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Monitoring and profiling of artisanal and small scale mining at Rogongon: effects on the physico-chemical and biological characteristics of surface water and mercury concentration in sediments of Mandulog River system

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Abstract. Small scale and artisanal mining are everywhere in the Philippines which made people think of it as dirty and dangerous, thus should be discouraged due to its negative environmental and social impacts. Mining inventory at Rogongon, Iligan City, and along the Mandulog River system was conducted. There were seven abandoned, one legal, and one unregistered small scale mining entities found in the area; and five groups and 15 individuals of artisanal riverbed miners were found active during the investigations. The effects of these mining activities were analysed through the physico-chemical and biological characteristics such as: pH, temperature, dissolved oxygen, biological oxygen demand, total dissolved solids, total suspended solids of surface water including mercury concentration in sediments of Mandulog River. Water samples were collected during wet and dry weather at nine (9) sampling points located near small scale mining area, tributaries and down to the mouth of the river and the sea of Iligan Bay. The results of the physico-chemical and biological parameters of the surface water suggest that the Mandulog River system conforms to the classification as Class C. The river was classified as Class D by the Department of Environment and Natural Resources Region X due to the mercury concentrations in sediments of the river even if it is lower than the standard which is 200 $\mu g\ kg^{-1}$ (0.2 $\mu g\ kg^{-1}$); thus implies mining wastes being flushed to it.

Key Words: artisanal riverbed mining, mining inventory, biodiversity.

Introduction. Gold is the number one mineral produced by the Philippines which contributed an annual average of 32.54% to the total value of mineral production (Israel & Asirot 2000). The small-scale mining sector is known to have contributed 40–50% of the country's total gold production during the period from 1990 to 1999. Small-scale miners in the country include individuals and family groups doing mining at subsistence level or as a business and established mining companies (Israel & Asirot 2000). It is estimated that 75% are in subsistence mining, 15% are small individual or family businesses and the remaining 10% are established commercial mining firms (Bugnosen 2001). Small scale and artisanal mining are everywhere in the Philippines which made people think of it as negative, dirty, dangerous and should be discouraged due to its environmental and social impacts. In the mid-80's, gold miners engaged actively in processing the ore using the crudest method of gold extraction by amalgamation. Improper use of mercury during gold smelting and uncontrolled disposal of mercury wastes into the environment became a practice. There are two main pathways of mercury contamination that can affect human populations: exposure to inorganic mercury (Hg) due to direct inhalation and skin contact during gold recovery processes; and exposure to Methyl mercury (Me-Hg) contaminated fish consumed by people who depend on riverine products for food sources (UNEP-DENR 2010). The small scale mining wastes which are polluting the water systems and tributaries resulted to fish kill, affects livestock and agricultural production in the Philippines. Republic Act No. 7076, 1991 also known as an act Creating a People's Small Scale Mining Program, defines small-scale mining as mining activities which rely heavily on manual labor using simple implements and methods and do not use explosives or heavy mining equipment. The extent of contract shall be determined by the Provincial/City Mining Regulatory Board the reasonable size and shape of the contract area following the meridional block system established under Presidential Decree No. 463, as amended, but in no case shall the area exceed twenty hectares (20 has.) per contractor. This law has been promulgated to address the problems and issues identified and caused by small scale and artisanal mining operations in the country.

Three years ago, dated December 17, 2011, the wrath of typhoon Sendong (international name: Washi) affected the residents of the cities of Iligan and Cagayan de Oro. Anecdotal information suggests that there are massive small-scale mining and illegal logging at Rogongon, Iligan City. These outlawed activities were evident with the large amount of mud which flowed down to Mandulog (Iligan City) and Iponan (Cagayan de Oro city) Rivers and the huge amount of logs which destroyed infrastructures especially residential homes, drowning many people whom some are still missing at present. Currently, there is no existing data on the presence of these small-scale miners, which we believe is heavily devastating the above mentioned rivers. An inventory on small-scale mining activities in the area was conducted to provide data profiling on the small-scale and artisanal mining at the mentioned site. Background information such as: investors, date of operation and location; scale in terms of tonnage; metal being mined; technology and heavy equipment used in mining were investigated. The physico-chemical and biological characteristics (pH, temperature, total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD)), were analyzed to assess the water quality of the Mandulog River system. These also showed the concentration of total Hg in sediments of the river from mining wastes which probably contributes to the degradation of the water quality of Mandulog River. The data generated gives awareness and knowledge to the people who are in one way or another utilizing the said river. This study also shows whether the Mandulog River conforms to its current classification as Class D (for agriculture, irrigation, livestock watering system, industrial water supply and etc.) based on DENR-EMB Administrative Order No. 34 Series (1990). The data serves as basis for the local government units (LGU) of Iligan City for the strict implementation of ordinances for the protection of the environment and Mandulog River system.

Material and Method. The study area (Figure 1) for inventory started at Sitio Santa Cruz, Barangay. Rogongon, Iligan City, where small scale mining groups were found. It could be reached through a 2 hour motorcycle "habal-habal" ride from the crossing of Brgy. Barinaut down to Brgy. Digkilaan and Mandulog. Artisanal mining were found along the riverbed of Mandulog River system of the said barangays.

