Potential Risks of Total Mercury Accumulation in Aquatic System at Luwuk Gold Mine Central Sulawesi, Indonesia

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Abstract

This study aimed to investigate the environmental risks of Total Mercury (THg) accumulation due to the traditional gold mine in Luwuk and vicinity areas in Central Sulawesi, Indonesia. THg was assessed around ore amalgamation process area and panning activity in the Topo River. Sampling survey for water column, sediment (0-5 cm) – (6-10cm) depth and bivalve (Anadara trapezia Sp.) in river as well as water column, tuna (Thunnus sp.), red fish (L. Campechanus) and oyster (Crassostrea virginica Sp.) in the sea were collected. Furthermore, the environmental risks show, THg in water column in river ranged from (0.13 to 0.48 µgL^{-1}), sediment 0-5cm depth (107.78 to 167.06 µg kg^{-1}dw), sediment 5-10cm depth (95.44 to 128.85 µg kg^{-1}dw) bivalve Anadara trapezia Sp. (17.33 to 89.02 µg kg^{-1}dw), respectively. Then in sea, water THg concentration ranged from (0.41 to 0.88 µg L^{-1}), Thunnus, SP. (43.49 to 62.37 µg kg^{-1}dw) and L. Campechanus (6.84 to 23.37µg kg^{-1}dw), and Crssostrea Virginica Sp ranged from (15.50 to 32.34) respectively. The highest elevation of THg was in St.4 where panning processes were occurred as well as the amalgam open burn delivered. Although all THgs concentration in aquatic system were still meet the standard value, some stations are very closed to allowable limit such as THg in Sediment at Aq4 and Aq.5, where the standard limit is 174 µg kg^{-1}dw, according to the environmental Canadian standard. Accumulation of THg in fishes both for Thunnus Sp. and (L. Campechanus) Sp. were safe according to permitted standard from EPA (500µg kg^{-1}dw.

Keywords*; Environmental risk, total mercury accumulation, aquatic system, river, sea, artisanal gold mining.*

I. Introduction

Hg released to the environment during the artisanal gold mining in a variety of ways from the panning and amalgamation as well as open burn. In the incomplete process, Hg is used to amalgamate gold, which facilitates the separation of gold from the unwanted materials. Hence, some Hg escapes to the atmosphere and some releases directly into water bodies as elemental Hg droplets or as coatings of Hg adsorbed onto sediment grains. The mercury that may forms the amalgam with gold is emitted to the atmosphere when the amalgam is burn (Telmer et al., 2006).[1] Mercury emitted in term of gasses will vapour from soil and water then enters the air in atmosphere, where it potentially might be transported and redistributed over the all Earth's surface (Risher et al., 2003).[2] Mercury can enter the air as a vapour, then drop both as dry and wet deposition, it settle to the bottom at sediment, be absorbed by phytoplankton, or be ingested by zooplankton and microorganisms, or fish as a high stage of food chain as transformation process life. It is noted that as a result of anthropogenic sources, mercury deposition to aquatic systems has increased over the past century (Mason et al., 1994; Fitzgerald et al., 1998).[3,4]

Some studies reported that if conducted in an appropriate manner, artisanal and small-scale gold mining can generate significant benefits in developing countries.

However, the poor health and safety record and use of environmentally destructive mining and processing practices have drawn much negativity and criticism to the sector (Nöestaller 1997).[5] It is obviously that Hg can form many stable complexes with organic (carbon-containing) compounds. MeHg is one of the most toxic, other are the compound organic mercury that is fairly soluble in water. In addition, inorganic mercury can be methylated by indigenous microorganisms to environmental such as; soils, sediments, fresh water, and salt water, to form organic mercury. Almost all of the Hg found in animal tissues is in the form of MeHg which is toxic for alive (WHO, 1989).[6]

