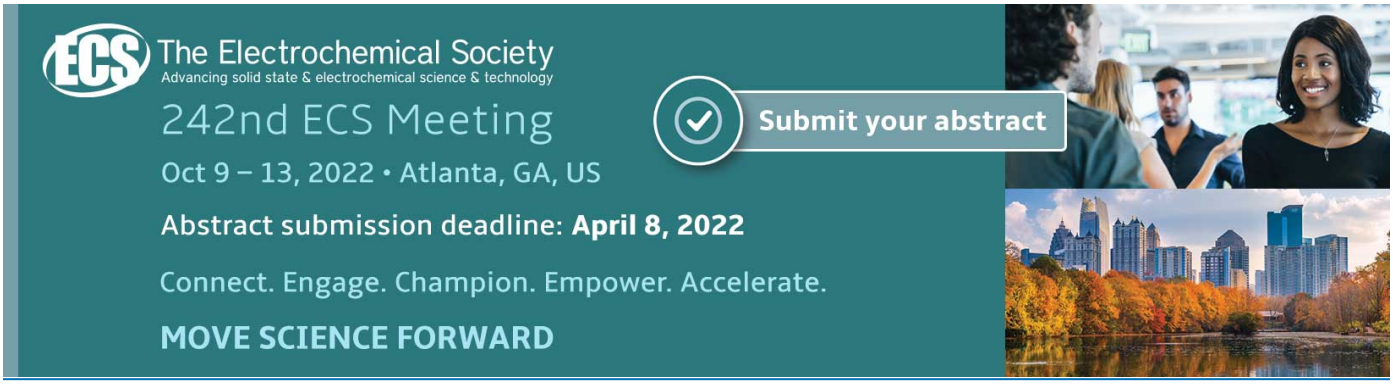
Distribution and accumulation of heavy metals from waters and sediments to *Scylla serrata* in Segara Anakan, Cilacap



Distribution and accumulation of heavy metals from waters and sediments to *Scylla serrata* in Segara Anakan, Cilacap

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Abstract. Some heavy metals of Cd, Cu, Pb, and Hg polluted in Segara Anakan Cilacap, but no information on a specific heavy metal pollution in this area and an edible mud crab of *Scylla serrata*. The research aimed to know their distribution in this area and their accumulation of heavy metals from waters and sediments to *Scylla serrata*. The study was done using a survey method with purposive random sampling at six stations from Station SA-2-28 and SA-3-46 (with a high percentage mangrove canopy cover) to Station SA-2-24, SA-3-35, SA-1-10, and SA-3-16 (with a low percentage mangrove canopy cover). Three replications were done in the dry season conditions from July to September. The researcher took all samples with the water sampler tool, sediment core, and baited trap for sampling. Then, they were analyzed using Atomic Absorption Spectrophotometry (AAS) method. The result showed that the lowest heavy metals were at Station SA-2-28 and SA-3-46 and followed by Station SA-2-24, SA-3-5, SA-1-10, and SA-3-16 due to the high percentage of mangrove canopy cover, while the reserve order was due to the increased pollution in east side areas of Segara Anakan Cilacap. The heavy metal accumulation of Cd, Cu, Pb, and Hg has occurred from waters and sediments to *Scylla serrata.*

1. Introduction

In general, the water quality of the Segara Anakan Cilacap was good enough, except for some variables such as TDS, COD, B, Cd, Cu, Cl, and H_2S [1]. In recently, some researchers were reporting separately, e.g., heavy metal Pb detected at shells *Polymesoda erosa* [2]; and also in waters, gills, and liver at fish *Mugil dussumieri* [3]. Another research detected heavy metal Hg in waters, sediment, and prawns *Metapenaeus monoceros* [4]. The pollution of heavy metal Cd was detected in waters, sediment, and prawn *M. monoceros*, *Penaeus indicus*, *P. merguensis*, *P. semisulcatus*, and *P. monodon* [5]; sediment and edible mud crab *Scylla serrata*, *S. transquebarica*, and *S. olivacea* [6]. A year later, the heavy metal Cd in *S.* spp [7]. The species of *S. serrata* were more contaminated to *P. monodon* [8].

