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DIFFUSION ANALYSIS OF INDUSTRIAL WASTE (MERCURY) IN STILL RIVER USING ALGAE AS BIO-INDICATOR

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ABSTRACT
Industries secured permit to operate and were granted of environmental compliance given the methods of waste disposal in their operations. However, eutrophication naturally occurred in the environment exposing the living to industrial wastes especially heavy metals such as mercury. This study used algae as primary social atom interacting with other social atom such as fish after diffusion of toxic waste like mercury in still waters. To describe the natural interactions of these social atoms, the researchers made use of complex adaptive system to simulate the real world where fish consumes algae and eventually fishes are consumed by humans. After 30 days period of interaction given the concentration level of mercury in still water at a given distance, results showed significant adaptation of fishes from "no mercury content" to "low and high mercury content". Thus, posing environmental and health hazards to humans.

Keywords: *diffusion, mercury, algae, complex adaptive system (CAS), bio-indicator*

1. INTRODUCTION

Algae have been widely used in various countries as heavy metal biological indicators in freshwater and marine environments due to its availability in every season and the ability to uptake and accumulate metals (Omar, 2010; Al-Homaidan et al., 2011). Heavy metal concentration is preferably measured in bio-indicator organisms because it provides a time integrated measure from minutes to years (Cooper et al., 2009). Mercury (Hg), a naturally occurring element, is classified as a global pollutant because of its ability to travel extensive distance from the source. Mercury is one of the top ten chemicals of major public health concern due to its ability to persist in the environment for longer periods (WHO, 2013).

Non-essential heavy metals such as mercury, naturally occur in the environment or from anthropogenic sources like mining, fossil fuels, combustion, and incineration, emission from smelters, fungicides, and catalyst activities. The presence of heavy metals in water is increasing due to the industrial development-disposal to which mercury posing one of the greatest hazards to human health. Underground disposal as currently being used by most industries in the Philippines is regarded as the safest disposal methods for wastes with high a water-soluble share or with toxic pollutant contents (e.g. given heavy metals, cyanides). However, eutrophication may occur to which excessive deposits of heavy metals diffuse in any body of water usually caused by run-off from the disposal source.

This occurrence elevates the heavy metal concentrations in these water sources especially in still water. Mercury is methylated once present in water and will be converted into methylmercury, the most toxic chemical species which may cause harm to the central nervous system, such as behavioral disorder and deficiencies in the immune system and development (Harada et al., 1998). Uptake and accumulation of heavy metals by algae represents the main entry pathway for potentially health-threatening toxic into human and animal food thereby putting human, plant and animal life at a very high risk.

Therefore, this study aims to determine potential environmental and health hazards (mercury pollution) based on the interactions of the algae as the primary social atom with other social atoms such as fish. Results may be used as basis for future policy formulation.

2. METHODS

This study utilized the model of complex adaptive system in which the algae as the primary social atom present in the living water interacts with the fish as another social atom in the still river. In this study, the aggregate element is the mercury content of each of the social atom after interactions in a given time. The following algorithm below is used to conduct the study.

- Compute the concentration level of the Mercury given the distance "x" with respect to time "t" using the formula below:

$$p(x,t) = \frac{1}{\sqrt{4\pi Dt}} \cdot e^{-\frac{x^2}{4\pi Dt}}$$

Where,

p(x, t) = probability of mercury given the distance with respect to time

Diffusion coefficient (D)= 47.46 mg/L

Time (*t*) = *1 unit of time = 30 days*

Distance (x)

a. x = 0 - 30 meters

b. x = 30 - 60 meters

c. x = 60 meters beyond

- Generate Algae Population (AP) = 30 algae
- Classify Algae based on Mercury Content (MC) relative to distance:

1. Algae (1)
   - High MC
   - within 0 – 30 meters from origin x
2. Algae (2)
   - Low MC
   - within 30 – 60 m
3. Algae (3)
   - No MC at all
   - beyond 60 m

Important Note: maximum mercury absorption of algae is 6.98 mg/L.

- Classify Fish based on its size. The size of the fish determines the maximum amount of mercury content that can be accumulated in it.

1. Small (S)
2. Medium (M)
3. Large (L)

- Interaction and Adaptation Table Between Algae and Fish

Social Atom	Natural Action	Interaction	Likelihood of Interaction	Adaptation
Fish (S)	No MC	Fish (S) – Algae 1 Fish (S) – Algae 2 Fish (S) – Algae 3	[.2, .4] [.3, .6] [.4, .8]	High MC Low MC No MC
Fish (M)	No MC	Fish (M) – Algae 1 Fish (M) – Algae 2 Fish (M) – Algae 3	[.2, .4] [.3, .6] [.4, .8]	Low MC Low MC No MC
Fish (L)	No MC	Fish (L) – Algae 1 Fish (L) – Algae 2 Fish (L) – Algae 3	[.2, .4] [.3, .6] [.4, .8]	Low MC No MC No MC

- Count the number of social atoms with:
  (1) High Mercury Content
  (2) Low Mercury Content
  (3) No Mercury Content
- Do a 30-simulation run equivalent to one month where 1-run simulation is equivalent to 1 day.

