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Bioaccessibility and Bioavailability of Mercury from Fish - A Narrative Review: Implications for Gold Mining Communities in Guyana

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ABSTRACT

Extractive methods for small-scale gold mining in Guyana can be potentially dangerous to human health and the environment due to the application of mercury. The harmful effects on humans include seizures, memory loss, tremors, and double vision. Gold is an economically important commodity in Guyana, accounting for 19.7% of exports, surpassed only by oil and gas (crude oil) in 2021. Most gold deposits in Guyana are in indigenous communities where mining operations are conducted near or in stream courses. Members of these communities depend on fish as their primary source of protein, obtaining their catch in the vicinity of the mining operations. This narrative review examined data on the presence of mercury in fish and explores the literature on the bioaccessibility and bioavailability of mercury from fish. The results show that mercury bioaccessibility in raw fish ranged from 106% in salmon to 10% in sardine and 100% in cod to 9.8% for methylmercury. The few studies on bioavailability indicate the potential for almost all the mercury (99%) to be released from the matrix into the intestinal lumen to be absorbed into the systemic circulation. Results also indicate that risk-mitigating strategies may include common culinary methods and changes to the diet by including phenolic compounds and fiber. As the Government of Guyana makes efforts to reduce mercury in mining in the long term, it is essential to focus on protecting the health of those directly impacted by current mining operations.

1. Introduction

Gold discoveries in Guyana were first made known in the seventeenth century. However, mining began in earnest in the latter part of the nineteenth century when deposits were discovered in sufficient quantities to make prospecting potentially profitable. This, together with changes in land ownership policy, led to mass migration from the sugar industry to gold, an event referred to as the “gold rush” (Moohr 1975). Gold is now among the pillars of Guyana's economy, contributing between 11.7% to 5.9% to the country's GDP and annually added between 109,057 to 56,950 (G$million) to Guyana’s treasury from 2012 to 2021 (Guyana Bureau of Statistics, 2022). The mining industry in Guyana is made up of mainly artisanal small miners (ASM) regulated by the Guyana Geology and Mines Commission (GGMC) (Clifford 2011). Mining operations release significant amounts of mercury into the environment by burning to clear the forest and the gold extraction method. Mercury pollutes the soil, water, and air. It is toxic to humans, and the principal exposure to this metal is through the consumption of fish and shellfish (World Health Organization 2021). Through ingestion and subsequent metabolic activities, the contaminant becomes bioaccessible when released from the matrix in the small intestine and bioavailable by circulation in the blood.

The common method of gold extraction is hydraulicking, which removes alluvial and colluvial material that contains the gold particles. The gold is then separated and amalgamated with mercury. These operations are usually done near the waterways and, if not conducted carefully, can lead to mercury discharge into the lakes, rivers, and streams with severe consequences. Among the dangers is the bioaccumulation in the food web, eventually concentrating in fish, especially in long-lived predatory species, such as sharks and swordfish. In their simulation, Dominique et al. (2007) demonstrated the potential for significant concentrations of mercury in sediments in waterways coming from gold mining operations and the consequential presence of methylmercury in the organs of fish.

This paper aims to review the bioaccessibility and bioavailability of mercury from fish to determine the risk mining communities face. Even more, the article intends to examine the implications of consuming a diet with fish as the primary protein source and explore solutions. This narrative review follows the guidelines provided by Gregory and Denniss (2018). To achieve the objective, we scope the literature using the criteria as any scientific article on bioaccessibility and bioavailability of mercury in fish that impact humans, written in English regardless of publication date.

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Articles were electronically retrieved from the University of Guyana databases PubMed and SCOPUS. An initial search was conducted using PubMed with search terms "bioaccessibility OR bioavailability" AND “mercury OR methylmercury” AND fish, 264 articles were found. This search was refined using the terms bioaccessibility AND “mercury or methylmercury” AND fish in Scopus and PubMed, where 51 and 41 articles were located, respectively. Further searches were conducted using the terms bioavailability AND “mercury or methylmercury” AND fish AND digestion, where 32 and 17 articles were obtained, respectively. In addition, four articles were retrieved with the terms “mercury or methylmercury” AND fish AND Guyana. All abstracts were read, and only those articles that met the inclusion criteria were selected. After eliminating articles not directly related to the study and duplicates, 38 articles were selected and read in their entirety. Information was also sourced from international public health agencies, such as the World Health Organization (WHO) and local news websites. The impact of mercury on human health is well documented, and therefore, it was decided to focus on the main effects. Three articles were published before 2000, but most of the other articles were from 2010 onward.

