URBAN DIETARY HEAVY METAL INTAKE FROM PROTEIN FOODS AND VEGETABLES IN DAR ES SALAAM

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ABSTRACT

Contamination of food and food products by heavy metals has made dietary intake as one of the major routes of these harmful elements to human beings. The human dietary intake of heavy metals cadmium, copper, lead and zinc from protein-foods (beans, meat, fish, milk) and green vegetables consumed daily from restaurants and street food-vendor kiosks in Dar es Salaam were determined using the Total Diet Study (TDS) method. The cooked food was bought from the restaurants and street food-vendors at several city locations (i.e. Buguruni, Manzese, Mwenge, Temeke and Ubungo) over several months and analyzed. Heavy metal concentrations were determined by Atomic Absorption Spectrophotometry (AAS) after wet digestion of the edible portions of pooled samples of the foodstuff. The results showed significant variation in heavy metal concentration among the foodstuff and at the different locations. The results were compared to the FAO/WHO levels for Acceptable Daily Intake (ADI) and Provisional Tolerable Weekly Intake (PTWI) to estimate risk of toxicity and to the US Recommended Dietary Allowance (RDA) and/or Estimated Safe and Adequate Daily Dietary Intake (ESADDI) for a deficiency in intake. The average weekly dietary intake of cadmium and lead from protein-foods and vegetables ranged from 0.20 - 0.42 µg/kg-bw/week (i.e. 2.82 - 6.00% of PTWI) and 4.77 - 9.83 µg/kg-bw/week (i.e. 68.1 – 140.4% of PTWI) respectively. These dietary intakes were below the ADI values of 0.5 µg/kg-bw/day and 3.6 µg/kg-bw/day of the WHO for cadmium and lead respectively. The daily dietary intake of zinc and copper at all the locations were also below the ADI for these elements, the average being 21.5% for copper and 19.8% for zinc. The results show clearly that the daily urban dietary intake of copper and zinc, from protein foods and vegetables along main streets at the above locations, was acceptable.

Key Words: Heavy metal, dietary intake, protein foods, vegetables, Dar es Salaam.

INTRODUCTION

Human exposure to toxic heavy metals such as cadmium, lead, copper and zinc is known to be responsible for many human health problems. Contaminated foods are a major source of such heavy metals to man (Ward 1995). Contamination of food usually takes place during harvesting, transportation, storage, processing and preparation. Most heavy metals are non-biodegradable and their bioavailability and long biological half-life accounts for their bioaccumulation. For man, food forms the major non-occupational source of exposure to heavy metals (UNEP/FAO/WHO 1988). Although human bodies have got homeostatic mechanisms that enable them to tolerate small fluctuations in the intake of heavy metals, the intake of such metals above or below certain permissible or recommended levels have devastating acute and chronic health effects (Alloway and Ayres 1993, WHO 1974, WHO 1995, WHO 1996, WHO 1998).

Street food-vendor and restaurant foodstuff are ready-to-eat foods that are prepared and/or sold along streets and other public places. Such food places can be found clustering around many places of work, schools, hospitals, railway stations and bus terminals (FAO 1997) and they usually serve breakfast and lunch packages. In the mornings, in Dar es Salaam, a cup of tea or coffee is usually taken with either chapatti, slices of bread or buns as a breakfast. The common lunch menu for these restaurants and street food-vendor places, in Dar es Salaam, is rice with curry and stew, Ugali (stiff maize porridge) with meat, fish relishes or beans, fried potatoes and cassava with beans and some mixed grills and stew (Ndosi 1995). Although such food places plays an important social role, the unlimited and unregulated growth in food preparation places has brought about concerns regarding the health and safeness of such food (Ndosi 1995).

In Dar es Salaam, pasture grass grown alongside roads (Luilo and Othman 2003) and green vegetables (Bahemuka and Mubofu 1999) have been found to contain heavy metals at concentration levels higher than recommended by FAO/WHO for foods. Food contamination monitoring is, therefore, important as it provides information on the levels of environmental contaminants in food thus ensuring the safety of food and other agricultural products. Total Diet Studies (TDS) are one of the most cost-effective methods for assuring people that they are not exposed to unsafe levels of toxic chemicals through food (WHO 2006).