2. Materials and methods

2.1 Research area and study design

This research was commenced in Luwuk traditional gold mining, central Sulawesi province, Indonesia. Luwuk is located along the Peling Strait and Sulawesi Sea, it has a tropical climate influenced by the dry season which is started from June to October and the rainy season from November to April. The North wind was blowing in from January to March along with the coming dry season, and West Wind during the two months ie from April to May. (Indonesia National Meteorological Department, 2012).[7] The topography of Luwuk regency consists of plains at the coastal area and a little bit hilly several hundred meters ahead from the shorelines toward the mine sites. The gold mining area itself is located at about 3500 – 4000 m from the sea and on hill sites, but the distance of amalgamation centre only about 1500 m from the capital regency and 2000 m from the sea.

Topo River run from upstream to downstream where the gold mine activities were conducted along it side. In this study, ten stations namely five stations (Aq1-Aq5) were selected as representative points for along the Topo River such as surface water, sediment and bivalve (*Anadara trapezia Sp.*), then five four stations (Aq6-Aq10) in the Sea for water column, fish (*Thunnus Sp.*) and (*L. Campechanus) and* oyster *Crssostrea Virginica Sp*. A duplicate set of samples for all samples was delivered; each sample was replicated for three parts which representing one station for every parameter.

2.2 Study Design

2.2.1Surface water sample collection and its procedures

Within one period of sampling, surface waters sample were collected at the mid depth at total of 10 stations from upstream to downstream both in Topo River (Aq1 – Aq5) then (Aq6 – Aq10) in Sulawesi Sea. Selected parameters for measurement of water quality both in the river and sea were analyzed both in the field study and those that transported to the certified laboratory in Laboratory Kesehatan (LabKes) Makassar, South Sulawesi Province. Some field parameters such as Power Hydrogen (pH) using a potable pH meter, temperature and conductivity were measured using a Salinity-Conductivity-Temperature (S-C-T) meter and Dissolved Oxygen (DO) was measured using a Dissolved Oxygen meter.

Suspended Particulate Matter (SPM) was measured using aliquot water sample which collected on pre-weighed TTFE membranes (polytetralfluoroethylene membrane) as the nucleopore membrane of 0.4µm pore size (Gambrell,1991).[8] Dissolved Organic Carbon (DOC) was measured using a total organic carbon analyzer (APHA et al, 1998).[9]

All sample were collected in February 2012, duplicate set of water samples were collected using high density bottle in the river and using non metallic convertible water sampler (Kremerer water sampler) in the sea. The laboratory analysis was done immediately following collection, then all water samples were determined against the national and international standard

