USING BENTHOS TO EVALUATE THE QUALITY OF MARINE ENVIRONMENT: CASE STUDY FROM CENTRAL VIETNAM AFTER THE INCIDENT CAUSED BY FORMOSA

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ABSTRACT

In this study, we evaluated the quality of marine environment in central Vietnam after the disaster caused by Formosa Ha Tinh Steel Corporation (Formosa), using both bio-indicators (benthos) and chemical indicators. Results show that using benthic fauna, especially meio-benthos can obtain data on the quality of marine environment faster and more accurate than using chemical indicators. In marine environment, monitoring contaminated areas and contamination sources is difficult since currents are normally strong, contaminants often move fast and far away from the sources. For the reasons, using benthos as indicator to localize the contaminated areas as well as assess the quality of marine environment can be an effective method. However, this indicator cannot help to identify the exact contaminants and using this requires a comprehensive knowledge on sea bottom topography, sedimentary characteristics, sea currents, biological competition, etc.

Keywords: marine environment, bio-indicators, chemical indicators, benthos.

1. INTRODUCTION

On 6th April 2016, the massive fish carcasses were washed up on the coast of Ha Tinh Province and later, dead fishes were found continuously southward to Quang Binh, Quang Tri and Thua Thien Hue Provinces until 18 April 2016. This disaster had negatively affected the marine environment, regional economy and society. It disrupted the livelihood of fishermen and heavily impacted the tourism industry in the whole region. The massive marine life destruction led to a number of protests by Vietnamese citizens in big cities from May 2016 till early 2017, calling for a cleaner environment and demanding transparency in the investigation process [1].

Responses from government after the disaster were not always consistent and effective, according to the public. There are some major scientific reasons for this ineffectiveness, as follows: 1/ The scientific investigations demand a large budget and a long time to a final conclusion; 2/ A very large research marine zone brings difficulties to scrutinize; 3/ The sea currents shift the contaminant (s) far and quickly from the discharged sources, resulting in the

difficulties in finding the contaminated factor(s). For these reasons, choosing the most appropriate method to localize the contaminated areas should be taken into consideration in every investigation of marine environmental quality.

In the present study, we evaluated the quality of marine environment where the massive fish carcasses were found, using chemical and biological indicators. Applying biological, especially benthos indicators in evaluation the quality of marine environment is popular in many other countries [2, 3, 4], however, those indices are not widely applied in Vietnam. By comparing between chemical and biological indicators, we find out which one provides a faster assessment in our research. The purpose of this research is to seek for a method to quickly assess the quality of marine environment, with a reasonable cost. Results of this study can be used to localize rapidly polluted areas for further detailed investigations, to reduce cost and also to shorten time for investigations whenever the marine environmental disaster happens.

2. MATERIALS AND METHODS

2.1. Study time and sites

The studied samples were collected from 2 periods: 16th - 22nd May 2016 and 4th - 9th September 2016. The 1st sampling campaign extended along the coastal areas from Quang Dong (Quang Binh Province) to Hoi An (Quang Nam Province) (Fig. 1, a), where the fish deaths were reported washed up on. Samples assembled from this campaign were analyzed chemically and biologically and from this, hot spots (sites show environmental degradation) were realized and used as guideline for the 2nd sampling trip, spanning from Vung Ang (Ha Tinh Province) to Cua Tung (Quang Tri Province) (Fig. 1, b). All chosen sites are located from 50 m to 6 km far from shoreline, with water depth ranges from 2-30 m. Because of some political reasons, we couldn't collect samples in Vung Ang (Ha Tinh Province) in the 1st sampling campaign but in the 2nd one. Totally, 66 sites were investigated in the 1st trip and 45 sites were examined in the 2nd one.

Figure 1. Maps indicated the positions of samples from: a) the 1st campaign and b) the 2nd campaign.

2.2. Sampling technique, lab treatment and data analysis

2.2.1. Sampling technique

To find out which kind of indicators allows to assess faster the quality of marine environment, we evaluated the quality of water and sediment environments, using chemical and biological indicators. Three types of samples were collected: sediments, water (surface and bottom) and benthos (hyper, epi- and infauna). Water and sediment samples were taken and pretreated following the guidance of ISO 5667-9: L992.

