

MERCURY CONCENTRATION IN SEAWATER AND SEAWEEDS OF ILIGAN BAY

Gervasio J. Riconalla and Merrian dela Cruz

Mercury is one of the elements which is widely distributed in nature. It occurs at low concentrations in different rocks and soils and still lower concentrations in surface waters. Minute amounts are also found in air. Mercury content in soil ranges from 30 to 500 ppb (parts per billion) with an average of about 100 ppb, while in rocks it ranges from 10 to 20,000 ppb (9). With this concentrations and state of mercury in nature, living organisms apparently do not accumulate or absorb enough of it to affect their systems.

Man's increasing knowledge has led to tremendous advancements in technology. Rapid industrialization has brought innumerable benefits to man but is also causing nature's ecological imbalance. For instance, industries using mercury in their operations discharge a part of this element and consequently increase its concentration level in the environment. It is believed that the element can remain in the muds of waterways (13) until it reaches dangerous levels, such as that which caused the outbreak of the "Minamata Disease" in Japan. Severe human neurologic disorder resulted from eating fish and shellfish from Minamata Bay contaminated with mercury compounds. Of the 120 cases of severe intoxication, forty-three died. A similar episode which took place later in Nigata, Japan, caused the death of six persons and the disabling some forty-seven others (9). Other incidents of mercury poisoning have been reported also in other countries.

The mercury crisis has spurred throughout the world the in-

vestigation of its presence in the environment, particularly in areas where mercury has been discharged from anthropogenic sources (e.g., chloralkali plants). In the U.S., a survey revealed a marked increase of mercury concentrations in some freshwater lakes and some rivers. Analyses of surface waters show that of 73 samples representing 31 states, 34 contained mercury less than 0.1 ppb, 27, 0.1–1.0 ppb, 10, 1.0–5.0 and 2 contained more than 5.0 ppb (9).

Studies in Japan showed that the average mercury content of seawater ranges from 0.1 ppb to 1.2 ppb as total mercury (9). In Nigata and Minamata Bays, the mercury concentrations of seawater were remarkably high (12). Horohara (1961) found the level of mercury to be 0.15 ppb in surface waters of the Pacific ocean and 0.27 ppb at 3000 meters depth. Egawa and Tajima reported 0.005 – 0.32 ppb mercury in seawater off the Japanese islands (9).

A study conducted by Dr. Amado Kapauan and his associates at Ateneo de Manila University on the mercury content of seawater and sediment on Honda Bay, Palawan where mercury is being mined, reveals that the element's concentration in surface seawater varies from zero to 0.242 ug/g (ppb) and in sediments, from 0.001 – 2.433 ug/g (ppm).

One of the Industrial Plants here in Mindanao which uses mercury in its operations has been conducting its own monitoring of mercury concentration since 1970 on surface seawater, sediments and a few fishes in its immediate vicinity. Table 1 shows the results of the analyses made by its laboratory personnel on seawater samples drawn from six places.

Table 1. Level of Mercury in Surface Seawater from Various Areas of Iligan Bay (ppb).

Date/Place:	Buru-un	Timoga	Agus	Fuentes	Tominobo	Iligan Proper
2/21/80	0.44	0.32	2.25	1.45	0.63	0.41

5/31/80	0.38	0.16	0.48	0.75	0.06	0.08
7/24/80	1.12	0.80	1.70	0.50	0.50	0.48
8/15/80	0.40	0.66	0.72	0.39	0.40	0.58
9/30/80	1.02	1.00	1.50	0.70	0.68	—
10/29/80	0.31	0.45	0.47	0.70	0.50	0.40

Analyses of 81 samples of different marine species from Californian coastal areas showed values from 0.4 to 21 ppm mercury on dry weight basis (8). All these investigations were focused mainly on fishes and shellfish, seldom on sediments and none on seaweeds.

