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Chromium (Cr) Contamination of Poultry from Use of Tannery-based Cr-contaminated Feed Ingredients and Public Health and Environmental Risks

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Abstract: In Bangladesh, India and Pakistan, protein-concentrates produced from tannery skin-cut solid wastes are used for poultry and fish feeds. These protein-concentrates are highly chromium (Cr)-polluted ingredients into the feeds. Wide use of such protein-concentrates in Bangladesh poses a potential public health threat due to the potential migration of high levels of Cr into food chain. In order to reveal public health risk and the environmental hazards associated with this practice, experiments were conducted simulating the real-world poultry rearing in farms with formulating poultry feeds incorporating such Cr-polluted protein-concentrate. One-day aged commercial broiler chicken line Cobb-500 and duck variety 'Khaki Campbell' were obtained from the commercial market for the experiments. The simulated feeds produced as per field-practice have a pollution level of (0.3–0.4) % dry weight basis Cr concentration. One week aged fowls through the experimentation exhibited low Cr accumulation in their body mass, while most of the Cr intake being discarded with excreta. As the age of the fowl increased, with sampling at three weeks and six weeks of age, the proportional Cr concentration inside the body increased, with simultaneous proportional decrease in excreta and gut mass. Compared to daily dietary adequate intakes (AIs) of Cr for humans, the dietary public health exposure from consuming 100 g standard fresh-weight breast meat per day from the contaminated fowls is found to be at least 100 to over 300 times higher than the AIs for any people type and any age group beyond three years, whereas for children under three years such becomes even higher. The environmental hazards are no less severe. Application of one metric ton dry weight excreta produced from the contaminated fowls could pose 2.94 kg environmental Cr load.

Key words: Chromium contamination, tannery solid waste, poultry, public health hazard, environmental hazard.

Introduction

At Hazaribagh tanning area in Dhaka, Bangladesh, tanned skin-cut solid wastes are converted into protein-concentrates to be used in formulating poultry feed, fish feed, and organic fertilizers. This potentially threatens a chromium (Cr) contamination of food chain. Hossain et al. (2007) reported this practice from field survey

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and chemical analysis. About 200 tanning industries at Hazaribagh, spanning over an area of 25 hectares in south-west Dhaka have been processing hides for over half a century with an associated release of (0.6-1) metric ton solid waste per metric ton of processed hide production (Zahid et al., 2004). This chrome tanning process involves use of large quantities of chrome powder and liquor, in addition to other chemicals, of which some 53% of the collagen and 15% of the used chemicals are retained in the leather (Hossain et al., 2009). Several large and numerous small feed mills nearing the tanning industries convert the released solid wastes into protein-concentrates at the scale of 200-250 metric tonnes of protein-concentrate production from each large mill a day. The maximum Cr content of the skin-cut wastes was found to be 3.2%, whereas the formulated feed products sampled at two different locations exhibited as high as 2.49% and 1.94% Cr content (Hossain et al., 2007).

Besides Bangladesh, the wide international simile of this hazardous practice includes India (Sudha, 2010) and Pakistan (Mahmud et al., 2011). The practice occurring in such densely populated countries renders the population to enormous health risk, besides the associated environmental hazards. Therefore, a regional focus and cooperation may assist in tackling the issue in terms of ameliorating the associated public health and environmental hazards. Hossain et al. (2009) reported on the extensive population exposure to this public health threat in Bangladesh as well as identified Cr contamination in eggs sampled from eight districts of central Bangladesh (including the capital Dhaka), with a dry weight basis mean Cr concentration of 1.9016 ppm. Converted into the mean Cr content in a single egg, this concentration represents 23.3809 μg, exceeding the adequate daily dietary intake for children up to eight years of age as well as corresponding to major part for all other age groups. In order to reveal the extents of associated public health and environmental hazards from the practice of formulating poultry feeds with protein-concentrates produced from tannery skin-cut solid wastes, this research studies the proportional Cr accumulation into different parts of broiler chicken and duck through administering the Cr-polluted poultry feeds in an experimental station.

