Potential Threat of Heavy Metal Accumulation in Aquatic Biota from Wadaslintang Reservoir, Central Java, Indonesia

by Diana Rahayu

ISSN: 04532198
Volume 62, Issue 06, July, 2020

Potential Threat of Heavy Metal Accumulation in Aquatic Biota from Wadaslintang Reservoir, Central Java, Indonesia

Diana R. U. S. Rahayu[1], Sutrisno Anggoro[2], Tri R. Soeprobowati[3, 4]

Doctorate Program of Environmental Science, School of Postgraduate Studies Diponegoro University, Semarang[1]
Faculty of Fisheries and Marine Sciences, Diponegoro University, Semarang Indonesia[2]
Department of Biology, Faculty of Science and Mathematics, DiponegoroUniversity, Semarang, Indonesia[3]
School of Postgraduate Studies, Diponegoro University, Semarang, Indonesia[4]

Abstract— Increased population and urbanization is one of the changes in the use of the Wadaslintang Reservoir catchment area, this condition has the potential to cause pollution of some heavy metals that can accumulate in this aquatic biota. This study aims to determine the concentration and bioconcentration of Pb, Zn, Cu, and Cd heavy metals in *Anodonta woodiana* Lea (freshwater shellfish), *Pomacea canaliculata* Lamarck (golden apple snail), and *Cherax quadricarinatus* Von Martens (crayfish) in the Wadaslintang Reservoir. Samples of freshwater shellfish, snails, and crayfish were randomly collected in an area of ± 100 m^2 in three research stations at a depth of 0.0 - 0.5 m. Sampling was conducted in August - October 2018. The results showed that the three aquatic organisms contained heavy metals Cu, Cd, Pb, and Zn. The highest concentration is in *A. woodiana*, then *P. canaliculata* and the lowest concentration is in C. quadricarinatus. The results of the BCF value calculation showed the highest bioaccumulation values found in *A. woodiana* and *P. canaliculata* were Zn, which included in the category of moderate accumulation. Whereas in *C. quadricarinatus* the highest bioaccumulation value is Pb, but it is still included in the low accumulation category.

Keywords— Bioaccumulation, Anodonta woodiana, Cherax quadricarinatus, Pomacea canaliculata, Wadaslintang Reservoir

1. Introduction

Wadaslintang Reservoir is one of the artificial aquatic ecosystems located in Wonosobo Regency, Central Java, Indonesia. These waters have many functions, especially for flood control, agricultural irrigation, hydroelectric power generation, tourism and fisheries. Local people consume fishery products derived from catches in these waters including fish, freshwater shell and shrimp. According to [1], Wadaslintang Reservoir has been polluted, especially occurred in September - December, in the reservoir overdraft area. Heavy metals that are dissolved and stored in the sedimentary layer, can also be consumed mainly by fish, crustaceans, and mollusks that have the ability to accumulate heavy metals in the tissues of these organisms. Urban development has led to a decrease in water quality. One component that causes a decrease in water quality is heavy metals [2]. Some types of heavy metals that are of global concern include tin (Pb), Zinc (Zn), Cu (copper), and Cd (Cadmium). The presence of heavy metals in waters, among others, occurs due to the influx of agricultural, livestock, industrial, mining and domestic waste. These problems have become serious problems in all countries. While heavy metal contaminants that enter the waters will be distributed to water, sediments and aquatic biota [3]. Several studies have shown that the concentration of heavy metals in water can affect the concentration of heavy metals in organisms that live in aquatic ecosystems. An increase in the concentration of heavy metals in the body of an organism can occur through the process of biomagnification or food chain, bioaccumulation and bioconcentration [4], [5]. According to [6], the ability to accumulate heavy metals can only be done by living organisms. The ability of aquatic organisms to naturally accumulate heavy metals will be transferred to the food chain [7]. Therefore, if humans consume aquatic biota contaminated with heavy metals, the impact can be seen in the long term, as is the case in the Minamata epidemic in Japan. Some aquatic organisms can accumulate heavy metals so that it can be used as a bioindicator of pollution. The ability to accumulate heavy metals in aquatic organisms is called bioaccumulation, according to [8], bioaccumulation aims to determine the adverse effects of the aquatic environment on biota. Some aquatic organisms that have the ability to accumulate heavy metals include freshwater shellfish [9], [10], [11], [7], snails [12], [13], and crayfish [6], [14], [15], [16].

