

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/249920466>

Mercury in fish: A critical examination of gold mining and human contamination in Ghana

Article in *International Journal of Environment and Pollution* · May 2010

DOI: 10.1504/IJEP.2010.033232

CITATIONS

4

READS

213

1 author:



Petra Tschakert

University of Western Australia

56 PUBLICATIONS 1,263 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



IPCC Working Group II Chapter 13 [View project](#)

All content following this page was uploaded by [Petra Tschakert](#) on 25 October 2014.

The user has requested enhancement of the downloaded file. All in-text references [underlined in blue](#) are added to the original document and are linked to publications on ResearchGate, letting you access and read them immediately.

Mercury in fish: a critical examination of gold mining and human contamination in Ghana

Petra Tschakert

Department of Geography and the Alliance for Earth Sciences,
Engineering, and Development in Africa (AEDESA),
315 Walker Building,
Pennsylvania State University,
University Park, PA 16802, USA
E-mail: petra@psu.edu

Abstract: This study examines the knowledge of miners, fishermen, fish sellers, and fish buyers regarding the linkages between elemental mercury, methylmercury, fish consumption, and health risks in and around mining areas in Ghana. While findings suggest that a clear grasp of the impacts of mercury on human health is lacking, few potentially polluted fish are consumed in the mining areas. Most customers prefer ocean fish from the Gulf of Guinea and freshwater fish from Lake Volta, neither of which is known for small-scale gold mining. Alarmist messages about contaminated fish from Ghanaian mining sites need to be treated with caution.

Keywords: methylmercury; *galamsey* mining; mercury contamination; freshwater fish; marine fish; bioaccumulation; trophic levels; mudfish; catfish; tilapia; fish smoking; Ghana; environmental pollution.

Reference to this paper should be made as follows: Tschakert, P. (2010) 'Mercury in fish: a critical examination of gold mining and human contamination in Ghana', *Int. J. Environment and Pollution*, Vol.

Biographical notes: Petra Tschakert is an Assistant Professor of Geography and the Alliance for Earth Sciences, Engineering, and Development in Africa (AESEDA) at the Pennsylvania State University. Her research focuses on complex social-ecological systems, with specific interests in environmental justice, political ecology and participatory research. She works on small-scale gold mining, climate change adaptation, and livelihood resilience and transformations among marginalised populations, primarily in Ghana. She has a PhD from The University of Arizona (Arid Lands Resources Sciences and Applied Anthropology) and was a James Martin 21st Century School Visiting Fellow at the Environmental Research Institute at Oxford University in 2009.

1 Introduction

Mercury is used in small-scale gold mining around the world to separate gold from sediments. Several studies have assessed environmental contamination from elementary mercury (Hg^0) and mercury vapour discharged through mine tailings and burning during the amalgamation process. The negative human health impacts of mercury contamination

are well known, ranging from dizziness and muscular tremors to kidney dysfunction and death (Hinton et al., 2003), although clinical evidence of mercury poisoning is scarce (Eisler, 2003). Mercury from gold mining is undoubtedly a dangerous neurotoxin and often emphatically condemned. For instance, Michael Bender, coordinator of the Zero Mercury Working Group, describes it as a substance that 'threatens pregnant women, their fetus and those who eat large amounts of fish' (Associated Press, 2009).

In Ghana, the second-largest gold producer in Africa, several impact-based assessments have shown various levels of mercury contamination in water, soils, sediments and crops (Donkor et al., 2006a, 2006b; Babut et al., 2001; Golow and Adzei, 2002; Golow and Mingle, 2003; Bannerman et al., 2003; Kuma, 2004; Tschakert and Singha, 2007), as well as in human hair, nails, urine and blood (Rambaud et al., 2000; Adimado and Baah, 2002; Donkor et al., 2006b; Amegbey and Eshun, 2003). While results of these studies vary from values clearly below to values above the World Health Organisation (WHO) safe guideline standards, small-scale gold miners are typically represented as environmentally reckless operators, especially those who mine without a licence, who in Ghana are known as *galamsey* operators. Moreover, a deliberate exclusion of non-registered miners, portrayed often as environmental villains and criminals, from the design and use of alternative gold extraction technologies, including retorts, further fuels a vicious cycle of contaminating and being contaminated (Hilson, 2006; Hilson and Pardie, 2006; Hilson et al., 2007; Tschakert and Singha, 2007).

Despite the high health risks and potential harm associated with the handling of mercury and amalgamation in mining activities, it would be incorrect to portray miners as utterly oblivious to these negative impacts. Tschakert and Singha (2007) have shown that awareness about potential negative impacts is exceedingly high among Ghanaian *galamsey* operators. Participants in a series of conceptual mapping exercises listed burning after amalgamation, spillage, dispersal into water bodies through rain, and direct contact with skin and mouth as main channels of contamination. The same study also demonstrated that, compared with collapsing shafts, pits, and sediments, on-site injuries, and waist and other bodily pains, risks from mercury contamination were perceived as rather insignificant. While miners were clearly aware of the fact that mercury could enter humans and animals through contaminated water and food chains, especially fish, these risks virtually disappear in the overwhelming evidence of numerous other health problems, in addition to economic and environmental risks, inadequate safety issues, and on-site conflicts. Yet, the existing knowledge about potential harm from mercury usage does not necessarily always translate into safe practices, neither for humans nor the environment.

