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Current Status of Heavy Metal Residues in Egg Samples Collected from Bagerhat District, Bangladesh

Md. Noman Hossain[1,*], Md. Asef Hossain[2], Md. Ziaur Rahman[3], Mounita Ghosh[4], Md. Shahin Hawladar[5], Md.Anowar Hossain[6], Rajonshaha Antu[7]and Shahela Akter[8]

[1]*Assistant Professor, Department of Physics, Imperial College of Engineering, Khulna, Bangladesh*
[2]*Lecturer, Department of Physics, Imperial College of Engineering, Khulna, Bangladesh*
[3]*Adjutant, Military Collegiate School Khulna, Bangladesh*
[4]*Phd student, Department of Biomedical Engineering, KUET, Bangladesh*
[5]*Lecturer, Department of Biology, Military Collegiate School Khulna (MCSK)*
[6]*Phd student, Department of Physics, KUET, Bangladesh*
[7]*M.Sc. student, Department of Physics, KUET, Bangladesh*
[8]*Assistant professor, Department of Biology, Military Collegiate School Khulna*

Abstract: *Based on numerous variables, including density and atomic weight, heavy metals can be characterized in a variety of ways. In small amounts, several heavy metals like iron, cobalt, and zinc are necessary for human nutrition but are poisonous in larger amounts. However, only a few elements, like lead, cadmium, and mercury are toxic even in trace amounts.The concentration of essential metals such as Fe, Cu and Zn and toxic metals such as Pb, Cd, Cr, As and Ni were determined in a number of egg samples by using atomic absorption spectrophotometry (AAS). The decreasing sequence of the concentrations of heavy metals obtained from hen(local), hen(farm), duck(local) & average all types of egg were Fe > Zn >Pb> Cu > Ni > Cr > As >Cd, Zn > Fe > Ni > Cu >Cr >Pb> Cd > As, Zn > Fe > Cu > Ni >Pb> Cr > As > Cd & Fe > Zn > Ni > Cu >Pd> Cr > As > Cd respectively. The average Fe, Zn, Pb, Cd & Ni concentration found in egg was higher than that reported from other countries, while the concentrations of Cu, Cr & As in some cases were lower than other countries. The average concentrations were also used to calculate average daily intakes for non-carcinogenic risk assessment. The non-carcinogenic health risk assessment (THQ) values never exceeded the hazard quotient threshold of 1. The carcinogenic risk, TCR values obtained for Pb were generally considered as an acceptable range (<10-6) and moderate risk for Cd and As, suggesting that there was little concern about carcinogenic risk for study area consumers by ingestion heavy metals contained in egg.*

Keywords: *Egg, Health risk, Heavy metals,Bagerhat&Bangladesh.*

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I. INTRODUCTION

Bangladesh is a densely populated developing country where approximately 85% people depend on agriculture for their livelihoods. By increasing the population and industrialization the shortage of protein also take place day by day [1]. Eggs have long been one of the most important protein containing foods for people because of their high nutritional value, low cost, and easy production [2]. The nutritional value varies markedly between the yolk and the white. The fat, cholesterol and some micronutrients are located in the yolk, while the egg white is mainly formed of water and protein. On the other hand, some minerals and water-soluble vitamins are found in higher concentrations in the yolk [3]. Moreover, egg is an excellent source of choline and selenium and a good source of vitamin B_{12}, riboflavin, phosphorus, folic acid and zinc [4].

Heavy metal contamination of the food chain is well documented in Bangladesh [5]. Due to the growing urbanization and industrialization, there has been an increase of pollution by the discharge of industrial waste; especially heavy metals; to the environment, consequently in foods [6, 7]. Egg-borne ailments are of huge public health concern due to eating of undercooked and contaminated eggs [8]. Farmers and homemakers now use inorganic materials in hen and duck feed for augmentation of health and production which plays an important role for the accumulation of heavy metals in eggs [9].