There were nine (9) sampling points: s1 to s3 were selected near abandoned small scale mining sites, s4 to s8 were the location of artisanal riverbed mining areas and intersection of any tributary along the Mandulog River, and s9 is the mouth of Mandulog River to the sea of Iligan Bay (Figure 2). Two replicate water samples and sediments for every sampling point were collected. The collection of samples were done during rainy and sunny weather "to find out the temporal variations of the water quality" (Butt & Ghaffar 2012).

Based on the Department of Water, Government of Western Australia (2009) for Standard operating procedures for water sampling methods and analysis, water samples will be collected in 1 litre plastic containers (polyethylene bottles). All the bottles will be washed with non-ionic detergent and rinsed with de-ionized water or acid washed container (HNO_3) prior to usage. Before the final water sampling will be done, the bottles will be rinsed three times with surface water at the point of collection. Each bottle will be labelled according to sampling location. All the samples will be preserved at 4°C and then transported to the laboratory.

All the collected water samples were analyzed for selected relevant physico-chemical parameters: pH, temperature, color, total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO) and biological oxygen demand (BOD). The total mercury concentration in sediment samples was analysed.

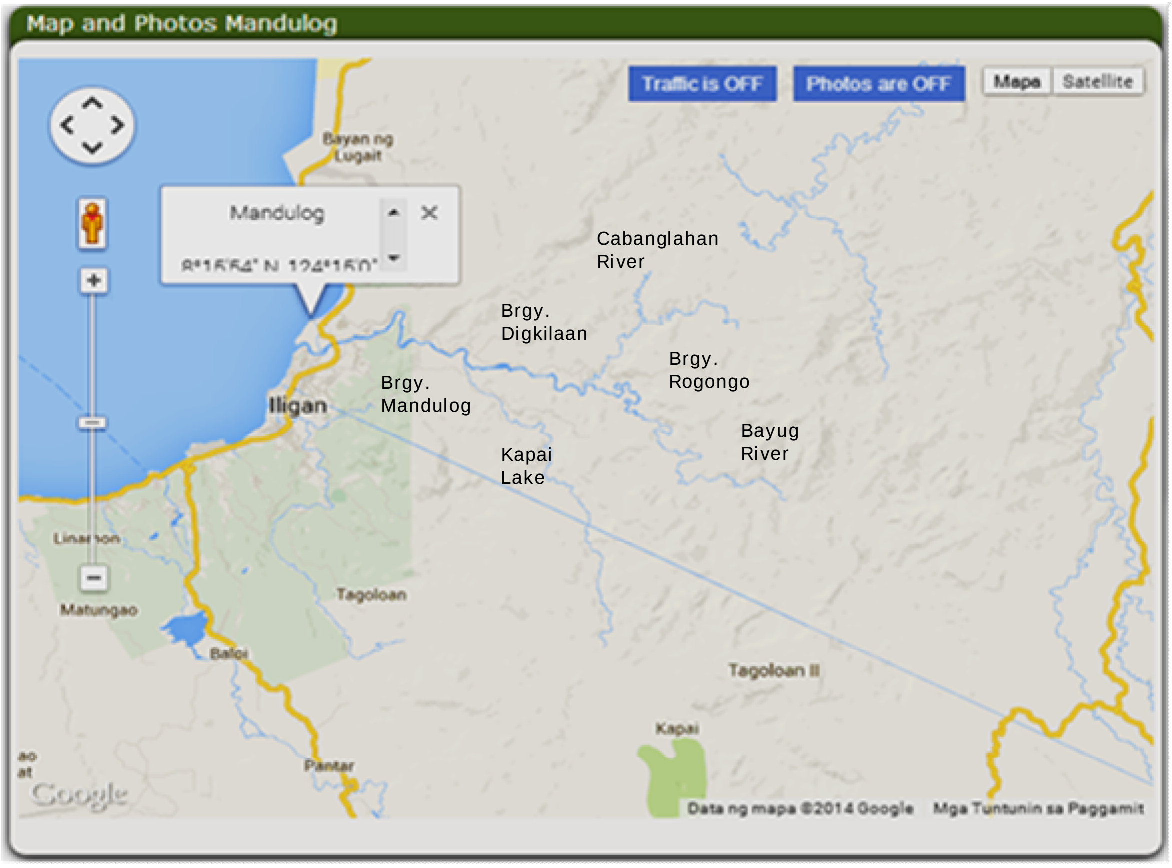

Figure 1. The flow of Mandulog River as the study area (http://www.gosur.com/map/).