This paper explores the existing knowledge regarding the so far overlooked linkages between mercury and fish consumption in and around mining areas in Ghana. Unlike conventional impact-based assessments, it examines the understanding of miners as well as fishermen, fish sellers and fish buyers with respect to health threats that are associated with the consumption of potentially contaminated fish and possible strategies to reduce these hazards. The paper starts with an overview of mercury contamination in fish populations, including specific reference to Ghana. The following section describes the research methods. Then, results are presented and, in the concluding section,

these findings are discussed in the broader framework of learning and environmental stewardship in mining communities.

2 Mercury in fish: an overview

Mercury appears in various chemical forms. Of particular concern is methylmercury (MeHg), including its toxicological pathways and effects, as it bio-accumulates and magnifies through the terrestrial and aquatic food webs. Methylation is the attachment or substitution of a methyl group on a certain substrate. Figure 1 illustrates such a process. Metallic, elemental mercury (Hg^0) that is released from mine tailings or during burning of the amalgam is the least toxic form of mercury. Through oxidation–reduction reactions, mercury is either oxidised to a higher valence state (e.g., from relatively inert Hg^0 to the more reactive Hg^{2+}) through the loss of electrons or is reduced to a lower valence state. When the oxidised or mercuric species (Hg^{2+}) gains a methyl group (CH_3), mercury is transformed into MeHg. The methylation of Hg^{2+} , as illustrated in Figure 2, is primarily a natural, biological process resulting in the production of highly toxic and bioaccumulative methylmercury compounds. It occurs mainly in aquatic, low pH (acidic) environments with high concentrations of organic matter, which can stimulate microbial populations and reduce oxygen levels, therefore increasing biomethylation. The presence of sulphates may stimulate the growth of certain methylating microbes. Methylmercury is readily absorbed by aquatic plants and animals. Through consumption of these organisms, mercury enters the food chain and subsequently humans. The most common pathway for human exposure to the highly toxic MeHg is through consumption of fish, which after direct occupational exposure is the single largest source of mercury to man (Voegborlo and Akagi, 2007).

Figure 1 Chemical transformation of elemental mercury (Hg^0) to methylmercury (MeHg)

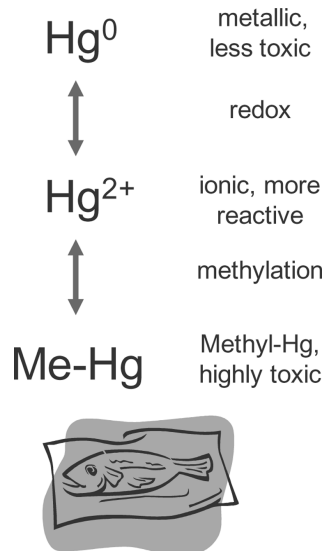
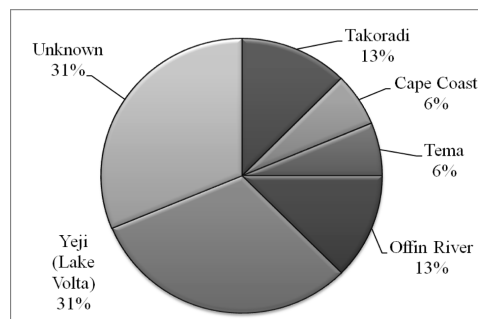


Figure 2 Origin of fish sold at three market towns in Ghana (Dunkwa, Bogoso, and Tarkwa), as estimated by local fish sellers



Source: Field work 2007

The source of mercury in aquatic systems can be a direct consequence of discharging elemental mercury through mining (e.g., spillage and runoff into water bodies through rain), erosion of naturally rich mercury soils and sediments, or, more frequently, atmospheric deposition of volatile mercury released through burning of the amalgam (Durrieu et al., 2005). While elemental mercury (direct source) is more likely to deposit with sediments because it is insoluble, volatile mercury is readily soluble and can be methylated by bacteria into MeHg. Once created, methylmercury is immediately absorbed by fish and plants and, unlike elemental mercury and volatile atmospheric mercury, has no residence time. Within surface water, several physical controls can accelerate the rate of methylation (interview with Voegborlo (2007)):

- a limited dissolved oxygen (anaerobic conditions)
- b increased levels of dissolved organic content
- c low pH levels (more acidic)
- d high temperatures.

Methylmercury enters fish in two ways. First, it can be absorbed by fish directly through their scales and gills. Second, plants and algae absorb MeHg that subsequently travels through the food chain. Once in the fish's body, MeHg resides in the liver and muscle tissue and is not fat-soluble (interview with Voegborlo (2007)). Since mercury biomagnifies through the food chain, larger and older fish at higher trophic levels tend to have the highest concentrations of mercury in their muscle tissues (e.g., Voegborlo and Akogi, 2007; Durrieu et al., 2005). In other words, herbivorous fish show low concentrations whereas omnivorous and carnivorous/piscivorous fish have higher mercury levels. Piscivorous fish are known to pass on potential neurotoxicity to both humans and wildlife (Kuwabara et al., 2007). According to Anku (2007), carnivorous fish can have up to one million times the mercury concentration than that of the contaminated water. Finally, the position of fish in a water column (their habitat) makes fish that reside at or close to the bottom of a water body (bottom feeders) more susceptible to accumulating mercury.