For these reasons, the authors thought that further study be made on the level of mercury in seawater at different distances and levels from the shore and also of the various seaweeds found in the littoral zone of Iligan Bay. Samples were taken from six places which the authors believed would give a good picture of the extent of pollution. These are Linamon, Timoga, MCCI, NASCO, Camague and Iligan City proper. From each place, three samples were taken, one very close to the shoreline, the second at mid-depth at a distance of about a hundred meters from the shoreline, and the third, at the bottom of the same distance. Seaweed samples were taken randomly from the same places.

Quantitative Determination

The quantitative determinations of mercury were done with the use of the Flameless Atomic Absorption Analyzer of Mabuhay Vinyl Corporation, the Coleman Model Mas-50 Mercury Analyzer.

Preliminary preparations of the seaweed samples were made by digesting them with concentrated sulfuric acid, diluting the digested samples with distilled water and treating them with potassium permanganate crystals until a distinct purple coloration persisted.

The prepared samples were then analyzed following the basic procedures for mercury determinations (1). Mercury in the sam-

ple is oxidized to mercuric ion with potassium permanganate in a nitric-sulfuric acid medium. The excess permanganate is reduced with stannous chloride. Mercury is vaporized and circulated by the bubbler system through the absorption cell. Radiation of 253.7 nm wavelength is passed through the cell. The change in radiant energy, detected by a UV sensitive phototube, is a measure of the amount of mercury in the sample.

Results and Discussion

The results of the analyses of 62 samples are shown in Tables 2 and 3. Pictures of the dried seaweed samples are shown in Fig. 2-10 with their corresponding common names and taxonomic identifications.

Table 2. Concentration of Mercury in Seawater from Linamon to Iligan City Proper (Dec. 1980—Jan. 1981)

	Shoreline samples	Samples at mid-depth, 100m away	Bottom samples 100 m from shoreline
Linamon	1.20	1.20	1.40
Timoga	0.51	0.86	1.28
MCCI	0.40	0.66	1.00
NASCO	0.94	0.72	1.38
Camague	0.41	0.61	0.96
Iligan proper	0.52	0.44	0.57

Table 3. Concentration of Mercury in Various Seaweeds of Iligan Bay (ppm, wet basis)

Weed/place	Linamon	Timoga	Camague
laya-laya	2.653	—	—
lumot	0.037	—	0.1161
lusay	0.9835	0.1594	0.2191
palaran	0.3156	—	—
guso-guso	0.2279	—	—

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bungot-bungot	0.1351	—	
samo	0.1094	—	0.1269
galaw-galaw	0.1242	—	0.1666

The values shown in Tables 2 and 3 are average values obtained from the analyses of samples taken at the various sites at two different times.

The concentrations of mercury in seawater in the places under study range from thirteen to forty-seven times that of the average value (0.03 ppb) given by Keckes and Miettinen (8). These results are in agreement with the values obtained by the personnel of the Quality Control Laboratory of said industrial plant (Table 1).

The variation in concentrations of mercury in shoreline surface waters with those at mid-depth at 100 meters from the shoreline does not follow a regular pattern. However, the concentrations of the metal at the bottom a hundred meters away are always greater than those at the shoreline and mid-depths. This may be explained by the path the river water takes as it goes to the sea and the constant movement of seawater. The river water which carries the metal goes to some distance into the sea. There most of the metal settle with the sediments. Microorganisms convert the metal into a water-soluble compound, methyl mercury (6, 7, 9, 13). Sea current distributes the compound randomly but the concentration at the bottom remains practically constant for as long as the Industrial Plant discharges the metal.

The concentration of the metal close to the mouth of the river is lesser than those farther from it, leading us to conclude that river water that carries the pollutant is fanned out to both sides by the current of the sea. As expected, the concentration of mercury decreases as the distance from the source increases.

