get exposed to heavy metals present in such water-bodies. Also there is hardly any data on the retention patterns of heavy metals as well as urinary excretions in birds. It is known that heavy metals are excreted through urine or faeces. The kidney of *Anas Platyrhynchos domesticus* retained Zn, Mn, Fe and Cr at high levels. These metals are eliminated through urine depending upon their retention levels in the kidney as well as on their degree of intake.

INTRODUCTION

The idea that the birds could be considered as biomonitors of the environment is ancient. Only recently, the birds have been studied widely for determining the deterioration of the environment. Several authors have studied the heavy metal toxicity, occurrence, distribution, retention, and the relationship with the food habits, (Prasad Rao *et al*, 1989; Lewis and Furness, 1991; Hontelez *et al*, 1992; Lock *et al*, 1992; Samuel *et al*, 1992; Denneman and Doubean, 1993; Kozulin and Pavluschick, 1993; Guitart *et al*, 1994). Lewis and Furness, (1991) reported mercury accumulation and excretion through faeces in laboratory reared gulls but there is hardly an report on the renal excretion of heavy metals by the bird. Goa has several active mining belts and majority of them are iron ore mines. As a result of extensive mining, large stock piles of iron ore rejects (iron concentration 50 > 60%) are dumped around and during monsoon the runoffs from the fresh as well as off the stockpiles run toward the waterbodies, a few kilometers (2-4) away, thereby contaminating them. The aquatic birds and terrestrial birds from such areas are likely to get affected from drinking contaminated waters, especially the aquatic bird, inhabiting such waterbodies would be exposed to the heavy metals present in them. Besides, it is observed that the populations of aquatic birds are dwindling over the years. Hence, here an attempt is made to assess the accumulation of heavy metals in the kidney of mallards.

MATERIALS AND METHODS

The iron ore rejects (IOR) (6 months to 1 year old) were collected from the mines from Ponda Taluka, Goa. The rejects were packed in boxes of size 3M × 3M × 25 cm (depth) attached with devices to collect the runoffs. The iron ore rejects were subjected to rainfall using the technique of Morrin *et al.*, (1967). The experiment was repeated five times, using IOR samples. The runoffs were collected in polysterene containers, mixed and then diluted to the concentrations of 0.1, 5.0, and 10.0 with glass distilled water. the mallards (*Anas platyrhynchos domesticus*) were collected from the local supplier. They were allowed to acclimate to the laboratory conditions of cageing at 28-30°C with 35-40% humidity for one fortnight. The animals were well fed with poultry feed and were provided with water adlibitum. The experimental animals were provided with the appropriate concentration of runoffs as drinking water while the controls were provided with glass distilled water for drinking. Five sets of five animals each were used for each concentrations of runoffs for each duration (6, 12, 24, 48, 72, 96 and 120 hours). The urine samples were collected by surgically fixing the special funnels on the uteral openings. The blood samples were collected from the wing vein and were allowed to clot to get the serum. The small corticular pieces of the kidney tissues were used for the study of heavy metal analysis. The appropriate aliquotes were prepared using standard methods and then the heavy metal analysis was carried out on inductive coupled plasma (Perkin Elmar Plasma 400 machine, sensitivity 0.1 ppm, for the metals analysed. The accuracy of the method was verified using biological reference standards (NIES, Japan).

Statistical Analysis : The significance of the resuits were tested with Student's "t" test and dose-duration effects were analysed by two point ANOVA tests.

RESUTLS AND DISCUSSION

The kidney showed 0.01 ± 0.0001, 0.10 ± 0.0001, 0.09 ± 0.001 and 0.08 ± 0.0001 ug/gm WW of Cr, Fe, Mg,

Table 1. Retention of heavy metals in kidney under influence of 0.1 and 1.0% M.E. (ROs), 0.1% M.E. (ROs) :