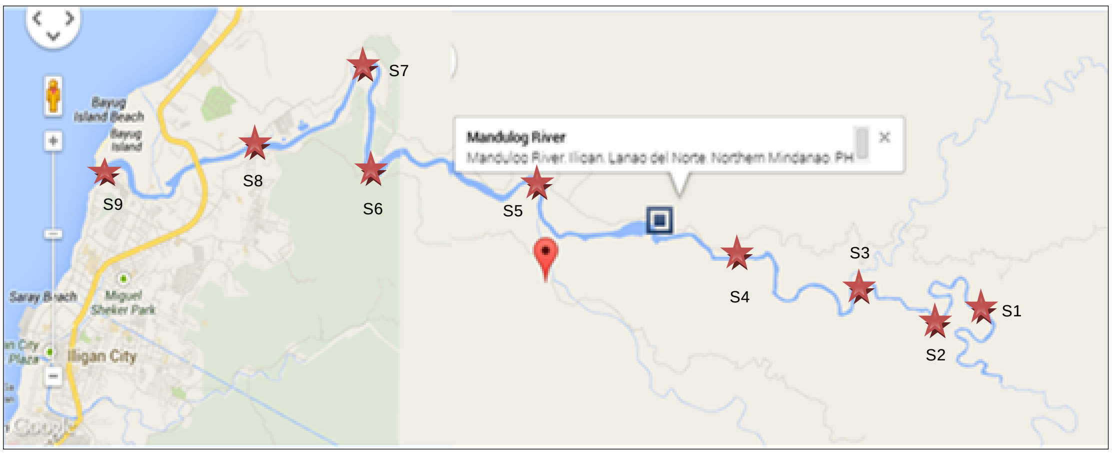

Figure 2. Sampling points.

Results and Discussion. The investigations and interviews conducted at the study area resulted to eight (8) small scale mining groups which are noted as Investor A to H in Table 1.

Investor A operated only a year from 2005 to 2006. The investor was mining for 8 kilograms per day of gold concentrate in 5 hectares of land located at Bae Katigunan (Binasan Creek) and used Poly Ethylene Pipe via gravity of water to break the land. Pascal's Law says that pressure at any one point in a confined liquid is the same in every direction and applies equal force on equal areas (Agarwal 2003). The same method was used by Investor B which was located at Putting Bato in a half hectare of space. The investor also mined for 8 kilograms of gold concentrate per day but lasted for only 2 months in 2009. Investor C depends on manual labors or artisanal miners and mined for 2 tons of copper concentrate in a day. The investor was located in abandoned 5 hectares of land at R.S. Tunnel 1, since he only operated one year, 2011. Open Cut method is to excavate a trench or a cut which must be roofed over and to concrete a tunnel in situ covered subsequently with fill material (Mouratidis 2008), a method used by Investor D which was located at 20 hectares of space in Tapwac. They have no specific amount of copper concentrate being mined. Investor E operated for only 3 months in 2009 after mining 20,000 kilograms of copper concentrate at 20 hectares of land in Kagoco Tunnel through artisanal miners. Investor F used heavy equipment like backhoe in their mining operations. They were located at Sakungan/Lagkong in a half hectare area with no exact amount of copper concentrate being mined and lasted for only 4 months in 2009. The seventh investor made use of screen or sluice box that is generally defined as an artificial channel through which controlled amounts of water flow. It can be made out of wood, aluminum, plastic or steel (Silva 1986).They were found at 2 hectares of land in Sinicabog and mined for 30 kilograms of gold concentrate per day but operated for just a year in 2012 to August 2013.

Investors A to G were not registered in the EMB-DENR X list of small scale mining because they have no Environmental Compliance Certificate (ECC), permit from the LGU and license to operate from the City Mayor's Office of Iligan City which are the necessary documents prior to mining operation; only Investor H was on the list holding a Small Scale Mining Permit No. SSMP -10-06-01. Investor H started its operation on January 8, 2010 until present at 20 hectares area in Auyan Mountain Range which they mined for 50,000 dry metric tons of copper and gold concentrate in a month. They made use of heavy equipment such as: dump trucks, backhoe and crasher in mining operations.

Table 1

Small scale mining inventory

Investor	*Date of operation*	*Location*	*Tonnage*	*Area (hec.)*	*Metal being mined*	*Methods and equipment*
A	2005 (1 year operation)	Bae Katigunan (Binasan Creek)	8 kg day^{-1} of concentrate	5	Gold	Hydraulic Poly Ethylene Pipe via gravity
B	2009 (2 months operation)	Putting Bato (tunnel)	8 kg day^{-1} of concentrate	½	Gold	Hydraulic Poly Ethylene Pipe via gravity
C	May 2011 (1 year operation)	R.S. Tunnel 1	2 tons/24hrs of concentrate	5	Copper	Manual
D	2011 (5 months operation)	Tapwac	N/A	20	Copper	Open cut Backhoe & dump trucks
E	2009 (3 months operation)	Kagoco (tunnel)	20,000 kgs. of concentrate	20	Copper	Manual
F	2009 (4 months operation)	Sakungan/ Lagkong	N/A	½	Copper	Backhoe
G	2012 - Aug. 2013	Sinicabog	30 kg day^{-1} concentrate	2	Gold	Screen box, backhoe
H	January 8, 2010	Aluyan Mountain Range	50,000 dry metric tons of concentrate/ month	20	Copper and Gold	Dump trucks, backhoe, crasher

The inventory for groups of artisanal riverbed miners was designated as G1 to G5 in Table 2. G1 to G4 consist of not greater than 10 persons aging 25 and above except for G3 which some are in minor ages. G5 has the greater number of artisans which are 100 plus with no age limits. All groups made used of bilingan, shovel and sledgehammer in mining for gold concentrate. They were compensated according to how much grams of gold they have sold to buyers and then divided equally by the numbers of artisans in a group.

