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Assessment of Ecotoxicological Fate of Lead Pollution in Environment through Investigating Bio-concentration in Agro-based Products in Bangladesh

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Abstract: Leaded gasoline has long been used as fuel for motor vehicles though the problem of lead pollution in Dhaka was identified only in 1980. Use of leaded gasoline has declined by most part though phasing out of leaded gasoline does not mean phase out of lead from the environment. Hence, fate of lead in polluted environment from various sources should get high priority in R & D programmes. The worst fate of lead in environment can be its entrance into food chain. To investigate bio-concentration of lead in agro-based products as an approach of assessing its ecotoxicological fate, commercially produced chicken eggs and liquid milks were selected as layer poultry feed and liquid milk production are directly dependent on feed crop production. Twelve eggs were sampled randomly each from Dhaka and its nearby seven districts covering the central region of Bangladesh. Thirteen kinds of liquid milks commercially produced by six prominent milk producers have been sampled with three replicates in each. Out of the 192 samples from 96 eggs, dry weight basis mean lead concentration was found to be 8.1611 ppm with a sample standard deviation of 0.5253, which is about 80 times higher than the maximum permissible limit, while the maximum detected value was found to be 34.5637 ppm. The mean concentration of lead in milks was found to be 1.5081 ppm with a sample standard deviation of 0.2177, which is some 75 times higher than maximum permissible limit in liquid milk. By consuming a single egg and 250 mL of commercially produced liquid milk in a day, a person is exposed to daily dietary exposure of some 99.9722 μg and 377.025 μg of lead, respectively excluding the other foods consumed.

Key words: Lead pollution, lead bioconcentration, chemical food safety, public health.

Introduction

In Bangladesh, leaded gasoline has long been used as fuel for motor vehicles. The problem of Pb pollution in the capital city, Dhaka, Bangladesh, was identified in 1980 (Khan et al., 1980) when a survey of trace elements in the whole blood of the adult population of Dhaka showed an average Pb level of 55 ± 18 μg/dL in a selected group of 100 adults. The high level of blood lead could not be understood until 1991, when high levels of Pb

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was found in 24 samples of total suspended particles in air (Khaliquzzaman et al., 1992). In Dhaka, Bangladesh, one of the highest air lead levels in the world was recorded in 1997, which was 463 ng/m^3 in low rainfall months, with the average value of 312 ng/m^3 (Khaliquzzaman et al., 1997). The yearly average Pb concentration reached a maximum value of 370 ng/m^3 in the particulate matter with an aerodynamic diameter <2.5 µm fraction in 1998. In 2000, the concentration decreased to approximately one-third (106 ng/m^3) of the high earlier values after the introduction of unleaded gasoline in 1999 (Biswas et al., 2003).

Bangladesh Petroleum Corporation is the sole agency concerned with the production and marketing of petroleum products in Bangladesh, and it has been working to phase out Pb over a period of time. In the 1980s, the Pb content was 0.8 g/L, and it was reduced to an average of 0.4 g/L by 1997. In 1998, low-octane (regular) gasoline was made Pb-free but the high-octane (premium) gasoline still contained 0.4 g/L of Pb. In early 1999, it was decided by the Energy Ministry to make gasoline Pb-free in Bangladesh which was coupled with some measurements showing that the gasoline dispensed at the pumps contained only a residual amount of Pb, less than 0.013 g/L (Akhter, 2000). So, from 1999 lead was phased out.

But the emission into atmosphere must have the residual effects in environment. Some studies in 2001 showed that in a survey of total of 779 school students aged 4-12, the mean blood lead level was 15.0 µg/dL (range 4.2–63.1 µg/dL). Almost 90% of the children had BPb levels ≥10 µg/dL; 50% had BPb levels ≥15 µg/dL; and about 20% had had BPb levels ≥20 µg/dL (Kaiser et al., 2001). An elevated blood lead level is defined as ≥10 µg/dL according to the guidelines of the Centers for Disease Control and Prevention (CDC, 1991).

Moreover, there are some other sources of lead pollution in environment such as paints and Pb-based battery industries. The worst fate of lead in environment can be its entrance into food chain which will directly interfere with public health through cycling for very long time. To investigate bio-concentration of lead in agro-based products as an approach of assessing its ecotoxicological fate, commercially produced chicken eggs and liquid milks were selected as layer poultry feed and liquid milk production are directly dependent on feed crop production.

