MONITORING AND ECOTOXICOLOGICAL ESTIMATION OF MERCURY POLLUTION LEVELS OF HUMAN AND AQUATIC ECOSYSTEMS COMPONENTS IN THE REPUBLIC OF UZBEKISTAN

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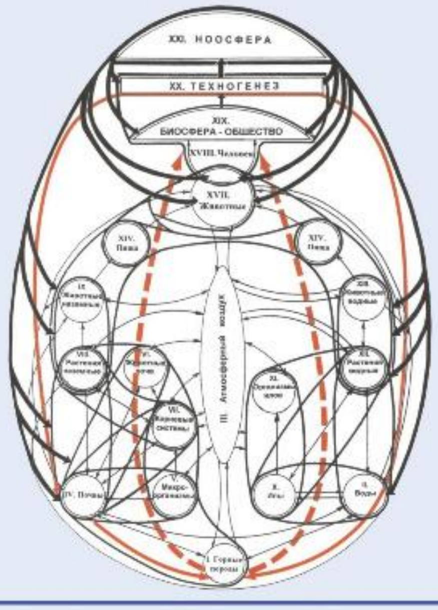
ПРОБЛЕМЫ БИОГЕОХИМИИ И ГЕОХИМИЧЕСКОЙ ЭКОЛОГИИ

THE PROBLEMS OF BIOGEOCHEMISTRY AND GEOCHEMICAL ECOLOGY



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MONITORING AND ECOTOXICOLOGICAL ESTIMATION OF MERCURY POLLUTION LEVELS OF HUMAN AND AQUATIC ECOSYSTEMS COMPONENTS IN THE REPUBLIC OF UZBEKISTAN

Mercury levels in bottom sediments varied between 4.0 and 26.4 μg/kg, with somewhat higher levels in Arnasay lakes (9.6–26.4) than in the lower reach of Amudarya river (4.0–21 μg/kg). Levels of mercury in fish varied between 28.7 and 137.7 μg/kg. Mercury content of human hair in Tashkent city varied between 42.8 and 387 (average 124) μg/kg, which was slightly lower than in Khorezm region (21.6 to 678; average 161 μg/kg). These values are much lower than the attention thresholds set by US EPA and WHO (1000 and 10000 μg/kg, respectively).

Keywords: *bottom sediments, lake, mercury, water systems.*

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Introduction

Mercury is one of the highest priority environmental pollutants of concern. Mercury is toxic, persistent, and bioaccumulates in food chains. Mercury circulates between air, water, soil and biota in various forms. Specific human subgroups such as high-end consumers of fish, groups living in industrialized areas, pregnant women, and newborns may be at risk from accumulating elevated levels of mercury threatening their health.

Air pollution can also be a significant source of exposure to mercury. In urban areas, power generation plants and emissions from cars are a growing threat to air quality. High levels of trace elements such as lead, nickel, copper, cadmium, manganese, mercury, tin, as well as antimony, selenium, and fluorine have been found in Uzbekistan's atmosphere, mainly from the burning of fossil fuels, inappropriate disposal of waste materials, and ferrous and nonferrous smelting (Ecological review of Uzbekistan, 2008). Especially high concentrations of heavy metals were reported for industrially developed Tashkent, Navoi and Fergana regions. Mercury introduced to the atmosphere can be deposited back to terrestrial and aquatic system where, especially in the latter case, can be converted to methylmercury, incorporated in the food chain, accumulated in fish and can result in high human exposure. Mercury pollution has indeed received much attention and is placed high on the political agenda in most developed countries. On the other hand, in Central Asian countries, it has been included only recently into the monitoring schemes. In 2001 the monitoring laboratories of the State Hydrometeorological

Service and Nature protection Committee of the Republic of Uzbekistan have been supplied with additional equipment to analyze additional specific toxic metals such as selenium, strontium, cobalt, antimony, mercury, etc.

Materials and methods

Fish and bottom sediment samples were collected during September-October 2009 from two largest river basins in Central Asia: the middle reach of Syrdarya River - Arnasay Lake System (ALS) which includes 3 interconnected large lakes (Eastern Arnasay, Tuzkan and Aydar and Central Golodnosteppe Collector –CGC) and the lower reach of Amudarya River where sampling points included Amudarya River itself, Main collector Ozerniy (MCO), collector Jirmizkol, andtap water from drinking water supply system of the region. Samples were also taken in upper reach of Chirchiq River near to village Botanical of Tashkent region, Uzbekistan (see figure).

The bottom sediment samples were collected in polyethylene plastic bags, transported to the laboratory in Tashkent, dried at room temperature and stored frozen without further treatment. They were then transported on ice to CNR-IRSA, UOS Brugherio, Italy by airplane and placed again into a refrigerator until further treatment.