Recent studies from Latin America and Asia show these patterns of mercury accumulation and biomagnifications in different fish species and trophic levels. Durrieu et al. (2005), who analysed 35 freshwater species in the Amazon basin of French

Guiana where gold mining has occurred for at least a century, found very high Hg concentrations (2.85–14.3 $\mu\text{g g}^{-1}$, dry weight) in fish with a piscivorous regime compared with low levels (0.00–1.01 $\mu\text{g g}^{-1}$, dry weight) for herbivorous and periphytophagous species, the latter feeding on algae, cyanobacteria, heterotrophic microbes and detritus. The top predators that accounted for >70% of metal consumed by local families have the ability to absorb MeHg in a highly efficient way through their digestive barriers while excreting it very slowly. These include highly popular and easy to catch aymara fish. Moreover, [Durrieu et al. \(2005\)](#) report that, except for infants (<1 year of age), all Amerindian communities exceeded the safe 200 μgHg intake per week through fish consumption. Similarly, [Gammons et al. \(2006\)](#) show high levels of Hg concentration (>0.5 $\mu\text{g g}^{-1}$, wet weight), which is beyond the regulatory limit for human consumption, in large piscivorous fish in Lake Titicaca, Peru. Yet, it is worth mentioning that large non-piscivorous bottom feeders also exceeded the US EPA 0.3 $\mu\text{g g}^{-1}$ fish tissue-based water quality criterion level. Unlike in the French Guiana case, no consensus could be reached as to the source of these high Hg concentrations; both mining and atmospheric deposition are, therefore, plausible. Finally, a recent study conducted through the Global Mercury Project reveals high Hg concentration (>0.5 $\mu\text{g g}^{-1}$, wet weight) in freshwater fish close to high-density mining areas in North Sulawesi, Indonesia, compared with marine fish sold at market towns and fish from non-mining areas, although no specific reference was made to the trophic level of the fish ([Castilhos et al., 2006](#)).

In Africa, little is known about the relationship between gold mining and mercury contamination in fish. In Tanzania, a recent study reported low MeHg contamination in fish in small-scale gold-mining areas ([Taylor et al., 2005](#)). In Ghana, few historic mercury measurements exist, although mercury levels in rivers, stemming from both mining activities and atmospheric volatilisation, appear to be within WHO standards (<0.001 mg L^{-1}) (WHO, 2004). [Darabor and Momade \(2002\)](#) report generally undetectable levels of mercury in water bodies in mined and non-mined areas in southern Ghana. [Donkor et al. \(2006b\)](#) confirmed mercury levels below WHO standards from the Pra River Basin. Similar results are described by [Amin-Sackey \(1997\)](#) for the Prestea area.

For the most common and popular freshwater fish consumed in Ghana – tilapia (herbivore or omnivore), mudfish (omnivore or carnivore) and catfish (omnivore or carnivore) – only two extensive studies exist with respect to mercury contamination, both of them master's theses. [Oppong \(2006\)](#), who sampled 160 species, including tilapia, mudfish and catfish, in the Pra River found that none were above the WHO limit of 0.5 $\mu\text{g g}^{-1}$ of mercury. The author explained the modest total mercury levels with low levels of dissolved organic content and relatively high pH levels in the Pra River, both of which are not conducive to methylation. [Anku \(2007\)](#) investigated total mercury in mudfish (clarias) and tilapia (*tilapia zilli*) along the Ankobra River. Out of a total of 169 samples, only 18 were above the WHO limit, and none of them were tilapia. This is not surprising, however, as tilapia have the lowest trophic level. Also, catfish and mudfish whose preferred habitat is at the bottom of a water body have a higher tendency to accumulate mercury. A third study, conducted by [Donkor et al. \(2006b\)](#) and involving a total of only 12 dried fishes, found MeHg concentration in catfish and mudfish (bottom feeders) of up to 0.005 $\mu\text{g g}^{-1}$ and 0.009 $\mu\text{g g}^{-1}$ for Kafue pike (*Hepsetus odoe*, a piscivorous species), although average total-Hg ranged 0.69–4.47 $\mu\text{g g}^{-1}$. Their results for tilapia showed mercury levels below 0.01 $\mu\text{g g}^{-1}$. Low values for MeHg are

hypothesised to be related to fish hydration via smoking. Table 1 depicts the most common fish species in Lake Volta and River Pra that are also subject of mercury studies. There is a small anatomical difference between catfish and mudfish, although the terms are typically used interchangeably in daily conversations in Ghana. In the *Twi* language, both are known as *adwene*.

Table 1 Common freshwater fish in Ghana (the trophic level refers to the feeding position in the food chain, ranging from plankton to fish, mollusks, insects, crustaceans, and young birds)

Name	Trophic level	Feeder	Habitat
<i>Tilapia zilli</i> (Lake Volta)	2.0	Herbivorous	Demersal (bottom)
<i>Tilapia guineensis</i> (LV, Pra)	2.8	Omnivorous	Benthopelagic (bottom to surface)
<i>Tilapia busumana</i> (Pra)	3.3	Omnivorous	Demersal
<i>Clarias gariepinus</i> (LV)	4.4	Omnivorous	Benthopelagic (prefers bottom)
<i>Clarias ebriensis</i> (LV)	3.3	Carnivorous	Demersal
<i>Clarias anguillaris</i> (Pra)	3.4	Omnivorous	Demersal
<i>Heterobranchus isopterus</i> (LV)	3.2	Omnivorous	Demersal
<i>Heterobranchus bidorsalis</i> (LV)	3.7	Omnivorous	Demersal
<i>Heterobranchus longifilis</i> (Pra)	3.7	Omnivorous	Demersal

Data source: <http://fish.mongabay.com/data/ecosystems/Volta.htm>

In a recent attempt to demystify mercury contamination in fish, the Ghana Minerals Commission directed a study examining mercury levels in the following six omnivorous species: *Brycinus intermedius* and *Brycinus mandibularis* (Characins), *Schilbe micropogon* (Butter fish), and *Mormyrus mystus*, *Mormyrus longipinnis*, and *Mormyrus hasselquistii* (Elephant Nose fish). While the results of this investigation are still outstanding, an analysis of 13 marine fish species off the Atlantic coast of Ghana revealed overall low Hg concentrations (0.004–0.122 $\mu\text{g g}^{-1}$, wet weight), all clearly below the 0.5 $\mu\text{g g}^{-1}$ WHO limit (Voegborlo and Akagi, 2007). Despite these generally low levels of mercury contamination in freshwater as well as marine fish species in Ghana, fish from *galamsey* areas is often stigmatised as ‘bad fish’, even though the origin of fish is far from being clear (interview with Voegborlo (2007)).