Materials and Methods

Research and Sampling Design

Broiler Chicken and Duck

One day aged commercial broiler line Cobb-500 chickens and one day old Khaki Campbell ducks were procured for the experimentation. The number of chickens and ducks required for the experimental design were 33 each.

Housing and Rearing of the Fowls

The chickens and ducks were housed in a specially designed three-storey Aluminum cage with the standard provisions of feed line, water line, and excreta tray. The lower two stories housed the chickens and ducks in each (with allocated 84 square inch space for each fowl), while the uppermost storey was designed to have 12 chambers (with separate feed and water containers for each chamber) in order to keep each fowl in a chamber from a day prior to sampling. Such design aids in collecting excreta of each particular fowl under sampling. The rearing, health, and septic/sterilization measures from before housing the one day aged fowls into the cage and throughout the rearing period were maintained as per the advice and regular physical presence of a veterinary surgeon from the Central Veterinary Hospital of the country.

Feed Design and Calculation

In 2005, about 52% of poultry feed were produced by commercial feed mills, whereas the remainder were prepared by the poultry farmers through mixing available feed ingredients (Poultry Business Directory, 2007). The feed produced by commercial feed mills are not Cr contaminated (Islam et al., 2007). Therefore, it is the locally produced feeds that are the concern for Cr contamination. The ingredients that the poultry farmers utilize in preparing their feeds include ‘corn crash’, ‘rice polish’, ‘soybean meal’, ‘meat-bone’, ‘fish meal’, plus a ‘vitamin premix and dicalcium phosphate mix’ that is commercially available in ready-to-use form, as well as general sodium chloride salt. The use of ‘meat-bone’ and ‘fish meal’ are mainly protein-concentrates. These ‘meat-bone’ and ‘fish meal’ were procured from the largest poultry feed market at Nimtoli, Dhaka, which were originally supplied from the Hazaribagh feed mills who convert the tanned skin-cut wastes into poultry feed, fish meal, and organic fertilizers. The rest of the feed ingredients were also procured from the same market. The feeds were prepared as per the growth stages of broiler fowls.

Two growth stages were maintained under the experimentation: the ‘starter’ stage spanning from one day old to 2 weeks of age; and the ‘grower’ stage spanning from 3rd to 4th weeks of age. Usually the broiler fowls are marketed from their 5th week of age onward. In our research design we expanded the 'grower' stage up to six weeks of age. Besides the distinction of two kinds of feeds for the two growth stages, for each growth stage there were two kinds of feeds prepared to administer two different batches from chickens and ducks. These two kinds of feeds for each growing stage were mainly separated by the type of protein-concentrate mixed, one containing 'meat-bone' whereas the other having 'fish meal'. The feed ingredient mixing ratios are collected from local farming practice, which is presented in Table 1. The feed mixes for the experimentation were prepared according to the ratios in Table 1. Under the ingredient #4 in Table 1 both 'meat-bone' and 'fish meal' are presented to indicate two types of feeds, each containing one at the exclusion of the other. Thus, the research design involved two parallel batches from each of chickens and ducks, administered with the feeds, one containing 'meat-bone' (identified as T-MB) while the other with 'fish meal' (identified as T-FM).

Table 1: Mixing ratios of feed ingredients for different growth stages

Ingre-dient serial	*Ingredient name*	*Percentage proportion in resultant poultry feed*	
		'Starter' stage	*'Grower' stage*
1	Corn crash	57%	58%
2	Rice polish	13.5%	14.5%
3	Soybean meal	9.5%	8.5%
4	'Meat-bone'/'Fish meal'	18%	17%
5	Vitamin premix and dicalcium phosphate mix	1.75%	1.75%
6	General sodium chloride salt	0.25%	0.25%

Sampling Plan and Proportional Cr Accumulation Modelling

The sampling plan includes sampling at four different ages of the fowls: at one day age before moving the fowl into the cage (this is blank sampling), and on both T-MB and T-FM treatments at their one week, three weeks, and 6 weeks of ages. All sampling were conducted with both chickens and ducks, and with three replicates. The blank sampling before the fowls are moved into the cage provides insight into Cr status of one day old fowls, being widely used by the poultry farmers, while sampling at the other three ages reveal the Cr accumulation status after the fowls are administered the Cr-contaminated feeds (T-MB and T-FM).