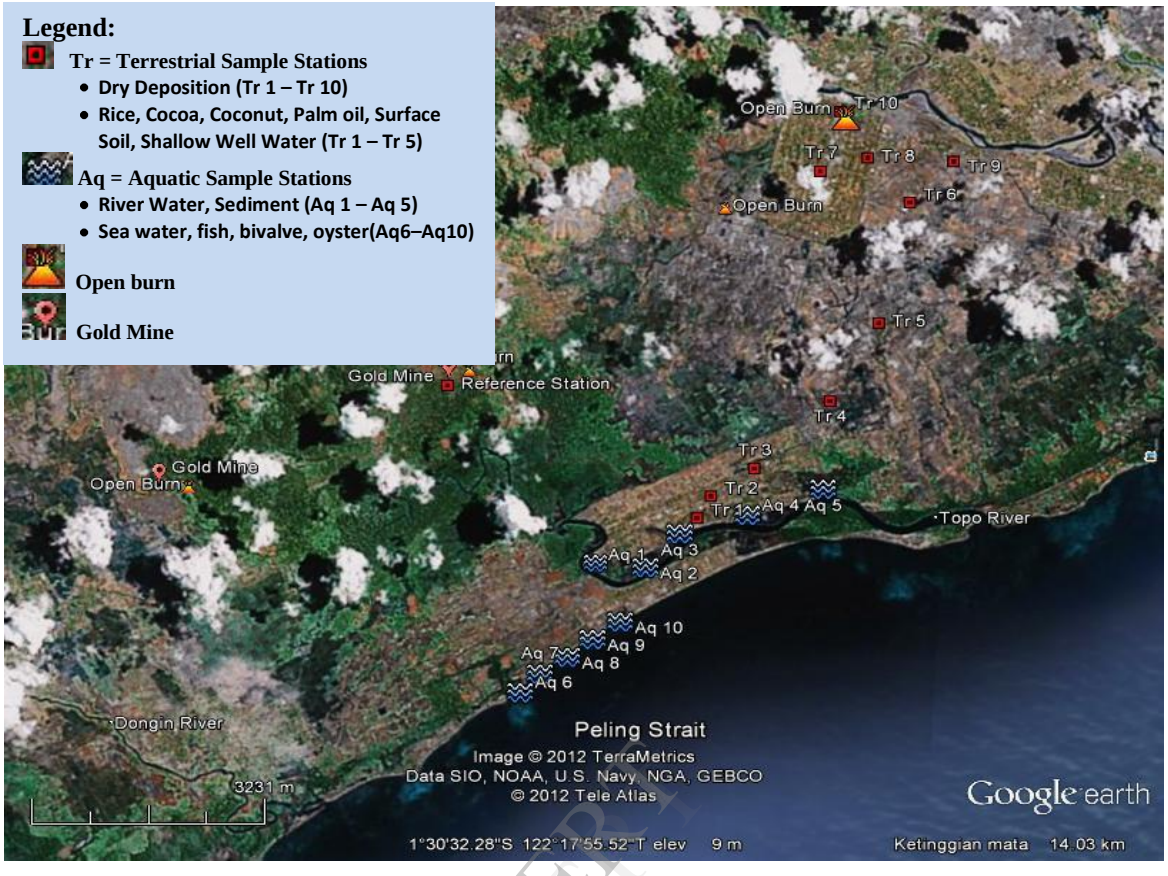

Figure 1: Map of Sampling Location

2.2.2 Sediment sample collection and its procedures

PVC cores (40 cm length and 4 inches diameter) were used to collect sediment samples. Sediment and water samples collection conducted at the same time. The PVC core was inserted into the sediments where water was collected as well. The number of sediment samples were collected the same as have done for the water sample in the river (5 stations), then divided into two sub samples. At first step, sample was collected individually from the total of five stations, sediment sample was separated at the depth of 0-5 cm and 5- 10 cm. Then, clean the collected bottom sediment of wood pieces, pebbles, shells, and root or leaf and pass it through a 2-mm mesh sieve to prepare a sediment sample (Dennis and Zupko, 1995).[10] After homogenization, mix an equal weight of each sample to obtain a final composite sample for the mercury analyses. Record the date, location, and general condition of the sediment samples such as appearance, color, smell impurities (USA Ministry of the Environment 2004, in UNEP, 2002).[11] Next, we used sealed plastic container to collect the sample, it was washed beforehand with hydrochloric acid. After collected, sample was stored in cool dark place. Moreover, the collection of sediment characteristics were done such as pH of sediment was measured by pH Meter (1 : 2.5 Sediment: Water) using a glass electrode, then Cation Exchange Capacity, CEC (meg/100g) by replacing the cation with 1 M ammonium acetate (NH_4OAc) at pH 7.0 followed by ethanol washing, NH4 displacement with NaCL and analysis of NH4 by Tjedal distillation (Chapman, 1965).[12] Organic carbon was converted into Organic matter and reported as percentage. Those sediment

characteristics were measured in order to evaluate the THg of sediment concentration and the selected sediment properties and assessed using standard reference material (SRM).