3 Methods

Data for this study were collected in and around mining sites in Southwestern Ghana during two time periods, each part of a larger investigation regarding human and environmental health in small-scale gold mining. The first part involved two conceptual mapping exercises (mental models) with four and two individual *galamsey* miners, respectively, near Dunkwa and Bogoso in August 2006. Participants were asked to think about possible causes for mercury contamination, draw or write these one by one on blank index cards, and position the cards on a large piece of paper, linking possible causes with arrows. Then, miners discussed consequences of mercury contamination for people, animals and the environment, also using index cards and arrows. The second part of this study, expanding on initial linkages between mercury and fish contamination,

was carried out in July 2007. Participants involved 11 fishermen from Dunkwa (all men), 16 fish sellers (all women) from Dunkwa, Bogoso and Tarkwa, and 18 fish buyers (two men and 16 women) from the same three mining towns. Participants were selected at random at fishing sites and marketplaces, depending on their interest and availability. In total, 45 interviews were conducted for this second part, ranging from 15 min to 45 min.

Questions for fishermen included areas of fish catch, types of fish caught and variations throughout the year, selling points and personal fish preferences. Towards the end of the interview, participants were asked to comment on any potential health risks associated with fish, their knowledge of mercury, and potential implications of this knowledge on fishing and consumption practices. Fish sellers were interviewed about the origin of the fish they sold, differences between freshwater (river) and marine (ocean) fish, most and least popular species, and health and quality differences between river and ocean species. As with fishermen, the last part of the discussion focused on potential health risks associated with fish, the person's knowledge of mercury, and whether she would sell fish she knew came from *galamsey* mining sites. Finally, fish buyers were asked about preferences for purchasing fish, health aspects of ocean vs. river fish, different ways of preparing fish, and again possible linkages between mercury, fish and contamination, and whether buyers would eat fish from *galamsey* sites.

4 Results

Fish in and around Dunkwa comes from the River Offin. The most widely caught species are tilapia, mudfish, and catfish, and also some lobster. No particular pattern was apparent with respect to the seasonality of fish other than the water level in the river being lower during the dry season, which makes it easier to catch fish. As for fishermen along the river, the majority sells their catch to local fish sellers (usually women) and some individual buyers in town. With respect to potential danger and harm in fish, 64% of the interviewed fishermen believe that contamination is in fact an issue that warrants caution. While only one participant (a former miner himself) referred to risks of mercury pollution, all other concerned fishermen condemned dangerous and illegal fishing practices that involve chemical poisoning with DDT and the use of dynamite, both of which facilitate the catch of large quantities within a short period of time. One participant described the dumping of chemicals (cyanide) by large-scale mining operations that can kill fish, but no incident had occurred on the Offin River. As for mercury, not a single fisherman, except the former miner, showed awareness of contamination in fish. While there was a general consensus that mercury was dangerous, it was inconceivable that a small amount in such large quantities of river water would have any effect on fish. In fact, most participants argued that mercury could not enter the fish. To further underscore his argument, one interviewee reported having once eaten fish out of a pan earlier used for mercury burning without feeling any health effects. Finally, most agreed that fishing in areas with dead fish floating in the water should be avoided.

Interviews with fish sellers revealed three interesting findings. First, roughly one-third of all fish sold at the three market towns appears to come from Yeji on Lake Volta whereas 22% are brought in from the Atlantic coast (Takoradi, Tema and Cape Coast), as shown in Figure 2. As explained, freshwater fish from Yeji is now readily available through improved transportation routes through the cities of Kumasi, Accra and

Nkwanta. Tilapia, mudfish and catfish are all widely sold. Only a small portion of the fish sold (13%) originates from the Offin River, which is explained by relatively high levels of subsistence consumption among local fishermen. It should be noted that roughly one-third of the participants was unaware of where their fish came from.

Second, when asked about linkages between fish types and health, the large majority (88%) of all the women fish sellers stated that freshwater fish were healthier than ocean fish. Their main reasons were refrigeration of ocean fish and associated problems as well as higher fat content. At the same time, almost half (44%) of the women reported that the most popular fish were those that came from the ocean. Only 19% said that river fish were the customers' preference, whereas one-fourth said people enjoyed fish from both waters. One seller lamented the dislike of buyers for fish from the Offin River – it is said to stink if not smoked. In contrast, most women agreed that the typical smoking of river fish (rather than freezing it) made it healthier for human consumption. Unhealthy or dangerous fish, by contrast, was feared by 63% of respondents. The most commonly cited health threats were chemical contamination, mainly from DDT, rotten fish due to untimely selling, pollution from refrigeration and ocean trash.

Third, mercury was mentioned by only one seller, although she was unsure about concrete linkages between the element and fish. When probed more directly on the issue of mercury, roughly half of the respondents saw no connection at all, while the other half was confident that smoking the fish or removing its head or insides would minimise any potential health risks, such as diarrhoea. One woman was quite blunt about the good quality of her fish, arguing that she would only sell live fish and not fish already killed by mercury. Most women stated that they would not sell fish from *galamsey* sites, not because of any concrete knowledge about the quality of the fish but rather as a result of the negative image and poor reputation attached to unregistered and hence illegal miners.