The heavy metal Cd was in waters, sediment, and mangrove leaf. The heavy metal was detected less on the silvofishery pond than the non-silvofishery pond [9]. The amelioration process occurs by absorption of heavy metals from the roots to stem and finally to plant leaf [10].

Chemical concentration can achieve a level that exceeds in an organism, and we called bioaccumulation, e.g., water for an organism. The bioconcentration factors or BCF can explain it [11]. It calculates heavy metal input from the surrounding environment [12].

This study was gaining to find out the accumulation of heavy metals from waters, sediment, and the meat of in more detail. This study aimed to analyzed the conditions of the distribution of heavy metals at each station in Segara Anakan Cilacap. In this study, we also observed conditions of the accumulation of heavy metal contamination from waters and sediments to *Scylla serrata*.

2. Methods

The research was conducted based on a survey method with purposive random sampling. Sampling was carried out randomly in a stasion with different conditions such as the percentage of mangrove canopy cover and salinity.

2.1. Study site

The study site was conducted in the Segara Anakan Management Area, Cilacap, with coordinate 8°35' - 8°48' S and 108°46' - 109°03' E. Six stations were taken in this area based on Science for the Protection Indonesian Coastal Marine Ecosystems (SPICE) in Figure 1. [13] with the following conditions:

1. Stations SA-2-28 (coordinate 7°41'54" S and 108°53'17" E) and SA-3-46 (coordinate 7°41'45" S and 108°57'11" E) which are in mangrove forest areas with the percentage of canopy cover as much 90% and salinity about 18‰.
2. Stations SA-2-24 (coordinate 7°39'35" S and 108°50'16" E) and SA-3-5 (coordinate 7°40'59" S and 108°59'59" E) which are in mangrove forest areas with the percentage of canopy cover as much 40% and salinity about 21‰.
3. Stations SA-1-10 (coordinate 7°40'46" S and 108°48'36" E) and SA-3-16 (coordinate 7°43'47" S and 108°59'10" E) which are in mangrove forest areas with the percentage of canopy cover as much 15% and salinity about 23‰.

Figure 1. Sampling stations in Segara Anakan, Cilacap (Nordhaus, 2009)

2.2. Sampling methods

The research was done in the dry season from July to September 2015 in full moon condition. The software program of WXTide32 version 4.0. was taken for choosing sampling time [14].

Water samples were taken with a water sampler and analyzed based on the reference book [15]. AAS analyzed heavy metals based on the reference book [16]. The supporting parameters of the water

quality studied refer to Peraturan Pemerintah Republik Indonesia Number 22 the Year 2021 about the protection and management of environment [17]. Some parameters were calculated, such as physics (temperature and TDS), chemistry (pH, BOD_5, COD, DO, H_2S, phenol, B, Cd, Cu, Cl, F, Pb, and Hg), and microbiology (coliform and fecal coli). This research did in the Environmental Laboratory in the Faculty of Biology, Universitas Jenderal Soedirman; and the Research Laboratory, Universitas Jenderal Soedirman.

Sediment samples were taken by core [18] and analysed in Laboratorium Riset Universitas Jenderal Soedirman. This research was done in the Soil Laboratory, Faculty of Agriculture, Universitas Jenderal Soedirman.

Crab samples were taken in low tide conditions [19] and preserved by alcohol [20]. Crabs were identified and determined by some references [21, 22, 23, 24]. This research did in the Aquatic Biology Laboratory, Faculty of Biology, Universitas Jenderal Soedirman, and the Research Laboratory, Universitas Jenderal Soedirman.