Table 2

Artisanal riverbed gold mining inventory in group

Group	*No. of laborers*	*Materials used in mining*
G1	3 (ages 25+)	*Bilingan, shovel, sledgehammer
G2	5 (ages 25+)	Bilingan, shovel
G3	7 (ages 15+)	Bilingan, shovel
G4	6 (ages 25+)	Bilingan, shovel
G5	100+ (no age limit)	Bilingan, shovel, sledgehammer

*Bilingan – is a pan-like material made from wood and rounded shape. It is used by miners to get the gold with the black sand "margaha".

Fifteen individuals were found actively mining for gold along Mandulog River during the investigation and labeled as I1 to I15 in Table 3. All identified miners were living at Barangay Rogongon, Digkilaan and Mandulog and mostly are married which only show that they were dependent on mining as their source of income in the said areas.

Table 3

Artisanal riverbed gold mining inventory individually

Individual	*Address*	*Gender (female/male)*	*Age*	*Civil status (married/single)*	*No. of children*	*Materials used in mining*
I1	Migsaliding	F	52	M	5	Bilingan, shovel
I2	Migsaliding	F	50	M	9	Bilingan, shovel
I3	Katipunan	M	69	M	1	Bilingan, shovel
I4	Poblacion	M	31	M	4	Bilingan, shovel
I5	Katipunan	M	34	M	5	Bilingan, shovel
I6	Sumagaysay	M	57	M	3	Bilingan, shovel
I7	Scàling	F	54	M	2	Bilingan, shovel
I8	Migsaliding	M	21	M	1	Bilingan, shovel
I9	Kalilangan	M	21	S		Bilingan, shovel
I10	Scàling	M	26	M	1	Bilingan, shovel
I11	Katipunan	M	67	M	1	Bilingan, shovel
I12	Bayanihan	M	41	M	12	Bilingan, shovel
I13	Bayanihan	M	23	S		Bilingan, shovel
I14	Bayanihan	M	18	S		Bilingan, shovel
I15	Bayanihan	M	24	M	2	Bilingan, shovel

The results of physico-chemical and biological analysis of surface water, and total mercury in sediments of Mandulog River system. The results of the different parameters of the surface water characteristics were plotted in bar graphs with the standard set by the DENR Administrative Order 2008 – XX and DENR 34 (1990). The surface water samples in all stations were found slightly alkaline with a pH higher than 7 during dry sampling; while during wet sampling the pH drops down which makes it acidic in some of the stations but still in range with the standard in Figure 3 below. It is known that due to the presence of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions in solution, the pH of most natural water lies between 6.5–8.5, but values lower than the minimum limit may be due to the presence of dissolved carbon dioxide and organic acids (fulvic and humic acids), derived from the decay and subsequent leaching of plant materials (Roshinebegam & Selvakumar 2014). This may also be related to the basic characteristics, particularly the wide distribution of lateritic soil whose pH is always acidic. Since the river is surrounded by extensive agricultural fields, the low pH could be related to the use of acid producing fertilizers like ammonium sulphates and super phosphates of lime (Khound et al 2012).

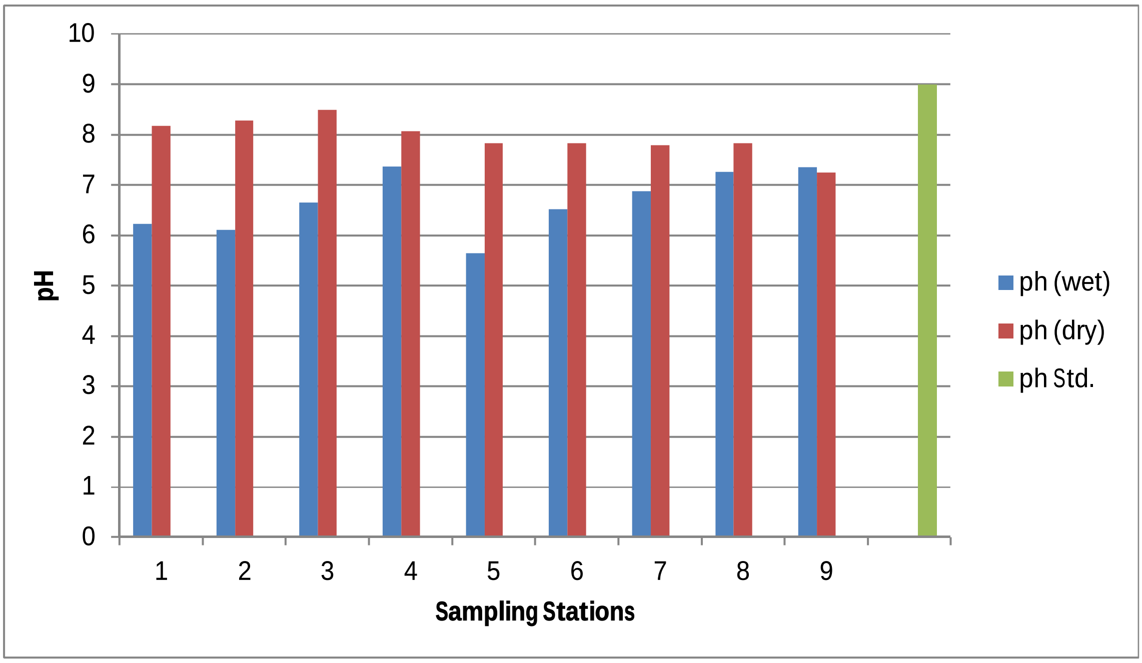

Figure 3. pH of wet and dry sampling.