2.2.3 Biota sample collection and its procedures

Bivalve *(Anadara trapezia SP.)* and oyster (*Crassostrea virginica Sp.*) were collected of the strait wall, and Tuna fish (*Thunnus Sp.) and (L. Campechanus)* were collected between the pier and the breakwater. Those fishes were collected with hook and line to complement dock sampling efforts. About 10-15 *Anadara trapezia Sp.* and *Crassostrea virginica Sp.* were collected for each station with size range of 4-6 cm for bivalve and 3-5 cm for oyster in length. Those two species available at all stations of sampling tracts. Then, 5-7 Thunnus and *L. Campechanus* with various sizes in length were collected from each station in the strait. The representing size two species fishes in the sea were about 40 cm– 90 cm and 15-25 cm in length respectively. Those biota tissues were removed from the shell and cut, then placed into polyethylene sample bags individually, labeled with collection date, species name, and fish, bivalve, oyster length (in cm). Each sample was packed in a sealed plastic bag, stored on ice in a cooler before being transported to laboratory and put into a freezer (-20^{o}C). Soft tissue of fishes, bivalves and oyster were removed and cut in section of small pieces and lastly homogenized which representing samples frozen prior to analyze.

2.3 Method of THg analysis

All samples for water and sediment and the biota were digested for THg analysis by the method used at the Wetland Biochemistry Institute, Lousiana State University (Gambrell, 1991).[13] Then the THg concentration was determined by Atomic Absorption using CV-AAS (Cold Vapor Atomic Absorption Spectrophotometer; SHIMADZU, Spectr. AA 6200) after $NabH_4$ (Sodium Borohydride) reduction for total Hg Analysis. The detection limit was 0.001 $\mu g\ L^{-1}$

2.3.1 Laboratory quality control

Samples were analyzed at Chemical Laboratory at the certified Laboratory of Health in Makassar, Indonesia. The analytical method precision and its accuracy were evaluated by comparing the concentration value of expected THg in certified reference material (SRM 1646a estuarine sediment) from the U.S. Department of Commerce, National Institute of Standard and Technology (NIST) Gaithersburg, MD 20899 with the measured values. All Hg analyses of parameters were done by three replicates. Then, method detection limit (MDL) with seven reagents blank was calculated used as a tool for verification as well.

2.3.2 Assessment of environmental risks

The potential environmental risks were determined by applying the quantitative screening the Hazard Quotient (HQ) approach. Here the estimates of ecotoxicity (Dose) to exposure respond is compared. The concentration at the background of the study area which is about 10 km upstream and downstream of the area concern is determined. The ratio of the exposure estimated to the effect concentration considered to represent a safe environmental concentration or screening benchmark as shown in the following formulation.

HQ = EEC/Screening Benchmark

EEC = Estimated (maximum) environmental contaminant concentration at the site; how much contaminant in sediment or water (e.g.mg contaminant/kg sediment).

Screening Benchmark = Generally a No-Adverse Effects level concentration (NOAEL); if the contaminant concentration is below this level, the contaminant is not likely to cause adverse effect. However, If the HQ value is > 1 then it indicates the state of risks to the environment (Environmental

Canada 1995; USEPA, 1997; Rayment, 2000).[14-16]

If: HQ < 0.1; hazard exists; HQ 0.1-1.0: hazard is low; HQ 1.1-10: hazard is moderate; HQ > 10: hazard is high (Lemly, 1996) [17]

3. Results and discussions

3.1 Surface water

Water samples from Topo River and Peling Strait were observed in February 2012. Water measured parameters is shown in (Table 1). The characteristic measured i.e depth, pH, temperature, conductivity, dissolved organic carbon and total dissolved carbon. The depth of the sampling sites range from 5-8m in river and 30- 40m in strait, pH range between (7.0 to 8.2), and DOC range from (6.76 mg L^{-1} to 7.48 mg L^{-1}). The highest temperature was in strait about 31.5 ^{0}C, and the lowest in river 25.8 ^{0}C. However, conductivity and TDS were significantly different between river and strait water samples. Those values in strait were significantly higher than those in river.