Responses from fish buyers reinforced the views of sellers consulted in the three towns. Almost half of all customers bought their fish at local markets and cold stores (shops that have a refrigerator, a freezer, or ice blocks) whereas only 20% claimed they would purchase directly through fishermen. Interviewees believed that less than 60% of their fish comes from Lake Volta, through Yeji and Kumasi. In terms of preferences, there was an equal split between freshwater and marine fish and a combination of both. Most popular fish species were again tilapia, mudfish and catfish, those that are available in large quantity throughout the year at the market. Some stressed their preference for lobster and occasionally knifefish, a specialty freshwater species (*Gymnarchus niloticus*).

With respect to potential health threats, most buyers confirmed the sellers' opinion that freshwater fish was healthier, largely for the same reasons (less DDT, dynamite, petrol, and other chemicals used during harvesting, less refrigeration, shorter transportation and hence less risk of rotting, less fat/oil content). Some also referred to the more diverse eating environment river fish inhabit and the absence of salt, both of which are believed to enhance the health of freshwater fish. Overall, 89% of all buyers believed that both salt- and freshwater fish could be dangerous. Yet, mercury was never mentioned. When probed about mercury, the large majority saw no connection to fish and human health. Others were convinced that mercury would kill fish instantaneously so they would never end up being sold at the market. As the sellers, buyers would not want to purchase fish originating from *galamsey* sites, but only one stated that such fish may cause nothing more than an upset stomach. When in doubt, one customer recommended

smoking and removing insides. Tables 2 and 3 summarise the results on fish, health and mercury from interviewed fishermen, fish sellers and fish buyers.

Table 2 Perceptions of potential danger of fish

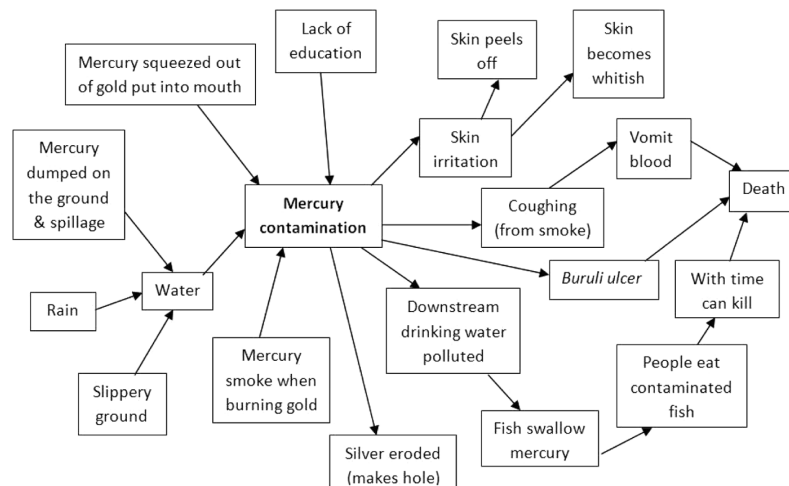
	<i>Fish harmful?</i>	<i>Reasons</i>	<i>Mercury mentioned</i>
Fishermen	64% yes	Chemical contamination (dynamite, DDT)	No
Fish sellers	62% yes	Chemical pollution (DDT, large-scale fishing), bad from refrigeration and salt (ocean fish)	No
Fish buyers	89% yes	Chemical pollution (large-scale fishing), rotten, inside danger, bad because frozen during transport (ocean fish)	No

Table 3 Understanding the linkages between mercury and fish

	<i>Mercury dangerous for fish</i>	<i>Fish consumption and mercury</i>	<i>Explanations</i>
Fisher men	91% no 9% yes (1 former miner)	Ate fish out of Hg pan once and was fine	Quantity of Hg in river too small to affect fish Fish would die instantaneously (cyanide)
Fish sellers	57% no 24% unsure 19% yes	Would purchase fish from <i>galamsey</i> sites: 80% no, 20% unsure	<i>Galamsefers</i> are bad (criminals) Hg can give diarrhoea Never purchase dead fish
Fish buyers	–	Would eat fish contaminated with Hg: 50% yes, 50% no	No danger, only upset stomach, danger removed when fish is smoked

Finally, the understanding of linkages between mercury and fish among *galamsey* miners seems largely dependent on the type of operation, whether it occurs along water bodies or at bedrock sites. The first group of miners, at a hard rock site near Bogoso, made no specific reference to mercury and fish. There, mercury is restricted to processing sites and only used by a small number of designated, usually young men. However, the group claimed that whenever mercury did enter a water body, it would gather at the bottom and by no means dissolve or mix with the water, which would not result in any negative impacts for the environment. By contrast, the owner and his secretary at a booming site directly adjacent to the Offin River had learned about the linkage between mercury and contaminated fish over the radio. As a consequence of an incident with Dunkwa Continental Goldfields, residents downstream of the company's formerly operational site were advised not to drink water from the river but instead carry drinking water from boreholes to the mining sites. The secretary, who had also participated in a mining-health training workshop organised through the Dunkwa District Hospital, explained how mercury in the water gets swallowed by fish. As depicted in Figure 3, he demonstrated clear awareness that the consumption of contaminated fish by people could 'kill with time'.

Figure 3 Mental model of *galamsey* miners near Dunkwa-on-Offin on causes and consequences of mercury contamination, including linkages between fish and human health



Source: Field work 2006

5 Discussion and conclusion

With the exception of small-scale miners, many of whom work with mercury on a daily basis, the findings of this study demonstrate that there is a low level of knowledge among fishermen, fish sellers and buyers about mercury and potential contamination of fish and subsequent health impacts for people. The large majority of participants had significant difficulties envisioning that a toxic element could be taken up through the food chain by fish in the water and simply be passed on to people through the consumption of this fish.