Time	Cd µg/gm Ww	Cr µg/gm Ww	Cu µg/gm Ww	Fe µg/gm Ww	Mg µg/gm Ww	Mn µg/gm Ww	Ni µg/gm Ww	Pb µg/gm Ww	Zn µg/gm Ww
6 hours	0.01 ± 0.0001	0.13 ± 0.001	0.09 ± 0.003	3.21 ± 0.02	0.09 ± 0.003	1.31 ± 0.002	0.02 ± 0.0001	0.01 ± 0.0001	0.2 ± 0.001
12 hours	1.27 ± 0.02	0.14 ± 0.002	0.03 ± 0.001	2.41 ± 0.004	0.03 ± 0.01	2.13 ± 0.002	0.05 ± 0.01	Nil	0.1 ± 0.0001
24 hours	2.10 ± 0.12	0.173 ± 0.002	0.04 ± 0.001	1.73 ± 0.021	0.13 ± 0.001	1.73 ± 0.02	0.07 ± 0.01	Nil	0.3 ± 0.001
48 hours	3.21 ± 0.05	0.12 ± 0.012	0.09 ± 0.021	5.97 ± 0.14	0.07 ± 0.001	0.71 ± 0.015	0.0-8 ± 0.002	Nil	0.38 ± 0.002
72 hours	2.81 ± 0.03	0.09 ± 0.003	0.10 ± 0.0001	3.2 ± 0.001	0.09 ± 0.003	0.59 ± 0.002	0.09 ± 0.001	Nil	0.17 ± 0.001
96 hours	1.93 ± 0.04	0.10 ± 0.002	0.09 ± 0.002	3.92 ± 0.040	0.05 ± 0.002	0.69 ± 0.021	0.06 ± 0.001	0.02 ± 0.0021	0.25 ± 0.002
120 hours	1.72 ± 0.024	0.139 ± 0.0001	0.13 ± 0.0012	7.26 ± 0.043	0.08 ± 0.001	1.03 ± 0.014	0.08 ± 0.002	Nil	0.31 ± 0.0012
1.0% M.E. (ROs) :									
6 hours	3.1 ± 0.003	1.00 ± 0.0012	0.03 ± 0.002	3.8 ± 0.016	3.2 ± 0.002	0.9 ± 0.002	0.07 ± 0.004	0.1 ± 0.001	1.73 ± 0.002
12 hours	2.17 ± 0.002	0.7 ± 0.016	Nil	4.7 ± 0.004	2.9 ± 0.05	0.30 ± 0.001	0.20 ± 0.006	0.1 ± 0.001	1.67 ± 0.002
24 hours	2.10 ± 0.008	0.4 ± 0.005	Nil	5.20 ± 0.051	2.70 ± 0.044	0.4 ± 0.002	0.090 ± 0.001	0.100 ± 0.003	1.43 ± 0.022
48 hours	2.39 ± 0.016	0.73 ± 0.03	Nil	5.3 ± 0.035	2.9 ± 0.06	0.57 ± 0.003	0.05 ± 0.021	0.20 ± 0.001	1.57 ± 0.004
72 hours	3.10 ± 0.041	0.18 ± 0.002	0.4 ± 0.03	4.10 ± 0.10	1.9 ± 0.066	0.71 ± 0.004	0.07 ± 0.001	0.20 ± 0.013	1.80 ± 0.06
96 hours	2.17 ± 0.003	0.07 ± 0.002	0.42 ± 0.004	6.3 ± 0.019	3.0 ± 0.012	0.81 ± 0.004	0.53 ± 0.001	0.04 ± 0.001	1.73 ± 0.002
120 hours	1.73 ± 0.031	0.09 ± 0.001	0.03 ± 0.001	7.20 ± 0.06	4.30 ± 0.006	0.71 ± 0.010	0.070 ± 0.005	0.07 ± 0.002	1.90 ± 0.002

ROs : Runoff
ME : Mining effluents

Mn and Zn respectively, while the normal bird excreted 4.0 ± 0.1, 2.0 ± 1.0 and 3.0 ± 0.1 ugms/Litre of Fe, Mn and Zn respectively. Thus, it appears that the normal mallard have in their kidney the metals of dietary origin along with the natives.