2.3. Data analysis

The conditions of the distribution of heavy metal contamination in waters, sediments, and meat of *Scylla serrata* in Segara Anakan Cilacap were analyzed by Peraturan Pemerintah Republik Indonesia Number 22 the Year 2021 about the protection and management of environment in Class II [17]. The conditions of the distribution of heavy metal contamination at each station in Segara Anakan Cilacap was analyzed descriptively using a dendrogram. It was analyzed by IBM SPSS Statistics ver. 25.0 [25].

The heavy metal bio-accumulation was analyzed by the OECD guidelines for testing chemicals in annex 1, such as the bioconcentration factor (BCF with an equation A5.4 as shown below) at any time during the uptake phase of this accumulation test [11].

$$BCF_{crab} = \frac{C_{crab}}{C_{water}}$$

$$BCF_{crab} = \frac{C_{crab}}{C_{sediment}}$$

Where BCF_{crab} is the chemical concentration test in crab (test organism) the concentration of test substance at steady-state in/on the organism or specified tissues thereof (C_{crab} as mg/kg) divided by the concentration of the chemical in the surrounding medium (C_{water} as mg/l and $C_{sediment}$ as mg/kg).

3. Results and Discussions

The water quality of the Segara Anakan Cilacap was categorized good based on in PP 22/2021, except for some variables such as COD, Cd, and H_2S (Table 1). Based on the specific research, Cd was a heavy metal variable considered to exceed Class II surface water quality standards [9]. In this research, variable Cd was one of the variables with the highest concentration among the heavy metals studied, so it was a heavy metal that needs special attention.

Previous research showed that the water quality of the East Swamp Management Area was categorized as well, except for several variables, including exceeding the Class II surface water quality standard in PP 22/2021 such as oil spill, pH, Cd, NO_2, phenol, and pathogen. The variable that exceeds the quality standard was in the Donan River, which has an industrial area [26]. The water quality was still categorized good, except for several variables such as TDS, COD, B, Cd, Cu, Pb, Cl, H_2S, and phenol, classified as not good at all stations. The same category was DO (Station SA-3-5) and F (Stations SA-3-46, SA-3-5, and SA-3-16). [27] also found the same condition.

Table 1. Water quality in Segara Anakan Cilacap

Variable	St. SA-2-28	St. SA-3-46	St. SA-2-24	St. SA-3-5	St. SA-1-10	St. SA-3-16	Standard (PP 22/2021)
Temperature (^{O}C)	30.17±0.29	30.17±0.29	30.33±0.29	30.83±0.29	31.0±0.00	31.0±0.00	Deviation 3
TDS (mg/l)	35.94±1.25	36.43±1.28	35.94±1.24	36.09±0.72	33.87±0.31	35.62±0.35	1,000
pH (unit)	7.67±0.06	7.63±0.15	7.80±0.00	7.67±0.06	7.83±0.12	7.87±0.06	6-9
BOD_5 (mg/l)	1.48±0.28	1.75±0.10	1.75±0.13	1.72±0.16	2.23±0.15	2.02±0.07	3
COD (mg/l)	32.27±2.68	32.49±3.02	32.34±3.03	32.43±3.04	32.49±3.02	32.34±2.74	25
DO (mg/l)	4.57±0.25	4.05±0.39	4.55±0.22	4.97±0.76	4.47±0.35	4.54±0.21	4
B (mg/l)	0.36±0.04	0.34±0.04	0.36±0.03	0.34±0.04	0.37±0.03	0.35±0.03	1
Cd (mg/l)	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.011±0.001	0.01±0.00	0.01
Cu (mg/l)	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.013±0.001	0.01±0.00	0.02
Pb (mg/l)	0.003±0.00	0.003±0.00	0.003±0.00	0.003±0.00	0.003±0.00	0.0033±0.00	0.03
Hg (mg/l)	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.002
Cl (mg/l)	10.17±0.21	9.94±0.64	9.29±0.43	9.23±0.28	9.11±0.19	9.69±0.79	300
F (mg/l)	1.07±0.01	1.48±0.01	1.20±0.06	1.43±0.01	1.12±0.01	1.42±0.01	1.5
H_2S (mg/l)	0.002±0.00	0.002±0.00	0.002±0.00	0.002±0.00	0.002±0.00	0.002±0.00	0,002
Fenol (mg/l)	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0,005
Fecal coliform (ind./100 ml)	10.77±5.41	16.67±2.65	95.33±6.81	42.0±1.00	459.67±7.51	40.0±3.00	1,000
Total coliform (ind./100 ml)	211.67±12.58	32.67±6.43	1,033.33±57.74	27.0±7.21	1,033.33±57.74	966.67±152.75	5,000
Salinitas ($^{o}/_{oo}$)	18.00±1.00	17.33±0.58	21.00±0.00	21.33±0.58	23.67±0.58	23.00±1.00	

