Fish and Seafood Safety

Subjects: Toxicology

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Toxic metals that are released into aquatic environments from natural and anthropogenic sources are absorbed by aquatic organisms and may threaten the health of both aquatic organisms and humans. Despite this, there have been limited studies on the metal concentrations in fish and humans in Central Asia.

fish toxic metals arsenic mercury

1. Distribution of Toxic Metals in the Water of Rivers, Lakes, and Seas in Central Asia

Central Asia, covering approximately 2.72 million km^2 of dryland, faces significant water challenges, particularly within its extensive endorheic basins. These basins, devoid of direct connections to the ocean, suffer from constrained surface and groundwater resources. Over the past century, intensified demands from agriculture, energy, and a growing population have resulted in detrimental environmental consequences, including diverse pollution in rivers, lakes, and groundwater. This degradation threatens both aquatic ecosystems and the socioeconomic development of the region [1][2][3]. In the lowlands of Central Asia, major river systems and lake basins, such as the Amu Darya-Syr Darya-Aral Sea Basin and the Ili River-Lake Balkhash Basin, grapple with substantial changes [3]. Natural ecosystems, originally adapted to the region’s natural water availability, have undergone significant disruptions due to population growth and intensified water-consuming economic activities. This shift has altered socioecological systems, posing a high probability of water-induced changes with potentially severe impacts on human societies.

The environmental contamination of water and sediments in Central Asia is becoming increasingly prominent. The Amu Darya Basin was found to be at a moderate pollution level of toxic metals, as assessed using several pollution indices and the ecological risk index [4]. According to Zhan et al. [4], toxic metal contaminations in the surface sediments of the lower Amu Darya Basin were assessed using pollution indices. Two key pollution indices, the single-factor pollution index (PI) and pollution load index (PLI), were utilized to evaluate contamination levels. The PI gauges individual toxic metal contamination, while the PLI combines these values for an overall pollution assessment. Concentrations of various toxic metals were measured, revealing a descending order: Zn > Cr > Ni > Cu > Pb > Co > Cd. Spatially, heavier metal accumulation was noted in cities and agricultural areas. Source identification methods, including correlation analysis and the positive matrix factorization (PMF) model, identified four distinct sources of contamination: natural sources, industrial discharge, agricultural sources, and a mixed source of traffic and mining activities. Geochemical background values (GBVs) were compared to regional values for context.

The spatial distribution maps revealed notable enrichment of Cr, Ni, and Cu in irrigated agricultural areas, while Zn, Pb, and Cd were predominantly concentrated in urban zones. Identified sources of these metals included natural factors, industrial discharges, agricultural activities, and a combination of traffic and mining, contributing 33.5%, 11.4%, 34.2%, and 20.9% to the overall contamination, respectively. The GBVs for Cd, Zn, Pb, Cu, Ni, Cr, and Co in the Amu Daryas Basin were measured at 0.27, 58.9, 14.6, 20.3, 25.8, 53.4, and 9.80 mg/kg, respectively, aligning closely with regional background values from lake sediments.

Despite this, high levels of toxic metals and other contaminants were detected in the blood of children and pregnant women in the lower Amu Darya Basin, leading to several health problems, including high infant mortality, low birth weight, growth retardation, acute respiratory diseases, anemia, miscarriage, and other recorded disorders [5][6][7][8].

Rzymski et al. [9] investigated toxic metal contamination in the lower course of the Syr Darya River and the small Aral Sea. They reported that in the Syr Darya River, As was detected at the level of 35.8 ± 21.2 (mean ± standard deviation). Overall, the measured As levels in Syr Darya and the Small Aral Sea were 2–7 times higher than the WHO guideline level of 10 μg/L [10]. The concentrations of Hg were below detection limits in both the Syr Darya River and the small Aral Sea region and thus below the WHO guideline level for Hg (6.0 μg/L) [10]. Cd and Pb were detected in the Syr Darya river and, at some locations, the Cd and Pb concentrations [9][11][12] exceeded the WHO guideline levels (3.0 and 10 μg/L, respectively) [10]. According to previous Kazakhstan Ministry of Ecology, Geology, and Natural Resources reports, the Syr Darya water in the Turkestan and Kyzylorda regions is only suitable for irrigation and industrial uses [13].

In the Ili River (Kazakhstan), the levels of Cd varied from 1.7 to 28.7 and the levels of Pb, from 0.2 to 87.0 μg/L, exceeded the WHO guideline levels more than five times at some locations [14]. Relatively high levels of As (approximately 16 μg/L) were measured in Issyk-Kul Lake (Kyrgyzstan) [15], exceeding the accepted drinking water level. The levels of Pb in Issyk-Kul Lake were approximately 0.09 μg/L [15].

