

# **Mercury contamination of the Nile Crocodile (*Crocodylus niloticus*) in the Okavango Delta, Botswana: A Baseline for the Assessment of Future Threats.**

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## **Abstract**

Mercury is a global neurotoxicant especially dangerous in wetlands and newly flooded areas which can be sites of enhanced monomethylmercury, a form of mercury that can be readily biomagnified. The study was conducted in the Okavango Delta, Botswana, a wetland ecosystem characterized by both permanent and seasonal floodplains. Because of the biogeochemical cycling properties of mercury it is expected that wetlands can potentially be sites of elevated levels of monomethylmercury which hold potential threats for both the subsistence fishing communities as well as crocodiles.

Samples from individual crocodiles (*Crocodylus niloticus*), fish (*Clarius gariepinus*, *Oreochromis andersoni*, *Serranochromis angusticeps* and juvenile *Tilapia* sp.), macrophytes (*Nymphaea* sp.) and bottom channel sediments were collected from the Delta and analysed for Mercury levels.

The results showed significant evidence of mercury biomagnification with mean concentrations for fish and crocodiles an order of magnitude higher than macrophytes and sediment. This exploratory study presents evidence for mercury biomagnification in the Okavango ecosystem.

## **Introduction**

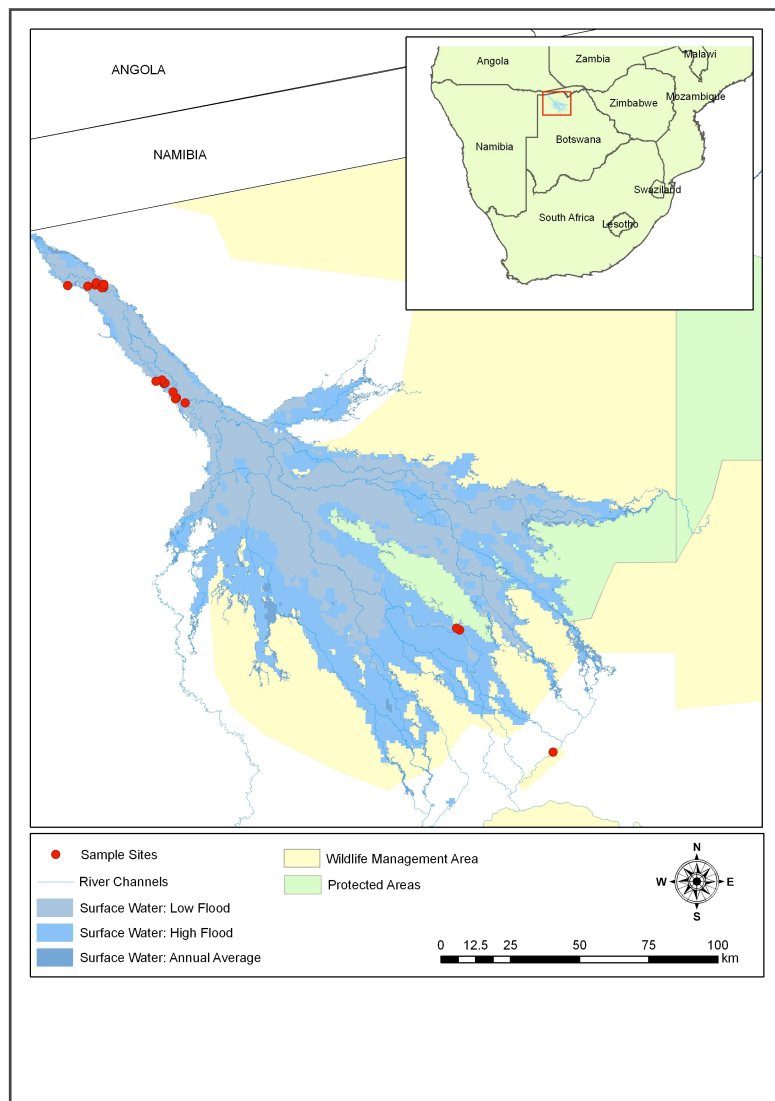
The transfer of heavy metals through the food chain is an issue which is of critical importance, especially in the case of elevated levels of Mercury (Hg). In concentrated levels, mercury acts as a neurotoxicant negatively affecting brain function in humans and the development of the young and juveniles (Boites et al 2003).