The objective of this study was to determine the content of the heavy metals cadmium, copper lead and zinc, in commonly consumed protein-foods and vegetables from restaurants and street food-vendors along major streets in urban Dar es Salaam and to calculate the total dietary intake of these heavy metals by the population.

MATERIALS AND METHODS

The Study Area: Food samples were collected from restaurants and street food-vendor kiosks at five locations in Dar es Salaam i.e. Buguruni, Manzese, Mwenge, Temeke and Ubungo.

Methods: The Total Diet Study method (TDS) (WHO 1985, Pennington 2000) was used. The foods studied included milk, cooked beans, fish, meat and green vegetables. The amount of foodstuff consumed per person and the consumption pattern was determined using the Food Frequency Check list (WHO 1985). Sample collection was done on weekly basis within the period of February to August 2001. The foodstuff amount equal to a one day-meal for a person per day (i.e. 2.65 kg on average) was collected at each site during each sampling session. Edible portion of the food samples were homogenized, stored in pre-cleaned polythene containers and deep frozen. Three individual samples from a site were combined to form a pooled sample which was homogenized and analyzed for the four heavy metals.

A Perkin Elmer, model AAnalyst 300, Atomic Absorption Spectrometer (AAS) (Perkin Elmer 1994) was used for the determination of concentration of heavy metal in the food samples. After weighing triplicate slurry samples of 5 g each, the samples were digested as per Srikumar and Ockerman (1990). Copper was determined directly using the prepared solution. For zinc determination the diluted (1:10, deionized water) prepared solution was used. Lead and cadmium were determined after a preconcentration of 50 cm^3 of the prepared sample solution to a 5 cm^3 solution was made (Roschinic 1973). All the glassware used were pre-cleaned using high purity nitric acid (Tahvonen and Kumplainen 1996) and rinsed with deionized distilled water before use. For analysis of each element the appropriate parameters for AAS (Perkin Elmer 1994) were followed.

The total concentration of cadmium, copper, lead, and zinc in each food sample was recorded and tabulated as shown in Tables 2 -5 below. Where the concentration of a particular element was below the detection limit, the detection limit value of the element was taken as its maximum concentration. In this study the body weight of an average adult person was taken to be 65 kg i.e. between 60 and 70 kg as per WHO (1985). The values calculated were compared to the tolerable/acceptable levels recommended by FAO/WHO (CAC 1984, WHO 1993).

RESULTS AND DISCUSSION

The amounts of foodstuff most commonly consumed by the population at each location and the average frequencies of consumption in a week are summarized in Table 1. The quantities of food consumed per person per day were quite similar to the quantities earlier reported by Lukmanji and Tanner (1985).

Table 1: Foodstuffs consumed in Dar es Salaam per person in a week

Foodstuff	Frequency (times/week)	Amount (g) per meal (range)	Average amount (g) per meal
Beans	8	170-215	185 ± 25
Green vegetables	14	50-60	55 ± 5
Fish	3	60-100	80 ± 15
Meat	3	110-120	115 ± 10
Milk	2	220-260 cm^3	250 ± 20 cm^3
Water	7	400-800 cm^3	500 ± 190 cm^3

The results of the dietary intake studies of the individual heavy metals per week and/or per day at the different sites are presented in the Tables 2 to 5. The content of heavy metals studied varied considerably amongst the foodstuffs, locations and even between restaurants and street food-vendors within the same location.

Cadmium intake ranged from 0.20 µg/kg-bw/week to 0.42 µg/kg-bw/week i.e. 2.82% to 6.00% of the Provisional Tolerable Weekly Intake (PTWI) (Table 2). The values measured by this study were much lower than the values found for such food by Schumacher et al. (1991) for Taragona province, Spain (86.63% of PTWI) and by Moreiras et al. (1996) i.e. 25 - 45% of PTWI for Madrid, Spain and lower than those by Brüggemann et al. (1996) for Germany (45% of PTWI). The dietary intake of cadmium from protein-foods and vegetables was below the PTWI of 7 µg/kg-bw/week at all locations.

Cooked beans stew was the main contributor of cadmium dietary intake at Buguruni and Temeke while boiled green vegetables were the main contributors at Mwenge, Ubungo and Manzese (Table 2). The average dietary intake of cadmium from green vegetables was 11.80 µg/week while that from beans was 6.96 µg/week. Green vegetables sold in Dar-es-Salaam have been previously shown to be contaminated with heavy metals (Othman 2001). The average contribution of fish, meat and milk to the daily intake was only 2.1 µg-Cd/week (i.e. 0.47% of the PTWI). The studies by Schumacher et al. (1991) and Moreiras et al. (1996) have also shown that protein-foods were the main contributors to cadmium dietary intake in Spain.