The contamination of rivers and reservoirs with toxic metals varies depending on location and season. During flood periods, the sediments release Hg, leading to increased Hg concentrations in the water [16]. In the river Nura, the highest concentrations of Hg were observed during spring and summer seasons followed by autumn and winter [17]. In contrast, seasonal variations in Hg concentrations in the Syr Darya River was low, with a low percentage of samples (0.85%) exceeding the guideline levels. The highest concentration of Cd in the Syr Darya River was observed in winter but Cd concentrations exceeded the guideline levels in all seasons [17]. The variations in As concentrations in the river Nura were also low, whereas As in the river Ili in winter and spring samples exceeded the WHO guidelines [17].

The Karbide chemical plant is located on the river Nura in northeast–central Kazakhstan and the uncontrolled release of wastewater from the plant has resulted in serious contamination of the river [16]. This area, particularly Temirtau City, is known for high contamination with mercury and the citizens of the area were reported to have a higher risk of hypertension and higher blood concentrations of inflammatory markers [18]. Heaven et al. [16] reported a range of Hg concentrations of 0.46–5.36 μg/L in the river Nura. Shinetova et al. [18] measured 4.5 ± 9.8 μg/L (mean ± standard deviation) of Hg in highly contaminated parts and 0.03 ± 0.08 μg/L in low contaminated parts of the river Nura.

Springs in Central Asia are traditionally popular as tourist attractions and are widely used for balneological and religious purposes and as a source of drinking water. For example, western Kazakhstan attracts pilgrims with many sacred historical constructions and natural springs, which are considered to have healing properties. In balneotherapy, people immerse themselves in spring water for health benefits or apply water to the skin for therapeutic purposes. In religious practices, people might use spring water for ritual cleansing. Exposure to toxic metals via skin in both cases would depend on the composition of the spring water. Regular analysis of the spring water would be necessary to assess the risk of exposure. Monitoring studies of the spring waters in the Aktobe region, western Kazakhstan did not detect the presence of Pb but identified three springs, where Cd concentrations exceeded the WHO guideline level as follows: in Islambulak by three times and in Bulak ayly and Akshat by five times [19]. In the Atyrau region, neither Cd nor Pb exceeded the guideline levels [20].

The presence of toxic metals in the aquatic environment poses substantial health risks to fish and humans. Thus, careful monitoring and human health risk assessments should be routinely performed.

2. Occurrence of Toxic Metals in Fish and Seafood in Central Asia

Fish products represent one of the main uptake routes of toxic metals by humans, especially MeHg. Fish and meat also contain Cd and As, making them potential sources of dietary exposure. Until recently, contamination with toxic metals and their food sources has been largely ignored in Central Asia. However, monitoring of the accumulated toxic metals in fish tissues is essential for evaluation of pollution and environmental hazards. Nowadays, concerns over the quality of food and its health effects are growing. Dietary intakes of toxic metals should be maintained within the permissible limits. To minimize human exposure to toxic metals, the Eurasian Customs Union established maximum permissible concentrations of toxic metals in fish and seafood products (on food safety). MeHg comprises the largest portion (up to 100%) of the total mercury in seafood. The concentration of MeHg in fish depends on the species, feed, size, and age. Large predatory fish are known to contain the highest concentrations of MeHg.

In 2007 and 2008, the results of the collaboration between the Norway, Kazakhstan, Kyrgyzstan, and Tajikistan (JNKKT) project and the NATO SfP RESCA project demonstrated that overall, the muscle Hg concentrations in studied fish species were low and did not represent any health risk [15][21]. In those projects, the following fish were sampled at the following locations: (1) Kurday, Kazakhstan; (2) Kadji Sai, situated on the southern coast of Issyk-Kul Lake, Kyrgyzstan; and (3) Taboshar and Digmai, Tajikistan. These locations were selected based on the fact that during the 1950s and 1960s, uranium mining sites operated as part of the USSR nuclear weapon program and large amounts of uranium-tailing materials and toxic compounds are still found at the sites, close to residential areas.