1.1. Mercury levels of fish in Guyana

Mercury exists in various forms, mainly as elemental mercury, inorganic mercury compounds, and organic mercury. Elemental mercury is liquid at room temperature and can easily volatilize into the atmosphere. Inorganic mercury exists as mercurous Hg+ and mercuric Hg2+. Methyl mercury and ethyl mercury are common organic forms combined with carbon. Humans are exposed to elemental and inorganic mercury through their occupation and to organic mercury in their diet. Exposure to methylmercury is mainly by the consumption of fish and shellfish (Park and Zheng 2012; World Health Organization 2017).

Most of Guyana’s gold mining operations are located away from the main city in six mining districts: Berbice Mining District 1, Potaro Mining District 2, Mazaruni Mining District 3, Cuyuni Mining District 4, Northwest Mining District 5, and Rupununi Mining District 6 (Howard et al. 2011). These areas are populated by indigenous communities that rely on fish caught from their waterways as their primary protein source (Hays and Vieira 2005b). A study done at a mining site operated by ASM in the Mazaruni River demonstrated higher concentrations of total mercury in fish compared to a non-mined area. In addition, there was evidence of biomagnification with the higher tropic level consisting of carnivores, piscivores, and herbivores, which are usually consumed by the residents, with higher concentrations of total mercury (Montaña et al. 2021). Similarly, in neighboring Brazil, sedentary piscivorous fish Cichla spp. from three rivers (Negro, Madeira, Tapajós) and two hydroelectric reservoirs (Balbina, Tucuruı') showed that the total mercury and methyl methylmercury concentrations ranged from 0.05 to 1.57 µg/g w.w. and 0.04 to 1.43 µg/g respectively within the Amazon. Relatively high levels of methylmercury and mercury were observed in fish where there is gold mining and deforestation activities compared to other areas (Kehrig, Howard, and Malm 2008).

1.2. Mercury levels in humans from fish consumption

Consumption of contaminated fish eventually leads to elevated mercury levels in humans' blood and tissues. A study involving three groups of individuals showed a significant relationship between fish consumption and total mercury and organic mercury in the blood. There were also positive relationships between total hair mercury and seafood consumption, total hair mercury and blood organic mercury, and total hair mercury and urinary mercury (Carla et al. 2002). Analysis of urine, blood, and hair are the common biomarkers to determine the presence of mercury in the human body. About 90% of the mercury in red blood cells is methylmercury. Total mercury in the red blood cells and hair are suitable proxies for methylmercury exposure. Studies relating mercury contamination to fish consumption have focused on the analysis of hair since it is a good biomarker for internal exposure (Berglund et al. 2005; Branco et al. 2017).

In the Guiana Shield, there is evidence of mercury contamination in residents, especially in areas associated with mining. In Guyana, a study involving residents of seventeen communities in four geographical areas with varied distances from mines demonstrated that residents closest to the mines and who consumed local fish daily had the highest levels of mercury in their hair. The total mercury concentration ranged from 0.87 µg/g to 50 µg/g with a mean of 9.84 µg/g, with the area closest to the mine having a mean of 27.62 µg/g while the area furthest had a mean of 2.74 µg/g (Watson et al. 2020). In a native Amerindian community in French Guiana, more than 57% of the population in the Wayana community had total mercury levels above the normal limits of 10µg/g. There was a positive correlation between mercury concentrations in hair and fish consumption, especially carnivorous fish (Fréry et al. 2001). Similarly, residents of Tapajós River, a major tributary of the Amazon in Brazil, had an average concentration of organic mercury in the blood (33.6 ± 19.4 µg/l) that was significantly higher than inorganic mercury (5.0 ± 2.6 µg/l) and there was a high correlation between blood inorganic mercury with consumption of carnivorous fish. The mercury in urine and fish consumption patterns were also positively related. Interestingly, there was a higher percentage of blood inorganic mercury in older participants, suggesting increased rates of inorganic mercury accumulation with time (Passos et al. 2007). An earlier study in Brazil in the Tucurui water reservoir, an area associated with gold mining, also demonstrated a positive correlation between mercury in the hair and consumption of predatory fish (Leino and Lodenius 1995).