It has been noted that wetlands can act as Hg traps, with elevated levels often found in biota (Zillioux et al. 1993) in which the microbial production of monomethylmercury (MMHg) (Hurley et al. 1995; St. Louis et al. 1996) occurs during flooding events. Mercury can biomagnify through trophic groups, leading to a higher concentration in secondary and tertiary consumers (National Research Council 2000; Mergler et al. 2007) and may be occurring at dangerously high levels in top predators (Lakowski 1991). From an environmental monitoring perspective, this has serious implications. The relationship between Hg exposure and the effects it has on aquatic organisms is poorly understood, largely due to the variable responses to contamination from different species (Croteau, Luoma & Stewart 2005).

Although numerous studies have been undertaken to analyse the presence of elements in fish, invertebrates, water and humans (Berg et al. 1995; Croteau, Luoma and Stewart 2005; Black et al. 2011), relatively few studies have analysed crocodile tissue. Crocodiles are ideal for monitoring levels of contamination as they are long lived carnivorous reptiles that exhibit high regional fidelity (Jeffree et al. 2001) and within the Okavango, have been shown to hunt a diverse range of invertebrates, amphibians, fish, birds and mammals (Wallace and Leslie 2008). They are keystone species and therefore their population status and health can have serious implications for the Okavango ecosystem.

This study aims to determine if Hg biomagnification is occurring in the Okavango Delta through analyses of aquatic biota within different trophic levels, up to the top predator, the Nile crocodile (*Crocodylus niloticus*).

### Field Sites



Four separate sites over the Okavango Delta were selected for data collection. These included the Upper panhandle (Shakawe), Lower Panhandle (Sepopa), Delta Proper (Nxaraga lagoon) and the lower Delta (Maun). These sites reflect differing flooding regimes and thus give a good overall representation of the Okavango Delta.

## **Sample Collection**

Data collection was carried out during the month of June ( high flood season in the lower Delta). A total of 20 crocodiles (45.3 – 362 cm TL), 3 adult fish (*Clarius gariepinus*, *Oreochromis andersoni*, *Serranochromis angusticeps*), 10 juvenile fish (*Tilapia* sp), 30 invertebrates (10 from each sample location), six macrophytes (*Nymphaea*), six sediment samples and six water samples were collected and exported to the United Kingdom. Strict international export and import regulations (four months quarantine) ensured that water samples were not included in the analysis. A lack of invertebrate tissue meant that only *Notonectidae* sp. were analyzed which left a total of three individuals (one from each sample location). In total 16 different samples were analysed for traces of Hg; five adult *Crocodylus niloticus*, four fish (one *Serranochromis angusticeps*, one *Oreochromis andersoni*, one *Clarius gariepinus* and one juvenile *Tilapia* sp.), two *Nymphaea* sp and five sediment samples.

Several studies have been done to assess heavy metal occurrence in crocodilian tissue. Almlil et al. (2005) looked at hepatic and renal tissue concentrations, Twining et al. (1999) and Jeffrey et al. (2001) assessed osteoderms and tail tissue, and Guillory et al. (2011) looked at tissue and bone concentrations. The present study was designed specifically so that the tail scutes that were removed in order to individually mark each crocodile could be analysed for mercury levels.