The highest kidney retentions of Zn (0.38 ± 0.002 ug/gm ww) Mn (2.13 ± 0.002 ug/gm ww), Fe (7.26 ± 0.043 ug/gm ww), Cd (3.21 ± 0.05 ug/gm ww), Cr (0.173 ± 0.002 ug/gm ww), Cu (0.13 ± 0.0012 ug/gm ww), Ni (0.09 ± 0.001 ug/gm ww), Mg (0.13 ± 0.001 ug/gm ww) and Pb (0.02 ± 0.0021 ug/gm ww), were observed at 48 h, 120 h, 72 h, 24 h and 96 h, respectively, under the influence of 0.1% ROs (Table 1), while the maximum urinary elimination of Cd (51.00 ± 2.40 ug/L), Cr (70.0 ± 0.020 ug/L), Cu (37.0 ± 1.0 ug/L), Fe (91.0 ± 2.00 ug/L), Mg (37.0 ± 4.0 ug/L), Mn (68.0 ± 1.0 ug/L), Zn (42.0 ± 4.0 ug/L) occurred at the end of 120h, 6h, 48h, 72h, 120h, 6h and 24h respectively.

The kidney retained maximum amount of Zn (1.90 ± 0.002 ug/gm ww), Pb (0.20 ± 0.001 ug/gm ww) at 48h and 72h, Ni (0.53 ± 0.001 ug/gm ww at 96h), Mn (0.9 ± 0.002 ug/gm ww at 120h), Mg (4.30 ± 0.006 ug/gm ww at 120h), Fe (7.20 ± 0.06 ug/gm ww at 120h), Cu (0.42 ± 0.004 ug/gm ww at 96h), Cr (1.00 ± 0.0012 ug/gm ww at 6h) and Cd (3.10 ± 0.003 ug/gm ww at

Table 2. Retention of heavy metals in the kidney under the influence of 5.0% and 10.0% M.E. (ROs), 5.0% M.E (ROs) :

Time	Cd µg/gm Ww	Cr µg/gm Ww	Cu µg/gm Ww	Fe µg/gm Ww	Mg µg/gm Ww	Mn µg/gm Ww	Ni µg/gm Ww	Pb µg/gm Ww	Zn µg/gm Ww
6 hours	3.10 ± 0.012	1.7 ± 0.014	0.5 ± 0.002	6.5 ± 0.4	3.3 ± 0.012	0.3 ± 0.001	1.2 ± 0.021	0.6 ± 0.026	6.2 ± 0.024
12 hours	1.37 ± 0.003	1.3 ± 0.004	1.0 ± 0.001	7.6 ± 0.007	4.2 ± 0.016	0.5 ± 0.014	1.0 ± 0.002	0.9 ± 0.013	12.8 ± 0.044
24 hours	1.81 ± 0.003	1.0 ± 0.06	0.7 ± 0.002	6.9 ± 0.006	2.1 ± 0.10	0.400 ± 0.010	1.2 ± 0.04	0.60 ± 0.014	6.6 ± 0.014
48 hours	1.71 ± 0.013	1.3 ± 0.003	0.6 ± 0.004	6 6 ± 0.012	3.0 ± 0.04	0.5 ± 0.002	1.1 ± 0.003	0.9 ± 0.003	7.0 ± 0.061
72 hours	1.71 ± 0.07	1.41 ± 0.041	0.6 ± 0.004	7.9 ± 0.004	4.2 ± 0.021	0.3 ± 0.002	0.9 ± 0.005	1.3 ± 0.001	8.7 ± 0.024
96 hours	2.31 ± 0.003	1.31 ± 0.029	0.8 ± 0.006	8.5 ± 0.013	3.3 ± 0.013	0.5 ± 0.001	1.3 ± 0.004	1.1 ± 0.005	10.8 ± 0.03
120 hours	1.37 ± 0.001	1.10 ± 0.04	0.7 ± 0.003	5.8 ± 0.055	3.9 ± 0.066	0.4 ± 0.001	0.7 ± 0.006	0.8 ± 0.004	0.8 ± 0.006
10.0% M.E. (ROs) :									
6 hours	1.34 ± 0.008	2.7 ± 0.002	0.3 ± 0.004	8.8 ± 0.04	9.3 ± 0.004	0.370 ± 0.002	0.9 ± 0.002	0.3 ± 0.001	3.9 ± 0.026
12 hours	2.17 ± 0.008	1.7 ± 0.040	0.5 ± 0.007	6.31 ± 0.032	13.0 ± 0.012	0.80 ± 0.006	1.2 ± 0.013	0.7 ± 0.001	4.7 ± 0.042
24 hours	1.98 ± 0.002	1.2 ± 0.001	0.5 ± 0.002	4.1 ± 0.002	9.8 ± 0.088	0.91 ± 0.001	1.37 ± 0.011	0.8 ± 0.032	4.0 ± 0.016
48 hours	1.63 ± 0.030	1.9 ± 0.014	0.7 ± 0.012	3.1 ± 0.021	7.3 ± 0.07	1.01 ± 0.010	1.47 ± 0.04	0.5 ± 0.002	5.9 ± 0.061
72 hours	2.81 ± 0.014	1.8 ± 0.002	0.8 ± 0.003	2.8 ± 0.06	6.4 ± 0.006	0.63 ± 0.014	1.9 ± 0.040	0.7 ± 0.022	3.1 ± 0.11
96 hours	1.76 ± 0.003	1.7 ± 0.001	0.7 ± 0.001	8.9 ± 0.006	5.7 ± 0.004	0.71 ± 0.006	1.73 ± 0.003	0.9 ± 0.11	3.9 ± 0.14
120 hours	3.10 ± 0.013	9.0 ± 0.034	0.6 ± 0.001	1.3 ± 0.003	7.9 0.061	0.87 ± 0.005	0.9 ± 0.008	0.6 ± 0.004	6.2 ± 0.066