Table 1. Water characteristics in Topo River and Peling Strait, 2012

Station	Station Description	Depth (m)	pH pH	Temp. (^{0}C)	Conductivity (µS/cm)	DOC (mg L^{-1}) Nucleopore	TDS (mg L^{-1})
Aq-1	Upstream	5	7.6	25.8	80.10	7.12	59.20
Aq-2	Upstream	6	7.6	27.5	68.20	7.48	35.71
Aq-3	Reservoir	5	7.5	27.7	70.05	6.76	35.76
Aq-4	Downstream	8	7.0	28.5	70.12	6.76	35.82
Aq-5	River mouth	8	7.4	28.5	72.40	7.12	35.75
Aq-6	Up to the North of estuary	30	7.8	30.0	110.60	7.12	208.32
Aq-7	In line the estuary	30	7.8	30.2	115.22	7.48	297.60
Aq-8	Down to South of estuary	35	8.0	31.5	152.25	7.12	291.64
Aq-9	South from Estuary	35	8.2	31.5	128.45	6.76	214.27
Aq-10	South far from estuary	36	8.2	31.0	130.15	7.22	221.32

* Aq.1 - Aq.5 = Topo River Aq.6 - Aq.10 = Peling Strait, about 50 m from shoreline

The water THg concentration were moderately low, from upstream to downstream in river, it were ranged from (0.13 to 0.48 µg L^{-1}). All stations were still lower than the maximum contaminant level considered by the U.S. Environmental Protection Agency which is permitted standard (2.0 µg L^{-1}). The highest value was at Aq.5 due to the closer distance to the mining activity and amalgam processing centre. Comparing the measured Hg accumulation in the area near gold mine activity in Asturias, Spain. THg concentrations found in this local stream vary from <0.5 to 90.8 g L^{-1}. Which have exceeded the given standard (Loredo et al., 2006).[18]

Although sample results were below the reporting limit, it indicated that the level of THg concentration tended to increase due to the increase number of opened mine at the site. This fact obviously different compare the background site which is much lower and almost no Hg reported. For risk assessment purposes, the maximum water concentration of 0.48 µg L^{-1} is used. This represents a very conservative assessment of the risk of mercury exposure for potential surface water dermal contact.

pH and DOC as two main parameters that may affect the water quality for THg concentration were not vary significantly among the stations in this study. The measured pH values are circumneutral, ranging from 6.0 to 7.8 units. In fact, it is the distance from the point source which was contributed a major effect to the existence THg in every station. The THg measured in

water was merely contributed from the fall out of emitted source. Thus may occurred due to the transformation process of Hg^0 (g-gas) to Hg(II) and Hg(II) (p-particulate) in turbid water by which anthropogenic sources of Hg^0 to air can generate in Hg deposition to both land and water (USGS, 2007).[19] Hg^0 is produced in freshwater by humic acid reduction of Hg(II) or demethylation of MeHg mediated by sunlight. An amount will remain in the dissolved gaseous state while most will volatilize. The water column MeHg concentration is a result of methylation of Hg (II) which occurs in the bottom sediment and the water column by microbial action and abiotic processes (Parks et al.,1989).[20] Estimates of the percent of total mercury in surface waters that exists as methylmercury vary. Generally, methylmercury makes up less than 20 % of total mercury in the water column which is determined by the balance between forward and reverse reaction (ASTDR, 1999; Goldblum 2006, et al)[21,22]

Table 2. THg in water, sediment (0-5cm and 5-10cm) depth, bivalve (*Anadara trapezia Sp.)* and oyster (*Crassostrea virginica Sp.)* in aquatic track in Luwuk gold mine, 2012.