In recent years food safety has become a major public health concern due to presence of toxic heavy metals, such as lead (Pb), cadmium (Cd), arsenic (As) etc., in food of animal origin [10]. These toxic metals are commonly defined as hazardous elements; bio-accumulative and do not degrade easily; typically accumulate in fatty tissues and are slowly metabolized often resulted in increasing their concentration through the food chain and cannot be broken down and persist in the environment [11]. Cadmium is suspected for renal arterial hypertension, cancer and bone weakness [12]. Chronic lead toxicity produces anaemia and paralysis. Development of deformities, shortage in intellect proportion and neurotoxicity effects in new-borns, increasing rate constipation and stomach pain are the main consequences of chronic exposure to Pb [13]. Copper toxicity may cause Wilson's disease (the extreme gathering of Cu in liver, brain, kidney and cornea) and Menkes's disease [14]. Cr compound have the properties of to be potent carcinogens [15]. Deficiency of Zn might cause skin problems, susceptibility to infection and as well as loss of taste. On the other hand, elevated amount of Zn causes diarrhoea, hair loss, brittle fingernails, weakness, anaemia, stomach and intestine problems [16]. Sub lethal exposure of avian embryos to Mn causes teratogenic effects, such as micromole, twisted limbs, and haemorrhage and neck defects [17].

Many developing and developed countries have started the regular monitoring of heavy metals in soil, water and foodstuff. Recently, Siddiqui et al. (2011) examined the essential trace metals (Pb, Cd, Cr, Co, Cu, Fe, Mn, and Zn) level in hen egg collected from the local market of London, UK. The study showed that the mean concentration of Pb, Cu and Zn in hen eggs was within tolerable limit [18]. In another study, Khan et al. (2016) determined the concentration of heavy metals in poultry eggs from three districts (Peshawar, Dir Lower and Malakand; Pakistan) and reported the egg albumen contains higher contents of Pb, Cd and Cr while egg yolk contains considerably higher levels of Fe, Mn and Zn. Moreover, this study revealed that the values of Cd, Cr and Zn through egg were found above the permissible values for daily intake reflecting a risk for public health [19]. In 2017, Giri et al. studied the health implications of heavy metals due to ingestion of local chicken eggs in the mining areas of Singhbhum copper belt, India and they reported EDI and THQ values do not pose health risk separately. However, considering the geometric mean of the metals, hazard index (HI) was above unity indicating a prime threat to the consumers of local chicken eggs around the mining regions [20].

To ensure the food safety, Bangladesh has also started regular monitoring of heavy metals in different types foodstuffs. In a study, Anup et al. (2017) investigated the concentration of Cr, Ni, Cu, As, Cd and Pb in albumen and yolk of eggs of Chicken collected from the North-Eastern region (Sylhet City Corporation) of Bangladesh. This study reported the concentration of As and Pb in egg of chicken was higher than the safe limit as stated by World Health Organization [21]. In a similar study, Hossain et al. (2017), determined chromium concentrations in poultry meat (flesh and liver) and eggs collected from poultry farms in Dhaka, Bangladesh, and they reported, intake of eggs from this region are safe from potential health risks [22]. Recently, Kabir et al. (2018) examined the heavy metals level in hens and ducks egg (Chittagong region, Bangladesh) and observed higher concentration Fe and Cu [23].

However, the previous studies revealed that intake of egg could be a possible route of heavy metal exposure among the population. Considering the aforementioned issues the present study provides significant importance in terms food safety, hygiene. Therefore the aim of this study was to assess the health risks (carcinogenic and no-carcinogenic) due to heavy metal exposure through the consumption of different type's eggs (local hen, poultry and duck).

II. MATERIALS AND METHODS

Description of the study area

Bagerhat District is located in between 21°49' and 22°59' north latitudes and in between 89°32' and 89°98' east longitudes. It has an area of area 3959.11 sq km, is bounded by Gopalganj and Narail districts on the north, Bay of Bengal on the south, Gopalganj, Pirojpur, and Barguna districts on the East, Khulna district on the west [24].