Table 2:Cadmium amounts (µg) found in protein-foods and vegetables contributing to the dietary intake of cadmium and as percentage of PTWI*

Foodstuff	Locations									
	Buguruni		Mwenge		Manzese		Ubungo		Temeke	
	FV	RES	FV	RES	FV	RES	FV	RES	FV	RES
Beans	19.56	18.25	0.74	0.72	0.76	0.73	0.78	0.71	12.33	15.05
Green vegetables	5.36	6.29	11.55	13.22	17.84	21.69	20.02	12.45	6.03	3.59
Fish	1.91	1.97	0.12	0.11	0.15	0.10	2.60	3.16	2.56	2.20
Meat	0.17	0.20	0.18	0.17	0.22	0.15	0.18	0.19	2.01	0.17
Milk	0.28	0.22	0.25	0.25	0.29	0.28	0.21	0.22	0.25	0.23
Total Intake µg per week	27.28	26.93	12.84	14.47	19.26	22.95	23.79	16.73	23.18	21.24
Intake µg/kg-‡bw/week	0.42	0.41	0.20	0.22	0.30	0.35	0.37	0.26	0.36	0.33
Intake µg/kg-bw/day	0.06	0.06	0.03	0.03	0.04	0.05	0.05	0.04	0.05	0.05
%age PTWI	6.00	5.92	2.82	3.18	4.23	5.04	5.23	3.68	5.09	4.67

*PTWI = FAO/WHO Provisional Tolerable Weekly Intake = 7 µg/kg body weight/week
‡bw = body weight taken as 65 ± 5 kg
FV = street food-vendors
RES = restaurants

When the dietary intake of cadmium from food from restaurants was compared to that of food from street-food vendors it was found that the cadmium levels from food vendors at Mwenge were almost half that of Buguruni (2.82% and 6.00% of PTWI respectively). The other locations had dietary intake values closer to that of Buguruni i.e. 4.23% for Manzese, 5.23% for Ubungo and 5.09% for Temeke. We strongly believe that the higher intake values for beans at Temeke and Buguruni may have been caused by the contamination of the beans during the preparation process. Food handling at these study locations was less hygienic as the food was being prepared in open spaces close to the roads and garages.

Copper dietary intake studies showed differences in amounts amongst the foodstuffs and locations (Table 3). The dietary intakes ranged from 0.09 mg/kg-bw/day (18.3% of the Acceptable Daily Intake (ADI)) to 0.15 mg/kg-bw/day (29.2% of ADI). These dietary copper intakes were higher than the copper intake values for other countries as reported by van-Dokkum et al. (1989) who reported a 0.02 mg/kg-bw/day (4.15% of ADI) for Holland and Moreiras et al. (1996) who reported a 26% of ADI for Madrid, Spain. The Estimated Safe and Adequate Daily Dietary Intake (ESADDI) of 1.5 - 3 mg/day (NRC 1989) was reached at all the study locations in Dar es Salaam with an average ESADDI of 233 percent. The copper dietary intake at all the studied locations was below the recommended ADI, the average being 21.5% of ADI.

Table 3: per amounts (mg) in protein-foods and vegetables contributing to the dietary intake of copper and as percentage of ADI† and ESADDI°

Foodstuff	Locations									
	Buguruni		Mwenge		Manzese		Ubungo		Temeke	
	FV	RES	FV	RES	FV	RES	FV	RES	FV	RES
Beans	5.77	7.20	40.37	33.03	31.54	18.31	8.10	8.57	8.22	6.44
Green vegetables	30.92	24.29	9.18	16.88	24.59	16.45	23.51	20.77	25.76	24.30
Fish	5.00	5.17	0.30	2.70	4.87	5.80	5.90	5.36	8.34	4.99
Meat	4.52	4.19	4.11	4.11	4.03	6.82	7.03	6.78	3.85	3.85
Milk	0.64	0.64	0.26	0.26	0.31	0.67	0.40	0.40	0.67	0.67
Total Intake mg per week	46.86	41.58	54.22	56.98	66.34	48.05	44.94	41.88	46.84	40.25
Intake mg per day	6.69	5.94	7.75	8.14	9.50	6.86	6.42	5.98	6.69	5.75
Intake mg/kg-‡bw/day	0.10	0.09	0.12	0.12	0.15	0.10	0.10	0.09	0.10	0.09
%age ADI	20.6	18.3	23.8	25.0	29.2	21.1	19.7	18.4	20.6	17.7
%age ESADDI	87.7	198.0	258.3	271.3	316.7	222.7	214.0	199.3	223.0	191.7