These relationships were further confirmed in other studies. In Sweden, a study including alveolar air demonstrated that mercury concentration was 2.6 times higher in consumers with high consumption of predatory freshwater fish than in the low-consuming group. Regarding mercury in the blood and hair, it was nine-fold and seven-fold higher, respectively, in the high-consuming group. The mercury content in the hair of the low-consuming group mirrored that of a sample of the Swedish population. The inorganic mercury content in urine was 15-fold higher than the low consumption group. The inorganic mercury content in fish is relatively low, therefore, it was suggested that there was demethylation of mercury and accumulation of inorganic mercury in the kidneys and urine (Johnsson, Schütz, and Sällsten 2005).

2. Bioaccessibility and bioavailablity of mercury from fish

The extent to which chemical compounds can cause effects in humans depends not only on how much is ingested but also on how much is absorbed by the body. Only a fraction of the amount ingested will reach the blood, organs, and tissues. Bioavailability is the proportion and rate at which an ingested contaminant reaches the systemic circulation. A component of this is bioaccessibility, which is the release of compounds from the food matrix in the small intestine and represents the maximum concentration available for absorption (Versantvoort et al. 2005; Schümann and Elsenhans 2002). Kwaśniak, Falkowska, and Kwaśniak (2012) determined that bioaccessibility is an important factor in determining the risk of mercury exposure from fish.

Food with contaminants passes through the gastrointestinal tract and is subjected to physical and chemical processing to form simpler digestive components. These include mechanical actions such as mastication in the mouth, peristalsis in the esophagus, and churning of the food in the stomach and small intestine. Chemical actions of enzymes at appropriate pH facilitate the breakdown of the macronutrients, proteins, fats, and carbohydrates. The predominant macronutrient in fish is protein. It is digested in the stomach by pepsin that acts on the internal peptide bonds of proteins and in the small intestine where the endopeptidases trypsin, chymotrypsin, and elastase hydrolyze internal peptide bonds of proteins, while the exopeptidases, carboxypeptidases, hydrolyze terminal peptide bonds on proteins. Dipeptidases from the duodenum cleave the peptide bond in dipeptides (Ng et al., 2015; Justin and Amit, 2023). The methylmercury in the blood is usually bound to protein thiol, a modification that is termed S-mercuration (Kanda, Shinkai, and Kumagai 2014). Almost all proteins are hydrolyzed and released in the bioaccessible fraction, but a slightly higher percentage for the raw than the cooked (Afonso, Costa, Cardoso, Bandarra, et al. 2015; S. Costa et al. 2015). The action of the proteases releases the mercury contaminants from the matrix into the gastrointestinal tract, and they become available for absorption from the small intestine, followed by metabolism (Brandon et al. 2006; De Angelis et al. 2014).

Bioaccessibility of mercury in fish is dependent on the source and type of fish and is also influenced by the chemical form of mercury. Using ten (10) types of fish commonly consumed in North America, it was determined that the mean bioaccessibility of methyl mercury was 50.1 ± 19.2%, with the lowest observed in canned tuna (48.4%) and the highest in shrimp and scallops at 100%. In Spain, a study on sixteen species of fish and shellfish with high domestic consumption showed that fresh swordfish had the highest mercury concentration (1621 ± 101 ng/g ww). Salmon, however, had the highest bioaccessibility of mercury at 106%. The species with the lowest concentration of mercury and lowest bioaccessibility were frozen shrimp (3.8 ± 0.1 ng/g ww) and sardine (35%), respectively. Overall, the median mercury concentration in fish (48 ng/g ww) was higher than in shellfish (11 ng/g ww). The median bioaccessibility was somewhat similar for fish at 68%, and that for shellfish was 65% (Calatayud et al. 2012). Observations in another type of shellfish, crayfish, showed much lower methylmercury bioaccessibility in cooked and raw crayfish of 7.8 ± 3.9% and 9.8 ± 0.8%, respectively. Methylmercury binding to the amino acid cysteine in crayfish may account for the lower bioaccessibility (Peng et al. 2017).