Where PP No. 22/2021 was used as the standard [17]

Based on [3], heavy metal Pb was detected in waters, gill, and liver of mullet in Segara Anakan Cilacap. Therefore, Pb accumulation has been finding in Segara Anakan Cilacap, although in safe amounts. Other variables also need attention due to their ability to accumulate in other aquatic organisms.

The variables Cd, Cu, Pb, and Hg were present in surface water (Table 1) and the sediment (Table 2). Therefore, the accumulation of four variables has occurred in Segara Anakan Cilacap.

Table 2. Sedimen quality in Segara Anakan, Cilacap

Variabel	St. SA-2-28	St. SA-3-46	St. SA-2-24	St. SA-3-5	St. SA-1-10	St. SA-3-16	Standard
Cd (mg/kg)	0.04±0.00	0.04±0.00	0.04±0.00	0.04±0.00	0.04±0.00	0.04±0.00	1
Cu (mg/kg)	37.29±1.04	36.07±3.21	42.36±2.71	44.84±1.71	38.74±1.49	23.65±2.08	100
Pb (mg/kg)	15.28±0.49	16.48±0.65	16.48±0.64	18.67±0.86	17.81±8.51	8.69±1.11	60
Hg (mg/kg)	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.001±0.00	0.5

Where the standard was based on [28]

The Cd variable, a heavy metal variable that exceeds the quality standards for surface water (Table 1), but sediment (Table 2) and crab meat (Table 3) found less than 0.5 mg/kg (Table 3). This heavy metal also affected fish *Cyprinus carpio* and *Oreochromis niloticus* in freshwater [29]. Another also found in sediment and mangrove leaves [9]. Therefore, the accumulation of Cd variable has

occurred in Segara Anakan Cilacap, especially in levels considered to exceed the surface water quality standard.

Table 3. The quality of mud crab meat at Segara Anakan Cilacap

Variable	St. SA-2-28	St. SA-3-46	St. SA-2-24	St. SA-3-5	St. SA-1-10	St. SA-3-16	Standard
Cd (mg/kg)							0.5
	0.014138± 0.00	0.019268± 0.00	0.009052± 0.00	0.019521± 0.00	0.009490± 0.00	0.029746± 0.00	
Cu (mg/kg)							
	0.007373± 0.00	0.007199± 0.00	0.010232± 0.01	0.008552± 0.00	0.014778± 0.01	0.014507± 0.00	
Pb (mg/kg)							0.5
	0.000185± 0.00	0.000132± 0.00	0.000228± 0.00	0.000180± 0.00	0.000266± 0.00	0.000303± 0.00	
Hg (mg/kg)							0.5
	0.000101± 0.00	0.000113± 0.00	0.000127± 0.00	0.000161± 0.00	0.000124± 0.00	0.000141± 0.00	
Average	0.01	0.01	0.01	0.01	0.01	0.11	

where a is the standard in Cd, Pb, and Hg (EC, 2011) and b is the standard in Cu (EC, 2006)

The highest concentration of Cd found in Station SA-3-16. This station was just a bit close to Station SA-3 based on [7]. He also found that this station was the highest concentration of Cd.