Materials and Methods

Sampling

The study area constituted eight districts including capital Dhaka and covered the central portion of Bangladesh. Dhaka, Narsingdi, Kishoreganj, Mymensingh, Tangail, Gazipur, Narayanganj and Munshigonj were selected for the study. Commercially produced poultry eggs were randomly sampled from each district's egg stock market. Twelve eggs were sampled from each district. In Dhaka, Gazipur and Tangail's egg stock market both brown and white coloured eggs were found. Six eggs from each type were sampled from these three districts. In the rest five districts only brown coloured eggs could be found. The sampling area is shown in gray colour in Figure 1.

Commercially produced liquid milks were randomly purchased from local markets with three replicates in each. A total of 13 kinds of milks were sampled which covered liquid white, mango, chocolate and banana milks. The sample class IDs for different commercial brands taken are: AR – white, chocolate and mango; MV – white and chocolate; RD – white, mango and banana; AM – white, chocolate and mango; PR – white; and SP – chocolate milk.

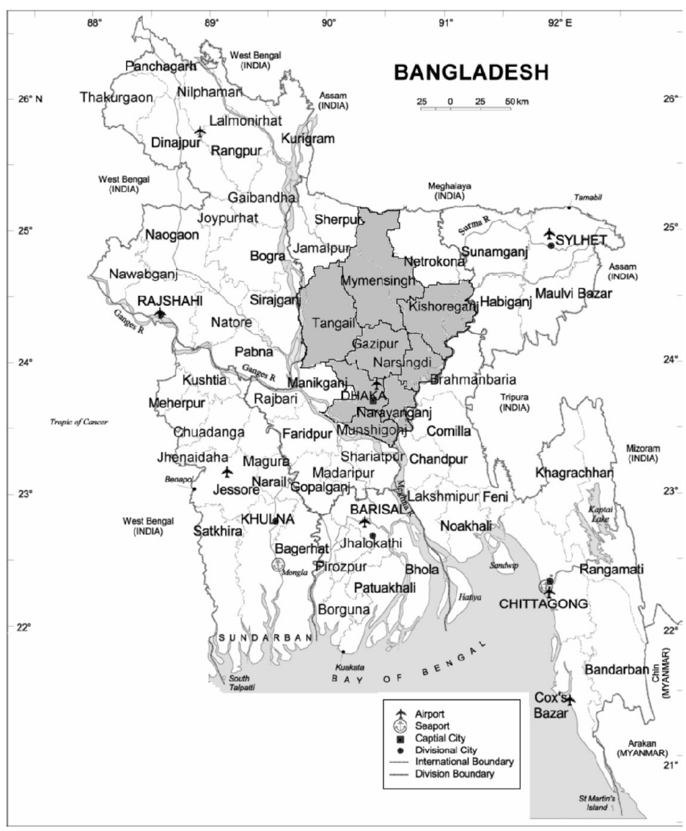

Figure 1: Map of Bangladesh representing the study area.

Egg Sample Classes and Identification

As per Table 1, samples were classified and identified.

Sample Pretreatment

The egg samples were boiled in deionized water and after complete boiling albumen and yolk were separately oven-dried at 80^{o}C to remove all moisture. The samples were oven-dried unless the difference between two readings of weight was found negligible. Each of oven-dried albumen and yolk were treated and analyzed separately. Milk samples were treated and analyzed as it is.

Sample Preparation Method

The samples were prepared by using HNO_3-$HClO_4$ digestion (Kebbekus & Mitra, 1998). Since the samples were of organic origin with a very high organic content, 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.

Sample Analysis

Analysis of all prepared samples was performed using atomic absorption spectrophotometry (AAS). BDH standard was used to prepare calibration curve. Lead determination was measured by air-acetylene flame AAS.

Results and Discussion

Regional Bio-concentration of Lead in Eggs

Some average physical parameters were estimated from all egg samples so that the regional bio-concentration of lead can be determined in a comparative way (Table 2).

Calculation of regional lead bio-concentration in eggs is shown in Table 3 (average dry weight basis).

Maximum permissible limit in chicken meat is 0.1 µg/g and in chicken fat is 0.1 µg/g, from which the average value is some 80 times higher (FAO/WHO, 2008). The average statistics for all egg samples, irrespective of albumen and yolk separately counted are presented in Table 4.