Epifauna and infauna were sampled by excavating sediment enclosed by metal frame to a depth of 15 cm, passed through a 1 mm sieve for macrobenthos and retained on a 38 μm sieve for meiofauna. Macro- and meiobenthos were then fixed with formaldehyde solution to a final concentration of 8 % and 4 %, respectively [2, 4]. Hyperbenthos were caught by a hyperbenthic sledge (mesh size of 0.125 μm), fixed and preserved in 4 % formaldehyde solution [4]. During the sampling process, characteristics of sediment and surface bottom, gathered with the details of water depth, tide, currents etc. of the investigated sites were recorded. These data later on enable us to clarify the differences of benthos densities between sites caused by natural or human-induced reasons.

2.2.2. Lab treatment and data analysis

With chemical indicators, sediment samples from the 1st sampling campaign were sent to the Center of Analytical Services and Experimentation HCMC (CASE) to identify heavy metals concentrations (As, Hg, Pb, Cd, total Cr, Cu and Zn), while the water samples were sent to the Lab of Nong Lam University, where the same heavy metals above plus Fe were analyzed. Those chemical indicators were chosen because Formosa was suspected of causing the disaster, and heavy metals could be responsible to the mass fish deaths. Sediments from the 2nd trip were target to identify POPs (persistent organic pollutants) contents (CETASD analyzed) since at this moment, phenols were confirmed to be the main contaminants. For this 4 groups were focused: PCB (polychlorinated biphenyl), PAH (polycyclic aromatic hydrocarbon), PBDE (polybrominated diphenyl ethers) and perflo alkylnoic acid and salts.

In the Lab, all benthos samples (hyper, epi- and infauna) were sorted into the corresponding groups, which included hyperbenthos (Amphipoda, Cumacea, Isopoda, Mysida, Copepoda, Decapoda,…), Pycnogonida, Nematode, Nemertea, Turbellaria, Polychaeta, Ostracoda, Bivalvia, Gastropoda, ect and counted. Densities of these groups were calculated to the number of individuals per square meter (ind./m^2). To assess the quality of environment, results gained from the 1st sampling campaign were compared between sites, as well as compared with historical references collected in 2013 (personal collection), when the marine environment over there was not polluted yet. In comparison with results of the 1st campaign, the results gained from the 2nd time help to check how the quality of the local marine environment has changed after 3.5 months since the 1st sampling time.

3. RESULTS

3.1. Quality of marine environment from 16-22 May 2016 based on the chemical indicators

Concentrations of heavy metals in sediment samples were generally lower than Vietnamese permissible levels (QCVN 43:2012/BTNMT). Total Cr basically varied from 12 to 58 mg/kg, except at 2 sites. Pb and As were between 3.3 -5 3 mg/kg and 0.8 - 129.5 mg/kg, respectively, while Cd is in the range of 0.1-1.0 mg/kg. Among 66 investigated sites, 9 sites indicated the As concentration above the permissible level. With total Cr and Cu, this number was 2 and 2, respectively. Concentrations of Hg, Pb, Cd and Zn were all under the permissible level. In water samples (surface and bottom), concentrations of As, Pb, Cd, total Cr, Cu, Zn were below permissible levels (QCVN 10-MT:2015/BTNMT). However, two samples with Fe and two samples with Hg concentrations were higher than permissible levels. Those all 4 samples came from Quang Binh Province. This indicated that the quality of water environment in the investigated region was more or less safe, based on the heavy metal concentrations.

3.2. Quality of marine environment during 4th-9th September 2016 based on the chemical indicators

Four sediment samples came from Bo Trach, Ngu Thuy, Quang Dong (Quang Binh Province) and Vung Ang (Ha Tinh Province) were chosen to analyze substances belong to PCB, PAH, PBDE and perflo alkylnoic acid and salts. The obtained results illustrated that POPs contents from those samples were all under permissible levels (QCVN43:2012/BTNMT), suggesting no danger from POPs on marine food chains in this region.