Fish sampling was carried out in Arnasay and Tuzkan lakes (ALS) using passive gill nets (mesh size between 32 and 80 mm). Various commercial fish species were measured (total length - L and total weight) and divided by species and sex whenever possible. Two to three fishes from each sampling point were selected (table 3). Fish muscle was taken from the dorsal portion of the fish, above the lateral line between the head and the dorsal fin. The 15-30 g of tissues from 2-3 individuals of the same species and sex were pooled together. Samples were stored at −20°C and transported on ice CNR-IRSA, UOSBrugherio, Italy where they were freeze-dried. The average content of water in dried-out fish muscles was 80.5%. After then dry fish muscles were homogenized in agrinder “MM 2000 Retsch” and were kept dry until analysis.

For mercury determination in human hair, a bundle of hair was taken from the occipital region, as close as possible to the scalp, using stainless steel scissors. Hair samples were collected in polyethylene plastic bags without further treatment. For each sample we collected the following information: age; occupation; sex; living region; amount, type and frequency of fish consumed; other factors which could contribute to increase Hg body-burden (e.g., use of peculiar cosmetics, professional exposure, living in the vicinity of coal-power plants or cement factories, etc). A special questionnaire was prepared for each volunteers.

For women with long hair (> 5 cm), the longest hair was lifted and the freshly grown hair on the occipital region and close to the scalp was collected.

Mercury concentrations in all samples were determined by atomic-absorption spectrophotometer using an Automated Mercury Analyzer (AMA. 254, FKV, Bergamo) with a detection limit of0.01 ng Hg (absolute concentration). Approximately 25–50 milligrams of hair, 40–70 mg of freeze dried sediments and 40–55 mg of freeze dried fish muscle tissue in each replicates (3 replicates) were used for the determinations.

Experimental results were evaluated based on quality standards accepted in former Soviet Republics (table 1).

Table 1 – Maximum permissible concentrations (MPC) of mercury and its compounds

Chemical form of presence	In air of residential areas, mg/m^3	In air of working zone mg/m^3	In water used for potable purposes mg/L	Soil, mg/kg	Consumer products, mg/kg
Mercury	0,0003	0,005	0,0005	2,1 (total content)	0,005-0,5 (e.g. Fish-0,3)
Inorganic mercury compounds	0,0003	0,05	0,0005		
Organic mercury compounds		0,005	0,0001		Not allowed

Figure. Location of sampling points in middle reach of Syrdarya and Lower reach of Amudarya Rivers (see arrows)

Results

The range of Hg contamination in bottom sediments varied between 4,0-26,35 µg/kg; with slightly higher levels found in ALS (9,59-26,35 µg/kg) than in the lower reach of AD (4,0-20,98 µg/kg) (table 2). These values are much lower than MPC for soils – 2 100 µg/kg and below the Consensus-Based Threshold Effect Concentration of 180 µg/kg for sediments.

In investigated fish species average accumulation levels of mercury varied between 28,7-137,7 µg/kg (table 3) which was also lover than MPC (300 µg/kg).

Mercury levels in human hair from volunteers in Tashkent city varied between 42,8-387 (arithmetic mean = 124,2) µg/kg and were slightly higher in samples from Khorezm region -21,65-677,68 (161,34) µg/kg. These values are much lower than the attention thresholds set by the US EPA and WHO (1000 and 10000 µg/kg, respectively). They were also lower than levels measured for comparison in hair from volunteers working at CNR-IRSA in Brugherio: 479,43-3 417,49 (1 486,66) µg/kg (table 4).

Table 2 – Mercury concentrations in bottom sediments of water bodies in Uzbekistan

Water body	Date of sampling	Place of sampling	Hg, mg/kg (ppm) dry weight			
			Repl.1	Repl.2	Repl.3	Mean
1.CGC (Central Golodnosteppe Collector)	Sep.21.2009	Lower reach	0,018	0,020	0,019	0,019
2. Arnasay reservoir	Sep. 22, 2009	Outflow	0,010	0,010	0,009	0,010
3. Lake Aydar	Sep.22, 2009	Eastern part	0,009	0,009	0,012	0,010

Continuation of Table 2

Water body	Date of sampling	Place of sampling	Hg, mg/kg (ppm) dry weight			
			Repl. 1	Repl. 2	Repl. 3	Mean
4. Eastern Arnasay	Sep.22, 2009	Hydromet	0,024	0,023	0,024	0,023
5. Lake Tuzkan	Sep.24, 2009	Western part	0,024	0,030	0,025	0,026
6. MCO (Main collector Ozerni)	Oct.06, 2009	Fish farm	0,004	0,004	0,004	0,004
7. Amudarya River	Oct.06, 2009	Khorazm	0,004	0,005	0,003	0,004
8. Collector Jirmizkol	Oct.06, 2009	Khorazm	0,032	0,018	0,014	0,021

The comparison of mercury pollution rate of human and fish consumption levels of population will give interesting, however expected results. It is well-known that the bioaccumulation rate of mercury in human organism correlates positively with fish consumption level. Indeed, people in Tashkent city consume an average 1.0 kg of fish/year and people in Italy – about 20 kg, i.e. difference is about 20 times. In turn people in Khorezm consume 0.5 kg of fish/year. Which is twice lower than in Tashkent city.