This lack of understanding may be due to empirical parallels people draw to the typically instantaneous impact of other chemical contamination on fish. For instance, most residents in mining areas have either witnessed or heard about cyanide spillages associated with large-scale gold mining. The cyanide process involves the mixing of high-grade ore with cyanide and the spraying of stacks of lower-grade ore with lower concentrations of the leach reagent. It is a fact that leaking or the breaking of cyanide tailing dams result in the release of this highly potent toxin that kills fish and other living fauna within a short period of time (hours). Indeed, pictures of dead fish floating on the surface of local streams have been seen repeatedly on the coverage of local newspapers. Moreover, most people have a clear visual image of DDT or dynamite slaying whole swarms of fish. Hence, they project this knowledge to other contaminants, including mercury. While non-miners do know that mercury is rarely spilled in large quantities, even if the intricacies of small-scale mining are not well understood, they do not believe that mercury could trigger devastating outcomes comparable with those from cyanide or DDT. A few participants argued that even in small amounts, fish would die immediately if mercury was that poisonous. Yet, hardly any interviewees are aware of the long residence time of mercury in sediments and water (decades compared with only hours as in the case of cyanide), and the fact that it accumulates and magnifies through the food web.

There were some exceptions. A few individuals recalled a mining incident from the early 1990s with Dunkwa Continental Goldfields, a large-scale mining company that employed significant amounts of mercury before it stopped being operational in 1999. As a consequence of a spillage incident, the local radio broadcasted an educational programme on mercury, including how to best avoid contaminated water and fish for consumption. Some *galamsey* miners along the Offin River remembered these programmes. One also evoked an outreach programme conducted by doctors and nurses from the Dunkwa Hospital, upon invitation from the Small-Scale Mining Association. To date, it is the Small-Scale District Mining Office, represented in seven mining towns in the country and established through Ghana's Minerals Commission to organise registration, monitor mining activities, and provide technical training that resumes responsibility in terms of mercury-related awareness raising, involving both registered and non-registered miners.

The more significant findings from this study, and this despite its limited scope, concern the actual consumption patterns of potentially contaminated fish. Contrary to initial assumptions, also propagated through the media and public discourse, few fish that may be suspected of pollution are in fact consumed in and around mining sites. As revealed through the interviews, the fish of choice for most customers are ocean fish from the Gulf of Guinea and freshwater fish that originate from Lake Volta. Neither the coast nor Lake Volta encompasses any gold mining; therefore, mercury levels are expected to be low. Both ocean and lake fish are transported via major market towns, such as Kumasi, to the mining areas. As shown by Voegborlo and Akagi (2007), ocean fish along the coast of Ghana has very low mercury values, clearly below the WHO safety standards and, for instance, similar to or below Hg values in marine fish in Indonesia (Castilhos et al., 2006). Potential health threats of lake and ocean fish are more significantly related to side effects from poor refrigeration during and after transportation and, in the case of large-scale marine fishing, contamination from chemical harvesting. Fish caught along streams and ponds in mining areas is used for subsistence consumption among fishermen and sold to local market women. Hence, fish from mining areas constitutes only a relative small fraction (approximately 20–30%) of consumed fish in these very areas.

Furthermore, several direct and indirect strategies are used among fish sellers and buyers, which, whether purposefully or not, reduce potential intake of mercury and other toxic contaminants. First, smoking of fish is widespread in Ghana. In fact, mudfish and catfish are always smoked. Interestingly, given their trophic level and their habitat preference, these two species are also the ones that are most likely to take up mercury through the food web. Tilapia, by contrast, has a clearly lower trophic level and is typically consumed in fresh form, either plain or salted. Donkor et al. (2006b) note that dehydration of fish through smoking, which is the preferred form of preservation, may degrade and reduce exposure to methylmercury. An FAO (2001) study estimates that 70–80% of marine and freshwater fish in Ghana are consumed in smoked form, and both processes of 'wet' and 'dry' hot smoking are performed at temperatures over 80°C. The high temperature kills bacteria and hence prolongs shelf life and allows storage for the lean season.

Second, several participants reported the removal of a fish's inner organs before consumption, especially the liver, which also reduces the actual amount of mercury uptake as MeHg resides primarily in fish muscles and inner organs. The interviews did not reveal whether the removal of inner organs is practised purposely to

reduce health risks, although this is highly possible as an animal's liver is widely known as a filter for contaminants. Third, the large majority of fish buyers eat a mix of tilapia (especially *Tilapia zilli*, a strict herbivore at a low trophic level) and mudfish and catfish (both benthic omnivores occupying higher trophic levels). Again, potential mercury intake is reduced. Fourth, consumers also report to purchase both small and large (often older) fish, which also diminishes risk of contamination. Fifth and finally, when asked about fish recipes, several buyers cited a variety of side dishes they typically prepare with fish. Interestingly, [Hinton et al. \(2003\)](#), in the context of mercury risk communication and cooking training for women at mining sites, recommend such dilution of methylmercury through vegetables.