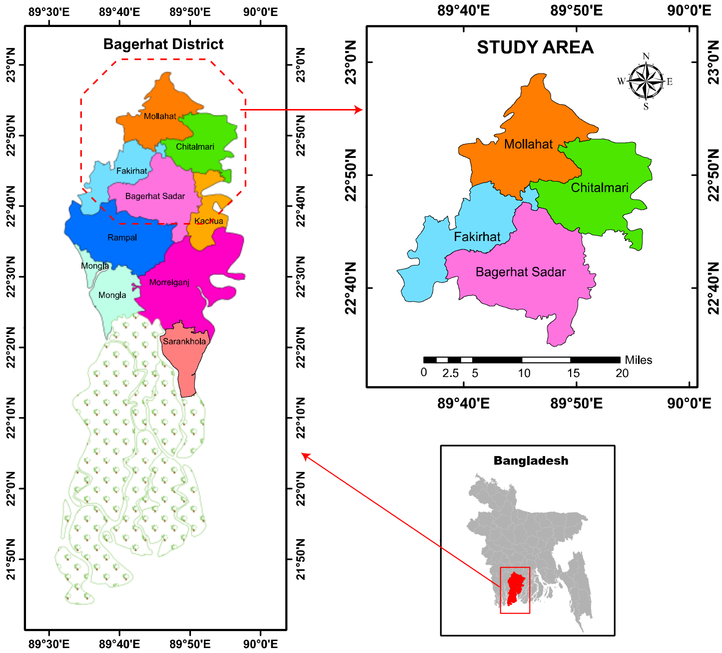
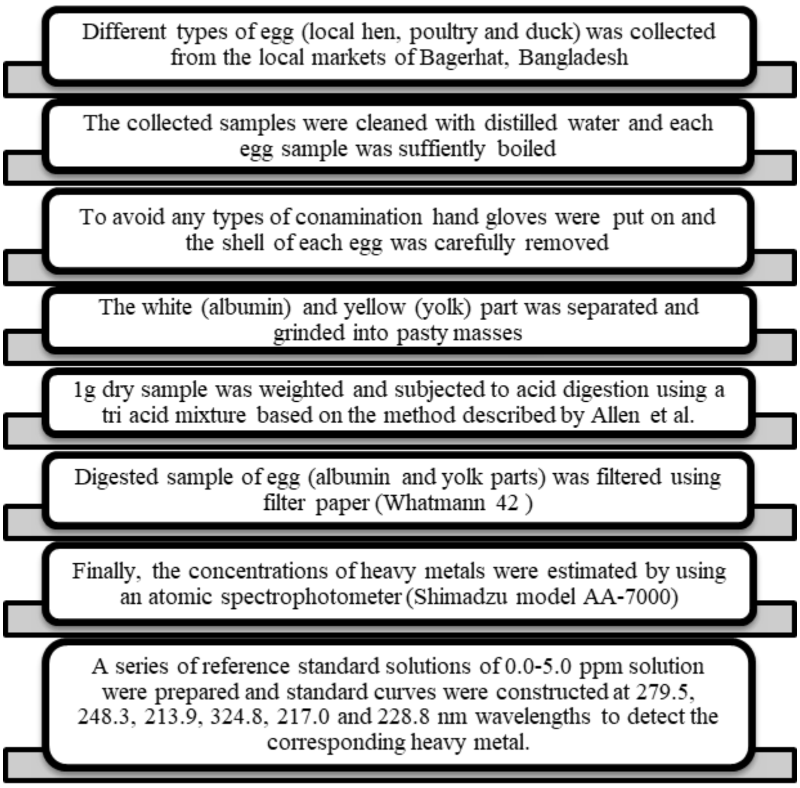


Figure 1: Map of the study area (Mollahat, Chitalmari, Fakirhat, and BagerhatSadar sub-districts)

Sample Collection

A total of 75 egg (25 local hen, 25 poultry and 25 duck) samples were randomly collected from the different markets of Bagerhat, Bangladesh. Analytical grade reagents (HNO_3, H_2SO_4, $HClO_4$ and deionized water) were purchased from the chemical suppliers and used without further purification. The analytical procedure has been summarized by the following flow diagram 1.



Assessment of health risk

The observed concentrations of heavy metals in different egg samples were used tocalculate the estimated daily intake of metals (EDI); non-carcinogenic health risk parameters (target health quotient, THQ;

total hazard index, HI); and carcinogenic parameter (target cancer risk, TCR). The general formulae of risk assessment parameters and the meaning of each symbol with reference values have been given in Table 1.