Pomacea canaliculata Lamarck is a freshwater snail from phylum mollusca which is commonly found in Wadaslintang Reservoir, especially in reservoir inlet, is a nocturnal organism, and cosmopolite. These aquatic animals are not rarely consumed by the local community, so that it has the potential to cause health problems. P. canaliculata is able to accumulate Cd and Pb [17]. Zinc tends to accumulate in the digestive organs and secretions of molluscs, especially in the kidneys [10]. This organism is a potential heavy metal biomonitor, because its population, reproduction rate and survival are high, adaptable, can be exposed for a long time and tend to be sessile. All soft tissue is used to transfer exposure to heavy metal Cu, with the highest concentration found in the gills [18]. Besides that, P. canaliculata has a behavioral response by opening and closing the operulum, the breathing pumping process, and the filter feeders diet. Besides snails, another species found in the Wadaslintang Reservoir is Anodonta woodiana Lea. These freshwater shells have an important functional role in freshwater ecosystems and are useful as Cd pollution biomarkers [19],). This is because freshwater mussels are organisms that come into direct contact with the polluted environment for a long period of time, so that the exposed body has the potential to accumulate these pollutant components. This species also belongs to the filter group fedeer. This is thought to be the cause of a positive correlation between the concentration of Pb in sediment and the concentration of Pb in bivalve tissue [20]. Cherax quadricarinata von Martens is an invasive species; this animal is often found in Wadaslintang Reservoir by fishermen. This organism has eating habits in the form of water macrophytes, macroinvertebrates, and detritus. So that this water organism has the potential to accumulate heavy metals found in water and sediments. C. quadricarinata is a benthos group that is more common in the bottom of sandy waters. Cd accumulation in C. quadricarinata tissue is positively correlated with Cd concentrations in the environment obtained from water as its life medium and food [21]. The three organisms are aquatic biota that are often found by fishermen if obtained a little will be consumed by themselves while if a lot will be sold to the community. Heavy metal pollution is an increasingly severe environmental problem, so that if not properly addressed and managed will have an impact on the surrounding environment it can eventually be consumed by humans through the food chain. Therefore, to find out the level of accumulation of heavy metals in aquatic organisms in the Wadaslintang Reservoir, research needs to be done, besides that it also functions to monitor them for community safety and other ecological problems. This study aims to determine the concentration and bioaccumulation of heavy metals Pb, Zn, Cu and Cd in Anodonta woodiana Lea, P. canaliculata Lemarck, and Cherax quadricarinatus Von Martens in the Wadaslintang Reservoir.

2. Methodology

Water and sediment samples were obtained from the location of capture of aquatic organisms consisting of *C. quadricarinatus*, *A. woodiana* and *P. canaliculata*. Samples of mussel, snails and shrimp are collected manually in an area of ± 100 m^2 at three research stations located at the edge to a depth of 0.5 m. Sampling was carried out in August-October 2017. The geographical position of the sampling station is presented in

TRKU ISSN: 04532198
ISSN: 04532198
Volume 62, Issue 06, July, 2020

Table 1. The Atomic Absorption Spectrophotometer (AAS) was used to analyze heavy metal content (Perkin Elmer, 2000). Bioaccumulation calculations are carried out using the BCF formula as follows:

$$\mathbf{BCF = C_{org} / C_{water}, \; BCF = C_{org} / C_{sediment}}$$

C_{org} = concentration of heavy metals in organisms

$C_{water/sediment}$ = concentration of heavy metals in water or sediment

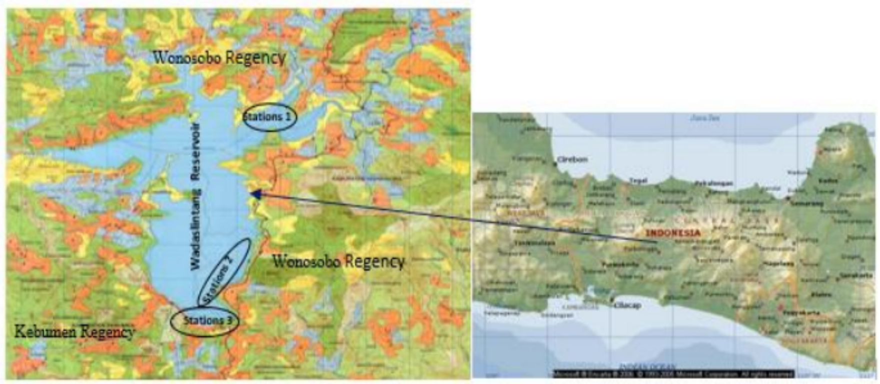

Figure 1. Map of sampling location.

Table 1. Sampling site

Stations	Geographical position
1. The reservoir inlet from the Tritis River	S 07°33'28.5" – E 109°48'02.8"
2. Around the tourist area	S 07°36'34.7" – E 109°47'05.9"
3. Around the outlet of the reservoir	S 07°36'29.0" – E 109°46'56.0"

3. Results and Discussion

The concentration of heavy metals in surface water varies and changes over time, depending on various factors including water conditions which include the speed of flow and the process of mixing water, physical-chemical factors of water, and the distance of water and sources of pollutants. The concentration of heavy metals in sediments and surface water from each research station is presented in Tables 2 & 3. The results of the analysis show that the concentration of heavy metals in the surface water is lower than the concentrations of heavy metals in sediments because dissolved heavy metals are adsorbed by suspense particles and will settle in the sediment. The average concentration of heavy metals in the surface water is as follows the lead concentration (Pb) is higher than the zinc concentration (Zn), the copper concentration (Cu) is the same as the zinc concentration, while the lowest concentration is Cd. The results also showed that almost all heavy metal concentrations in surface water in the three research stations had exceeded the Republic of Indonesia government regulation threshold number 82 of 2001 except Zn concentration, still below the quality standard threshold. The concentration of Cd in surface water has exceeded the quality standards of grade 1 - grade 4; Pb concentration has exceeded grade 1 - grade 3 quality standard, whereas for Cu concentration only exceeds grade 1 quality standard.

Table 2. Concentration of heavy metals in water at each station (mg.kg^{-1})

Heavy metals	Average concentration at each station			Water quality standard*			
	1	2	3	grade 1	grade 2	grade 3	grade 4
Cu	0.017	0.021**	0.025	0.02	0.02	0.02	0.20
Cd	0.019**	0.016**	0.016**	0.01	0.01	0.01	0.01
Pb	0.035**	0.033**	0.032**	0.03	0.03	0.03	1.00
Zn	0.019	0.023	0.022	0.05	0.05	0.05	2.00

* Republic of Indonesia Government Regulation number 82 of 2001,
** exceed the quality standard threshold.

Table 3. Concentration of heavy metals in sediment at each station (mg.kg^{-1})

Metals	Concentration in stations (mg.kg^{-1})			ANZECC		Holland (mg.kg^{-1})	Canada (mg.kg^{-1})
	1	2	3	ISQG-Low (mg.kg^{-1})	ISQG-High (mg.kg^{-1})		
Cu	3.45	1.53	1.40				
Cd	2.49	0.54	0.68	1.5	10	0.8	0.7
Pb	5.93	6.01	5.24	50	220	85	30.2
Zn	8.29	1.42	1.23				

Heavy metals in the water will undergo a process of precipitation so that it will accumulate in the sediment. the order of the average concentration of heavy metals in sediments is as follows: The Pb concentration is higher than the average concentration of Zn > Cu > Cd. Based on [22], the low value for the concentration of Pb heavy metals in sediments is 50-220 ppm, Cd is 1.5-10 ppm, Cu is 65-270 ppm and Zn is 200-1010 ppm. Under this provision, all concentrations of heavy metals in sediment are still below the threshold. The results of the analysis of heavy metals in *C. quadricarinatus*, *P. canaliculata*, and *A. woodiana* are presented in Figure 2. Overall, the order of the highest heavy metal concentrations to the lowest concentrations found in each of these aquatic organisms is as follows: *A. woodiana* > *P canaliculata* > *C. quadricarinatus*. The average concentration of heavy metals contained in *C. quadricarinatus* and *P. canaliculata* has the following sequence: concentration of Pb > Zn > Cu > Cd. Whereas in *A. woodiana* in the order of concentration Zn > Pb > Cd > Cu.

