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Arsenic and Cadmium Contamination in Water, Sediments and Fish is a Consequence of Paddy Cultivation: Evidence of River Pollution in Sri Lanka

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ABSTRACT

The upper Malwathu Oya is a seasonal river. The main livelihood of people living in the immediate vicinity of the river is paddy cultivation, and chronic kidney disease is reported among them. Farmers utilize different types of agricultural chemicals in their fields expecting bumper harvests. Several agricultural chemicals have been reported to contain toxic trace elements in Sri Lanka. Therefore, arsenic and cadmium might end up in the river water. The presence of these trace elements in the river water and sediments can result in their bioaccumulation in fish tissues. The main purpose of this study was to investigate the presence of two trace elements in water and sediments, as well as in fish tissues (gills, kidney, liver and muscle) of three food fish species, *Etroplus suratensis*, *Anabas testudineus* and *Channa striata* during cultivating and non-cultivating seasons of the year. Further, the level of bioaccumulation of two trace elements in fish tissues in relation to the contamination level of water and sediments was assessed. Data were gathered for 43 months. Arsenic and cadmium concentration in water showed a significant ($P < 0.05$) seasonal variation. Generally, the two trace elements in the river water were highest during the cultivating seasons than in other seasons. In all species, both trace elements in the gills highly depended on the concentration in the water. In all species, two trace elements in water and sediment did not significantly affect the levels in muscle tissue. Therefore, the trace element levels in the edible parts of these three fish were well below the maximum permissible levels of international institutions.

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Introduction

Arsenic (As) and cadmium (Cd) are widely found in the environment (Patrick, 2003) both from natural occurrence and due to anthropogenic activity (EFSA, 2009). Use of agricultural chemicals has been indicated as the main anthropogenic source of As and Cd pollution in aquatic environments of Sri Lanka (Illeperuma, 2000; Jauasumana et al., 2011). As both trace elements are

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potentially toxic (Patrick, 2003; Godt et al., 2006; Wang et al., 2012; Chen et al., 2015) at some bioavailability (Luoma and Rainbow, 2008), their presence in aquatic environments can result in deleterious effects on aquatic organisms (Mason et al., 2000). Similarly, As and Cd can exist in both abiotic (water and sediments) and biotic (organisms) components of aquatic environments at different concentrations. However, toxicity occurs in aquatic animals when the rate of uptake of a trace element exceeds the combined rates of efflux and detoxification of metal into metabolically inert forms (Luoma and Rainbow, 2005). In fish, metal uptake differs fundamentally from that of terrestrial animals as they are constantly submerged in the solution of metal ions (Perera et al., 2015). As a result, metal distribution in fish is determined mainly by its content in water and food (Farkas et al., 2000; Mohamed, 2008). Further, fish have a tendency to accumulate heavy metals depending on their position in the food chain and their feeding habits (Houserová et al., 2007). Therefore, the concentration of As and Cd in water and bottom sediment, as well as the trophic position of fish can have significant effects on bioaccumulation of these two trace elements in fish.

Malwathu Oya ("Oya" refers to seasonal rivers) is the second longest (164 km) river which originates from a mountain range in the North Central Province (NCP) in Sri Lanka (The National Atlas of Sri Lanka, 2007). The upper reach of Malwathu Oya (latitude 8°15′ and 8°05′, longitude 80°26′ and 80°40′) runs across a remote area that consists of two distinct land use types, forest areas and paddy lands. People living in the upper Malwathu Oya area mainly depend on paddy cultivation as their livelihood (Perera et al., 2014). All paddy farmers in the area utilize different types of weedicides, pesticides, fungicides, rodenticides and inorganic fertilizers expecting high yield (Perera et al., 2014). The water utilized in their paddy lands diverts directly or indirectly to the upper Malwathu Oya by paddy outlet canals (POCs).