Station	Station description	THg in Aquatic Track (Topo River)									
		Water column ($\mu g L^{-1}$)	SD	Sediment ($\mu g\ kg^{-1}$ dw) (0-5 cm depth)	SD	Sediment ($\mu g\ kg^{-1}$ dw) (6-10 cm depth)	SD	Bivalve *Anadara trapezia Sp.*	SD	Oyster *Crassostrea virginica Sp*	SD
Aq. 1	Upstream	0.13	0.01	107.78	0.26	103.30	0.12	17.33	1.37	15.50	2.12
Aq. 2	Upstream	0.13	0.01	136.95	0.22	101.31	0.01	20.11	1.22	18.43	1.87
Aq. 3	Reservoir	0.39	0.06	139.80	0.37	95.44	0.18	86.17	0.44	32.34	1.20
Aq. 4	Downstream	0.35	0.03	167.06	0.08	112.29	0.10	89.02	0.24	30.45	0.80
Aq. 5	River mouth	0.48	0.02	157.51	0.14	128.85	0.02	29.09	0.26	18.80	0.75
Permitted conc.		2.0 ($\mu g\ L^{-1}$)		174 ($\mu g\ kg^{-1}$dw)				100 ($\mu g\ kg^{-1}$dw)			

3.2 Surface sediment

Surface sediment samples were collected in February, 2012 along the main aquatic tracts (Aq1 to Aq5) which was the same where surface water were collected in the river. Results show that the organic matter (OM) was low, while cation exchange capacity (CEC) of the sediment moderately high. Most of the stations have OM less than (2%) in averages except in St3 which was above 3%. CEC were vary from 6.97 to 72.94 which was higher than (12 meg/100g) in averages. Particle content in sediment dominated by sand and clay with percentages range from (38.57 - 57.64 %), (36.08 – 57.94 %) then followed by silt (0.33 – 8.89%) respectively. The lower content of silt was found in the upstream. At this site sand and clay as the original sediment texture more dominant. No tailing or waste dumped intentionally to this river tract as local people use the river for fishing and use the water for irrigation.

Table 3. Sediment characteristics in river tract, Luwuk gold mining area,2012

Station	Station Description	Depth (cm)	pH pH	OM (%)	CEC (meg/ 100g)	Particle size analysis			Sediment Texture
						Sand (%)	Silt (%)	Clay (%)	
Aq-1.1&	Upstream	0 - 5	6.40	0.82	19.46	45.52	0.57	53.90	Sandy loam
Aq-1.2		5-10	6.60	0.61	15.27	47.58	7.12	45.31	Loamy sand
Aq-2.1&	Upstream	0 - 5	7.10	1.15	11.62	57.87	0.33	41.80	Loamy sand
Aq-2.2		5-10	6.90	0.96	72.94	55.25	6.94	37.80	Loamy sand
Aq-3.1&	Reservoir	0 - 5	6.20	3.02	31.26	38.57	3.49	57.94	Loamy sand
Aq-3.2		5-10	6.20	3.44	13.42	41.75	4.08	54.17	Loamy sand
Aq-4.1&	Downstream	0 - 5	6.60	1.24	43.19	48.83	3.28	47.89	Loamy sand
Aq-4.2		5-10	6.50	2.26	29.81	49.12	1.15	49.73	Loamy sand
Aq-5.1&	River mouth	0 - 5	6.20	0.54	6.97	57.64	2.84	39.51	Silty clay loam
Aq-5.2		5-10	6.30	0.93	12.21	55.03	8.89	36.08	Silty clay loam

It was found that THg concentrations vary from 107.78 (µg kg^{-1}dw) at the upstream and to 167.06 (µg kg^{-1}dw) at downstream at the depth of 0-5 cm. Similarly, THg concentration in the depth of 6-10cm range from 95.44 to 128.85 (µg kg^{-1}dw) which was not significantly different. The higher elevated THg in downstream potentially generated by the closer distance from the amalgam open burn, compare to the surround mine open pit which is less mercury used. At a distance of 1500m downstream of the mining site, close to the Toili village, some gold buyers conducted ore amalgam process and burn the bullion amalgam. As a result, Hg emitted to the atmosphere and fall down as the dry deposit on the ground, river and other media. The cycle process may lead to the accumulation of mercury in the sediment. THg in sediment has been indicated to change in response to changes to external Hg loading. Dated depth profiles of THg in sediment cores clearly show changes in Hg accumulation rates over time that correlate well with documented Hg utilization and environmental releases (Wang and Driscoll, 1995; Engstrom and Swain, 1997; Harris at el, 2007).[23-25] Since Indonesia has no any established sediment quality guidelines at this temporary the Canadian guidelines was used as interim measure to assess whether or not the THg heavy metal in sediment could have an adverse biological effect.