Of the 24 seaweed samples from three places, six contained less than 0.1 ppm, 15, 0.10-0.50 ppm, 1, 0.5-1.0 ppm and two contained more than 1.0 ppm mercury on a wet weight basis. The

above findings reveal that the levels of mercury in all seaweed samples exceed considerably over those of seawater samples. This is because seaweeds attach themselves to the solid substratum of the sea where concentration of mercury compounds in this location is quite high. Thus, they absorb mercury and accumulate them into their system. The modes of accumulation are not well understood but two mechanisms have been proposed to account for it. One mechanism is the direct absorption of mercuric compounds from the water and its long retention time in tissues. The other is the indirect formation of mercury compounds by microorganisms on the surface of the leaves and its subsequent absorption into the seaweed tissues (9). The form of mercury in the weeds' tissues has not yet been determined and subject to further studies.

Of the species analyzed, *Gelidiella acerosa* (laya-laya) contains the highest amount of mercury. This species, although it is not yet eaten by man or animals may be used as a source of animal feed and/or human food (10). In contrast to *Gelidiella acerosa*, *Halimed tuna* (lukay-lukay) does not absorb mercury compounds. This species is utilized in the manufacture of medicine for its purgative property (10). Majority of the seaweeds contain mercury in the range of 0.1-0.5 ppm. This includes *Padian japonicum* (palaran), *Sargassum polycystum* (samo), *lusay* (seagrass), *Antinnotrichia fragillis* (bungot-bungot) and *Gracilaria* (galaw-galaw). Lesser amounts are found in *Galaxaura oblongata* (guso-guso) and *Enteromorpha intestinalis* (lumot). From an interview with Pillsbury-Mindanao Flour Milling Corp. personnel, it was learned that *Sargassum polycystum* comprises the bulk of the exported seaweeds to Japan for the manufacture of animal feeds. Locally, this seaweed is used as one of the components of livestock feeds, constituting 2-5% of the total feed mixture (3). Because of its high agar content, *Gracilaria* is processed into various forms of food or dessert and chemical algenate products. *Enteromorpha intestinalis* is the main diet of some fishes. *Lusay* and some of the above species serve as egg's nest of most fishes (10). Generally, all the spe-

cies studies are sources of foods for aquatic organisms.

Environmental Impact

The environmental impact brought about by mercury pollution vary widely. The worst one falls on living organisms. Concentrations as low as 0.1 ppb are toxic to most phytoplanktons (13) and to some microorganisms it is markedly toxic at the level of less than 1 ppm (9). Jones and Cobet believe that the trace metal ion in seawater is the principal factor in the death of some aquatic microbes in the medium. However, most bacteria have the capability to develop tolerance to some degree (9). They are now responsible for the biotic transformation of mercury from one form to another. Of the several forms of mercury found in the environment, such as elemental mercury, mercuric or mercurous ions and organomercury compounds, an organic form of mercury, methyl mercury, is by far the most toxic (6, 9, 13). This is because it is the least subject to degradation in the human system. Practically all the mercury in fish has been shown to be in the form of methyl mercury (7). Concentration of 0.05 ppm results to chromosomal damages and abnormal cell division (13). The accumulation in the body also attacks the nervous system (9). The organic part of the molecule to which mercury is attach makes it easily soluble in fats. Therefore it dissolves in the thin fat layer surrounding the nerve cords (12). Long retention time in the system and further concentration to neurotoxic level can cause severe neurologic disorder and finally lead to human death.

Conclusion and Recommendation

The results of this study show that as expected a particular area of Iligan Bay contains significant amounts of mercury. The industrial plant which is its source has been operating and may continue to operate for some future time and the concentration of mercury may reach a level where its effects on living organisms

may be manifested in a much shorter time if no additional preventive measures are undertaken.

Treatment technology for mercury must be fully studied and properly implemented. Among them are precipitation, ion exchange, absorption and coagulation, reduction of ionic mercury to elemental form and removal by filtration. The effectiveness of each treatment, however, depends largely on the state of mercury and the presence of other constituents which interfere in that specific treatment. Spentwastes from various sources must be treated before they are allowed to reach the aquatic world. We cannot eliminate mercury from the environment but through the different elimination processes we can greatly reduce the amounts we deliberately introduce into it.