Figure 4 shows the results of TDS during wet and dry sampling for all stations are very low than the standard. TDS are naturally present in water or are the result of mining or some industrial treatment of water. TDS contain minerals and organic molecules that provide benefits such as nutrients or contaminants such as toxic metals and organic pollutants (Weber-Scannell & Duffy 2007).

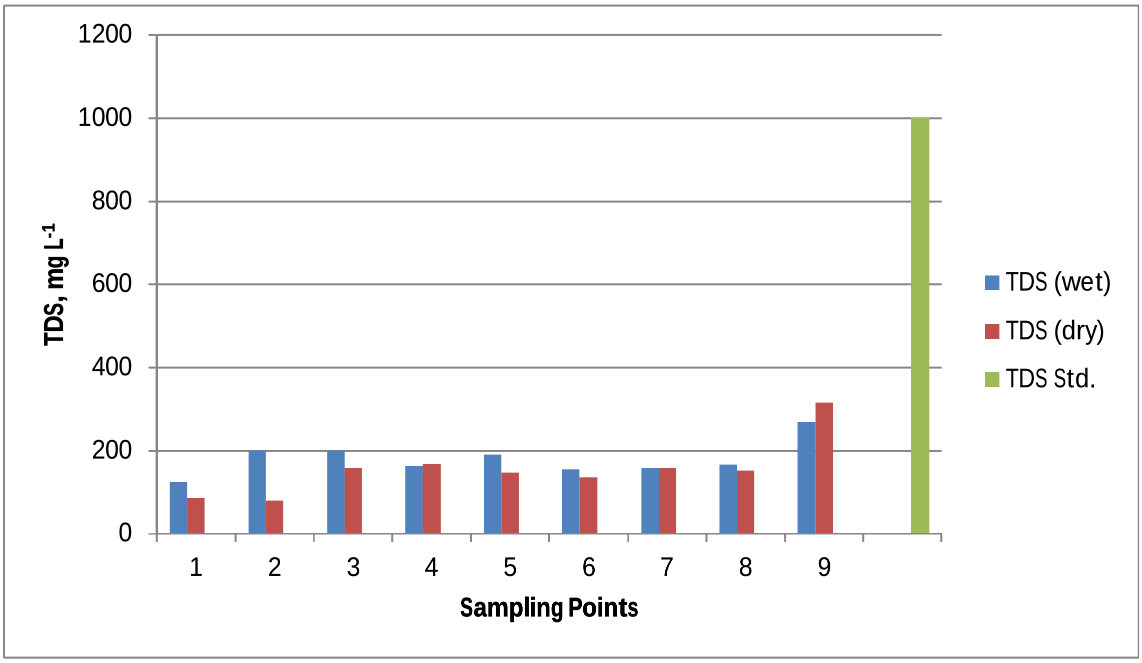

Figure 4. Total Dissolved Solids of wet and dry sampling.

Water temperature results in Figure 5 are in range with the standard set by the Department of Environment and Natural Resources of the Philippines. It is important to be monitored because it not only establishes the maximum oxygen-holding capacity of water, but also has direct influence on rates of biochemical reactions and transformation processes occurring within the water column and in the sediment bed. Warmer temperatures decrease oxygen solubility in water while at the same time increasing metabolic rates that affect BOD decay, sediment oxygen demand, nitrification, photosynthesis, and respiration (Minnesota Pollution Control Agency 2009).