3.3 Biota lower and upper food web in sea

Bivalve and oyster were available from Aq1 to Aq 5 and collected from the sea wall in the main sea track. THg concentration in the lower food web such as Bivalve *(Anadara trapezia SP.)* had a mean of 48.34 µg kg^{-1}(dw) and it ranged from 17.33 to 89.02 µg kg^{-1}(dw), and oyster (*Crassostrea virginica Sp.*) had a mean of 23.10 µg kg^{-1}(dw) and ranged from 15.50 to 32.34 µg kg^{-1}(dw) Moreover, biota upper the food web such as (*Thunnus Sp.) and (L. Campechanus.)* were collected between the pier and the breakwater. The THg concentration in (*Thunnus Sp.)* had a mean of 50.02 µg kg^{-1}(dw), it ranged from 36.85 to 62.37 µg kg^{-1}(dw) *and (L. Campechanus.)* had a mean of 12.64 µg kg^{-1}(dw) and it ranged from 8.10 to 23.37 µg kg^{-1}(dw), respectively. Overall, Hg concentration tended to increased both in lower and upper aquatic food web near the estuary.

Result from this study obviously confirmed that the closer of distance between the station and the point source amalgamation practice process the higher of

THg in the biota accumulated. Stations Aq 1 and Aq 2 as the nearest point to the point source have the highest concentration of THg. In addition, THg accumulation in biota have a linier association with the THg concentration in water and have a significant correlation with the THg accumulation in sediment. This finding is similar with the result from gold mining operation in Phanom Pha, Thailand where elevated THg in water (0.4 to 4 µg L^{-1}), sediment (96 to 402 µg kg^{-1}) and bivalve (15 to 584 µg kg^{-1}) near the mining operation were higher than those station outside the mine operation, (Pataranawat at el, 2000).[26] In this study area in fact, all biota species' were consumed by local people in Luwuk and surround area as a main protein source.

THg concentration in sea water from St.1 to St. 5 was slightly vary which ranged from 0.41 µg L^{-1} to 0.88 µg L^{-1} with the mean of 0.66 µg L^{-1}. Of those five different sample stations in the sea, the highest THg concentration was in St.4 (0.88 µg L^{-1}) and the lowest one in St.1 (0.41 µg L^{-1}). All sea water samples were taken at about 30-40 m of mid depth. These THg concentrations are above than what would be expected since the accumulation of THg in sea usually lower due to the mobilization of pollutants. It is not significantly different from the results found of THg concentration in Napoleon Gulf averaged 4.1ng/L at 13m depth, and in Lake Michigan waters the THg only 0.32ng/L (Mason and Sullivan, 1997; Ramlal at el, 2003).[27,28]

Those findings were similar and have a linier agreement in this study. The bigger the fishes size the higher THg concentration in those fishes. THg concentration in Thunnus Sp. had a mean of 50.03 µg/kg^{-1}(dw) and ranged from 36.85 µg/kg^{-1}(dw) to 62.37 µg/kg^{-1}(dw), respectively. in addition THg concentration in *L. Campechanus* had a mean of 12.64 µg/kg^{-1}(dw) and it ranged from 8.45 to 23.37 µg/kg^{-1}(dw), respectively. The highest THg concentration in the biggest fish at both species. All the values for the THg were stll meet the national standard (500µg/kg dw), so it safe to consume.

Table 4. THg in sea water and the accumulation in *Thunuus Sp*. and *L. Campechanus* Sp.