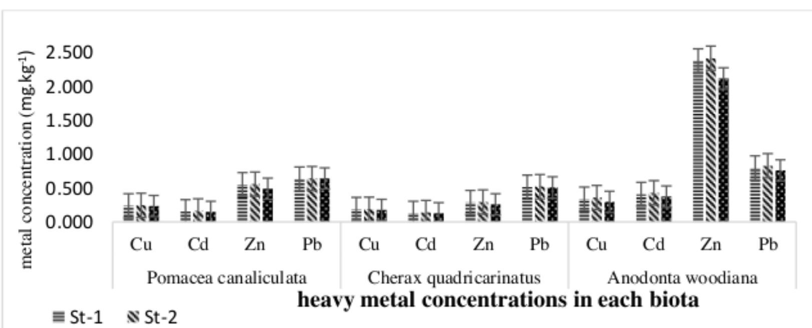

Fig. 2 Heavy metal content in A. woodiana, C. quadricarinatus, and P. canaliculata at each research station (mg.kg^{-1}) (wet weight)

ISSN: 04532198
Volume 62, Issue 06, July, 2020

Bioconcentration factor (BCF), is often used to give an overview of heavy metal concentrations in an organism. In Table 4. it can be seen that the average value of BCF (o-w) > BCF (o-s), means that the three aquatic organisms have a higher ability to accumulate heavy metals from water than from sediments. The results of the calculation of BCF (o-w) values of the three aquatic organisms show the same tendency with the following sequence of BCF values: BCF (o-w) Zn > BCF (o-w) Cd > BCF (o-w) Pb > BCF (o-w) Cu. Whereas BCF (o-s) Zn > BCF (o-s) Cd > BCF (o-s) Cu > BCF (o-s) Pb. The higher the BCF value in an organism, the greater the ability of the organism to accumulate heavy metals [23].

Table 4. BCF values in *Anodonta woodiana*, *Cherax quadricarinatus*, *Pomacea canaliculata* at each research station

St	Organism	Cu		Cd		Pb		Zn	
		$BCF_{(o-s)}$	$BCF_{(o-w)}$	$BCF_{(o-s)}$	$BCF_{(o-w)}$	$BCF_{(o-s)}$	$BCF_{(o-w)}$	$BCF_{(o-s)}$	$BCF_{(o-w)}$
1	*Anodonta woodiana*	0.238	13.486	0.595	25.292	0.152	24.927	2.688	150.303
2		0.217	15.841	0.756	25.830	0.133	23.930	2.329	143.768
3		0.096	19.569	0.163	21.298	0.135	22.575	0.399	171.034
1	*P. canaliculata*	0.172	9.770	0.228	9.708	0.122	20.000	0.435	24.318
2		0.158	11.476	0.290	9.915	0.107	19.200	0.377	23.261
3		0.070	14.176	0.062	8.175	0.108	18.113	0.065	27.672
1	*C. quadricarinatus*	0.132	7.514	0.195	8.292	0.099	16.135	0.229	12.803
2		0.121	8.825	0.248	8.468	0.086	15.490	0.198	12.246
3		0.054	10.902	0.053	6.982	0.087	14.613	0.034	14.569