For reasons of instant comparison, it is worth stressing that mercury levels found in fish in Europe, the USA and Australia are considerably higher than those reported for both marine and freshwater fish in Ghana. For instance, Voegborlo and Akago (2007) refer to mercury levels as high as $1.29 \mu\text{g g}^{-1}$ measured in codfish in the highly contaminated strait between Denmark and Sweden, which is even more elevated than the average for North Sea cod ($0.15\text{--}0.195 \mu\text{g g}^{-1}$). Recent reports from the Western United States revealed levels $>0.3 \mu\text{g g}^{-1}$ (the EPA's tissue-based water quality threshold) in piscivores such as large bass, walleye and northern pike whereas only few herbivores such as rainbow and cutthroat trout exceeded this limit (Science Daily, 2007). In coastal Victoria, Australia, mercury levels in stranded dolphins amounted to $3.45 \mu\text{g g}^{-1}$, which was roughly twice as high as levels in living dolphins (Science Daily, 2008). In both cases, contamination is more likely to stem from atmospheric sources, including distant coal power plants and the burning of fossil fuels, historic gold mines, and current point sources such as mines, dump sites and gravel pits.

This study, although limited in scope, demonstrates that blanket criminalisation of *galamsey* and other small-scale gold miners as reckless polluters of drinking water and other natural resources is not only problematic but also largely unwarranted. While those who directly handle mercury as part of the amalgamation process are more likely to encounter potential harm, mercury contamination in fish in and around mining sites in Ghana appears to be significantly lower than portrayed in local and international media. Alarmist language evoking 'killer toxins' and "threats to women and their fetus", such as in a recent Associated Press paper (January, 2009), may be informative and arguably even essential to provoke a shift to alternative gold extraction techniques. At the same time, it puts an easy blame on an already ostracised target population – marginalised small-scale miners – offering neither substantiating evidence for their actual implication nor practicable and affordable substitutes.

Although knowledge among the general public in Ghana regarding linkages between mercury as a toxin, fish, and human consumption is largely lacking, cooking and eating habits lessen potential health risks. Actual fish intake reflects a combination of smoked and plain fish, alterations of freshwater and marine fish, the removal of inner organs, and blending with side dishes such as vegetables, all of which reduce potential MeHg transfer into the human body. The eagerness to discover more about potential contamination and most effective ways of risk prevention, as witnessed among research participants in this study, indicates a clear need for collective learning activities around human and environmental health in the mining sector. Such activities, designed within an appropriate participatory space, would constitute a welcome alternative, or at least complement, to dominant impact-based assessments that tend to exclude mining communities rather than viewing them as capable and committed research partners.

Acknowledgements

The author gratefully acknowledges the contributions of US students Jennie Karalewich and Jessica Lehman as well as Raymond Tutu and Jones Adjei from the Regional Institute for Population Studies, University of Ghana, who proved invaluable in the data collection process. I want to thank Ray Voegborlo (Kwame Nkrumah University of Science and Technology, Kumasi) for the time he spent sharing his inside on fish and mercury with Jennie. I am grateful for a Faculty Research Grant from the Africana Research Center at the Pennsylvania State University, and the opportunity to share findings at the International Workshop “Small-Scale Gold Mining, Mercury and Environmental Health: Challenges and Ways Forward in Rural Ghana”, funded by the Royal Society and held at the University of Reading in March 2008.

References

- Adimado, A.A. and Baah, D.A. (2002) ‘Mercury in human blood, urine, hair, nail, and fish from the Ankobra and Tano River Basins in Southwestern Ghana’, *Bull. Environ. Contam. Toxic.*, Vol. 68, pp.339–346.
- Amegbey, N.A. and Eshun, P.A. (2003) ‘Mercury use and occupational exposure in the Ghanaian small-scale gold mining industry’, *Ghana Mining Journal*, Vol. 7, pp.54–61.
- Amin-Sackey, C. (1997) *Water Pollution and Small Scale Mining Activities in the Prestea Area*, Master’s Thesis, Kwame Nkrumah University of Science and Technology, Ghana.
- Anku, W.W. (2007) *Assessment of Total Mercury Concentrations in Fish and Sediments from River Ankobra and Its Major Tributaries*, Master’s Thesis, Kwame Nkrumah University of Science and Technology, Ghana.
- Associated Press (2009) *Mercury in Gold Mining Poses Toxic Threat: Substance Used in Developing Nations Threatens Miners*, *Environment*, 10 January, Obtained through the internet: <http://www.msnbc.msn.com/id/28596948/from/ET/> [accessed 24/7/2009].
- Babut, M., Sekyi, R., Potin-Gautier, M., Tellier, S., Bannerman, W., Casellas, C. and Rambaud, R. (2001) *US/GHA/99/128 – Assistance in Assessing and Reducing Mercury Pollution Emanating from Artisanal Gold Mining in Ghana – Phase I: Part II – Conduct of Surveys on River Systems and Overall Conclusions*, UNIDO.
- Bannerman, W., Potin-Gautier, M., Amoureux, D., Tellier, S., Rambaud, A., Babut, M., Adimado, A. and Beinhoff, C. (2003) ‘Mercury and arsenic in the gold mining regions of the ankobra river basin in Ghana’, *J. Phys. IV France*, Vol. 107, DOI: 10.1051/jp4:20030255.
- Castilhos, Z.C., Rodrigues-Filho, S., Rodrigues, A.P., Villas-Bôas, R.C., Siegel, S., Veiga, M.M. and Beinhoff, C. (2006) ‘Mercury contamination in fish from gold mining areas in Indonesia and human health risk assessment’, *Science of the Total Environment*, Vol. 369, pp.320–325.
- Darabor, G.A.S. and Momade, F.W.Y. (2002) *Quality of Water Resources in the Southern Parts of the Ashanti Gold Belt*, Master’s Thesis, IMME, KNUST, Kumasi, Ghana.
- Donkor, A.K., Bonzongo, J.C., Nartey, V.K. and Adothey, D.K. (2006b) ‘Mercury in different environmental compartments of the Pra River’, *Society and the Total Environment*, Vol. 368, pp.164–176.
- Donkor, A.K., Nartey, V.K., Bonzongo, J.C. and Adothey, D.K. (2006a) ‘Artisanal mining of gold with mercury in Ghana’, *West Africa Journal of Applied Ecology*, Vol. 9, January–July, Paper 2, pp.1–8.