In the table, mean content of lead in each egg (albumen + yolk) has been shown to simulate the daily dietary exposure of a person consuming a single egg in a day, excluding the other foods consumed.

The comparison between albumen and yolk for their likelihood to contain lead is shown in Figure 2. From Figure 2, it is evident that egg albumen has some likelihood to contain lead, whereas its concentration greatly varied in yolk.

Table 1: Identification of collected sample classes

Sampling districts	*ID for brown coloured egg samples*	*ID for white coloured egg samples*
Dhaka	Dhaka – Brown	Dhaka – White
Narsingdi	Narsingdi – Brown	-
Kishoreganj	Kishoreganj – Brown	-
Mymensingh	Mymensingh – Brown	-
Tangail	Tangail – Brown	Tangail – White
Gazipur	Gazipur – Brown	Gazipur – White
Narayanganj	Narayanganj – Brown	-
Munshigonj	Munshigonj – Brown	-

Table 2: Average physical parameters of eggs for comparative regional bio-concentration

Physical parameter	*Average values*	*Std. error*
Whole weight of eggs, g	55.5098	0.7590
Shell : albumen : yolk ratio	1 : 4.8672 : 1.9775	NA*
Albumen raw weight, g	34.4401	-
Albumen moisture content, %	84.0603	0.1512
Albumen dry weight, g	5.4900	-
Yolk raw weight, g	13.9930	-
Yolk moisture content, %	51.3656	0.1616
Yolk dry weight, g	6.8054	-

* = Not applicable

Table 3: Calculation of regional lead bio-concentration in eggs

Sample class	*Sample size and Standard error*	*Pb in egg albumen, µg/g (dry weight)*	*Pb in total egg albumen, µg*	*Pb in egg yolk, µg/g (dry weight)*	*Pb in total egg yolk, µg*	*Total Pb in each egg (albumen + yolk), µg*	*Concentration in total edible egg (albumen + yolk), µg/g*
Brown Egg	6	5.5905	30.6918	18.3190	124.6680	155.3599	12.6356
(Dhaka)	Std. Error	1.1043	-	4.2439	-	-	-
White Egg	6	11.1847	61.4041	6.4769	44.0777	105.4818	8.5790
(Dhaka)	Std. Error	1.7396	-	2.1627	-	-	-
Brown Egg	12	10.4818	57.5453	15.0153	102.1849	159.7302	12.9911
(Narsingdi)	Std. Error	2.3770	-	3.1458	-	-	-
Brown Egg	12	9.4945	52.1248	10.6030	72.1574	124.2822	10.1080
(Kishoreganj)	Std. Error	0.5917	-	0.7616	-	-	-
Brown Egg	12	9.4769	52.0279	5.7009	38.7969	90.8248	7.3869
(Mymensingh)	Std. Error	1.1593	-	0.6024	-	-	-
Brown Egg	6	11.0565	60.7000	5.4060	36.7898	97.4898	7.9290
(Tangail)	Std. Error	4.4361	-	1.8938	-	-	-
White Egg	6	11.3587	62.3594	0.7730	5.2602	67.6197	5.4996
(Tangail)	Std. Error	2.4524	-	0.4713	-	-	-
Brown Egg	6	6.8734	37.7349	1.6755	11.4023	49.1372	3.9964
(Gazipur)	Std. Error	2.0868	-	0.6178	-	-	-
White Egg	6	5.9167	32.4825	2.2874	15.5666	48.0491	3.9079
(Gazipur)	Std. Error	2.1738	-	1.2855	-	-	-
Brown Egg	12	0.7702	4.2285	5.4222	36.9002	41.1288	3.3451
(Narayanganj)	Std. Error	0.4071	-	1.9852	-	-	-
Brown Egg	12	11.3360	62.2346	8.8177	60.0079	122.2426	9.9421
(Munshigonj)	Std. Error	2.3649	-	2.7654	-	-	-

Table 4: Statistics of all egg samples

Total sample number	192
Mean	8.1611 ppm
Std. Error of Mean	0.5253
Minimum	ND*
Maximum	34.5637 ppm
Mean Pb in each egg (albumen + yolk)	99.9722 µg