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AN EXAMPLE OF EACH SPECIES OF SEAWEEDS ANALYZED
WITH ITS' MERCURIC CONTENT

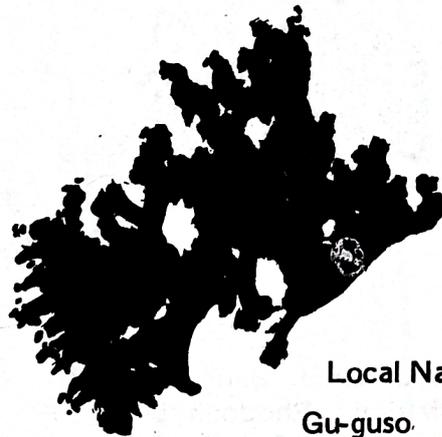
Figure 2



Local Name
Lu mot

Division : Chlorophyta
Class : Chlorophyta
Order : Ulvales
Family : Ulvaceae
Genus : Enteromorpha
Scientific Name: Enteromorpha
Intestinalis

Figure 3



Local Name
Gu-guso

Division: Rhodophyta
Class: Florideophyceae
Order: Rhodariales
Family : Rhodangiaceae
Genus : Galaxaura
Scientific Name:
Galaxaura Oblongata

Figure 4



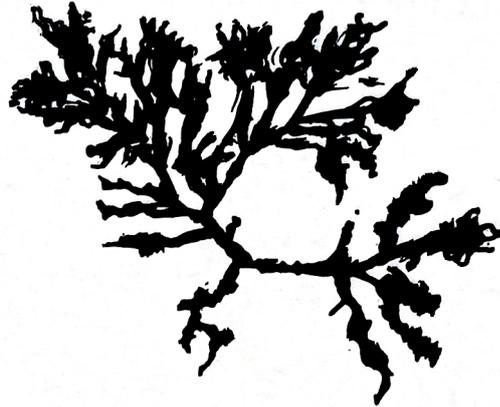
Local Name: PALARAN
Division: Phaeophyta
Class : Isogonales
Order: Dictyotales
Family : Dictyotaceae
Genus : Padina
Scientific Name:
Padina Japonicum

Figure 5



Local Name: Bungot Bungot
Division: Rhodophyta
Class: Florideophycidae
Order: Nemalidnales
Family: Chaetangiaceae
Genus: Actinotrichia
Scientific Name:
Actinotrichia fragilis

Figure 6



Local Name: Laya Laya
Division: Rhodophyta
Class: Florideophycidae
Order: Gelidiales
Family: Gelidiales
Genus: Gelidium
Scientific Name:
Gelidium acerosum

Figure 7



Local Name: Galaw Galaw
Division: Rhodophyta
Class: Florideophycidae
Order: Gigartinales
Family: Gracilariaceae
Genus: Gracilaria
Scientific Name:
Gracilaria

Figure 8



Local Name: Lukay lukay
Division: Chlorophyta
Order: Siphonales
Family: Cod: Aceae
Genus : Halimeda
Scientific Name:
Halimeda Tuna