The research design does not involve any conventional experiment with regard to 'control' vs. 'treatment'. This is because, the farmers who manually mix their feed with the available ingredients from feed markets do either use 'meat-bone' or 'fish-meal' in their feed in order to provide protein-concentrate, whereas both of these 'meat-bone' and 'fish-meal' are Cr-contaminated. This means, the farmers who manually mix their feed mostly use only Cr-contaminated protein-concentrates, which is a remarkable consideration. Therefore, there was no scope to compare with Cr-uncontaminated protein-concentrate as that would distance it from what is practiced in reality as per the concern of food chain contamination with Cr. Therefore, the simulation took consideration of the only two available practices conforming to the reality with regard to Cr contamination. These are the T-MB and T-FM feeds, one of which could have been considered as 'control' if it was not polluted with Cr. Therefore, in the research design both T-MB and T-FM could be considered as 'treatments', and would be useful only for observing the consequences of administering these feeds into the fowls.

As the aim of this study is to observe proportional Cr accumulation among different body organs of the fowls with respect to the Cr-contamination of protein-concentrates as well as translating the findings into real-world public health and environmental risk exposures, the impossibility of using 'control' experiment does not impair this goal. Due to complete conformity to the poultry-rearing practice in reality including the feed design and rearing conditions, the experimentation undertaken in this study did not require any ethical approval. Instead, the farmer who volunteered in this study (duly acknowledged in the acknowledgment section) had conducted his business-as-usual commercial farming, where in the relevant component with this study, the fowls were sampled rather than sold to customers for consumption. The farmer had processed the fowls for sampling in the same method as he processes them for consumers, compliant with the local legal and regulatory framework.

In view of the public health and environmental risk exposures, the fowls' body is separated into three major components: edible, offal and refuse. The 'edible' is further modelled as comprised of three components: (#1) breast meat, (#2) thigh meat and (#3) fat, and the 'offal' contains (#4) liver, (#5) gizzard and (#6) skin; whereas the 'refuse' is comprised of the remainder five components: (#7) blood, (#8) bone, (#9) feather, (10) gut and (#11) fresh excreta. Although physiologically a fowl's body contains other organs beyond these 11 components, in this proportional Cr accumulation modelling all remainder organs beyond these 11 components are considered as included in component #10 i.e. gut, with respect to public health and environmental risk exposures. The proportional Cr accumulation modelling implies that all Cr intakes via feed and drink have to be expended completely, which means the Cr accumulation inside the body (components #1 - #10) plus the presence of Cr in the excreta should equal 100% of the total Cr intake. Although the flesh could be considered as one component, due to varied consumption preference between breast meat (white coloured) and thigh meat (dark coloured), the flesh was separated into two items: (#1) breast meat and (#2) thigh meat, with the results presented accordingly.

Data Analysis Mechanism

As the absorbed Cr quantities into each body component should depend on body weight gain, further depending on a number of factors in the rearing process; this is modelled rather than measured in the risk exposure. There can also be a perceived potential for error in keeping 'excreta' into the scenario due to the consideration of the proportion of Cr to be excreted to depend on body weight gain. However, this is treated in the data analysis mechanism in two steps: (#1) the absorbed Cr are measured as concentration rather than the total quantity, and (#2) by converting those Cr accumulation concentrations into percentage proportions across different body components including 'excreta'.

The risk exposure is modelled by distributing the Cr content of model feed intake into respective concentrations for different body components as per the proportional Cr accumulation potential obtained from experimental findings. In data calculation, averages of the three sampling replicates are used to calculate proportional Cr accumulation potential among the different body components, while in some cases one extreme value from the three replicates is discarded in order not to impart abnormality into the average.

Sample Pretreatment, Preparation and Analysis

All samples from chickens and ducks, the excreta samples, and feed samples (ingredients as well as the final products) were oven-dried at 80 °C in order to remove all moisture. The oven-drying was repeated until difference between two subsequent readings was found to be negligible. The water samples provided as drinking water for the fowls did not involve any pretreatment and, therefore, those were analyzed directly.