Discussion

According to (Kuncova, 2004) in Kyrgyzstan, Tadjkistan and Russian Federation the primary production of mercury in 2000, 2002, 2003 was 594, 300 and 250 tonnes and by-production in 2003 – 100 tonnes. Mercury is a main product and by-product of mining or refining of other metals (zinc, gold, silver) in Kyrgyzstan (Maylisu, Khaydarkam) and other production plants in Tajikistan).

There are very limited data concerning pollution level of aquatic systems with mercury in Uzbekistan. According to Z. Suleymanova (2004) in water of small mountain river Shahimardonsay in Uzbekistan during 2000-2003 the concentrations of mercury 0,001-0,004 mg/L was observed in water. Much lower concentrations have been registered in the water of Zarafshan river (plain territory) in may 2001 – 0,2–0,04 μg/L. The mercury content in the environment in another former Soviet Republic of Moldova was following: water – less than 0,0001 mg/L, bottom sediments – within 0,03-3,05 mg/L (Bulimaga, 2004). Although water contamination was not assessed, these values are above the water quality standard of 50 ng/L set by the European Community for inland waters and calls for further verification in future studies.

For bottom sediments, contamination levels in the study areas were much lower than levels measured in freshwater systems in industrialized areas of Italy (Camusso et al., 2002; Vignati et al., 2008). In the case of fish, R. Schoeny (2004) summarized data for fish mercury contamination for various countries and fish species (table 5). Comparing these values with those obtained for fishes living in water bodies in plain territories of the Republic of Uzbekistan, we conclude that Hg pollution levels in are quite low. We do note however that the European Community proposes an ecological standard of 20 μg/kg total mercury in fish, so that more data are needed to evaluate the Hg risk in the investigated area.

Finally, fish consumption is usually the most common route of Hg uptake by humans. Hg levels in hair from Uzbek volunteers were low (or even extremely low) compared with those measured in Italian volunteers. People in Tashkent city and Khorezm consume an average of 1,0 kg and 0,5 of fish/year, while the corresponding figure for people in Italy is about 20 kg. The results therefore reflect the different patterns of fish consumption between the two countries. However, individuals with comparatively higher levels of Hg (i.e., volunteer number 8 from Khorezm) can be found and our very little database does not allow drawing any conclusion on the general population exposure.

Table 3 – Mercury concentrations in fish muscles from Arnasay lake system (ALS) and Khorezm fish farm of Uzbekistan

Waterbody	Date of sampling	Specimen	Sex	Body lenth, cm (L)	Weight, G	Hg, mg/kg (ppm) dry weght			
						Repl.1	Repl.2	Repl.3	Mean
1. Eastern ALS	Sep.22, 2009	Common carp -*Cyprinus carpio L.*	Juvenile and female	24 and 36	840 and 1565	0,024	0,029	0,032	0,029
2. Lake Tuzkan	Sep.24, 2009	Pike-perch -*Stizostedion lucioperca L.*	Juveniles	21, 24 and 27	300, 410 and 506	0,100	0,109	0,112	0,108
3. Lake Tuzkan	Sep.24, 2009	Aral shemaya - *Chalcalburnus chalcoides aralensis* (Berg)	Juveniles	18, 18,5 and 19	167, 171 and 180	0,117	0,143	0,154	0,138
4. Lake Tuzkan	Sep.24, 2009	Roach - *Rutilus rutilus aralensis* Berg	Unknown	15, 17 and 17,5	125, 132 and 143	0,058	0,064	0,075	0,065
5. Lake Tuzkan	Sep.24, 2009	Vostrobryushka – *Hemiculter lucidus* (Pub.)	Unknown	16, 18 and 19	96, 106 and 117	0,059	0,067	0,068	0,065
6. Fish farm Khorezm	Oct.06, 2009	Silver carp - *Hypophthalmichthus molitrix* (Valenciennes)	Unknown	40, 41 and 43	480, 520 and 600	0,065	0,073	0,071	0,070