Later studies on fish and seafood in Central Asia generally reported levels of toxic metals below maximum permissible concentrations, although the levels greatly varied depending on the sampling location and fish species. However, at some locations, fish with high Hg concentrations were detected. Lake Balkyldak in North Kazakhstan is a highly contaminated area because of the chlor-alkali plant in Pavlodar, which operated during 1975–1993 and was based on Hg-cell technology. In 2001–2002, fish caught from Lake Balkyldak had high Hg levels (0.16–2.2 mg/kg) [22] and in 2006–2007, the Hg levels were slightly lower (1–1.5 mg/kg) [23]. Nevertheless, Hg levels in the majority of fish exceeded the maximum permissible concentration of Hg in freshwater fish in Kazakhstan of 0.3 mg/kg [22][23]. Moreover, Kaliyeva and Ermienko [24] observed several physiological, biochemical, and morphological abnormalities in fish from Lake Balkyldak.

The poor environmental conditions in the Pavlodar region are also coupled with the former activity of the Semipalatinsk Nuclear Test Site, the test site for testing nuclear weapons during the Soviet era [25]. The Semipalatinsk nuclear test site covers 18,500 km^2 in the northeast of Kazakhstan near the city of Semey. In 1949–1989, the Soviet Union intensively conducted nuclear tests there but the health consequences of exposure to radiation, toxic metals, and other contamination are still unclear. A large number of studies have focused on assessing the radioactive contamination due to the nuclear tests at the Semipalatinsk nuclear test site. However, more data are needed on the contamination with toxic metals. Additionally, co-exposure effects should be considered. Studies of this kind are scarce. Sharov et al. [26] analyzed toxic hotspots in eight former Soviet countries using a global contaminated sites database. The research has identified 424 polluted sites in Armenia, Azerbaijan, Kazakhstan, Kyrgyzstan, Russia, Tajikistan, Ukraine, and Uzbekistan, assessing contamination levels of seven key pollutants (pesticides, lead, radioactive metals, arsenic, mercury, chromium, and cadmium). These sites collectively endanger an estimated 6.2 million residents, with existing data likely capturing only a fraction of actual contaminated sites, indicating potentially severe public health consequences. The study emphasizes the need for additional assessments to comprehensively understand the risks posed by toxic pollution in the region.

The levels of Hg in fish (roach and perch) from the Intumak Reservoir, which is located on the Nura River, also exceeded the permissible level [27]. The concentrations of Pb in roach muscle tissue from the Shardara Reservoir, situated in the southeastern part of the Kyzylkum desert, along the river Syr Darya, ranged from 0.1 to 3.8 μg/g wet weight [11].

Integrated water management approaches like water resources management and the water–food–energy nexus are crucial to securing a sustainable future. This thematic issue delves into the intricate water challenges of Central Asia, offering insights derived from hydrological research, water quality investigations, and ecosystem assessments. Within this framework, reviews and case studies provide field-tested solutions for effectively managing the region’s water resources [2][3][28].

3. Intake of Fish and Seafood in Central Asia

Achieving food sufficiency to meet dietary recommendations is one of the major objectives of the agricultural sector. However, current research on fish and seafood consumption in Central Asia is limited. According to

FAOSTAT data, there are substantial variations in fish and seafood consumption among Central Asian countries [29]. These differences might be related to the different levels of supply of fish and seafood, income levels, awareness of healthy diets, gastronomic traditions, and consumer preferences. During the last 20 years, a significant increase in fish and seafood consumption was observed in Uzbekistan possibly due to increased supplies and changed consumer preferences. A slight increase was also recorded in Tajikistan, while consumption somewhat decreased in Kazakhstan, Turkmenistan, and Kyrgyzstan. Large variations between countries were observed in the most frequently consumed fish species and seafood. In Kazakhstan and Kyrgyzstan, the most consumed fish group was pelagic fish followed by freshwater fish. In contrast, Uzbekistan, Tajikistan, and Turkmenistan mainly consume freshwater fish and, to a lesser extent, other fish groups. Interestingly, the consumption of crustaceans, mollusks, and other aquatic food items was negligible in Uzbekistan, Tajikistan, Kyrgyzstan, and Turkmenistan**.** It should be emphasized that this consumption was calculated for the entire population within each country and does not reflect the per capita consumption. The wide difference in fish and seafood consumption between countries can be attributed to various factors, including geographical location, income levels and affordability, culinary traditions, and dietary preferences. Tajikistan does not have direct access to the sea. In contrast, Uzbekistan is also landlocked but has better access to imported seafood through trade networks. Countries with coastlines such as Kazakhstan have easier access to fish and seafood. Seafood can be costlier than other protein sources. In countries with lower income levels, people might prioritize more affordable protein options. Educational and awareness factors are also important. Understanding these factors can help explain the wide differences in fish and seafood consumption between countries and inform strategies to promote healthier dietary patterns where needed. Generally, fish and seafood consumption was much below the recommended intake. In contrast to countries with the highest fish consumption, such as the Maldives, Iceland, and Macau (over 70 kg/year/capita), Tajikistan stands among the nations with the lowest fish consumption per capita. It is surpassed only by Ethiopia and Afghanistan, where the consumption figures are 0.53 kg/year/capita and 0.36 kg/year/capita, respectively. The Ministry of Health of Tajikistan recommended 10 kg/year/capita. During the former USSR, per capita annual consumption in Tajikistan was 5–6 kg but due to low domestic fish production and decreased import of fish, the consumption dramatically decreased [30]. A recent study demonstrated that only 3.9% of Tajik women of childbearing age consumed fish [31].