The bioconcentration factors of the three aquatic organisms at each research station have different values, freshwater shells *Anodonta woodiana* have the highest BCF value, then freshwater shrimp (*Cherax quadricarinatus*) and the lowest snail / the golden snail (*Pomacea canaliculata*), based on this, it can be said that freshwater mussels have the greatest accumulative ability among the three aquatic organisms. The study by [9] on *Anodonta woodiana* (Lea, 1834) and *Dreissena Polymorpha* (Pall.) Showed that *Anodonta* sp has the ability to accumulate higher heavy metals than *Dreissena polymorpha*. Furthermore, according to [19], *Anodonta woodiana* is one of the members of bivalves that has very good accumulation ability to heavy metals so that it can be used as a bioindicator of polluted waters such as in Lake Tahitu, China. Bivalves is one of the aquatic biotas that breathe using gills contained in the mantle cavity. These organisms tend to settle somewhere, immerse themselves in sediments, and their movements are slow so that it is relatively difficult to avoid contaminated areas and have a high tolerance to heavy metals with certain concentrations. The value of BCF (ow) of freshwater shellfish (*Anodonta woodiana*) in Wadaslintang Reservoir has a BCF (ow) Zn > BCF (ow) Cd > BCF (ow) Pb > BCF (ow) Cu, while the BCF (os) value has the order as following BCF (os) Zn > BCF (os) Cd > BCF (os) Cu > BCF (os) Pb. Based on the calculation of BCF (o-w) value of zinc metal in freshwater shells has the highest value compared to BCF (o-w) in Pb, Cd and Cu means that shellfish have a tendency to accumulate zinc heavy metals greater than other heavy metals (Table 4). The average BCF (o-w) zinc value in shells is 155,035 with the highest BCF (o-w) value found at station three at 171,034, meaning that shells at station three (outlet reservoir) have the ability to accumulate 171,034 times that of zinc metal contained in sediments. Zinc is the highest component found in the body of shellfish (*Anodonta* sp) but it is an essential component of living things, its existence is needed for the continuation of physiological and enzymatic processes, including as part of the components of dehydrogenase and carbonic anhydrase [15]. At high concentrations of zinc is needed to maintain certain biological functions, because zinc is an enzyme cofactor [24], and in certain conditions can reduce the adverse effects of the presence of Pb in an organism. The high concentration of zinc in the shellfish is also suspected because of the many components that contain zinc derived from various anthropogenic activities, where station three is the outlet of the reservoir that holds all the water that originates from the entire reservoir inlet. The BCF (o-w) value of Zn metal in *A. woodiana* of 171,034 is included in the medium accumulation category [25].

Crayfish BCF (o-w) value has the following sequence of values BCF (o-w) Zn > BCF (o-w) Pb > BCF (o-w) Cu > BCF (o-w) Cd. While the order of BCF (o-s) values is as follows BCF (o-s) Zn > BCF (o-s) Cd > BCF (o-s) Pb ≈ BCF (o-s) Cu. Based on this, crayfish also has a greater tendency to accumulate zinc heavy metals than other heavy metals. After zinc, crayfish has the ability to accumulate against Pb metal. The Pb metal BCF (o-w) value of *C. quadricarinatus* of 20 is found at station one, meaning that the crayfish from station one (reservoir inlet from Tritis River), is able to accumulate 20 times the Pb metal dissolved in water. According to [26], crayfish has a high resistance to environmental conditions that experience heavy metal contamination, for Pb metal mostly accumulated in several organs including hepatopancreas, gills, gonads, and exosceleton. Besides zinc and lead, crayfish also has the ability to accumulate Cu. Although the ability to accumulate Cu dissolved in water belongs to the category of low accumulation, Cu is one of the components needed by crustaceans as one of the important components that play a role in carrying haemocyanin pigments [15]. *P. canaliculata* is an organism that has the lowest accumulation ability of heavy metals compared to mussel and crayfish. The value of the bioconcentration factor in snail, with the order of BCF (o-w) as follows BCF (o-w) Pb > BCF (o-w) Zn > BCF (o-w) Cu > BCF (o-w) Cd. While the order of BCF (o-s) is as follows BCF (o-s) Cd > BCF (o-s) Zn > BCF (o-s) Cu > BCF (o-s) Pb. The value of bioconcentration of Pb metal to water or BCF (o-w) Pb in snail has the highest value of 16,135, meaning that the snail at station one (reservoir inlet from the River Tritis) can accumulate 16,135 times the Pb heavy metal dissolved in water. While the highest BCF (o-s) bioconcentration value in snail is Cd metal which is equal to 0.248, meaning that snail at station two (around the tourist area) can accumulate as much as 0.248 times the metal Cd contained in the sediment. Pb and Cd are included in the group of non-essential metals, they are toxic elements, because their presence in the body is not expected and the benefits are not yet known even at relatively small concentrations. These heavy metals also have accumulative abilities and are able to inhibit the adsorption and absorption of essential metals [15]. According to [13], *Pomacea canaliculata* accumulates Cd in soft tissue especially on the viscera and legs. Besides Pb, Cd and Zn snail also have the ability to accumulate Cu even in the low accumulative category. According to [12], Snails (*Pomacea canaliculata*) are able to accumulate Cu in several organs including gills, muscles, and digestive tract. The organism also has the ability as a bioindicator and biomarker of Cu contamination in the water [27]. The bioaccumulation value between organisms varies and this depends on the level of absorption, detoxification and environmental conditions [15]. The mechanism of absorption of heavy metals in mussel generally takes place through a filter feeder process. The clam will filter the food particles by moving the vibrating hairs on the gills that drain the water so that it enters the gills contained in the mantle. According to [25], the high and low value of BCF in an organism depends on the type of metal and its organism. According to [23], the organism's ability to accumulate heavy metals depends on several factors including the concentration of heavy metals in water, organism's feed habits, and metabolic rate. However, basically studying and predicting the bioaccumulation value of a heavy metal is an effort to understand the nature and level of toxicity of each metal in the aquatic environment as a mitigation effort [8].