Torres-Escribano et al. (2010), in their assessment of bioaccessibility, focused on the muscle of frozen swordfish, a predatory species. The total mercury concentration ranged from 0.41 to 2.1 mg kg-1, with 37% of the samples exceeding the maximum limit of 1 µg/kg ww for mercury in swordfish in Spain (Commission of the European Union 2006). There was a wide range for bioaccessibility of total mercury from 38% to 83% with a mean of 64% ± 14%. The researchers further estimated methylmercury bioaccessibility to be between 71% to 105%. Swordfish was included in another study that involved ten species. The highest concentration of mercury (0.866 mg kg-1) and methylmercury (0.623 mg kg-1) was observed in grilled swordfish. This was followed by tuna with mercury and methylmercury concentrations at 0.185 mg kg-1 and 0.142 mg kg-1, respectively. However, the highest mercury and methylmercury bioaccessibility were observed in cuttlefish (77%) and tuna (77%), respectively (Cano-Sancho et al. 2015). While bioaccessibility appears to be independent of mercury concentration, in other studies, there seems to be a negative correlation where there was low bioaccessibility of mercury from fish with high concentrations of the metal (Cabañero, Madrid, and Cámara 2004; Laird and Chan 2013).

Human exposure to mercury and methylmercury will depend on the concentrations that reach the systemic circulation. Although few studies investigate bioavailability, it is suggested that mercury in seafood is less than 100% bioavailable in humans (Bradley, Barst, and Basu 2017). Siedlikowski et al. (2016), in their analysis using Caco-2 cells, observed that bioavailability ranged from 67.5% in salmon to 29.3% in crab, and generally, bioavailability was lower than bioaccessibility. On the other hand, Li and Wang (2019) found that bioaccessibility was lower than bioavailability. They used different fish species and tested with mice since they have a digestive system like humans. They found that short-term bioavailability of mercury (7 days) ranged from 82.5% to 95.7%, with a positive relationship indicating that bioavailability depended on mercury concentration. The long-term bioavailability of total mercury was between 38% to 99% and decreased as mercury concentration increased. More mercury was detected in the liver and kidney for both durations studied than in the blood.

3. Mitigation strategies for reduction of bioaccessibility and bioavailability of mercury

Common culinary methods applied to process fish impact the bioaccessibility of mercury. Using five freshwater fish species - Lake Whitefish (Coregonus clupeaformis), Lake Trout (Salvelinus namaycush), Northern Pike (Esox lucius), Walleye (Sander vitreus), and Burbot (Lota lota) - gathered from the Northwest Territories (NWT), Canada, it was observed that bioaccessibility was higher in the raw than the cooked fish. The bioaccessibility range for raw and cooked fish was between 73% to 86% and 31% to 46%, respectively. Although the mercury concentration was higher in the cooked fish in this study, it was suggested that the water loss may have accounted for the increased concentration (Packull-McCormick et al. 2023). Torres-Escribano et al. (2011) focused on four predatory species that usually have high methylmercury concentrations. Swordfish had the highest concentration of mercury (1.30 ± 0.09 µg/g ww) and highest bioaccessibility (89%). The concentration of mercury increased in the cooked fish, but bioaccessibility decreased in all four species. When farm-raised meagre (Argyrosomus regius) was subjected to three processing methods - boiling, roasting, and grilling - the bioaccessibility of mercury and methylmercury was lowest in the grilled fish followed by roasting; then raw and boiled that had similar levels (Afonso, Costa, Cardoso, Bandarra, et al. 2015). Similar results were obtained where boiled gilthead seabream (Sparus aurata) had higher bioaccessibility of mercury (52%) compared to grilled and roasted, with similar results of 38-39%. The trend was the same for methylmercury (Afonso et al. 2018). In another study, grilled tuna also had low bioaccessibility of mercury and methylmercury (both 78%) compared to boiled and raw, it was the canned tuna in oil that had the lowest bioaccessibility of mercury and methylmercury (both 18%) (Afonso, Costa, Cardoso, Oliveira, et al. 2015). Grilled and steamed blue shark (Prionace glauca) also had much lower mercury and methylmercury bioaccessibility than the raw fish (Matos et al. 2015). These results differ from another study where the bioaccessibility of grilled black scabbard fish (42%) was not that much lower than the uncooked (45%). In that study, the fried scabbard had the lowest bioaccessibility of 24%. In general, it was determined that frying resulted in much lower bioaccessibility than other methods, such as boiling, steaming, baking, and grilling, with the raw fish displaying the highest percentage (Costa et al. 2022; Liao et al. 2020). Fish preparation with ingredients such as onion, tomato, broccoli, garlic, and potato also contribute to lowering bioaccessibility (Marmelo et al. 2020; Milea et al. 2023).