* = Not detected

Table 5: Heavy metal concentrations in sample classes

Sample classes	*Average density, g/mL*	*Mean Pb conc., µg/mL (ppm)*	*Std. error*
AR - white	1.0207	0.8102	0.2451
AR - chocolate	1.0511	1.5344	0.2675
AR - mango	1.0554	0.9447	0.3961
MV - white	1.0226	0.9739	0.3212
MV - chocolate	1.0548	1.2925	0.6512
RD - white	1.0193*	1.9657	0.1987
RD - mango	1.0523	1.6984	0.4812
RD - banana	1.0552	1.2090	0.5012
AM - white	1.0257	1.4943	0.1246
AM - chocolate	1.0577	0.8181	0.1789
AM - mango	1.0619**	0.8163	0.8542
PR - white	1.0256	1.2886	1.0079
Sp - chocolate	1.0508	4.7589	1.4347

*ND = Not Detected, * = Minimum density, ** = Maximum density

Table 6: Mean heavy metal concentrations for all milk samples

Lead (Pb)	*Mean for all milk samples*	*Std. error*	*Content in 250 mL milk volume*
	1.5081 ppm	0.2177	377.025 µg

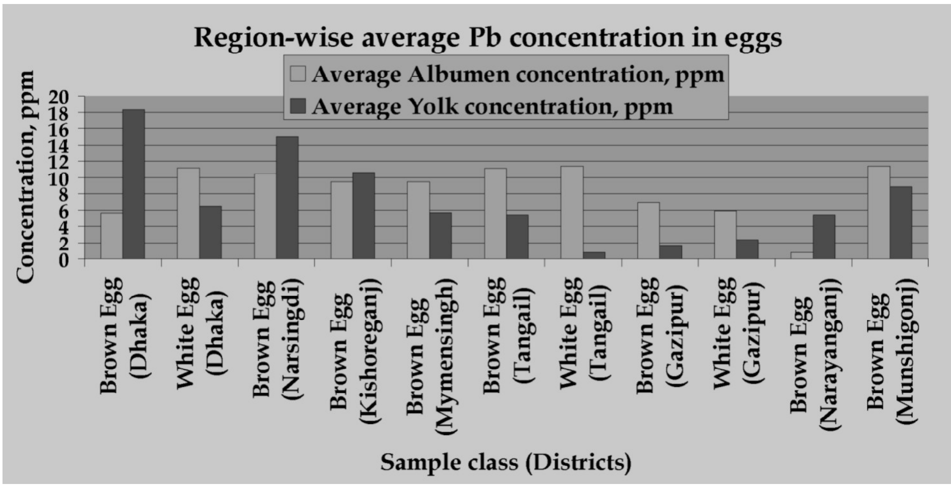

Figure 2: Comparative lead concentration in egg albumen and yolk.

Lead Concentration in Commercially Produced Liquid Milks

The concentration of lead in the milk sample classes are presented in Table 5 along with standard errors for each mean value. The concentrations were found within the range of 0.8102 ppm to 4.7589 ppm. From the data it is evident that concentrations have widely varied.

Lead concentration for all milk samples irrespective of the milk types are presented in Table 6. In the table, mean content of Lead for a 250 mL milk volume has been shown to simulate the daily dietary exposure of a person consuming the same volume of milk in a day, excluding the other foods consumed.

The maximum permissible limit of lead in milks is 0.02 ppm, from which the average value is some 75 times higher (FAO/WHO, 2008). The possible reason may be the bioaccumulation of lead in grasses through deposition on soil from extensive auto-exhaust emission as well as through cycling into food chain.

Conclusion

With a maximum concentration of 34.5637 ppm, the dry weight basis mean lead concentration in eggs was found to be 8.1611 ppm, which is about 80 times higher than the maximum permissible limit. The mean concentration in commercially produced liquid milks was found to be 1.5081 ppm, which is also some 75 times higher than maximum permissible limit in liquid milk. By consuming a single egg and 250 mL of commercially produced liquid milk in a day, a person is exposed to daily dietary exposure of some 99.9722 µg and 377.025 µg of lead, respectively excluding the other foods consumed. So it can be concluded that extensive previous lead pollution in Bangladesh is having its fate in environment through deposition on soil and entrance into food chain. This consequence can be more devastating with long lasting effects than its pollution in air.

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