Variables Cu, Pb, and Hg were also found in surface water and sediment. However, these three variables were included in levels that have not exceed the surface water quality standard. Its accumulation ability can be even more significant in *Scylla serrata* meat (Table 3). There was no standard of Cu because the regulation (EC) No. 1334/2003 was deleted due to the high concentration of a substance as much as 50 mg/kg in crustacean [32].

The lowest heavy metal distribution was SA-2-24 and followed by SA-2-28, SA-1-10, SA-3-46, SA-3-5, and SA-3-16 with 0.004909 mg/kg, 0.005425 mg/kg, 0.006165 mg/kg, 0.006678 mg/kg, 0.007026 mg/kg, and 0.111743 mg/kg respectively (Table 3.). The first three stations are on the west swamp managed areas, whereas the second one is on the west swamp managed areas [26]. Conversely, the highest heavy metals were at Station SA-3-16 and followed by Stations SA-3-5, SA-3-46, SA-1-10, SA-2-28, and SA-2-24 due to the high point source of pollution in east side areas of Segara Anakan Cilacap.

The heavy metals at Stations SA-2-28 and SA-3-46 tend to be lower than at Stations SA-2-24, SA-3-35, SA-1-10, and SA-3-16 (Figure 2). This tendency is due to mangrove trees' ability at Stations SA-2-28 and SA-3-46 more than other stations. [33] stated that more carbon stored in mangrove trees was at Station SA-3-46 than Station SA-2-28. In this study, there were more mangrove trees at Station SA-3-46 than at Station SA-2-28.

The bioconcentration factor can predict the bioaccumulation of heavy metals. The heavy metal accumulation of Cd, Cu, Pb, and Hg has occurred from surface waters and sediments to edible mud crab meat, especially in Cd concentration in Station SA-3-16 (Figure 3.). This station was just a bit close to Station SA-3 based on another research [7] that this station was the highest concentration of Cd. In general, the heavy metal concentrations was more elevated in waters and sediments than edible crab meat, as showed in Table 1, 2, and 3.

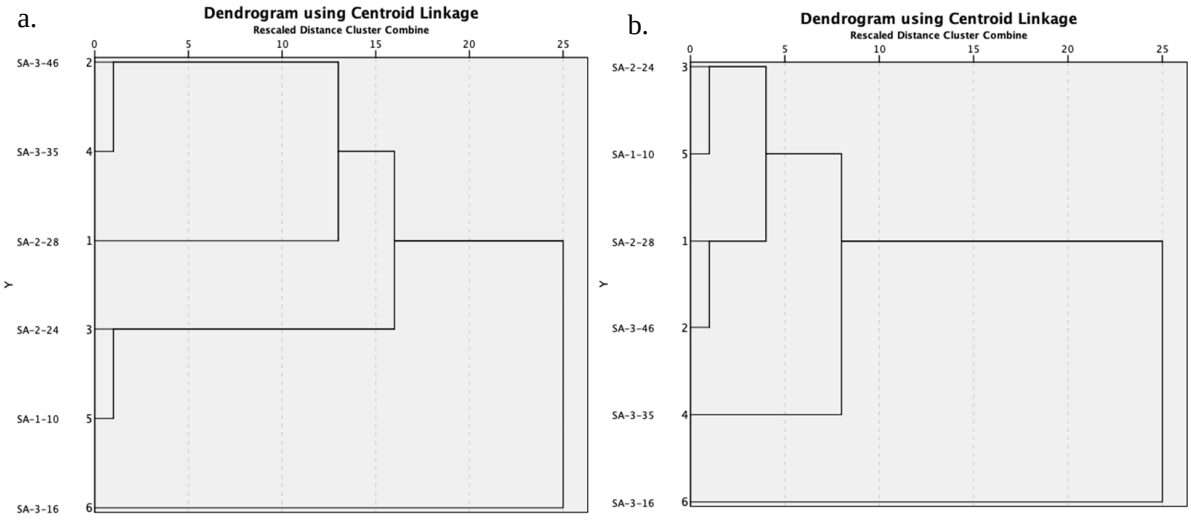

Figure 2. Distribution of heavy metal contaminations at each station from waters to crab (a) and from sediments to crab (b)