4. Conclusion

A. woodiana has higher ability to accumulate heavy metals, particularly zink rather than *C. quadricarinatus* and *P. canaliculata*. The highest bioaccumulation value in shrimp and shellfish is found in Zn heavy metals, while on golden snail is found in Pb heavy metals. The bioconcentration of Zn heavy metals is included in the medium accumulation category, while Pb, Cd and Cu are included in the low category.

5. Acknowledgments

Thank you to Sugiyanti for helping to analyze heavy metals, thank you also to Raditya L. D. for supporting field sampling.

6. References

[1] A. A. Kader, G. Y. Osman, A. H. Mohamed, M. M. Gharieb, N. M. M. Ismail, and A. Abdel-motleb, “Bioaccumulation of heavy metals in freshwater snails in relation to lining of water courses in Egypt”. Journal of Bioscience and Applied Research, Volume 2, Issue 8, 2016, pp 561- 573.

[2] A. A. Otitoloju, D. O. Ajikobi, and R. I. Egonmwan, “Histopathology and Bioaccumulation of Heavy Metals (Cu & Pb) in the Giant land snail, Archachatina marginata (Swainson)”. The Open Environmental Pollution & Toxicology Journal, Volume 1, 2009, pp. 79-88.

[3] A. Kouba, M. Buřič, and P. Kozák. “Bioaccumulation and effects of heavy metals in crayfish”: a review, Water, Air, & Soil Pollution, Volume 211, Issue 4, 2010, pp. 5 -16.

[4] A. M. Hidayah, Purwanto and T. R Soeprobowati. “Bioconcentration factors of heavy metals Pb, Cd, Cr and Cu in Tilapia (Oreochromis niloticus Linn.) on net cages Rawapening Lake”, BIOMA Volume 16, Issue 1, 2014, pp. 1-9.

[5] Amriani. “Bioaccumulation of Lead Metal (Pb) and Zinc (Zn) in Blood Shells (Anadara Granosa L.) and Mangrove Shells (Polymesoda bengalensis L.) in Kendari Bay Waters”. Thesis. Master’s Program in Environmental Sciences, Post-Graduate Program, Diponegoro University, Semarang. 2011. (in Indonesia).

[6] A. M. Younis, H. F. Amin, A. Alkaladi, and Y. Y. I. Mosleh. “Bioaccumulation of Heavy Metals in Fish, Squids and Crustaceans from the Red Sea, Jeddah Coast, Saudi Arabia”, Open Journal of Marine Science, Volume 1, Issue 5, 2015, pp. 369-378. http://dx.doi.org/10.4236/ojms.2015.554030.