ROs : Runoff
ME : Mining effluents

6h) under the influence of 1% of 1% ROs, while the highest urinary excietion of Zn was equal to 17.0 ± 1.20 ug/L at 24h, of Pb was 10.0 ± 1.10 ug/L at 48 h and 72 h, of Mn was 40.00 ± 3.00 ug/L at 6, 72 and 120 h, of Fe was 182 ± 4.0 ug/L at 120h, of Cu was 45.00 ± 1.00 ug/L at 120h, of Cd was 75.0 ± 2.00 ug/L at 120 h, Ni was 9.00 ± 2.00 ug/L at 120 h, of Mg was 90.0 ± 1.00 ug/L at 24 and 120h, and of Cr was equal to 92.0 ± 2.0 ug/L at 96 hours, (Table 3).

The birds exposed to 5% ROs exhibited quite high retentions of metals in the kidney, (Table 2). The highest kidney retentions of Zn, Pb, Mn, Fe, Cu, Cd, Ni, Mg and Cr were equivalent to 12.8 ± 0.044 (at 12h), 1.3 ± 0.0001 (at 72h), 0.5 ± 0.0014 (at 12, 48 and 96 h), 8.5 ± 0.013 (at 96h), 1.0 ± 0.001 (at 12 h), 3.10 ± 0.012 (at 6h), 1.3 ± 0.004 (at 12 and 72h) and 1.7 ± 0.014 (at 6 h) ug/gm ww respectively, (Table 2), while the highest urinary eliminations of Cd, Cr, Cu, Fe, Mg, Mn, Ni, Pb, and Zn were equivalent to 130.0 ± 1.0, 89.0 ± 4.0, 50.0 ± 1.40, 1130.0 ± 3.10, 700.0 ± 1.10, 50.0? 3.0, 70.0 ± 1.20, 50.0 ± 2.0 and 460.0 ± 4.0 ug/L respectively at the end of 72h, 96h, 24h, 72h, 48h, 120h, 6h, 48h, and 96h respectively (Table 4).

Under the influence of 10% ROs the greatest accumulations of metals in the kidney were equal to 6.2 ± 0.066 (at 120 h), 0.9 ± 0.11 (at 96 h), 8.9 ± 0.006 (at 96h), 0.8 ± 0.003 (at 72 h), 2.81 ± 0.014 (at 72h), 1.9 ± 0.040 (at 72 h), 13.0 ± 0.012 (at 12h), 9.0 ± 0.034 (at 120 h) and 1.10 ± 0.010 (at 48 h), ug/g ww for Zn, Pb, Fe, Cu, Cd, NI, Mg, Cr and Mn

Table 3. Renal clearance of heavy metals in ducks exposed to 0.1% and 1% M.E. (ROs), 0.1% M.E. (ROs) :