Table 1: General description of health risk assessment parameters

Health risk assessment parameters	Description
$\mathbf{EDI} = \frac{C_m \times I_g}{W_b}$	C_m= Concentration of metals in egg.
	I_g= ingestion rate (which is taken as 0.0132 kg.day^{-1} for vegetables)
	W_b= an average body weight(49.5 kg) of Bangladeshi people.
$THQ = \frac{EDI}{D_f}$	D_f= reference doseof Fe, Mn, Cu, Zn, As, Ni, Pb are 0.7, 0.14, 0.04, 0.30, 0.0003, 0.02 and 0.0035 (mg.kg^{-1} day^{-1}) respectively [15, 27].
$HI = \sum THQ$	S_{cpo} = The value of carcinogenic potency slopeof Pb,Cd and As are 0.0085, 6.1 and 1.5 mg.kg^{-1} bodyweight days^{-1} respectively [25].
$TCR = EDI \times S_{cpo}$	

III.RESULTS AND DISCUSSIONS

Heavy Metal Concentration

The concentration of heavy metals withdetailed information in eggs (hen, duck) content from different local market ofBagerhat is summarized in Table 2. According to the observed results the decreasing order of the levels of heavy metals obtained from hen(local), hen(farm), duck(local) & average all types of egg were Fe>Zn>Pb>Cu>Ni>Cr>As>Cd, Zn>Fe>Ni>Cu>Cr>Pb>Cd>As, Zn>Fe>Cu>Ni>Pb>Cr>As>Cd & Fe>Zn>Ni>Cu>Pd>Cr>As>Cd respectively. The average concentrations were also used to calculate average daily intakes for non-carcinogenic risk assessment.

Table 2. Mean concentration and range of heavy metal residues in studied samples

Sample ID	Portion	Fe	Cu	Zn	Pb	Cd	Cr	Ni	As
Hen (local)	Albumin (Range)	11.05 (7.50-28.51)	2.12 (1.25-3.59)	3.24 (1.37-5.38)	0.29 (0.12-0.46)	0.07 (0.05-0.13)	0.22 (0.08-0.42)	1.21 (0.34-2.79)	0.10 (0.02-0.18)
	Yolk (Range)	145.21 (56.12-231.29)	2.89 (1.26-4.05)	67.92 (25.62-89.27)	8.45 (2.51-15.38)	0.05 (0.03-0.24)	0.34 (0.10-0.76)	3.16 (1.94-6.26)	0.11 (0.06-0.21)
(Albumin + Yolk)		**156.26**	**5.01**	**71.16**	**8.74**	**0.12**	**0.56**	**4.37**	**0.21**
Hen (farm)	Albumin (Range)	3.53 (1.49-7.91)	1.34 (0.51-2.98)	12.68 (5.29-23.80)	0.85 (0.34-2.07)	0.08 (0.05-0.19)	0.62 (0.27-1.88)	10.41 (3.18-20.16)	0.07 (0.03-0.13)
	Yolk (Range)	32.98 (12.25-81.71)	1.67 (0.48-3.29)	82.36 (40.37-131.51)	0.41 (0.19-1.37)	0.10 (0.06-0.21)	0.73 (0.31-2.56)	5.90 (1.62-12.48)	0.08 (0.02-0.19)
(Albumin+ Yolk)		**36.51**	**3.01**	**95.04**	**1.26**	**0.18**	**1.35**	**16.31**	**0.15**
Duck(local)	Albumin (Range)	35.23 (11.58-65.26)	1.56 (0.71-3.69)	1.27 (0.36-3.79)	0.30 (0.13-0.67)	0.06 (0.05-0.18)	0.15 (0.07-0.34)	1.65 (0.79-3.61)	0.05 (0.02-0.11)
	Yolk (Range)	9.76 (2.36-26.09)	1.90 (0.82-4.28)	56.37 (28.21-73.83)	0.23 (0.11-0.56)	0.05 (0.03-0.14)	0.32 (0.14-0.68)	0.89 (0.42-2.16)	0.07 (0.03-0.12)
(Albumin + Yolk)		**44.99**	**3.46**	**57.64**	**0.53**	**0.11**	**0.47**	**2.54**	**0.12**
Average of 75 samples		**79.25**	**3.82**	**74.61**	**3.51**	**0.136**	**0.793**	**7.74**	**0.16**