The samples were then prepared by using HNO_3–$HClO_4$ digestion (Kebbekus and Mitra, 1998). Being organic origin the samples had a very high organic content and, therefore, HNO_3–$HClO_4$ digestion was preferred over the more common HNO_3 extraction for the determination of heavy metals. This strongly oxidizing digestion decomposes organics quickly and efficiently.

The samples were analyzed for Cr contents in atomic absorption spectrophotometry (AAS). BDH standards were utilized to prepare calibration curves, and the measurements were conducted in air-acetylene flame AAS.

Results and Discussion

Feed Cr Concentrations

The dry weight basis Cr concentrations in feed ingredients are presented in Table 2. From among the ingredients, corn crash hardly contained Cr (less than 1 ppm dry weight basis) while rice polish and soybean meal were found to contain very less Cr (2.0 ppm and 10.01 ppm dry weight basis, respectively). However, 'meat-bone' and 'fish meal' were severely contaminated with Cr (1.829% and 2.143% dry weight basis, respectively). Therefore, the sources of Cr contamination into the prepared feeds were from 'meat-bone' and 'fish meal', compared to the contents in the other feed ingredients. Following the mixing ratios of feed ingredients presented in Table 1, the Cr concentrations of the four resultant feeds (Starter T-MB and T-FM, and Grower T-MB and T-FM) are presented in Table 2. The drinking water that was provided to the fowls was sampled at one day, one week, three weeks and six weeks of experimentation for both chicken and duck, and their Cr concentrations averaged.

Proportional Cr Accumulation

Tables 3 and 4 present dry weight basis proportional Cr accumulation (the dry weight basis Cr concentrations, expressed in percentages) among the 11 components of chicken and duck, respectively. In the tables, 'C' and 'D' stand for 'chicken' and 'duck', 'W' represents the age of fowl in weeks, T-MB and T-FM are the two feed mixes where T-MB includes 'meat-bone' at the exclusion of 'fish meal' while T-FM includes 'fish meal' at the exclusion of 'meat-bone', and C_Blank and D_Blank represent one day old chicken and duck before commencing the experiments, respectively. As revealed in the results, Cr is arbitrarily distributed (dry

Table 2: Cr concentrations in feeds and feed ingredients

Ingredient	*Sample size and Standard Error*	*Average Cr conc. µg/g (dry weight)*	*Final 'Starter T-MB' Cr conc. µg/g (dry weight)*	*Final 'Starter T-FM' Cr conc. µg/g (dry weight)*	*Final 'Grower T-MB' Cr conc. µg/g (dry weight)*	*Final 'Grower T-FM' Cr conc. µg/g (dry weight)*
Corn crash	3	0.39				
	Std. Error	0.67				
Rice polish	3	10.01				
	Std. Error	8.31				
Soybean meal	3	2.00				
	Std. Error	2.81				
'Meat-bone'	2	18294.87	3295.13	3859.99	3112.26	3645.74
	Std. Error	2204.50				
'Fish meal'	3	21432.99				
	Std. Error	319.76				
Vitamin-Mineral	3	15.65				
	Std. Error	7.14				
General NaCl	3	4.84				
	Std. Error	6.98				
Water	8	1.36	-	-	-	-
	Std. Error	0.48				

Table 3: Proportional Cr accumulation (dry weight basis Cr concentrations, expressed in percentages) in different body components of chicken

Component No.	*Component name*	*Proportional Cr accumulation (dry weight basis Cr concentrations) at different ages*						
		C_Blank	*C_1W_T-MB*	*C_1W_T-FM*	*C_3W_T-MB*	*C_3W_T-FM*	*C_6W_T-MB*	*C_6W_T-FM*
1	Breast meat	6.85	0.8	2.48	3.52	2.91	6.1	3.35
2	Thigh meat	5.74	0.59	2.5	2.94	3.14	5.38	3.77
3	Fat	1.76	0.91	1.64	10.95	7.96	5.62	2.78
4	Liver	4.18	0.53	2.04	3.95	3	5.61	2.95
5	Gizzard	6.1	2.91	4.83	5.39	3.64	8.23	5.69
6	Skin	10.66	0.86	1.21	3.34	4.04	6.57	3.13
7	Blood	14.42	1.67	0.71	3.21	3.8	6.19	3.26
8	Bone	6.19	0.67	0.81	3.03	2.75	6.04	2.97
9	Feather	5.55	1.61	1.05	3.93	4.43	6.44	4.74
10	Gut	17.15	19.25	27.56	12.25	9.16	15.28	17.21
11	Fresh excreta	21.4	70.2	55.17	47.49	55.17	28.54	50.15
	Total	100%	100%	100%	100%	100%	100%	100%