Time	Cd µg/l	Cr µg/l	Cu µg/l	Fe µg/l	Mg µg/l	Mn µg/l	Ni µg/l	Pb µg/l	Zn µg/l
6 hours	Nil	70.00 ± 0.20	30.00 ± 1.00	71.00 ± 1.00	3.00 ± 0.10	68.00 ± 1.00	1.00 ± 0.01	Nil	30.00 ± 1.00
12 hours	13.00 ± 0.20	3.00 ± 0.01	20.00 ± 1.00	71.00 ± 1.00	2.00 ± 0.01	56.00 ± 3.00	Nil	Nil	37.00 ± 2.00
24 hours	32.00 ± 2.00	4.00 ± 0.01	10.00 ± 0.01	81.00 ± 1.00	1.00 ± 0.01	49.00 ± 5.00	2.00 ± 0.01	1.00 ± 0.01	42.00 ± 4.00
48 hours	42.00 ± 2.00	Nil	37.00 ± 1.00	71.00 ± 4.00	23.00 ± 0.01	21.00 ± 1.00	1.00 ± 0.01	2.00 ± 0.01	31.00 ± 2.00
72 hours	51.00 ± 2.40	Nil	28.00 ± 2.00	87.00 ± 2.00	24.00 ± 2.00	9.00 ± 1.00	1.00 ± 0.01	1.00 ± 0.01	25.00 ± 2.00
96 hours	42.00 ± 8.00	7.00 ± 0.11	29.00 ± 0.11	91.00 ± 2.00	32.00 ± 0.01	32.00 ± 0.11	Nil	Nil	17.00 ± 1.20
120 hours	51.00 ± 2.00	8.00 ± 1.20	37.00 ± 2.00	82.00 ± 1.00	37.00 ± 4.00	27.00 ± 1.00	2.00 ± 0.01	1.00 ± 0.01	27.00 ± 2.00
1.0% M.E. (ROs) :									
6 hours	40.00 ± 1.40	50.00 ± 1.00	Nil	90.00 ± 4.00	70.00 ± 1.50	40.00 ± 3.00	8.00 ± 1.30	4.00 ± 0.1	120.00 ± 4.00
12 hours	45.00 ± 3.00	70.00 ± 1.00	9.00 ± 1.00	137.00 ± 4.00	50.00 ± 1.20	20.00 ± 3.00	3.00 ± 1.10	9.00 ± 2.00	150.00 ± 1.10
24 hours	57.00 ± 1.60	20.00 ± 0.02	20.00 ± 1.40	131.00 ± 2.00	90.00 ± 4.00	10.00 ± 0.01	4.00 ± 0.02	Nil	170.00 ± 1.20
48 hours	60.00 ± 1.00	27.00 ± 3.00	30.00 ± 0.26	130.00 ± 2.00	50.00 ± 6.00	30.00 ± 3.10	7.00 ± 0.20	10.00 ± 1.10	80.00 ± 2.40
72 hours	70.00 ± 1.70	Nil	30.00 ± 3.00	150.00 ± 2.00	70.00 ± 1.00	40.00 ± 2.00	2.00 ± 0.01	10.00 ± 1.00	90.00 ± 1.20
96 hours	57.00 ± 4.00	92.00 ± 1.00	35.00 ± 3.00	173.00 ± 2.00	80.00 ± 2.00	31.00 ± 1.200	3.00 ± 0.01	Nil	110.00 ± 1.00
120 hours	75.00 ± 2.00	72.00 ± 6.00	45.00 ± 1.00	182.000 ± 4.00	90.00 ± 1.00	40.00 ± 2.00	9.00 ± 2.00	3.00 ± 0.01	140.00 ± 4.00

ROs : Runoff
ME : Mining effluents

Table 4. Renal clearance of heavy metals in ducks exposed to 5% and 10% M.E (ROs). 5.0% M.E. (ROs) :