Among all metals, the essential metals were most abundant in the egg content of all types of egg. In this study, Fe and Zn had the highest average concentration and contribution (91% of the total metal concentration) in all the egg samples. In an attempt of a rough comparison, the level of heavy metals was compared to data reported by other studies (Table 3). The average Fe, Zn, Pb, Cd & Ni concentration found in egg was higher than that reported from other countries, while the concentrations of Cu, Cr & As in some cases were lower than other countries. Average concentration of As content in eggs was lower than Sylhet, Bangladesh and Malaysia in most strains of laying hens [1, 28-29], while its concentration was higher than egg in Egypt & Iran [21, 28-29]. For Cr, average content in egg lower than Malaysia, Sylhet, Bangladesh and higher than Iran and India [1, 19, 27-29]. Generally, the concentration of Cr in the farm hen egg is higher than local hen egg. This result implied that the food sources could be regarded as the most significant pathway to additional intake of these heavy metals from commercial farm hen eggs. Findings from this work are in agreement with several other studies that the food pathways are the most significant source for additional intake of heavy metals [8, 27-29].

Table 3. Comparison of heavy metals concentration of egg samples in present study with other similar studies [27-29].

Name of Egg	Fe	Cu	Zn	Pb	Cd	Cr	Ni	As
Sylhet (Hen) (a)	-	1.79	-	0.229	0.081	1.61	3.28	0.317
Chittagong(Hen, L)	76.414	3.88	-	-	<0.05	<0.05	-	-
Chittagong(Hen, F)	77.544	2.71	-	-	<0.05	<0.05	-	-
Chittagong(Duck)	75.904	3.534	-	-	<0.05	<0.05	-	-
China	-	1.608	13.93	0.052	0.002	-	-	-
Malaysia	-	-	-	0.42	0.054	3.24	1.11	0.3
India	37.66	11.13	14.2	0.15	-	0.33	0.25	-
Egypt	73.2-86.1	5.6-6.3	56.8-64.3	0.17-0.3	0.006-0.015	-	-	0.033
Tehran, Iran	34.37	1.46	-	0.074	0.01	0.014	-	0.03
Sudan	2.20	0.195	3.335	0.305	0.07	-	-	-
Present Study	79.25	3.82	74.61	3.51	0.136	0.793	7.74	0.16

The dietary exposure approach is a useful method to evaluate the diet quality in terms of bioactive contaminants and compounds, intake levels of nutrients, identifying potential exposure to food contaminants [13].The EDI values of heavy metals fromegg consumption by study area consumers are shownin Table 4. For study area population, the EDI for local hen, farm hen and local duck showed the descending order of Fe>Zn>Pb>Cu>Ni >Cr>As>Cd, Zn >Fe>Ni>Cu>Cr>Pb>Cd>As and Zn>Fe >Cu>Ni >Pd>Cr >As>Cd respectively.

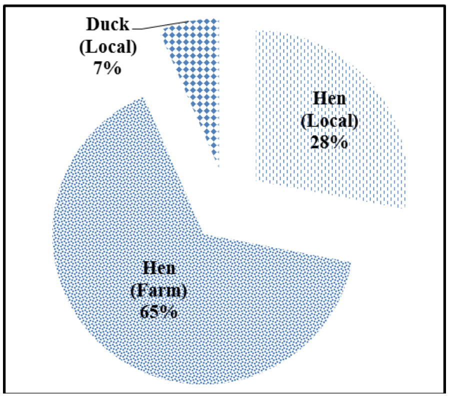
The EDI values for examined egg samples were far below provisional tolerable daily intake (PTDI) and tolerable daily intake (TDI) limits, suggesting that health risk associated with the intake of each examined metal through the egg consumption was absent in this study. The non-carcinogenic health risk assessment (THQ) and hazard index (HI) from the egg ingestion for study area consumers are summarized in Table 3. As seen from the data, THQ values never exceeded the hazard quotient threshold of 1. This demonstrated that the daily intake level of examinedheavy metals in this study was lower than thelevel of concern for all consumers, indicating that these levels ofhuman exposure tothese metals could not cause any adverse effects during consumer’s lifetime. The contributionsof individual heavy metals to the non-carcinogenic risk were different for each strains of laying hens. As shown in Fig. 1, in egg samples Pb and As were the major contributors (55% and 17% contribution) to THQ causing agents among heavy metal compounds. Therefore, the features of metal toxicity could be different for an individual. Further, the risk assessment model was only conducted based on the heavy metal toxicity, but the fact is that egg content also contains other toxic compounds from other possible exposure pathways such as dioxins, PAHs, and organo-chlorines. Therefore, the cumulative carcinogenic and non-carcinogenic risk of all toxic compounds from egg consumption could be higher than that calculated values in this study.