- Durrieu, G., Maury-Brachet, R. and Boudou, A. (2005) 'Goldmining and mercury contamination of the piscivorous fish *Hoplias aimara* in French Guiana (Amazon basin)', *Ecotoxicology and Environmental Safety*, Vol. 60, pp.315–323.
- Eisler, R. (2003) 'Health risks of gold miners: a synoptic review', *Environmental Geochemistry and Health*, Vol. 25, pp.325–345.
- FAO (Ed.) (2001) 'Improved fish smoking: Ghana', *Sharing Innovative Experiences, Examples of Successful Initiatives in Agriculture and Rural Development in the South*, Vol. 5, Food and Agricultural Organization (FAO), Rome, Italy, pp.240–254.
- Gammons, C.H., Slotton, D.G., Gerbrandt, B., Weight, W., Young, C.A., McNearny, R.L., Cámac, E., Calderón, R. and Tapia, H. (2006) 'Mercury concentrations of fish, river water, and sediment in the Río Ramis-Lake Titicaca watershed, Peru', *Science of the Total Environment*, Vol. 368, pp.637–648.
- Golow, A.A. and Adzei, E.A. (2002) 'Mercury in surface soil and cassava crop near an alluvial goldmine at Dunkwa-on-Offin, Ghana', *Bull. Environ. Contam. Toxicol.*, Vol. 69, pp.228–235.
- Golow, A.A. and Mingle, L.C. (2003) 'Mercury in river water and sediments in Some Rivers near Dunkwa-on-Offin, and alluvial goldmine, Ghana', *Bull. Environ. Contam. Toxicol.*, Vol. 70, pp.379–384.
- Hilson, G. (2006) 'Abatement of mercury pollution in the small-scale gold mining industry: restructuring the policy and research agendas', *Science of the Total Environment*, Vol. 362, pp.1–14.
- Hilson, G. and Pardie, S. (2006) 'Mercury: an agent of poverty in Ghana's small-scale gold-mining sector?', *Resources Policy*, Vol. 31, pp.106–116.
- Hilson, G., Hilson, C.J. and Pardie, S. (2007) 'Improving awareness of mercury pollution in small-scale gold mining communities: challenges and ways forward in rural Ghana', *Environmental Research*, Vol. 103, No. 2, pp.275–287.
- Hinton, J.J., Veiga, M.M. and Beinhoff, C. (2003) 'Women, mercury and artisanal gold mining: risk communication and mitigation', *J. Phys. IV France*, Vol. 107, pp.617–620.
- Kuma, J.S. (2004) 'Is groundwater in the Tarkwa gold mining district of Ghana potable?', *Environmental Geology*, Vol. 45, pp.391–400.
- Kuwabara, J.S., Arai, Y., Topping, B.R., Pickering, I.J. and George, G.N. (2007) 'Mercury speciation in piscivorous fish from mining-impacted reservoirs', *Environmental Science and Technology*, Vol. 41, No. 8, pp.2745–2749.
- Opong, S. (2006) *Total Mercury Levels in Fish, Sediments, and Soil Samples from the Pra River Basin*, Master's Thesis, Kwame Nkrumah University of Science and Technology, Ghana.
- Rambaud, A., Casellas, C., Sackey, O.S., Ankrah, N-A., Potin-Gautier, M., Tellier, S., Bannerman, W. and Babut, M. (2000) *US/GHA/99/128 – Assistance in Assessing and Reducing Mercury Pollution Emanating from Artisanal Gold Mining in Ghana – Phase I: Part I – General Introduction and Assessment of Human Health*, UNIDO, Vienna.
- Science Daily (2007) *Mercury Prevalent in Many Western Fish, Study Finds*, Oregon State University (25 January, 2007), Obtained through the internet: <http://www.sciencedaily.com/releases/2007/01/070123143248.htm> [accessed 24/7/2009].
- Science Daily (2008) *Mercury Contamination Found in Stranded Victorian Dolphins*, Monash University (11 June 2008), Obtained through the internet: <http://www.sciencedaily.com/releases/2008/06/080610092720.htm> [accessed 24/7/2009].
- Taylor, H., Appleton, J.D., Lister, R., Smith, B., Chitamweba, D., Mkumbo, O., Machiwa, J.F., Tesha, A.L. and Beinhoff, C. (2005) 'Environmental assessment of mercury contamination from the Rwamagasa artisanal gold mining centre, Geita District, Tanzania', *Science of the Total Environment*, Vol. 343, pp.111–133.
- Tschakert, P. and Singha, K. (2007) 'Contaminated identities: Mercury and marginalization in Ghana's artisanal mining sector', *Geoforum*, Vol. 38, pp.1304–1321.

Voegborlo (2007) Interview conducted by J. Karalewich, Kumasi, July 2007.

Voegborlo, R. and Akagi, H. (2007) 'Determination of mercury in fish by cold vapour atomic absorption spectrometry using an automatic mercury analyser', *Food Chemistry*, Vol. 100, pp.853–858.

WHO (2004) *World Health Organization, Mercury and Drinking Water*, Obtained through the internet: http://www.who.int/water_sanitation_health/dwq/chemicals/mercuryfinal.pdf [accessed 24/07/2009].