weight basis) among the 11 body components of one day old chicken and duck, which can be attributed to egg Cr content and its distribution through egg hatching process. After being administered with the T-MB and T-FM feeds, one week-old chicken and duck discarded most of the ingested Cr (through feed and drinking water) through the excreta (component #11). The second subsequent highest Cr concentrations were found in their gut (component #10). Compared to the Cr concentrations in fresh excreta and gut, very tiny proportions of Cr were absorbed into the remaining nine body components (components #1-9). At their three weeks of age, the dry weight basis proportional Cr accumulation continued to increase within the #1-9 body components, with a resultant decrease in Cr concentrations in gut (component #10) and excreta (component #11). The same trend continued at their six weeks of age as well.

Table 4: Proportional Cr accumulation (dry weight basis Cr concentrations, expressed in percentages) in different body components of duck

Component No.	Component name	*Proportional Cr accumulation (dry weight basis Cr concentrations) at different ages*						
		D_Blank	*D_1W_T-MB*	*D_1W_T-FM*	*D_3W_T-MB*	*D_3W_T-FM*	*D_6W_T-MB*	*D_6W_T-FM*
1	Breast meat	5.06	0.59	0.32	3.37	2.03	4.53	5.83
2	Thigh meat	8.67	0.42	0.06	2.78	1.44	5.02	7
3	Fat	30.44	1.61	1.03	4.98	5.74	8.13	8.52
4	Liver	3.67	0.25	0	3.04	2.17	4.02	4.94
5	Gizzard	2.18	0.89	0.79	3.93	2.08	5.19	4.07
6	Skin	12.35	0.49	0.44	3.73	2.8	3.86	5.22
7	Blood	7.87	0.4	0.02	2.71	2.11	3.93	5.43
8	Bone	5.46	0.35	0.13	3.86	2.23	6.87	5.35
9	Feather	8.88	3.36	4.39	8.61	7.55	6.48	9.06
10	Gut	2.95	17.91	16.5	18.03	12.17	8.51	5.82
11	Fresh excreta	12.47	73.73	76.32	44.96	59.68	43.46	38.76
	Total	100%	100%	100%	100%	100%	100%	100%

Accumulation Projection from Feed Cr Concentrations

Tables 5 and 6 present dry weight basis Cr accumulation projection for chicken and duck, respectively. These are modelled from proportional Cr accumulation among different body components of chicken and duck (in Tables 3 and 4), utilizing the Cr concentrations of the feed mixes (T-MB and T-FM feeds for starter and grower stages, presented in Table 2). Although a question arises as to how the Cr accumulation can be projected while there are other organs in a fowl's body where Cr can accumulate at different concentrations? As described in an earlier sub-section (Research and Sampling Design) that the remaining organs other than the sampled 11 components are considered to be included in component #10 (i.e. gut). This assumption is supported by the results in Tables 5 and 6 where gut absorbed more Cr than any of the other #1-9 components (except for excreta, which anyway is not body organ). Therefore, the inclusion of other internal organs (other than the sampled 11 components) into the gut (component #10) does not compromise with the public health and environmental hazard potential of the #1-9 components (which should be the same as projected in next two sub-sections, or even higher if the other internal organs and components other than the 11 sampled components absorb lesser Cr concentrations than found in the gut).