Table 4. Calculated values of health risk assessment parameters (EDI, THQ, HI and TCR) in different egg samples

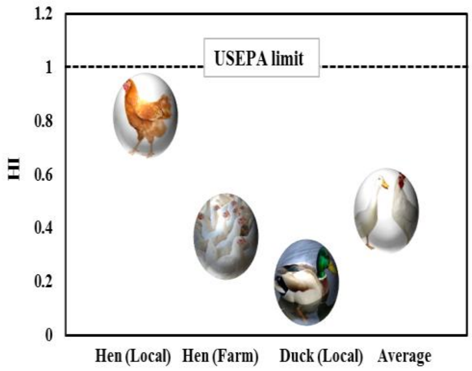
Parameters	Sample	Fe	Cu	Zn	Pb	Cd	Cr	Ni	As
EDI	Hen (local)	0.0416	0.0013	0.0189	0.0023	0.00003	0.00015	0.00117	0.00006
	Hen (farm)	0.00974	0.00080	0.02534	0.00034	0.00005	0.00036	0.00435	0.00004
	Duck (local)	0.01200	0.00092	0.01537	0.00014	0.000003	0.00013	0.00068	0.00003
MeanEDIof 75 samples		**0.0211**	**0.00102**	**0.0199**	**0.00094**	**0.00004**	**0.00021**	**0.00206**	**0.00004**
PTDI [a]		**0.8**	**0.5**	**1**	**0.00357**	**0.00066**	**0.003**	**0.0005**	**0.00214**
MTDI [b]		**0.8**	**0.1667**	**0.3**	**0.003**	**0.0008**	**0.0028**	**0.0043**	**0.0018**
THQ	Hen (local)	0.05953	0.0334	0.06325	0.58267	0.03200	0.04978	0.05827	0.18667
	Hen (farm)	0.01391	0.02007	0.08448	0.08400	0.04800	0.1200	0.21747	0.13333
	Duck (local)	0.01714	0.02307	0.05124	0.03533	0.02933	0.04178	0.03387	0.10066
MeanTHQof 75 samples		**0.03019**	**0.02551**	**0.0663**	**0.2340**	**0.03644**	**0.07052**	**0.10320**	**0.14222**
HI	Hen (local)	0.82063							
	Hen (farm)	0.37046							
	Duck (local)	0.19789							
MeanHIof 75 samples		**0.46299**							
TCR	Hen (local)	-	-	-	$1.9E^{-5}$	$1.8E^{-4}$	-	-	$9.0E^{-5}$
	Hen (farm)	-	-	-	$2.9E^{-6}$	$3.1E^{-4}$	-	-	$6.0E^{-5}$
	Duck (local)	-	-	-	$1.2E^{-6}$	$1.8E^{-5}$	-	-	$4.5E^{-5}$
MeanTCRof 75 samples		-	-	-	$\mathbf{7.7E^{-6}}$	$\mathbf{1.6E^{-4}}$	-	-	$\mathbf{6.5E^{-5}}$

[a] Provisional tolerable daily intake values of heavy metals based on the data established by the joint FAO/WHO Expert Committee on Food Additives,[b] Maximum tolerable daily intake (mg kg^{-1} BW day^{-1}).