3.3. Density of benthic fauna from the 1st sampling campaign and the quality of marine environment based on this data

Our results show that benthic densities from the 1st sampling campaign were largely different between sites. Highest value was 17.500 ind/m^2 and the lowest was only 390 ind./m^2. Generally, those densities range from about 2000 - 6000 ind./m^2 in Da Nang - Hoi An; 850 - 8000 ind./m^2 in Hue; 390 - 17.500 ind./m^2 in Quang Tri and 600 - 15.200 ind./m^2 in Quang Binh Province (Fig. 2a).
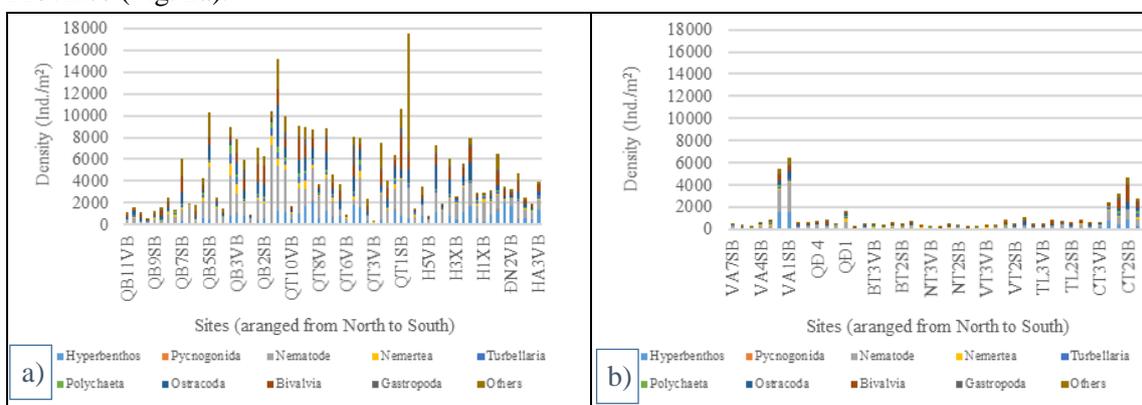

Figure 2. Benthos densities collected from the 1st sampling campaign (a) and 2nd sampling campaign (b). Locations of samples are arranged from north to south (left to right).
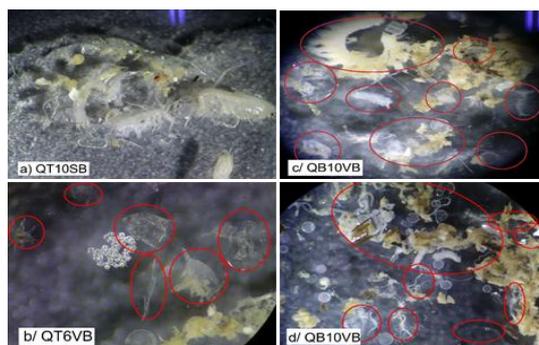

Figure 3. Hyperbenthos from sites where the environment was healthy (a) and degraded (b, c, d). Figure b. Most hyperbenthos were decomposed and Fig. c,d: Hyperbenthos and worms were decomposing.

Compared these data with data from the reference samples, the benthic densities in Da Nang - Hoi An between two time intervals are more or less the same. The samples, which shows

densities less than the densities of the references were the ones collected from sites where sediments are coarse or clean, or having larger average size of benthic group(s), indicating the natural conditions such as dynamic of the currents, nutrient, ecological competition, etc.

In Thua Thien Hue Province, there is one historical reference (4100 ind./m^2), collected in Lang Co. Among twelve samples assembled in Hue, two had benthic densities far lower than this reference, four ones indicated higher and six ones have a little less values. Four among these six samples came from the sites where sediments were very clean or coarse (low nutrient) and two remaining ones have larger benthic groups. Therefore these samples are eliminated from being affected by unexpected, human generated causes. In two samples, which show low benthic densities, a lot of carrions of hyperbenthos and some decomposing worms can be seen. Our addition experiments proved that these benthos were killed just 4-5 days before being collected. It can be concluded as follows: 1) This two samples were seriously affected by unexpected factor(s), and 2) The examined environment was dangerous for benthos, specially hyperbenthos at the time those benthos were collected.

In Quang Tri Province, we have two historical references in Vinh Linh, where the benthic densities were 3850 and 5130 ind./m^2. Compared to the references while eliminating natural reasons which caused the low densities from some sites, we concluded that among 18 investigated sites, four sites have the abnormal low benthic densities. Those sites also have large number of decomposing benthos carrions, specially hyperbenthos (Fig. 3, b). The observation reveals that these benthos groups were dead about 5-7 days before collected. Hence, it is can indicated that at the moment of collecting samples, the environment was facing to serious concerns in the bottom water column and the sediments at those sites.

In Quang Binh, one historical reference was recorded from shallow water in Duc Trach (6760 ind./m^2). Among 24 investigated sites, 11 sites have the benthic densities more or less equal or higher than the reference. Under microscope, the good health of specimens were observed from those samples, indicating the safe environment for benthic communities at the assembling time. However, in 13 remaining samples, benthic specimens, specially hyperbenthos were badly preserved. High density of decomposing benthos carcasses in these samples (Fig. 3, c and d) displayed the poisoned environment in related locations just 4-5 days before the collecting day.