Table 5: Cr accumulation projection (dry weight basis) for chicken at different ages

Component No.	Component name	*Cr concentration (µg/g, dry weight basis) projection in chicken*					
		C_1W_T-MB feed	*C_1W_T-FM feed*	*C_3W_T-MB feed*	*C_3W_T-FM feed*	*C_6W_T-MB feed*	*C_6W_T-FM feed*
		3295.13 µg/g	*3859.99 µg/g*	*3112.26 µg/g*	*3645.74 µg/g*	*3112.26 µg/g*	*3645.74 µg/g*
1	Breast meat	26.36	95.73	109.55	106.09	189.85	122.13
2	Thigh meat	19.44	96.50	91.50	114.48	167.44	137.44
3	Fat	29.99	63.30	340.79	290.20	174.91	101.35
4	Liver	17.46	78.74	122.93	109.37	174.60	107.55
5	Gizzard	95.89	186.44	167.75	132.70	256.14	207.44
6	Skin	28.34	46.71	103.95	147.29	204.48	114.11
7	Blood	55.03	27.41	99.90	138.54	192.65	118.85
8	Bone	22.08	31.27	94.30	100.26	187.98	108.28
9	Feather	53.05	40.53	122.31	161.51	200.43	172.81
10	Gut	634.31	1063.81	381.25	333.95	475.55	627.43
11	Fresh excreta	2313.18	2129.56	1478.01	2011.35	888.24	1828.34
	Total	**3295.13 µg/g**	**3859.99 µg/g**	**3112.26 µg/g**	**3645.74 µg/g**	**3112.26 µg/g**	**3645.74 µg/g**

Table 6: Cr accumulation projection (dry weight basis) for duck

Component No.	*Component name*	*Cr concentration (µg/g, dry weight basis) projection in duck at different ages*					
		D_1W_T-MB feed	*D_1W_T-FM feed*	*D_3W_T-MB feed*	*D_3W_T-FM feed*	*D_6W_T-MB feed*	*D_6W_T-FM feed*
		3295.13 µg/g	*3859.99 µg/g*	*3112.26 µg/g*	*3645.74 µg/g*	*3112.26 µg/g*	*3645.74 µg/g*
1	Breast meat	19.44	12.35	104.88	74.01	140.99	212.55
2	Thigh meat	13.84	2.32	86.52	52.50	156.24	255.20
3	Fat	53.05	39.76	154.99	209.27	253.03	310.62
4	Liver	8.24	0.00	94.61	79.11	125.11	180.10
5	Gizzard	29.33	30.49	122.31	75.83	161.53	148.38
6	Skin	16.15	16.98	116.09	102.08	120.13	190.31
7	Blood	13.18	0.77	84.34	76.93	122.31	197.96
8	Bone	11.53	5.02	120.13	81.30	213.81	195.05
9	Feather	110.72	169.45	267.97	275.25	201.67	330.30
10	Gut	590.16	636.90	561.14	443.69	264.85	212.18
11	Fresh excreta	2429.50	2945.94	1399.27	2175.78	1352.59	1413.09
	Total	3295.13 µg/g	3859.99 µg/g	3112.26 µg/g	3645.74 µg/g	3112.26 µg/g	3645.74 µg/g

Dietary Public Health Risk

Although the functional mechanisms of Cr inside the body are not very clearly understood, Cr is a required mineral for humans in trace quantities (NRC, 1980; Mertz, 1998). The National Academy of Sciences established the Cr range of 50-200 µg as 'estimated safe and adequate daily dietary intake' (NRC, 1989). However, the dietary reference intakes (DRI) for Cr was not established until 2001, where due to insufficient research base to establish RDAs (recommended dietary allowances) Cr AIs (adequate intakes) were rather developed (Institute of Medicine, 2001). Yet no tolerable upper intake level (UL) was established for Cr due to the consideration of evidence of adverse effects linked to high Cr intakes (Stoecker, 2001; Institute of Medicine, 2001). Therefore, the standard that exists for assessing potential toxicity due to Cr intake is the Cr AIs, which are listed in Table 7.