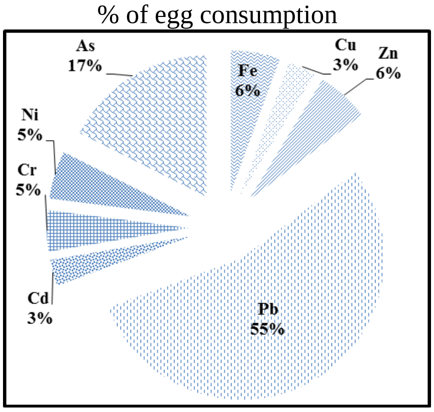
The TCR was estimated using the intake level of Pb, Cd and As since these heavy metals may increase both carcinogenic impacts depending on the exposure dose [13, 27-29].The TCR value denotes not only an estimation of expected cancer but also it represents the probability of developing carcinogenic risk to the human[30].In this study, the possibility of developing cancer was calculated based on the US-EPA deterministic approach. Prolonged exposure of a specific carcinogen may develop cancer and the probability increases with the contact time. According to NYSDOH the TCR categories are described as; if the TCR value is less than equal to 10^{-6} the carcinogenic risk is low; when this value is 10^{-5} to 10^{-3} the risk is moderate; but when this value is 10^{-3} to 10^{-1} and $\geq 10^{-1}$ the risk is high and very high [30]. According to this study, Pb was categorized as less carcinogen group and Cd, Asas a moderate carcinogen group [11]. The average of TCR value for Pb, Cd and As due to exposure from egg consumption was $7.7E^{-6}$, $1.6E^{-4}$ and $6.5E^{-5}$ respectively (Table 3). Therefore, the TCR values obtained for Pb were generally considered as an acceptable range ($<10^{-6}$) and moderate risk for Cd and As, suggesting that there was little concern about carcinogenic risk for study area consumers by ingestion heavy metals contained in egg.



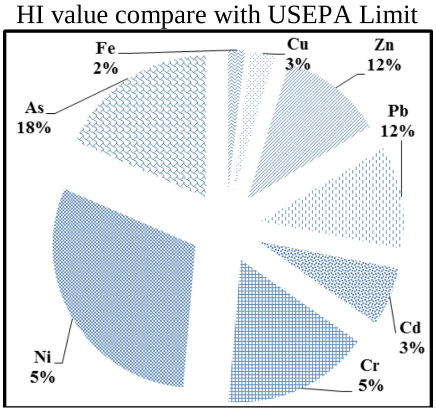
% of egg consumption



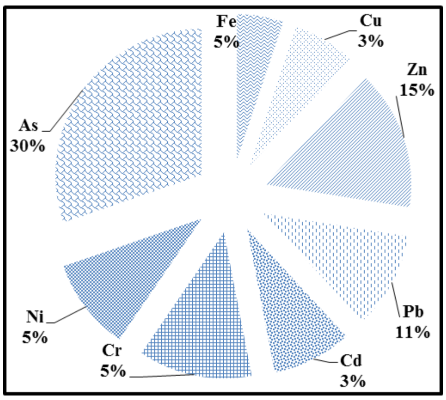
HI value compare with USEPA Limit



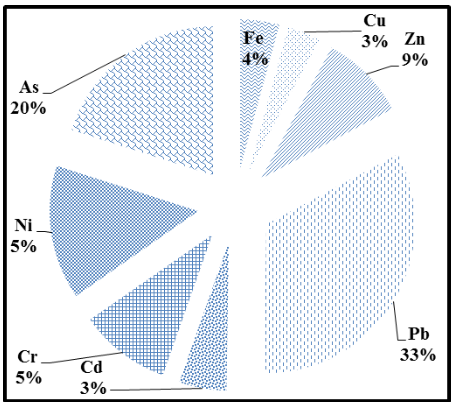
THQ for Local Hen



THQ for farm Hen



THQ for farm Duck



THQ for average egg

IV. CONCLUSION

According to the results, the average Fe, Zn, Pb, Cd & Ni concentration found in egg was higher than that reported from other countries, while the concentrations of Cu, Cr & As in some cases were lower than other countries. According to this study, Pb was categorized as less carcinogen group and Cd, Asas a moderate carcinogen group. Therefore, the TCR values obtained for Pb were generally considered as an acceptable range ($<10^{-6}$) and moderate risk for Cd and As, suggesting that there was little concern about carcinogenic risk for study area consumers by ingestion heavy metals contained in egg. The concentration of Cr in the farm hen egg is higher than local hen egg. This result implied that the food sources could be regarded as the most significant pathway to additional intake of these heavy metals from commercial farm hen eggs. The relevant authority of Bangladesh has not set specific standard regarding heavy metal. Specification standard about heavy metal extraction from food chain is needed. It is even more ominous that advanced study is needed about the impact of heavy metal in human health that is containing trough poultry feed.

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