3.4. Density of the benthic fauna from the 2nd sampling campaign and the quality of marine environment based on this data

45 samples located in coastal areas from Cua Tung (Quang Tri Province) to Vung Ang (Ha Tinh Province) were collected and analyzed. Results show that the benthos densities in this region significantly decreased since the 1st sampling campaign (Fig. 2, b). Considering the natural factor(s) that could affect the benthos densities (dynamic of the currents, waves, organic content, biological competition, etc.), in brief, 28 samples present a severe degraded environment at the time samples collected, six samples showed the moderate degradation and another 11 samples suggested that the combination between natural and accidental, human-induced reasons are the main causes for the low densities of benthos in those samples.

Since most of those benthic groups recorded in this region belong to the 2nd or 3rd trophic level in marine food change and regarding to the marine ecological efficiency is about 10 %, it can be seen how the quality of marine environment has degraded during 3.5 months since the 1st sampling time, as well as the real situation of the ecosystems here at the assembling moment.

3.5. Benthos or chemical indicators first?

We compared the cost for identification of both chemical and biological indicators, the efficiency of using these indicators in assessing the quality of marine environment (Table 1). As can be seen in Table 1, using benthos as indicators give a better way to identify sites which have environmental issues compared to chemical indicators, with much lower cost.

As has been noted, the sea currents are naturally strong, so that the contaminants are often shifted quick and far away from the discharged sources. Consequently, chemical indicators don't give expected results to examine the quality of marine environment, as well as to localize the contaminated areas, and our study is an example for this problem.

In the case of the heavy contaminants sunk into the bottom, focusing on chemical indicators in sediments is a better option. However, among a variety of chemical indicators, it's difficult to select appropriate indicators without any trustful clues. This method might lead to time-wasting and high expense whether positive results can be obtained or not, as we experienced in this study.

Table 1. Summaries the cost and efficiency of chemical and biological indicators in the studied region (Level of environmental degradation: + slight, ++ moderate, +++ severe, ? may be affected by natural elements).

Sampling time	Level of environmental degradation shown by benthos	Heavy metal concentrations in water	Heavy metal concentrations in sediments	POPs in sediments
16-22/5/2016	4/61 sites: +++ 9/61 sites: ++ 6/61 sites: +	13/66 sites: +	4/66 sites: +	N/A
4-9/9/ 2016	28/45 sites: +++ 6/45 sites: ++ 11/45 sites: +?	N/A	N/A	No degradation observed
Test cost (vnd)	800.000/test	500.000/metal	500.000/metal	2.000.000 /group

Furthermore, benthic fauna in this study were generally small, they are very vulnerable with the changes in their surroundings. Slight and negative shift in marine environment can cause mass deaths of benthic communities. These ocean creatures are less affected by the currents, therefore quantitative (at some cases, also qualitative) studies on benthic fauna can be the more accurate, rapid and inexpensive way to inspect the marine environment more than using chemical indicators.

However, as benthic communities are very sensitive, other natural factors (coastal dynamics, sediment grain size, nutrient content, ecological competition, etc.) can also affect the densities of those communities. These indicators require a deep knowledge on natural factors as mentioned. Additionally, although benthos cannot help identifying the exact contaminants, it is effective in localizing the polluted areas for further research. This time-saving and low-cost method is useful to look up the contaminant(s) and discharged sources.

4. CONCLUSIONS

Our study reveals that when the disaster in marine environment occurs, quantitative and qualitative investigations on benthic communities can effectively help to assess the quality of marine environment, with a reasonable budget, in comparison with chemical indicators. This finding can reduce the bias in assessing the quality of marine environment, which caused by sea currents. Moreover, it permit to localize exactly the contaminated areas for further detailed examination, including of the identification of the contaminants and the discharged sources with limited period of time and low cost. Benthos quantitative and qualitative investigations present a standard procedure in the investigation of the marine environment disaster.

REFERENCES

1. Vu T. K. - Vietnam protesters seek answers over mass fish death, Wall Street Journal Retrieved **8** (2016).

2. Carlo H. - Meiobenthos as a tool in the assessment of marine environmental quality, Explor. Mer., **179** (1980) 182-187.

3. Kennedy A. D. and Jacoby C. A. - Biological indicators of marine environmental health: meiofauna - a neglected benthic component? Environmental Monitoring and Assessment **54** (1999) 47-68.

4. Salasa, F., Marcosa C., Netob J.M., Patrı´ciob J., Pe´rez-Ruzafaa A., Marquesb J. C. - User-friendly guide for using benthic ecological indicators in coastal and marine quality assessment. Ocean & Coastal Management **49** (2006) 308-331.