## **Analytical Methodology**

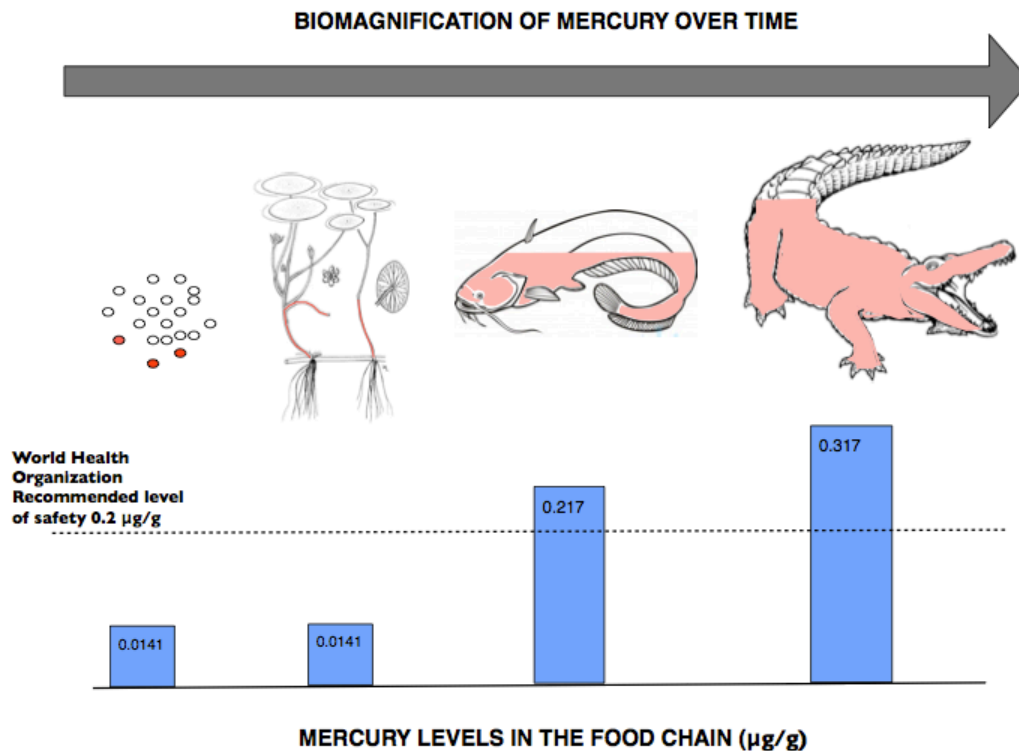
### Cold Vapour-Atomic Fluorescence Spectrometry (CV-AFS)

Samples were analysed for traces of Hg using a Cold Vapour-Atomic Fluorescence Spectrometer (CV-AFS) using the following methodology: 0.2 g (exact weight recorded) of either freeze-dried sediment or freeze dried tissue samples that had been disaggregated and homogenized with a pestle and mortar were weighed into a 50 ml polypropylene DigiTUBE (SCP Science), to which 8 ml reagent-grade aqua-regia was added. This was gradually heated on a hot plate to 100°C to avoid a violent reaction. The sample was then digested for a further 2 hours. After cooling, the digested solution was diluted to 50 ml with distilled deionised water. Mercury concentrations in digested solutions were then measured by CV-AFS. Standard solutions and quality control blanks were measured every five samples to monitor measurement stability.

## Results and Discussion

The Okavango Delta provides large areas of seasonal floodplains that, when dry, collect and build up mercury deposits that become biologically active when flooding occurs.

In this study, the mean concentrations for fish and crocodiles were an order of magnitude higher than the mean concentrations for macrophytes and sediment. Mercury was present in relatively low concentrations in sediment and macrophytes, but mean levels in fish and crocodiles were above the WHO recommended levels of  $0.2 \mu\text{g/g}$



This trend is worrying, particularly for fish which are consumed by humans in this area up to 7 times per week (Black et al. 2011). Initial investigations in the Okavango indicate that Mercury exposure could potentially be provided by the following sources:

- Distant fossil fuel (coal) power plants and cement manufacture may emit Hg to air
- Municipal landfill and sewage plants are significant potential emitters to land and water
- Burning of fossil fuels emits Hg to air

These data represent preliminary findings due to the limited sample size. Future studies should aim to increase the total sample size processed as well as target sediments which are exposed to both flooding and drying periods.

## *Future Threats*

Although these data are limited through small sample numbers, they raise concerns over the potential for future threats to higher trophic levels in the Okavango Delta. Future threats include:

- Industrial and agricultural expansion in Angola
- Approved mining concessions in the Okavango Panhandle
- Atmospheric deposition of Hg (unpredictable in nature).

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