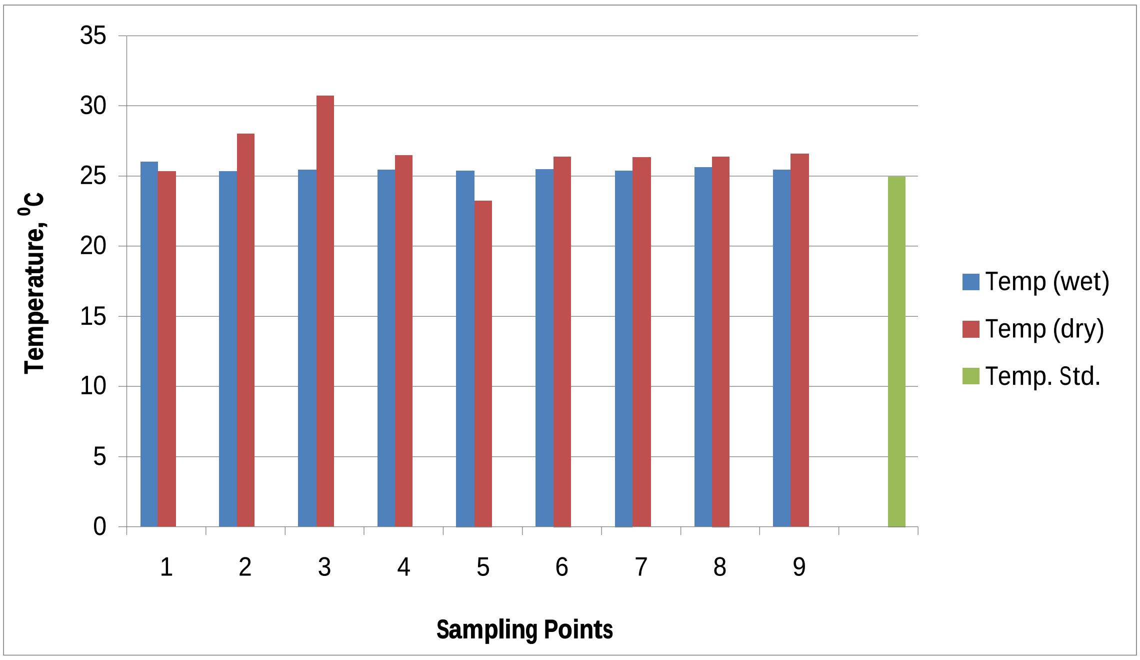

Figure 5. Temperature of wet and dry sampling.

The results of the dissolved oxygen (DO) of the water samples collected during dry sampling are lower compared during wet sampling but all stations are higher than the standard (Figure 6). DO is the measure of gaseous oxygen in water, and it is necessary for good water quality. It is essential for gilled fish and insects, and influences many different biological and chemical processes in lakes and streams (Jones 2011). Low DO primarily results from excessive algae growth caused by phosphorus. Nitrogen is another nutrient that can contribute to algae growth. As the algae die and decompose, the process consumes dissolved oxygen. This can result in insufficient amounts of dissolved oxygen available for fish and other aquatic life. Die-off and decomposition of submerged plants also contributes to low dissolved oxygen (Minnesota Pollution Control Agency 2009). Chesapeake Bay scientists generally agree that dissolved oxygen concentrations of 5.0 mg L^{-1} or greater will allow the Bay's aquatic creatures to thrive (Wicks et al 2007).

The resulting decrease in dissolved oxygen is known as the Biochemical Oxygen Demand (BOD). Measurement of BOD has long been the basic means for determining the degree of water pollution. If water of a high BOD value flows into a river, the bacteria in the river will oxidize the organic matter, consuming oxygen from the river faster than it dissolves back in from the air. If this happens, fish will die from lack of oxygen, a consequence known as a fish kill (Boyles 1997). The BOD results in Figure 7 are lower than the standard.

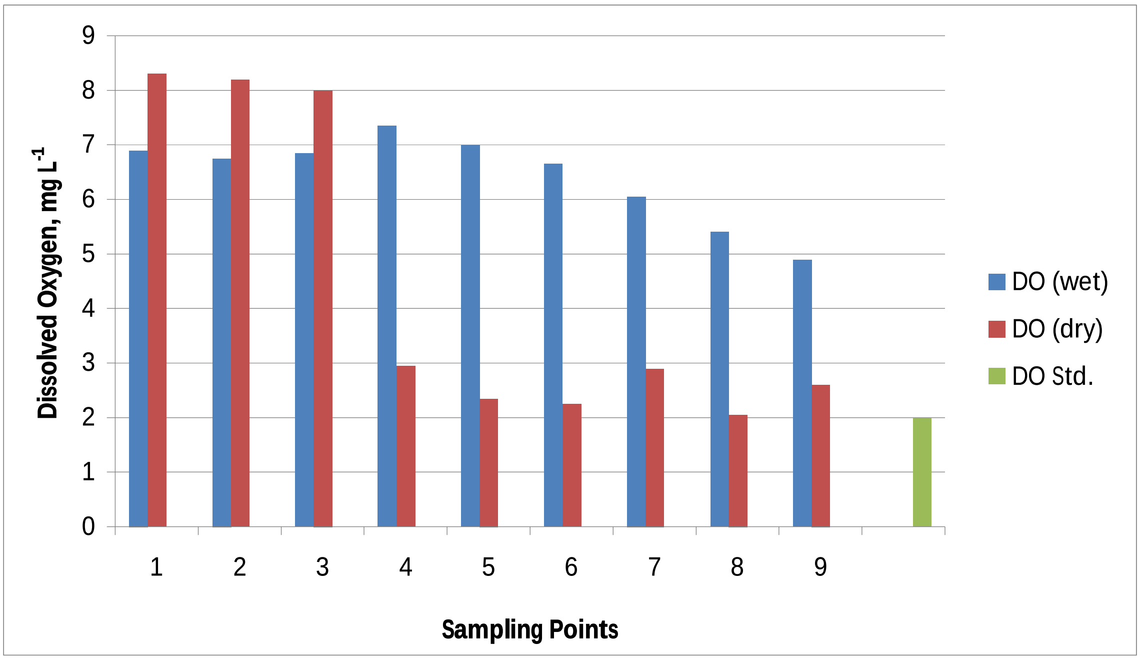

Figure 6. Dissolved Oxygen of wet and dry sampling.