According to a food frequency survey, conducted in Kazakhstan, fish consumption for fishermen was 103 g/day and 49 g/day for non-fisherman [32], corresponding to 721 and 343 g/week, respectively. These values are higher than the 123 g/week later reported for young adults in Kazakhstan [33]. Jia et al. [34] reported the per capita consumption of fish in Kazakhstan of 9.59 kg (184 g/week). In that study, the food consumption data were obtained from the Republic of Kazakhstan Bureau of National Statistics [34], whereas Akhmetova et al. [33] and Hsiao et al. [32] used the food frequency consumption questionnaires. Dietary studies of school-aged children of 9–10 years in Kazakhstan depicted very low fish consumption, especially among the children with obesity [35]. Fish consumption among obese children was 5.8 times lower than the recommended consumption in Kazakhstan.

In the neighboring countries Tajikistan, Kyrgyzstan and Turkmenistan, fish consumption is even lower [36]. In Uzbekistan, residents in Tashkent city and Khorezm consume an average of 1.0 kg and 0.5 kg of fish per year [37]. An assessment of dietary habits of residents in Mary city in Turkmenistan showed the fish consumption of 3.28

kg/year [38]. The current diet in Tajikistan contains only 1% of fish and seafood and mainly relies on bread and vegetables [39].

4. Human Biomonitoring of Toxic Metals in Central Asia

Various studies have been conducted on human populations to determine exposure to toxic compounds. These include both epidemiological studies to determine the health risk associated with exposure to toxic metals and biomonitoring of human populations to assess exposure from the environment. However, only a few studies on biomonitoring of exposure to toxic metals were performed in Central Asia, which were mainly focused on contaminated areas.

Erdinger et al. [40] studied the urine levels of As and Hg in children from two villages in Kazakhstan, namely Aralsk (located in the area close to the Aral Sea, which is regarded as highly polluted) and Akchi (northeastern Kazakhstan). The levels of Hg were numerically but not statistically significantly higher in the children from Aralsk (mean value 0.94 µg/L) compared to Akchi (0.29 µg/L). Both groups of children had Hg levels comparable to or higher than preschool children in China (range 0.03 to 2.63 µg/L) [41], Korea (geometric mean 0.4 µg/L) [42], Italy (range of 0.04–2.18 µg/L) [43], USA (0.7 and 0.9 µg/g creatinine, [44]) and other countries. Those values were below health-based guidance values for the total Hg in urine of 25 µg/L, above which there is an increased risk for adverse health effects [45]. The urine levels of As were 6.4 and 9.6 µg/L in the children from Aralsk and Akchi, respectively.

Children in Pavlodar had Hg concentrations in the hair of 0.44 ± 0.5 mg/kg, which is considered as high and was explained by the activities of metal processing plants and the chemical industry in the Pavlodar region [46]. Moreover, children living in the districts close to the industrial zone had higher Hg concentrations in the hair (up to 0.7 mg/kg).

A cross-sectional study in hospitals in Kazakhstan, Kyrgyzstan, and Uzbekistan detected high concentrations of Pb in the hair of children diagnosed with anemia [47]. Similar results were observed in other countries such as Egypt [48] and India [49]. This might be explained by the fact that the intake of small amounts of Pb can compete with iron absorption and increase the risk of anemia [48]. The same is true for Cd and hair lead and cadmium levels are usually positively correlated [47]. The concentrations of Pb varied from 0.02 to 36.00 µg/g in Kazakhstan and from 1.13 to 27.40 µg/g in Uzbekistan. In Kyrgyzstan, the concentrations of Pb were particularly high and varied from 2.71–50.10 µg/g [47]. Moreover, hemoglobin levels in the children from Kyrgyzstan tended to be lower compared to Kazakhstan and Uzbekistan. Generally, average blood Pb levels have been declining in most countries over the last decade but exposure to Pb during childhood still remains a significant public health problem. Hair Cd and Hg concentrations were highest in Uzbekistan, they were 0.01–1.41 µg/g for Cd and 0.02–2.90 for Hg [47].

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