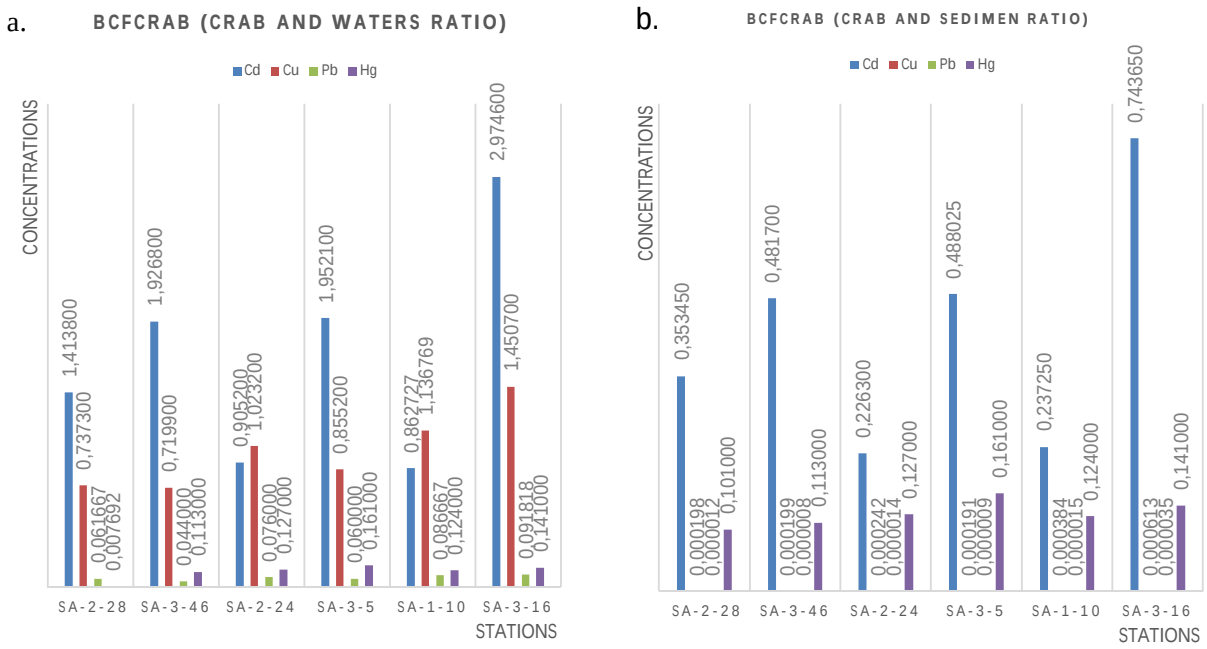

Figure 3. Bioconcentration factor from waters to crab (a) and from sediments to crab (b)

4. Conclusion

The heavy metals at Station SA-2-28 and SA-3-46 were lower than Station SA-2-24, SA-3-35, SA-1-10, and SA-3-16. SA-2-28 had a high percentage of mangrove canopy cover. Conversely, the highest heavy metals were at Station SA-3-16 and followed by Stations SA-3-5, SA-3-46, SA-1-10, SA-2-28, and SA-2-24 due to the high point source of pollution in east side areas of Segara Anakan Cilacap. Based on bioconcentration factor, there was the highest accumulation of heavy metal of Cd, and

followed by Cu, Pb, and Hg from surface waters and sediments to the edible mud crab of *Scylla serrata*.

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