Differences in species, digestion model used, such as enzyme concentrations and activity, are among the reasons for variation in the results of the bioaccessibility studies (Maulvault et al. 2011; Alves et al. 2018). Generally, the application of processing methods with thermal treatment results in lower bioaccessibility. Plausible reasons include those denatured proteins are not accessible to enzymatic degradation, allowing for the release of mercury, and the oil used in frying and baking may form a surface layer around the tissue, thereby preventing digestion. Determination of the risk involved in the consumption of fish is complex, requiring the inclusion of significant variables such as bioaccessibility, access to local foods, and consumption rate (Charette et al. 2021).

Other strategies can mitigate the risk of mercury exposure. Fish consumption with added dietary compounds reduced the bioaccessibility and bioavailability of mercury and methylmercury (Table 1). It was suggested that the phytochemicals in green tea, black tea, and coffee chelate with mercury to form insoluble complexes. In addition, water-insoluble dietary fiber in wheat bran, oat bran, and psyllium can bind to mercury, thus decreasing its concentration and bioaccessibility (Shim et al. 2009; Ou et al. 1999). Reduction observed with the cassava pulp, composed of modified dietary fiber (MDF) may also be the result of binding or changes in the fish matrix (Kachenpukdee et al. 2016). Neutral detergent fiber (NDF) formed by enzymatic reactions on MDF reduced bioaccessibility and bioavailability mainly by inhibiting mercury transfer (Kachenpukdee et al. 2016). A study conducted in a village located along the Amazon River, where previous research indicated high levels of mercury in residents due to fish consumption, demonstrated that eating at least one fruit per day reduced mercury levels in hair. This observation is likely due to fibers and phytochemicals in the fruit (Passos et al. 2003).

Table 1 – Mitigating strategies for the bioaccessibility and bioavailability of mercury from fish

Food Component	Matrix	Results	Reference
Green tea	Nineteen fish samples (7 species)	Without green tea, bioaccessibility of THg 35% to 53%; With green tea 21% to 30% MeHg 21% to 67% bioaccessibility	Anacleto et al. 2020
Tannic acid	Swordfish Tuna	Low and high conc. decreased Hg bioaccessibility respectively – 68% and 84% Low and high conc. decreased Hg bioaccessibility respectively – 47% and 73%	Jadán Piedra et al. 2016
Lignin	Swordfish Tuna	Low and high conc. decreased Hg bioaccessibility respectively – 68% and 82% Low and high conc. decreased Hg bioaccessibility respectively – 86% and 95%	Jadán Piedra et al. 2016
Pectin	Swordfish Tuna	Low and high conc. decreased Hg bioaccessibility respectively – 55% and 72% Low and high conc. decreased Hg bioaccessibility respectively – 30% and 66%	Jadán Piedra et al. 2016
Cassava pulp (modified dietary fiber)	Swordfish	Decreased bioaccessibility range - 35% to 85%. Bioavailability is reduced and dependent on the concentration of mercury	Kachenpukdee et al. 2016
Green tea and black tea	Three species (Tuna, shark, mackerel)	Shark and mackerel, mercury bioaccessibility reduction ranged from 10% to 60%; Tuna – 35%	Ouédraogo and Amyot 2011
Green tea, black tea, coffee	Swordfish and tuna	Swordfish - 75% reduction with 120 mg green tea; Tuna - 60% reduction with 120 mg green tea; Swordfish – 60% reduction with coffee	Girard et al. 2018
Coffee	Three species (Tuna, shark, mackerel)	50% reduction	Ouédraogo and Amyot 2011

Food Component	Matrix	Results	Reference
Corn Starch	Three species (Tuna, shark, mackerel)	No significant reduction Tuna – 20%	Ouédraogo and Amyot 2011
Selenium	Three species (Tuna, shark, mackerel)	Shark and mackerel, mercury bioaccessibility reduction ranged from 10% to 60%; Tuna – 35%	Ouédraogo and Amyot 2011
Oat bran	Mackerel	Decreased mercury bioaccessibility by 59% – 75%	Shim et al. 2009
Wheat bran	Mackerel	Decreased mercury bioaccessibility by 84%	Shim et al. 2009
Psyllium	Mackerel	Decreased mercury bioaccessibility by 15% - 31%.	Shim et al. 2009
Soy protein	Mackerel	Decreased mercury bioaccessibility by 44% - 87%	Shim et al. 2009