Several studies reported the prevalence of overusing agricultural chemicals by farmers in many parts of Sri Lanka (Selvarajah and Thiruchelvam, 2007; Padmajani et al., 2014). NCP of Sri Lanka is famous for chronic kidney disease (CKDu[1]) (Kabata et al., 2016; Wimalawansa, 2015a, b) of which the apparent aetiology is most controversial among intellectuals. According to studies, As and Cd may be vital in spreading the disease among farmers in NCP (Jayasumana et al., 2014a, b). Many studies have been carried out in the NCP to investigate the impacts of inorganic fertilizers and other agricultural chemicals (e.g., pesticides and weedicides) that can contribute As and Cd into aquatic environment (Illeperuma, 2000; Jauasumana et al., 2011; Kumar and Singh, 2010). Paddy cultivation activities that take place in the upper Malwathu Oya catchment would also release As and Cd into the water. As a result, As and Cd can appear in water, sediment and fish tissues. Accumulation of As and Cd in fish tissues can result in deleterious effects on fish (Govind and Madhuri, 2014). However, various metals show different affinities to fish tissues (Jezierska and Witeska, 2006a, b). For example, the non-edible tissues of fish can accumulate more metals than the edible muscle meat (Canli et al., 1998; Jezierska and Witeska, 2006a, b; Mohamed, 2008; Ambedkar and Muniyan, 2011). As freshwater fish is the cheapest source of animal protein for villagers in the NCP (Amarasinghe and Silva, 1999), the elevated levels of As and Cd in edible fish tissues can cause health risks (EFSA, 2009) as well.

Therefore, the main the purpose of this study is to investigate the effects of paddy cultivating activities (which take place in nearby river catchments) on the river water and fish. To understand the effects, the current study mainly focuses on As and Cd in water and sediments, and as the two elements have created a platform of arguments in various aspects of CKDu, in three common food fish species, *Etroplus suratensis*, *Anabas testudineus* and *Channa striata* (Pethiyagoda, 1991), collected from forest and paddy cultivating areas of upper Malwathu Oya. *E. suratensis* is mainly a herbivore (Pethiyagoda, 1991) and habitual bottom feeder (Costa, 1983; Joseph and Joseph, 1988; Vidhya and Radhakrishnan, 2012). *A. testudineus* is an omnivore (Pethiyagoda, 1991; Zalina et al., 2012) and *C. striata* is highly carnivorous (Ali, 1990; Courtenay and Williams, 2004). As the trace element accumulating tendency in different fish species and their tissues can be varied, four tissues (gill, liver, kidney and muscle) of the above-mentioned three fish species were analysed for As and Cd. Further, this study assessed the level of accumulation of As and Cd in fish tissues in relation to the contamination level of water and sediments and tried to predict the suitability of these three fish species for use as bioindicators. Finally, the human health risk due to consumption of the muscle meat of Malwathu Oya fish will be discussed.

Materials and Methods

Study Location and Sampling Sites

This study was conducted in a 30-km-long reach in upper Malwathu Oya between Ritigala Strict Nature Reserve (latitude 8°12′ and longitude 80°65′) and Nachchaduwa perennial reservoir (latitude 8°15′ longitude 80°29′) in the Anuradhapura District in the NCP of Sri Lanka (Fig. 1). The first 17 km stretch of the river was considered as the Upper River Segment (URS) and the second 13 km stretch was considered as the Lower River Segment (LRS). Twelve sampling sites were selected from the two different types of land uses (forest and paddy lands) of the river catchment. Six sampling sites were situated in forest areas (non-paddy) while the other six sites were situated in paddy cultivating areas.

Sample Collection, Preparation and Analysis

Water, sediment and fish samples were collected monthly from March 2012 to September 2015 (43 months). Water samples were collected from paddy-area-sites in the URS (P1–P3) and the LRS (P4–P6) as well as from forest-area-sites in the URS (NP1–

[1] CKDu, chronic kidney disease of unknown aetiology.

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