†ADI (Acceptable Daily Intake) = 0.5 mg/kg body weight/day
°ESADDI (Estimated Safe and Adequate Daily Dietary Intake) = 1.5-3 mg/day
‡bw = body weight taken as 65 ± 5 kg
FV = street food-vendors
RES = restaurants

The trend in foods that contributed to the dietary copper intake were green vegetables > beans > meat > fish > milk. Green vegetables and cooked beans were the main foods contributing to dietary intake of copper at 34.4% of total dietary intake for beans and 44.5% for green vegetables. This may be due to the higher amounts and higher frequency of consumption of these foods as they are consumed almost every day of the week. In Germany the study by Brüggemann *et al.* (1996) showed that the main food groups contributing to copper intake were cereals (10 - 20% of total dietary intake). In Spain Moreiras et al. (1996) reported that cereals, vegetables and meat were the main contributors to copper intake while van-Dokkum *et al.* (1989) reported that bread, potatoes and beverages were the main dietary copper contributors in Holland. In general, the dietary intake of copper from protein-foods and vegetables consumed at the studied locations was within safe limits.

Lead dietary intake data from protein foods and vegetables eaten in Dar es Salaam is presented in Table 4. The weekly dietary intake of lead ranged between 4.77 and 9.83 µg/kg-bw/week. Most of locations except for Buguruni and Temeke showed lower dietary intake values than the PTWI value of 7 µg/kg-bw/week. The higher intake values found for Buguruni and Temeke may be due to contamination from various sources. Food preparations at these locations, especially by street food-vendors, were done very close to the roads where dust and car exhaust gas might have easily contaminated the water and/or the raw food directly during preparation. At both locations, lead amounts in foods prepared by street food-vendors were higher than those from restaurants.

Table 4: Lead amounts (µg) in protein-foods and vegetables contributing to the daily dietary intake of lead and as percentage of PTWI*

Foodstuff	Locations									
	Buguruni		Mwenge		Manzese		Ubungo		Temeke	
	FV	RES	FV	RES	FV	RES	FV	RES	FV	RES
Beans	206	170	44	44	46	49	45	44	163	179
Green vegetables	247	242	293	229	308	319	246	210	298	254
Fish	101	89	7	7	63	53	69	71	101	98
Meat	70	78	10	15	12	13	18	10	39	14
Milk	15	16	13	15	19	17	15	15	18	17
Total Intake µg per week	639	595	367	310	448	451	383	350	619	562
Intake µg /kg-‡bw/week	9.83	9.15	5.65	4.77	6.89	6.94	5.89	5.38	9.52	8.65
Intake µg/kg-bw/day	1.40	1.30	0.81	0.68	0.98	0.99	0.84	0.77	1.36	1.23
%age PTWI	140.4	130.8	80.7	68.1	98.5	99.1	84.2	76.9	136.0	123.5

*PTWI = FAO/WHO Provisional Tolerable Weekly Intake = 7 µg/kg body weight/week
‡bw = body weight taken as 65 ± 5 kg
FV = street food-vendors
RES = restaurants

The measured dietary intake values for lead were lower than those reported by Moreiras *et al.* (1996) for Spain. The main contributors to dietary lead intake in Dar es Salaam were beans (44 to 206 µg/week), green vegetables (210-319 µg/week) and fish (7-101 µg/week). On average Buguruni and Temeke were giving higher lead dietary intake (562 to 639 µg/week) than the other locations. In the study by Brüggemann *et al.* (1996) and that by Moreiras *et al.* (1996) cereal foods were found to be the main contributor to the dietary intake of lead. The study by Schumacher *et al.* (1991) in Spain also showed that bread and cereals contributed highly to the total daily intake of lead.