Selenium forms a complex with mercury resulting in reduction in bioaccessibility in the latter when both are present (Cabañero et al., 2007; Ouédraogo and Amyot 2011). Of the 28 compounds analyzed by Jadán-Piedra et al. (2016), the cellulose compounds - tannic acid, lignin, and pectin - were effective in reducing bioaccessibility. These compounds reduce the Hg and CH3Hg soluble fraction during digestion, thus reducing the quantity available for absorption by more than 75%. Tannic acid is also among food ingredients that reduce bioavailability. Others capable of reducing bioavailability include those that form complexes with low solubility, such as quercetin, those with high antioxidant capacity, or compounds with affinity for thiol groups, such as homocysteine and cysteine (Jadán-Piedra, Vélez, and Devesa 2018).

4. The effects of mercury in humans

Mercury is a pollutant that can have a range of adverse effects on humans. These effects may vary by several factors, including age, geographical location, chemical form, and exposure route. The harmful effect of mercury was discovered in Minamata, Japan, in the 1950s, where residents experienced severe neurological symptoms with some deaths following the consumption of fish from waterways where mercury had been discharged from a nearby industry (Hachiya 2006; Grandjean et al. 2010). The severity of the disease led to global discussions and the formation of the Minamata Convention, an international treaty that seeks to protect human health and the environment from anthropogenic (caused by humans) emissions and releases of mercury and mercury compounds (United Nations Environment Programme 2023). Because of the potentially severe harmful effects to humans, JECFA, the CONTAM Panel established a tolerable weekly intake (TWI) for inorganic mercury of 4 µg/kg b.w., expressed as mercury and TWI for methylmercury of 1.3 µg/kg b.w., expressed as mercury (European Food Safety Authority 2012).

High concentration of mercury in the diet is a public health risk. Sheehan et al. (2014) indicated that among the categories of greatest health concern for methylmercury biomarkers were children and women living near tropical small-scale gold mining sites that depend on locally caught freshwater fish as part of their diet. Methylmercury easily passes the blood-brain barrier, leading to higher levels of mercury in the brain. It was demonstrated that in a fish-eating population, methylmercury in the diet has a marked impact on total mercury in the brain (Harris et al. 2003; Björkman et al. 2007). There is a positive correlation between mercury levels in children residing near artisanal and small-scale gold mining and the prevalence of neurotoxic symptoms such as neurologic impairment, tremors, and loss of memory (Sharma et al. 2019). Evidence of this is the association between high levels of mercury in hair and lower cognitive development in children living near an artisanal gold mine in the Peruvian Amazon (Reuben et al. 2020).

Hu et al. (2018), in their review, observed that although the association between low to moderate mercury concentrations and blood pressure was inconclusive, there is a positive association between high mercury exposure and systolic blood pressure and diastolic blood pressure. Afrifa et al. (2019), in their discussion on the impact of mercury on artisanal small-scale gold miners, illustrated the multiplicity of effects, for example, the kidney where it causes tubular dysfunction, reduction in thyroid hormone function, genotoxicity, and immunotoxicity.

The effect of mercury on cardiovascular disease appears to be dependent on the duration of exposure. Hu et al. (2021), in their meta-analysis, observed that cardiovascular disease risk increases when the mercury concentration in hair exceeds 2µg/g. Mice studies showed that long-term exposure to methyl mercury causes dyslipidemia and hypercholesterolemia, indicators of cardiovascular disease. In this study, locomotor impairment was evident after 21 days of exposure to methylmercury (Moreira et al. 2012). Impairment is dependent on the dose and duration of exposure to methylmercury (Dietrich et al. 2005).

In Guyana, there has not been any comprehensive study to determine and document the effect of mercury on human health. The evidence is mainly anecdotal. For example, one report described a miner who almost lost his sight, and had uncontrollable tremors among other symptoms of mercury poisoning (Ebus and Sutherland 2020). Results of tests from one mining company indicated that from 2020 to 2023, almost one-fifth (19.1%, n=128) of those evaluated had mercury levels ≥ 10 mcg/L (Eureka Medical Laboratories Inc.). This evidence, therefore, suggests the urgency of conducting studies to determine the extent of the effect of mercury poisoning on miners and residents in communities in the vicinity of mines.