Therefore, in this analysis, the dietary public health hazard potential of Cr is compared with the Cr AIs. As no RDAs and as well as no ULs have been developed for Cr, the intakes exceeding Cr AIs could be potentially hazardous. Through utilizing the Cr accumulation projection for different ages and different feed mixes presented in Tables 5 and 6, Tables 8 and 9 present the dietary public health hazard potential for 100 g consumption (dry weight) of each of the 'edible' (components #1-3) and 'offal' (components #4-6) components of chicken and duck, respectively. The results are presented for one week, three weeks, and six weeks of fowl ages. As seen from Table 7, the Cr AIs range between 0.2 and 45 µg for all age groups and all people types. To compare the projected Cr contents (in µg) in 100 g (dry weight) of the 'edible' and 'offal' components with Cr AI levels, Cr contents of all components except for liver in (D_1W_T-FM) greatly exceed the maximum range of adequate daily Cr intakes

Table 7: Adequate Intakes (AIs) for chromium (Institute of Medicine, 2001)

Age	*Infants and children (µg/day)*	*Males (µg/day)*	*Females (µg/day)*	*Pregnancy (µg/day)*	*Lactation (µg/day)*
0 to 6 months	0.2				
7 to 12 months	5.5				
1 to 3 years	11				
4 to 8 years	15				
9 to 13 years		25	21		
14 to 18 years		35	24	29	44
19 to 50 years		35	25	30	45
>50 years		30	20		

Table 8: Dietary public health risk exposure from consuming Cr contaminated chicken

Component No.	*Component name*	*Cr content (µg) projection for each 100 g consumption (dry weight) of edible and offal components*					
		C_1W_T-MB	*C_1W_T-FM*	*C_3W_T-MB*	*C_3W_T-FM*	*C_6W_T-MB*	*C_6W_T-FM*
1	Breast meat	2636	9573	10955	10609	18985	12213
2	Thigh meat	1944	9650	9150	11448	16744	13744
3	Fat	2999	6330	34079	29020	17491	10135
4	Liver	1746	7874	12293	10937	17460	10755
5	Gizzard	9589	18644	16775	13270	25614	20744
6	Skin	2834	4671	10395	14729	20448	11411

Table 9: Dietary public health risk exposure from consuming Cr contaminated duck

Component No.	*Component name*	*Cr content (µg) projection for each 100 g consumption (dry weight) of edible and offal components*					
		D_1W_T-MB	*D_1W_T-FM*	*D_3W_T-MB*	*D_3W_T-FM*	*D_6W_T-MB*	*D_6W_T-FM*
1	Breast meat	1944	1235	10488	7401	14099	21255
2	Thigh meat	1384	232	8652	5250	15624	25520
3	Fat	5305	3976	15499	20927	25303	31062
4	Liver	824	0.0	9461	7911	12511	18010
5	Gizzard	2933	3049	12231	7583	16153	14838
6	Skin	1615	1698	11609	10208	12013	19031

for all age groups and all people types. Moreover, except for liver and thigh meat in (D_1W_T-MB and D_1W_T-FM), all other minimum values (i.e. Cr contents at one week of age) are found well over 1000 µg Cr while the maximum values (i.e. Cr contents at six weeks of age) reached well over 10,000 µg.

This gradual increase in Cr accumulation with increase in fowl age reveals increased dietary risk with increased fowl age (from one week to six weeks of age). Considering the standard moisture content of chicken and duck breast meat reported as 75.47% and 76.41%, respectively (Ali et al., 2007), 100 g fresh weight chicken and duck breast meat would correspond to 24.53 g and 23.59 g dry weights, respectively. Thus, converting the dry weight basis Cr content projection from Tables 8 and 9 for each of 100 g fresh weight chicken and duck breast meat reveals the Cr exposure of 4657 µg and 5014 µg, respectively. These are at least 100 to over 300 times higher than the AIs (to be intaken from all foods and drinks in an entire day) for any people type and any age group beyond three years, whereas for people under three years such becomes even higher. The risk exposure between breast and thigh meat are similar as well, in both chicken and duck. In addition, there are similar risks from consuming fat, liver, gizzard and skin of the fowls.