Results of dietary zinc intake are presented in Table 5. The recommended ADI for zinc i.e. 1 mg/kg-bw/day (WHO 1982) was not reached at all locations. The RDA of 12-15 mg/day was only reached for restaurant food at Buguruni and Manzese and food-vendors at Mwenge. The dietary intake values for zinc ranged from about 0.08 mg/kg-bw/day or 5.48 mg/day (i.e. 8.43% of the ADI) to 0.29 mg/kg-bw/day or 19.03 mg/day (i.e. 29.3% of the ADI). At all the locations studied, the dietary intake of zinc was less than the ADI, the average being 19.8% of ADI. The values obtained were similar to the values of 10.31 to 11.4 mg/day reported for Egypt by Hussein and Brauggeman (1997); 6.8 to 15 mg/day reported for Sweden by Jorhem et al. (1998) and 14.9 mg/day reported for Galicia, Spain by Moreiras et al. (1996).

The main food contributors of zinc dietary intake found by this study were cooked beans (21.03 to 75.18 mg/week), green vegetables (9.61 to 48.30 mg/week) i.e. 52.3% and 33.8% of the total dietary intake respectively. Brüggemann *et al.* (1996) had reported that bread was the main contributor to dietary intake of zinc in Germany while Schumacher et al. (1991) and Moreiras et al. (1996) have reported meat and dairy products were the main contributors in Spain.

Table 5: Zinc amounts (mg) in protein-foods and vegetables contributing to the human dietary heavy metal intake and as percentage of ADI† and RDA#

Foodstuff	Locations									
	Buguruni		Mwenge		Manzese		Ubungo		Temeke	
	FV	RES	FV	RES	FV	RES	FV	RES	FV	RES
Beans	43.77	66.11	75.18	47.26	45.09	55.94	42.43	21.03	23.48	51.31
Green vegetables	35.68	34.21	45.20	32.93	25.20	48.30	20.01	9.61	21.79	32.06
Fish	5.41	5.95	2.22	2.17	7.13	5.21	7.44	3.14	5.55	5.96
Meat	7.82	8.14	10.47	10.81	5.60	5.99	5.09	4.30	7.33	7.67
Milk	0.06	0.07	0.16	0.16	0.16	0.21	0.49	0.25	0.11	0.07
Total Intake mg per week	92.74	114.48	133.23	93.33	83.18	115.65	75.46	38.33	58.26	97.07
Intake mg per day	13.25	16.35	19.03	13.33	11.88	16.52	10.78	5.48	8.32	13.87
Intake mg/kg-‡bw/day	0.20	0.25	0.29	0.21	0.18	0.25	0.17	0.08	0.13	0.21
%age ADI	20.38	25.15	29.35	20.51	18.28	25.41	16.58	8.43	12.8	21.34
%age RDA	88.3	109.0	126.9	88.9	79.2	110.1	71.9	36.5	55.5	92.5

†ADI = Acceptable Daily Intake = 1 mg/kg body weight/day
#RDA = 12-15 mg/day
‡bw = body weight taken as 65 ± 5 kg
RES = restaurants
FV = street food-vendors

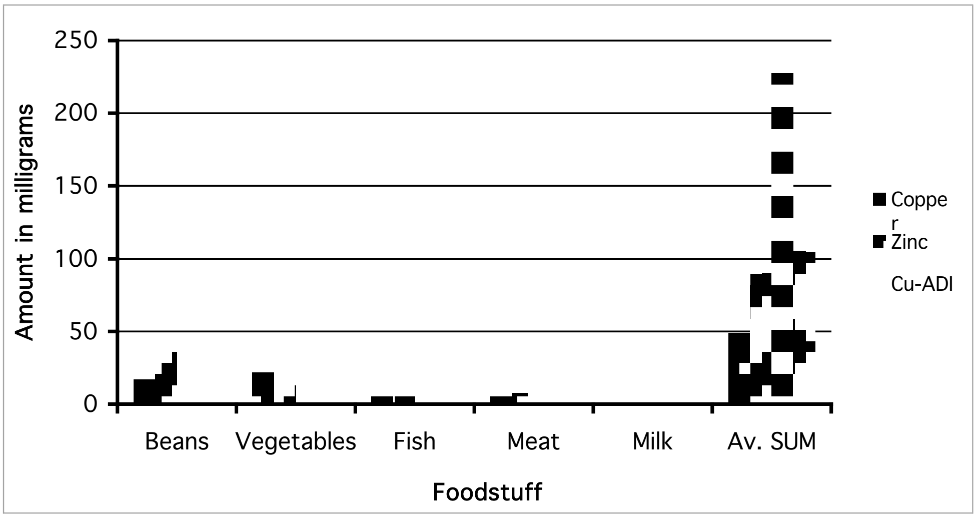

Figure 1: Average weekly dietary intake of copper and zinc in milligrams per week