5. Implications for the gold mining communities

The livelihood of residents of mining communities is dependent on rivers and lakes for transport, domestic activities, commerce, and as their food source. Guyana ratified the Minamata Convention in September 2014, and the date of the force of entry was 2017. In doing so, the country committed to phase out the use of mercury in all operations where the metal is used (UNEP 2021). However, there is still no viable alternative to mercury use in ASGM (Stabroek News 2022). Hence, it is important to examine strategies to limit the exposure of residents in the communities. These include awareness as well as technical solutions.

From the literature, it appears that residents of mining communities are likely to be exposed to harmful levels of mercury in fish used as part of their daily diet. The common fish used are at the top of the food web, where mercury is bioaccumulated (Montaña et al. 2021). Hence there should be concerns about mercury, especially since there is higher bioaccessibility in carnivorous fish at the higher trophic level than herbivorous and omnivorous fish (He and Wang 2011). Information gathered from the studies shows that mercury was bioaccessible and bioavailable, given its presence in the blood, urine, and hair. Bioaccessibility was as high as 100% in raw fish and lower in processed fish. Interventions with the community should suggest the consumption of other types of fish, decrease the frequency of fish in their diet, or increase the consumption of alternative protein sources. Further, residents may be advised that grilling and frying are the best cooking methods to reduce mercury in fish. The inclusion of phytochemicals and fiber also has the potential to reduce the bioaccessibility of mercury in fish. The communities may not have access to the teas that have been proven to reduce bioaccessibility. However, residents of mining communities may use plant/plant parts with phytochemicals as part of their culture, which can decrease bioaccessibility. This is a potential area of research. Cassava is an integral component of the diet in Indigenous communities. Therefore, another suggestion for exploration is to determine the extent to which cassava and its products can reduce the bioaccessibility of mercury in fish.

Efforts to build awareness should not be sporadic but continuous, with structured schedules through training programs and other forms of networking. Brown et al. (2020) reported on a training program conducted in Guyana involving participants from government, academia, non-governmental organizations, and miners' organizations discussing the presence of mercury in the environment, the global mercury cycle, and the health effects of mercury and hands-on practical session measuring mercury in the environment and safety strategies. As recently as January 2023, there was a conference to discuss responsible mining in Guyana for equipment suppliers, members of mining associations, and other stakeholders (planetGOLD 2023). In addition, there are other initiatives, including a booklet on ‘Equipment for Responsible Mining’ and a pamphlet, ‘Mercury Nah Easy’ that illustrates the effects of mercury on human health produced by collaborators Planet Gold Guyana, Global Environment Facility (GEF), UN Environment Programme (UNEP), Conservation International - Guyana, and Norwegian Agency for Development Cooperation (NORAD).

Given the likely contamination by mercury in fish and other mechanisms of exposure, there should be adequate healthcare facilities available to miners and community residents. However, mining communities are usually located in areas that have limited infrastructure and personnel to provide specialist and decent quality health care. Despite this, minimal service should be available to respond to emergencies and provide basic treatments. The healthcare sites should endeavor to be a hub for information on mercury and a place for regular testing, particularly for miners and at-risk residents, such as women of childbearing age. There is also a need for short-term and long-term studies on the effect of mercury on the health of miners and residents of mining communities.

4. Conclusion

This review highlighted the issue of mercury contamination resulting from mining. Studies in Guyana indicate the presence of high mercury concentrations in predatory fish, which was also highlighted in other studies. These fish are frequently consumed by indigenous residents in mining communities. As revealed by this review, mercury from the fish becomes bioaccessible and bioavailable, thereby reaching the systemic circulation. The evidence of this is the presence of mercury in human hair. Even more, there is the potential to cause severe effects on human health. There are current strategies that can be applied to mitigate the risk. Contemporary approaches can be developed through research and consultation.

Moreover, residents in mining communities must advocate for themselves. This should begin at the community level by examining and understanding the scope of issues that confront them. Approaches should be made to the government and all stakeholders to seek mutually beneficial solutions.

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