Station	Station description	THg in aquatic column (Sulawesi Sea)							
		Water (µg L^{-1})	SD	Fish (µg kg^{-1}dw)					
				(Thunnus Sp.)	SD	cm length	*L. Campechanus*	SD	cm length
Aq. 1	Up to the North of estuary	0.41	0.01	62.37	5.77	90	23.37	1.22	60
Aq. 2	In line the estuary	0.63	0.02	54.30	4.68	82	16.42	1.10	45
Aq. 3	Down to South of estuary	0.59	0.02	53.14	1.15	82	8.10	0.01	45
Aq. 4	South from estuary	0.88	0.01	43.49	4.72	50	8.45	0.02	30
Aq. 5	South far from estuary	0.81	0.02	36.85	4.36	40	6.84	0.02	30
Permitted Concentration		2.0 (µg L^{-1})		500 (µg kg^{-1}dw)					

The sources of THg include indirect deposition from watershed runoff, direct atmospheric deposition, point sources, and internal recycling mechanisms such as sediment resuspension (WHO, 2004).[29] Methylmercury is very bioavailable and accumulates in fish through the aquatic food web; nearly 100% of the mercury found in fish muscle tissue is methylated (Bloom et al., 1991).[30]

4. Environmental risks evaluation

The potential environmental risks evaluation calculated by using hazard quotient (HQ) equation. The objective of this formulation earmarked for the estimation of environmental risks to the potential receptors that were performed in aquatic system for Hg of surface water, both for river and sea and sediment in 0-5 and 5-10 in depth. For surface water in this study, the Screening Benchmark base on the Indonesia National Standard setting that the mercury contamination in surface water was not exceed 2.00 µg L^{-1}. In addition the maximum allowable sediment is not exceed of (174 µg kg^{-1}dw) according to the standard of environmental Canadian. More detail of evaluation of Hq for Hg concentration value is presented table 5 below.

Table 5 Potential environmental risks evaluation HQ of Hg in aquatic habitat for surface water and sediment both for 0-5cm and 5-10cm depth.

Station	Station description	HQ of THg			
		Water column (µg L^{-1})	Sea mid depth water (µg L^{-1})	Sediment 0-5cm (µg kg^{-1}dw)	Sediment 5-10cm (µg kg^{-1}dw)
Aq. 1	Upstream	0.07	0.21	0.62	0.59
Aq. 2	Upstream	0.07	0.32	0.79	0.58
Aq. 3	Reservoir	0.20	0.29	0.80	0.55
Aq. 4	Downstream	0.18	0.44	0.96	0.65
Aq. 5	River mouth	0.24	0.41	0.91	0.74
Permitted conc.		2.0 (µg L^{-1})		174 (µg kg^{-1}dw)	

Results in table 5 described that the high THg concentration for surface water were lower in most of the station (St1-ST5) and did not exceed the screening benchmark value (2.0 µgL^{-1}) and none > 1, which means not at risks (HQ<1). This fact indicated that the concentration of Hg in this area initiate by the tailing form the amalgam centre were still less both in river and in sea. In addition, THg accumulation in the sediment both in the 5cm and 10 cm depth tended to be correlated to the THg concentration in water. However, the exception was made for the downstream and river mouth where the accumulation of Hg in the river mouth started to increase toward to the sea. Results show that the potential environmental risks evaluation in sediment of contaminated sites were in range of 0.62 to 0.96 in 5 cm depth and 0.55 to 0.74 in 10cm depth, respectively and were not at risks (HQ <1).

5. Conclusion

The presence of THg bearing and Hg bearing waste in aquatic is the primary environmental concern due to its accumulation in all environmental compartments and the potential impact to human surround the mine site. Most of the findings in this research have THg concentration in surface water, sediment and living organism such as Thunnus Sp. and *L. Campechanus* in Luwuk traditional gold mine and adjacent of the mining area were still lower than the allowable limit and not at risks for the environmental risks evaluation. All of those aquatic food sources are safe to be consumed. However, there might be some biological significance for long term exposure, since this Luwuk gold mine only opened for four years.

6. Acknowledgement

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