Environmental Risk

The environmental hazard potential from the Cr contaminated fowls are even greater than dietary public health hazard potential, due to much higher Cr presence in excreta and gut; with blood, bone and feather containing similar proportions of Cr concentrations as with the edible and offal components (Tables 3 and 4). Tables 10 and 11 present the environmental hazard potential from 1 kg (dry weight) environmental use of each of the sampled 'refuse' components (components #7-11) from chicken and duck, respectively. The gut and excreta contain more Cr per unit dry mass in early fowl age (such as one week of age) than later (such as three weeks and six weeks of age). On the contrary, the blood, bone and feather have a general likelihood of accumulating more Cr through increase in age. The highest Cr contents per unit dry mass in excreta are found in one week old fowls, while the lowest contents per unit dry mass are found in six weeks aged fowls (for both chicken and duck). For an estimated environmental use of one metric tonne dry weight excreta, the minimum and maximum Cr load could be 888.24 g to 2.3 kg for chicken excreta, and 1.35 kg to 2.94 kg for duck excreta. These environmental uses include application as fertilizer in agricultural soils for crops and vegetable production, and using in fish

Table 10: Environmental risk exposure of Cr contaminated chicken

Component No.	*Component name*	*Cr content (mg) projection for each 1 kg (dry weight) use of sampled 'refuse' components*					
		C_1W_T-MB	*C_1W_T-FM*	*C_3W_T-MB*	*C_3W_T-FM*	*C_6W_T-MB*	*C_6W_T-FM*
7	Blood	55.03	27.41	99.90	138.54	192.65	118.85
8	Bone	22.08	31.27	94.30	100.26	187.98	108.28
9	Feather	53.05	40.53	122.31	161.51	200.43	172.81
10	Gut	634.31	1063.81	381.25	333.95	475.55	627.43
11	Fresh excreta	2313.18	2129.56	1478.01	2011.35	888.24	1828.34

Table 11: Environmental risk exposure of Cr contaminated duck

Component No.	*Component name*	*Cr content (mg) projection for each 1 kg (dry weight) use of sampled 'refuse' components*					
		D_1W_T-MB	*D_1W_T-FM*	*D_3W_T-MB*	*D_3W_T-FM*	*D_6W_T-MB*	*D_6W_T-FM*
7	Blood	13.18	0.77	84.34	76.93	122.31	197.96
8	Bone	11.53	5.02	120.13	81.30	213.81	195.05
9	Feather	110.72	169.45	267.97	275.25	201.67	330.30
10	Gut	590.16	636.90	561.14	443.69	264.85	212.18
11	Fresh excreta	2429.50	2945.94	1399.27	2175.78	1352.59	1413.09

farming as feed. Nonetheless, the environmental hazards due to contamination also feed back into food chains through biogeochemical cycles, thereby adding into the dietary public health risk exposure for both humans and the biodiversity.

Conclusion

The Cr contamination of poultry feeds is found to occur from the Cr-contaminated protein-concentrates referred to as 'meat-bone' and 'fish meal'. Inclusion of these protein-concentrates result in 0.3–0.4% dry weight basis presence of Cr in poultry feeds. The 'fish meal' is also applied as feed in fish farming, therefore, rendering fish to accumulate Cr in body mass from an exposure of a high Cr contaminated feed (2.14% Cr, dry weight basis). In the experimentation with chicken and duck, Cr accumulation inside the fowl body occurs slowly during early age (one week of age), where most of the Cr intake through feed and water gets discarded through excreta, along with a highly concentrated storage in the gut. From then on as the age of the fowl increases, the proportional Cr concentration in gut and excreta start to decrease, with a resultant increase in Cr accumulation in other body components.

Compared to human Cr AIs (to be intaken from all foods and drinks in an entire day), the dietary public health exposure from consuming 100 g fresh weight breast meat from a Cr contaminated fowl in a day could be at least 100 to over 300 times higher than the AIs for any people type and any age range beyond three years, whereas for people under three years such becomes even higher. This reveals an enormous public health threat with regard to the Cr contamination. Besides, the environmental hazard potential is no less severe. Application of one metric ton dry weight excreta from the contaminated fowls could render as high an environmental Cr load as approximately 3 kg (2.94 kg). The linkage between environmental hazard potential and dietary public health risk are neither too distant. Yet, the phenomenon is one not only existing in Bangladesh, but also being practiced in India and Pakistan to the least (in terms of producing feed ingredient from Cr-contaminated tannery solid wastes). The objective of this study was to elucidate the public health risk and environmental hazard potential arising from such practice. However, the extent of the problem based on the findings demand actions and cooperation in research, management, and administration at a regional level for devising common solutions.

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