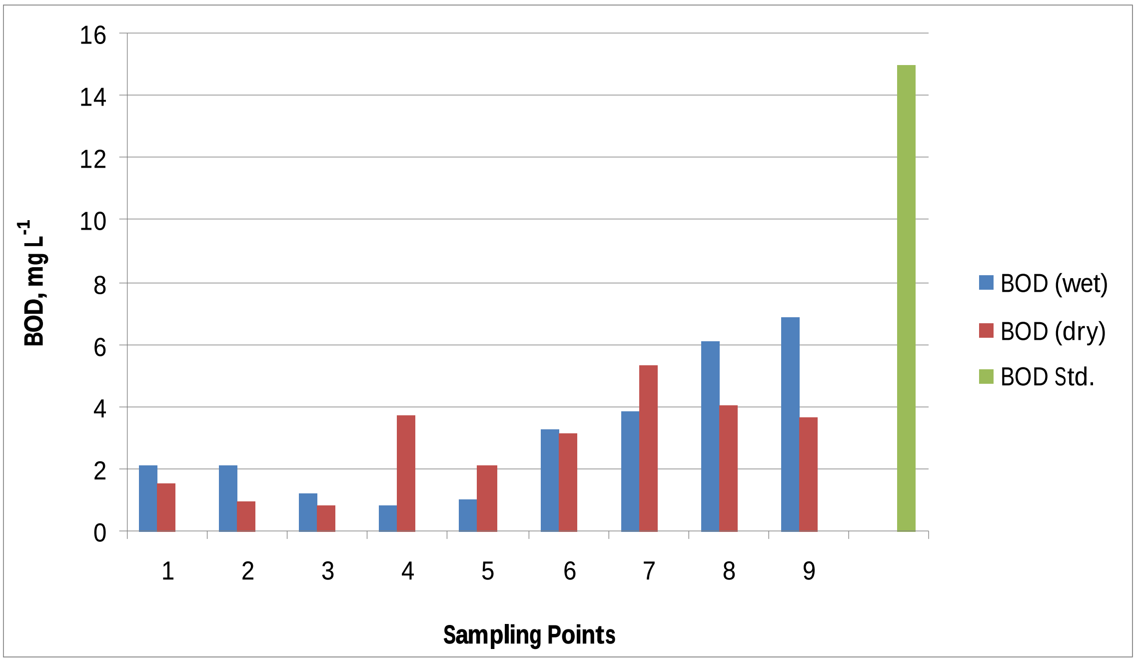

Figure 7. Biological Oxygen Demand of wet and dry sampling.

An important measure of water quality is the amount of material suspended in the water. Another commonly used measurement of suspended material is the Total Suspended Solids (TSS) analytical method. The TSS method originally was developed for use on wastewater samples, but has been widely used as a measure of suspended material in stream samples because it is mandated or acceptable for regulatory purposes and is a relatively inexpensive laboratory procedure (Gray et al 2000). The results of TSS during wet sampling are higher compared during dry sampling (see Figure 8).

Total Mercury concentrations in all sampling points were lower than the standard set by US-EPA (2007) which is 200 µg kg^{-1} (0.2 mg kg^{-1}). However, even if the results were lower than the standard, mercury could still be absorbed in aquatic organisms and be more concentrated in humans utilizing the water and eating the fishes from the sea nearby (Safina 2012).