3. FINDINGS & ANALYSIS

The Figure 1 shows the movement of mercury from a distance of higher to a distance of lower concentration during the diffusion process within a given time of 30 days. On day 1, Mercury stay concentrated within 30m of distance but shows very minimal concentrations at a distance of 60m and none at 90m. Furthermore, the concentration of mercury started to manifest on day 3, though very minimal, it gradually increases until day

30. It is also very important to note that within 30m, concentrations of mercury decreases until it stabilizes regardless of the distance with the same concentration levels in a period of time.

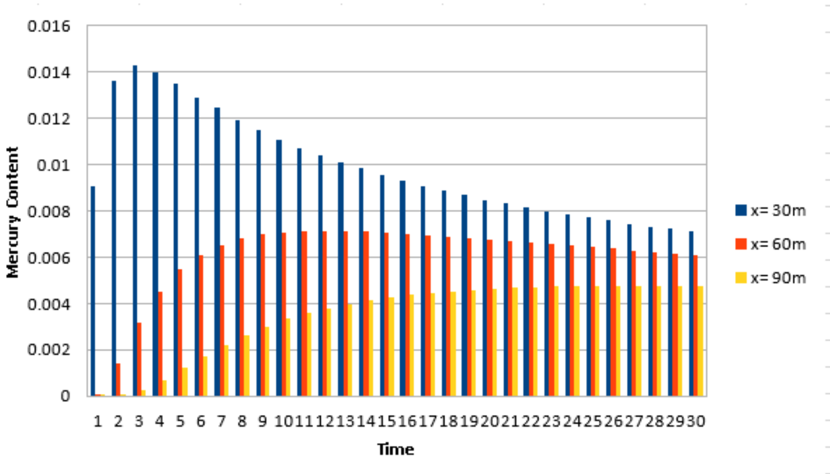

Figure 1: Concentration Level of Mercury Content in a Given Distance with Respect to Time

Adaptation Table (Table 2) shows the total number of fishes adapted from "no mercury content" to "with high and low mercury content" after 30 days interaction. Out of the total population of fish, 50% have remained to "no mercury content" after consuming some of the algae. This results showed that more fishes interact where there is less concentration level of mercury.

Table 2: Adaptation Table of Fish after Interaction

Social Atom	Original	Adaptation		
	No MC	High MC	Low MC	No MC
Fish (S)	13	3	4	5
Fish (M)	9		5	4
Fish (L)	8		2	6
Total	**30**	**3**	**11**	**15**

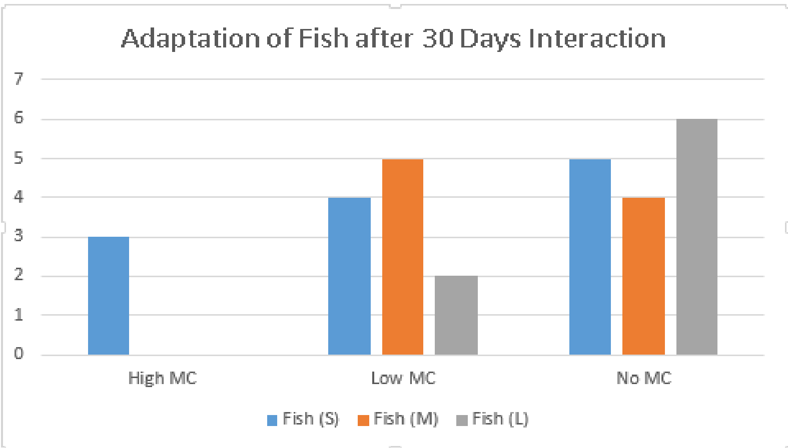

Figure 2: Graph of Mercury Accumulation of Fish After Algae Consumption

Mercury accumulation of fishes (small, medium, large) after 30 days interaction (Figure 2) shows that small fishes are most likely to accumulate "high mercury" content because of less tolerance and resistance capacity, while large fishes, despite consuming high mercury content algae, only accumulates "low mercury" content.

In general, among 13 small fishes, only 3 fishes becomes high mercury content, 4 fishes becomes low and 5 remains no mercury content.

4. CONCLUSION

As apparently observed in the results, there is potential and health hazards on mercury when there is industrial taking in place near in any body of waters especially in still waters. Because of eutrophication, industrial waste like mercury diffuse in water resulting to water becomes eutrophic in time. The high concentration of mercury attracts blue green algae where they are consumed by fish. Fishes tend to adapt in its environment through ingestion of contaminated algae where they are also eventually consumed by humans putting risk to health.

5. RECOMMENDATIONS

It is highly recommended to include the interactions among fishes and other species present in the water. Furthermore, it is very important to review the policy in granting permit in industrial operations and the environmental compliance of industrial's waste disposal.

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7. BIOGRAPHY

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