Time	Cd µg/l	Cr µg/l	Cu µg/l	Fe µg/l	Mg µg/l	Mn µg/l	Ni µg/l	Pb µg/l	Zn µg/l
6 hours	30.00 ± 1.00	20.00 ± 1.00	20.00 ± 1.00	Nil	30.00 ± 3.00	Nil	70.00 ± 1.20	10.00 ± 0.5	310.00 ± 1.50
12 hours	70.0 ± 4.00	Nil	20.00 ± 3.00	Nil	50.00 ± 5.00	10.00 ± 0.01	30.00 ± 1.00	3.00 ± 0.1	250.00 ± 2.2
24 hours	90.00 ± 1.00	Nil	50.00 ± 1.40	20.00 ± 1.00	60.00 ± 3.00	10.00 ± 1.00	20.00 ± 6.00	50.00 ± 4.00	410.00 ± 1.20
48 hours	100.00 ± 0.40	Nil	20.00 ± 1.2	Nil	700.00 ± 1.10	10.00 ± 0.10	40.00 ± 0.40	50.00 ± 2.00	260.00 ± 1.00
72 hours	130.00 ± 1.00	Nil	50.00 ± 4.00	1130.00 ± 3.10	90.00 ± 1.40	10.00 ± 0.10	20.00 ± 1.90	2.00 ± 0.06	65.00 0.60
96 hours	90.00 ± 6.00	89.00 ± 4.00	10.00 ± 0.1	Nil	80.00 ± 3.00	10.00 ± 1.00	40.00 ± 1.00	30.00 ± 3.00	460.00 ± 4.00
120 hours	91.00 ± 6.00	20.00 ± 1.30	40.00 ± 1.40	40.00 ± 1.10	70.00 ± 4.10	50.00 ± 3.00	30.00 ± 1.00	30.00 ± 1.20	410.00 ± 1.40
10% M.E. (ROs) :									
6 hours	80.00 ± 2.20	Nil	20.00 ± 4.00	10.00 ± 0.10	80.00 ± 2.00	70.00 ± 2.00	30.00 ± 1.10	20.00 ± 1.00	290.00 ± 1.90
12 hours	30.00 ± 1.00	10.00 ± 0.10	30.00 ± 2.00	190.00 ± 1.20	70.00 ± 4.10	20.00 ± 0.10	40.00 ± 3.00	10.00 ± 0.10	320.00 ± 6.00
24 hours	70.00 ± 3.7	30.00 ± 1.10	40.00 ± 1.40	210.00 ± 1.10	90.00 ± 2.10	20.00 ± 4.00	70.00 ± 1.70	20.00 ± 1.00	190.00 ± 2.00
48 hours	50.00 ± 2.00	40.00 ± 2.00	50.00 ± 2.00	100.00 ± 1.00	70.00 ± 2.00	10.00 ± 0.10	20.00 ± 0.10	70.00 ± 2.00	310.00 ± 1.30
72 hours	60.00 ± 3.00	70.00 ± 3.7	60.00 ± 1.00	170.00 ± 7.00	80.00 ± 1.7	30.00 ± 0.60	30.00 ± 0.30	30.00 ± 1.30	220.00 ± 2.00
96 hours	50.00 ± 4.40	50.00 ± 1.00	30.00 ± 1.30	170.00 ± 1.10	50.00 ± 4.00	40.00 ± 1.50	20.00 ± 0.60	80.00 ± 8.00	320.00 ± 4.20
120 hours	70.00 ± 3.40	30.00 ± 4.00	20.00 ± 0.30	230.00 ± 6.00	90.00 ± 1.00	21.00 ± 1.00	40.00 ± 1.00	90.00 ± 2.00	390.00 ± 1.90

ROs : Runoff
ME : Mining effluents

respectively. The notable renal excretion of the above referred metals was at 120, 120, 120, 72, 6, 6, 24, 120, 72 and 6 hours respectively, (Table 4).

The kidney retains Zn, Mn, Fe, Cr at higher levels when exposed to the diluted ROs in a concentration and exposure period dependent manner. Generally, the urine excretions of metals depend upon their retentions in the serum and kidney. Thus, it appears that the animals tend to eliminate toxic metals through urine which normally passes to be colon for elimination along with faeces. Similarly, fecal elimination of Hg is reported by Lewis and Furness (1991).

Similary, heavy metal retentions by bird kidneys, liver, bones and feather are reported by Hontelez *et al* (1992), Samuel *et al.*. (1992), Hahn (1991), Lock *et al* (1992), Guitart *et al* (1994), Kozulin and Pavluschick (1993). Thus, it is concluded that the ducks drinking water contaminated with mining effluents tend to retain the heavy metals in the kidney and a few heavy metals are eliminated by the kidney through urine.

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