Figure 9



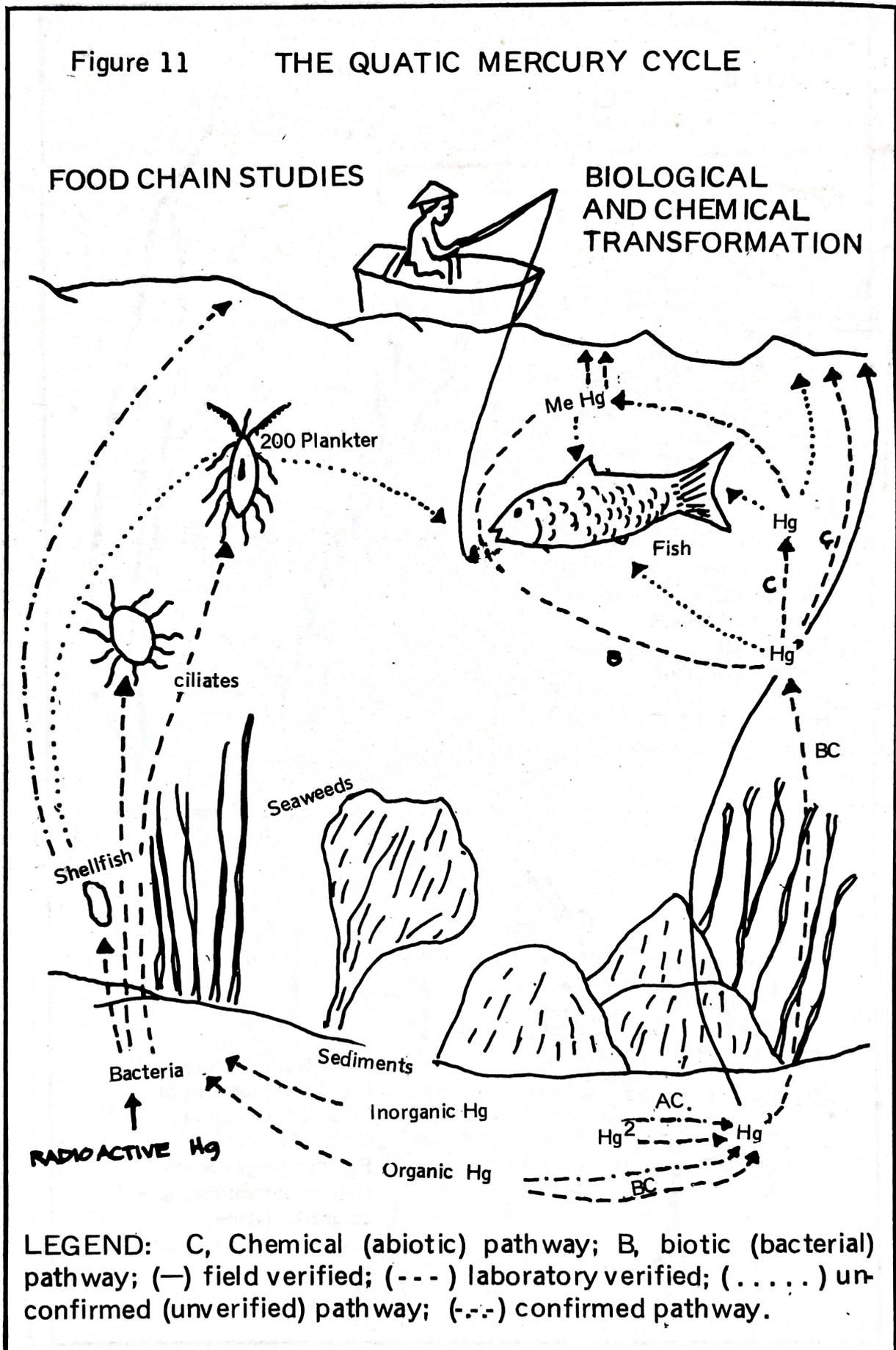
Local Name: Lusay
A Sea Grass



Figure 10

Local Name: Samo
Division: Phaeophyta
Class: CY Closporae
Order: Fucales
Family: Sargassaceae
Genus: Sargassum
Scientific Name:
Sargassum Polycystum

Figure 11 THE QUATIC MERCURY CYCLE



LEGEND: C, Chemical (abiotic) pathway; B, biotic (bacterial) pathway; (—) field verified; (---) laboratory verified; (.....) unconfirmed (unverified) pathway; (-.-.-) confirmed pathway.