[7] Australian and New Zealand Environment and Conservation Council (ANZECC), interim sediment quality guidelines, Report for the Environmental Research Institute of the Supervising Scientist, Sydney, Australia. 2000

[8] C. J. Mc Geer, K.V. Brix, J. M. Skeaff, D. K. Deforest, S. I. Brigham, W. J. Adams, and A. Green. “Inverse Relationship Between Bioconcentration Factor and Exposure Concentration for Metals: Implications for Hazard Assessment of Metals in The Aquatic Environment”. Environmental Toxicology and Chemistry Volume 22, Issue 5, 2003, pp. 1017–1037.

[9] D. R. U. S. Rahayu, S. Anggoro and T. R. Soeprobowati, “Plankton community structure and trophic status of Wadaslintang Reservoir, Indonesia”, AACL Bioflux, Volume 13, Issue 2, 2020, pp. 1138-1151.

[10] E. Królak, and B. Zdanowski. “The Bioaccumulation of Heavy Metals by The Mussels Anodonta Woodiana (Lea, 1834) and Dreissena polymorpha (Pall.) In The Heated Konin Lakes”. Archives of Polish Fisheries Volume 9, Issue 2, 2001, pp. 229-237.

[11] F. Huang, Peng Li, J. Zhang, W. Lin, and S. Chen, “Cadmium bioaccumulation and antioxidant enzyme activity in hepatopancreas, kidney, and stomach of invasive apple snail Pomacea canaliculata”, Environmental Science and Pollution Research, 2018. https://doi.org/10.1007/s11356-018-2092-1.

[12] H. A. Abdel-Salam and S. A. H Hamdi, “Heavy metals monitoring using commercially important crustaceans and mollusks collected from Egyptian and Saudi Arabia coasts”, Animal and Veterinary Sciences., Volume 2, Issue 3, 2014, pp. 49-61. doi: 10.11648/j.avs.20140203.11

[13] H. Liu, J. Yang, and J. Gan. “Trace Element Accumulation in Bivalve Mussels Anodonta woodiana from Taihu Lake, China”. Arch Environ Contam Toxicol. Volume 59, 2010, pp. 593–601. doi: 10.1007/s00244-010-9521-6.

[14] J. C. Madu, G. E. Od, C. N Asogwa and C. D Nwani, “Heavy metal concentrations in, and human health risk assessment of, three commercially valuable fish species in the lower Niger River, Nigeria”. African Journal of Aquatic Science, Volume 42, Issue 4, 2017, pp. 341-349. doi: 10.2989/16085914.2017.1410463.

[15] M. A. Baki, M. M. Hossain, J. Akter, S. B. Quraishi, Md. F. H. Shojib, A. K. M. Ullah, and A. Md. F. Khan, “Concentration of heavy metals in seafood (fishes, shrimp, lobster and crabs) and human health assessment in Saint Martin Island, Bangladesh”. Ecotoxicology and Environmental Savety. Volume 159, 2018, pp. 153-163. http://doi.org/10.1016/j.ecoenv.2018.04.035.

[16] M. B. Kouba, and P. Kozák. “Bioaccumulation and Effects of Heavy Metals in Crayfish”: a review. Water Air Soil Pollut, Volume 211, 2010, pp. 5–16. http://dx.doi10.1007/s11270-009-0273-8

[17] M. I. Khan, M. Khisroon, A. Khan, N. Gulfam, M. Siraj, F. Zaidi, ... and F. Qadir. “Bioaccumulation of heavy metals in water, sediments, and tissues and their histopathological effects on Anodonta cygnea (Linea, 1876) in Kabul River, Khyber Pakhtunkhwa, Pakistan”. BioMed research international, 2018.

[18] Ministry of Environment of the Republic of Indonesia “Government Decree Number 82 of 2001”, Water quality standard in Indonesian, 2001.

[19] M. Zabochnicka-Świątek, and M. Krzywonos, “Potentials of Biosorption and Bioaccumulation Processes for Heavy Metal Removal”, Polish Journal of Environmental Studies, Volume 23, Issue 2, 2014.