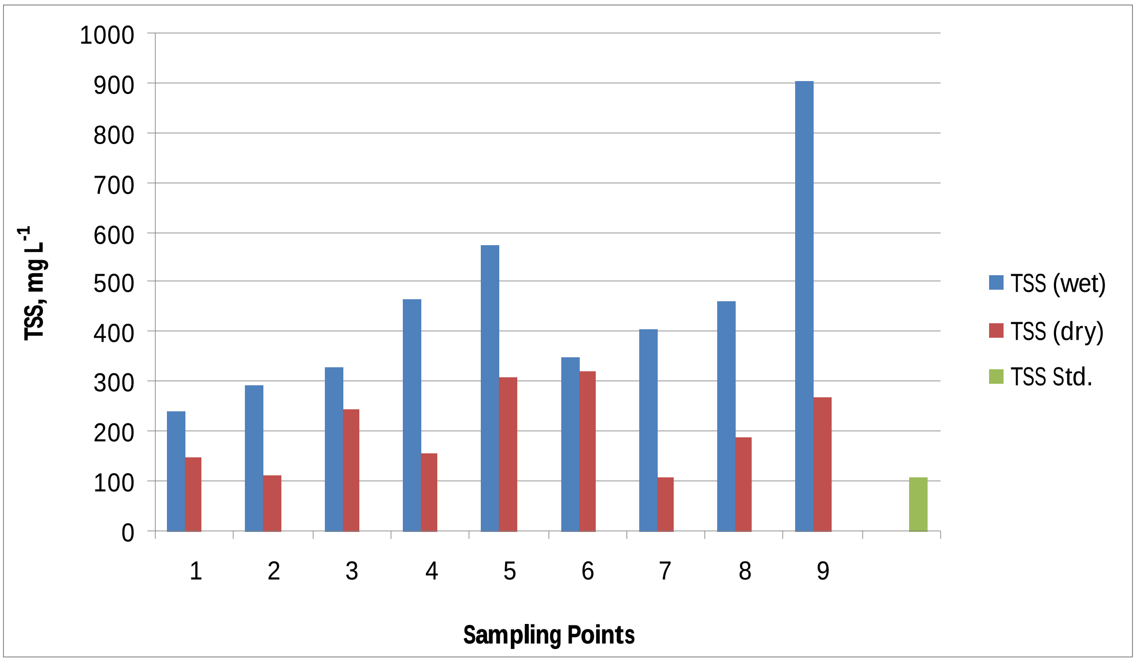

Figure 8. Total Suspended Solids of wet and dry sampling.

With reference to Figure 9, it is observed that the highest concentration of Mercury was 42.45 µg kg^{-1} which is sampling point 9 located at the mouth of Mandulog River to the sea of Iligan Bay. The sampling was done during dry weather. However, the lowest concentration was in sampling point 4, 4.79 µg kg^{-1}, located at the intersection of Digkilaan and Mandulog Rivers. The samples were collected after a heavy rainfall. It is found to be concentrated during dry than wet weather due to flushing of the mercury downstream and dilution effects.

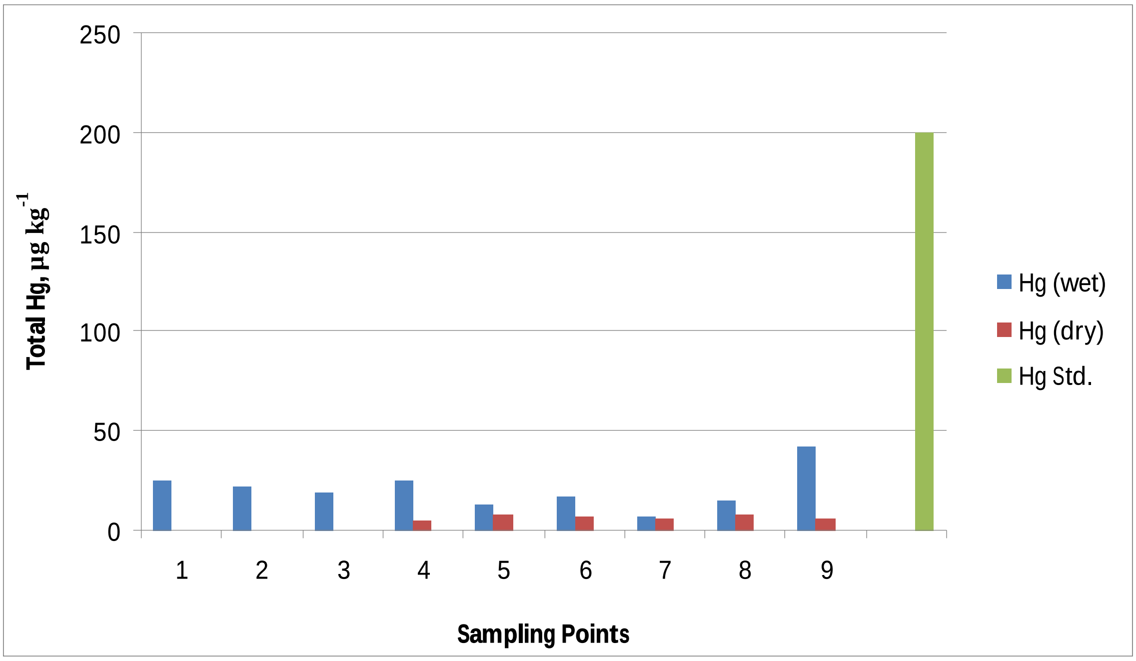

Figure 9. Total mercury level in sediments of Mandulog River.

Conclusions. Based on the inventory conducted, illegal small scale mining activities on upland areas of Brgy. Rogongon, Iligan City, group and individual riverbed mining along the Mandulog River were found evidences of tragic Typhoon Sendong experience. The physico-chemical and biological characteristics of surface water of Mandulog River system were analyzed during wet and dry sampling to determine the condition of the said river. The result for pH and temperature of all sampling points were in range with the standard for Class D River. The DO is higher than the standard which is an indicator of a good habitat for aquatic organisms, and a less BOD. The TDS is lower than the standard while the TSS is very high from the standard due to some organic and inorganic matters that were suspended in sediments of the river from anthropogenic factors of human activities like mining. Based on the physico-chemical and biological characteristics results, the river belongs to Class C river classification. But with the presence of mercury concentration in sediments even if it is lower than the US-EPA standard, the River is classified as Class D by the DENR Memorandum Circular (1999), for irrigation and agricultural purposes only. The increasing mercury concentrations in the sediments and TSS of the river show the effects of mining wastes being flushed to the river.

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