The average total zinc dietary intake value of 90.17 mg/week for Dar es Salaam (Figure 1), as obtained by this study was below the RDA, signaling a possibility of zinc deficiency for the population as far as protein-foods and green vegetable sources are concerned. The average total dietary intake of copper and zinc from the different protein-foods and green vegetables are shown in Figure 1. Green vegetables and cooked beans contributed 78.9% of the total dietary intake of copper and 86.1% of the total dietary intake of zinc. Fish and meat contributed 20.1% of the total dietary intake of copper and 13.7% of the total dietary intake of zinc. Milk gave the lowest contribution to the total dietary intake of both copper and zinc at 1.01% and 0.20% respectively.

The average total dietary intake of cadmium and lead from the different protein-foods and green vegetables are shown in Figure 2. Green vegetables and cooked beans contributed 76.7% of the total dietary intake of lead and 89.9% of the total dietary intake of cadmium. Fish and meat contributed 19.7% of the total dietary intake of lead and 8.9% of the total dietary intake of cadmium. Milk gave the lowest contribution to the total dietary intake of both lead and cadmium at 3.38% and 1.20% respectively.

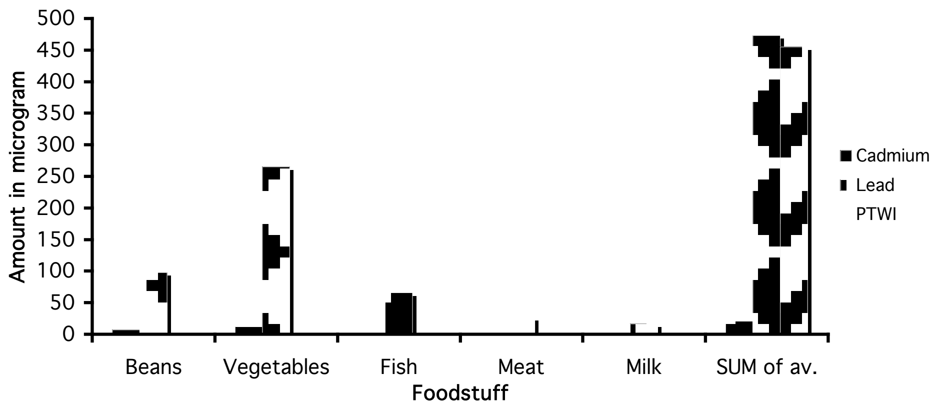

Figure 2: Average weekly dietary intake of cadmium and lead in micrograms per week

CONCLUSION

The study has shown that there were variations in concentration of heavy metals in prepared protein-foods and green vegetables among the study locations in Dar es Salaam. Such variations could be due to, among other causes, secondary contamination. The food consumption patterns were found to be the determining factor for the amount of heavy metals taken in via foods. The dietary intake of cadmium was lower than the PTWI recommended by FAO/WHO at all locations while dietary intake of lead exceeded the PTWI value at some of the locations (Buguruni and Temeke) thus showing that protein-foods and vegetables were unsafe as far as lead dietary intake was concerned. The dietary intake of copper at almost all locations exceeded the ESADDI even though the values were lower than the ADI. The dietary intake of zinc was also lower than the ADI at all locations but showed higher RDA percentages at Buguruni and Manzese for restaurant foods and for street food-vendor meals at Mwenge.

RECOMMENDATIONS

To ensure adequate and safe intake of mineral elements and minimal intake of heavy metals and other chemical contaminants from the foods urban people eat, the authors suggest the following:

i) Public education on general sources, exposure routes and health impacts of heavy metals and other chemicals.

ii) Establishment and strengthening of monitoring programmes on environmental and health risk assessment of chemicals and pharmaceuticals.

iii) Control of discharge of heavy metals and other toxic chemicals to the environment.

iv) Establishment of a Food Preparation Practice and Selling-Environment legislation and enforcement of the same.

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