[20] P. Rzymski, P. Niedzielski, P. Klimaszyk, and B. Poniedziałek. “Bioaccumulation of selected metals in bivalves (Unionidae) and Phragmites australis inhabiting a municipal water reservoir”. Environmental Monitoring and Assessment, Volume 186, Issue 5, 2014, pp. 3199 – 3212. doi:10.1007/s10661-013-3610-8.

[21] R. Li, X. Tang, W. Guo, L. Lin, L. Zhao, Y. Hu, and M. Liu, “Spatiotemporal distribution dynamics of heavy metals in water, sediment, and zoobenthos in mainstream sections of the middle and lower Changjiang River”, Science of The Total Environment, Volume 714, 2020, 136779. https://doi.org/10.1016/j.scitotenv.2020.136779

[22] R. Mc Pherson, and K. Brown. “The Bioaccumulation of Cadmium by the Blue Swimmer Crab Portunus pelagicus”, L. The Science of the Total Environment Volume 279, 2001, pp. 223-230.

[23] S. Aroonsrimorakot, T. Sakulkiatpanya, and S. Muangkun “Heavy metal concentration in the components of golden apple snail (Pomacea canaliculata) and pond snail (Filopaludina martensi)”. Journal of Thai Interdisciplinary Research, Volume 12, Issue 5, 2017, pp. 5-10.

[24] S. C. Peña. "Accumulation of copper and other elements by the apple snail Pomacea canaliculata". Biology and management of invasive apple snails, 2017, pp.133-144

[25] S. C. Peña, and G. N. Pocsidio, "Accumulation of Copper by Golden Apple Snail Pomacea canaliculata Lamarck", Philippine Journal of Science Volume 137, Issue 2, 2008, pp. 153-158.

[26] T. R. Soeprobowati, and R. Hariyati. "The phycoremediation of textile wastewater discharge by Chlorella pyrenoidosa H. Chick, Arthrospira platensis Gomont, and Chaetoceros calcitrans (Paulson) H. Takano". AACL Bioflux, Volume 10, Issue 3, 2017, pp. 640-651. http://www.bioflux.com.ro/aacl

[27] V. Dummee, P. Tanhan, M. Kruatrachue, P. Damrongphol, and P. Pokethitiyook, "Histopathological changes in snail, Pomacea canaliculata, exposed to sub-lethal copper sulfate concentrations". Ecotoxicology and Environmental Safety, Volume 122, 2015, pp. 290-295. http://dx.doi.org/10.1016/j.ecoenv.2015.08.010.

[28] Y. Li, H. Yang, N. Liu, J. Luo, Q. Wang, and L. Wang, "Cadmium Accumulation and Metallothionein Biosynthesis in Cadmium-Treated Freshwater Mussel Anodonta woodiana", PLoS ONE, Volume 10, Issue 2, 2015. e0117037 https://doi:10.1371/journal.pone.0117037

Potential Threat of Heavy Metal Accumulation in Aquatic Biota from Wadaslintang Reservoir, Central Java, Indonesia

ORIGINALITY REPORT

12%	10%	5%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	jsla.ejournal.unri.ac.id Internet Source	3%
2	elearning.medistra.ac.id Internet Source	2%
3	www.bioflux.com.ro Internet Source	1%
4	Submitted to Universitas Trunojoyo Student Paper	1%
5	Dita Fatryani, Sulistiono, Djamar TF Lumban Batu. "Heavy Metal Contents of Hg, Cd, Pb, and Cu in Mud Crab (Scylla Serrata) in Banten Bay, Indonesia", IOP Conference Series: Earth and Environmental Science, 2022 Publication	1%
6	philjournalsci.dost.gov.ph Internet Source	1%
7	iopscience.iop.org Internet Source	1%

8	ojs.omniakuatika.net Internet Source	1 %
9	Manjula Menon, Rangaswamy Mohanraj, Joemon VB, Akil Prasath RV. "Bioaccumulation of heavy metals in a gastropod species at the Kole wetland agroecosystem, a Ramsar site", Journal of Environmental Management, 2023 Publication	1 %
10	assets.researchsquare.com Internet Source	1 %

Exclude quotes	Off	Exclude matches	< 1%
Exclude bibliography	On		