Table 4 – Mercury concentrations in human hair in Khorezm region and Tashkent city of Uzbekistan and Brugherio city of Italy

No.	Age	Sex	Hg, mg/kg (ppm)			
			Repl.1	Repl.2	Repl.3	Mean
Uzbekistan, Tashkent City						
1.	34	F	0,440	0,365	0,356	0,387
2.	14	M	0,063	0,044	0,046	0,051
3.	34	F	0,055	0,064	0,067	0,062
4.	31	F	0,044	0,041	0,043	0,043
5.	50	M	0,151	0,150	0,157	0,152
6.	4	M	0,052	0,043	0,055	0,050
Tashkent, mean						0,124
Uzbekistan, Khorezm						
7.	23	F	0,140	0,133	0,118	0,130
8.	50	M	0,761	0,658	0,613	0,678
9.	48	F	0,096	0,075	0,083	0,085
10.	56	M	0,056	0,050	0,056	0,054
11.	47	M	0,089	0,098	0,099	0,095
12.	65	F	0,018	0,020	0,026	0,022
13.	43	F	0,065	0,071	0,060	0,065
Khorezm, mean						0,161
Italy, Brugherio						
14.	40	F	2,76	2,59		2,67
15.	25	M	1,26	1,46		1,36
16.	33	M	0,522	0,489		0,506
17.	69	M	3,16	3,68		3,42
18.	29	F	1,02	0,612		0,816
19.	28	F	0,491	0,467		0,480
20.	31	F	1,14	1,16		1,16
Italy, mean						1,49

In general, the present work did not highlight serious mercury pollution problems, but it must be considered as a seminal work to develop more organized and larger studies. In particular, similar investigations are needed in the most industrialized regions of Uzbekistan and in other neighboring Republics where large sources of mercury pollution exist.

Table 5 – Examples of Hg levels in various fish species from other regions (values obtained from UNEP, Schoeny, 2004)

Location	**Fish species**	**Hg concentration, ppm**
Thailand	5 marine fish species	0,05-0,7
Fiji	Canned tuna	0,01-0,97
Philippines	Tilapia	0,1-0,5
Australia	Redfin perch	0,12-1,3
UK	Swordfish	0,15-2,7
	Shark	1,0-2,2
Sweden	Northern pike	0,1-2,0
USA	Large mouth bass	0,1-1,4

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АДАМНЫҢ СЫНАППЕН ЛАСТАНУ ДЕҢГЕЙІ ЖӘНЕ ӨЗБЕКСТАН РЕСПУБЛИКАСЫНЫҢ СУ КОМПОНЕНТТЕРІНІҢ МОНИТОРИНГІ ЖӘНЕ ЭКОТОКСИКОЛОГИЯЛЫҚ БАҒАЛАУЫ

Б.К. Каримов, М.Ф. Бекчанова, Дж. Тартари, Д. Вигнати

Сынап концентрациясы түп шөгінділерінде 4,0 – 26,4 мг/кг аралығында аутқыды, жоғары концентрациялар Амударья өзенінің төменгі ағысымен салыстырғанда Арнайск көлдерінде(9,6–26,4 және 4,0–21 мг/кг) байқалды. Сынап мөлшері балықтарда 28,7 – 137,7 мг/кг аралығында ауытқыды, ал Ташкент және Хорезмск облыстарындағы адамдардың шашында 42,8 – 387 және 21,6 - 678 μг/кг, АҚШ бекіткен ЕРА мен БДС (1000 және 10000 мг/кг, сәйкесінше) зияндылық шектеріне қарағанда төмен болып шықты.

МОНИТОРИНГ И ЭКОТОКСИКОЛОГИЧЕСКАЯ ОЦЕНКА УРОВНЯ РТУТНОГО ЗАГРЯЗНЕНИЯ ЧЕЛОВЕКА И КОМПОНЕНТОВ ВОДНЫХ ЭКОСИСТЕМ РЕСПУБЛИКИ УЗБЕКИСТАН

Б.К. Каримов, М.Ф. Бекчанова, Дж. Тартари, Д. Вигнати

Концентрации ртути в донных отложениях колебались в пределах 4,0 – 26,4 μг/кг, повышенные концентрации наблюдались в Арнасайских озерах по сравнению с нижним течением реки Амударьи (9,6–26,4 и 4,0–21 μг/кг). Содержание ртути в рыбе варьировало в пределах 28,7 – 137,7 μг/кг, а в человеческом волосе из г. Ташкента и Хорезмской области в пределах 42,8 – 387 и 21,6 - 678 μг/кг, которые оказались низкими, чем границы вредности, установленные ЕРА США и ВОЗ (1000 и 10000 μг/кг, соответственно).