NATIONAL DATABASE OF METAL IN COMPARATIVE PERSPECTIVES OF THE UNITED KINGDOM & INDONESIA

BASIS DATA NASIONAL UNTUK LOGAM DALAM PERSPEKTIF KOMPARASI ANTARA INGGRIS DAN INDONESIA

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ABSTRACT: The ocean is a source of mega-biodiversity that is supposed to perform optimally for current and future generations. The health of the ocean must be evaluated by measuring heavy metals in sediment because they can be accumulated and stored in long term. This metal can be released and absorbed by an organism, and affect the ecological risk and human health. The purpose of this article is to share viewpoints and those in a comparative study in terms of the metal database of both countries, the UK and Indonesia. The methodology used in this paper is critical review and analysis to compare a success story about compiling metal data into a national database in the United Kingdom (UK). Indonesia already has an open public access database issued by the Ministry of Environment and Forestry. The further step is to strengthen collaboration between research institutes, universities, and government to assign a Standard Operational Procedure (SOP) to collect, analyze and report the data to a national depository. This database will be worthwhile to describe the pollution status in Indonesia and basic data for best practice decisions.
Keywords: database, Indonesia, metal, United Kingdom

***ABSTRAK**: Laut adalah sumber dari megabiodiversitas yang mendukung kehidupan saat ini dan generasi mendatang secara optimal. Kesehatan laut harus dievalusi dengan mengukur kadar logam berat dalam sedimen karena logam berat dapat terakumulasi dan tersimpan dalam sedimen dalam waktu yang lama. Logam dapat terlepas kembali dan terserap oleh organisme yang mempengaruhi risiko ekologis dan kesehatan manusia. Tujuan penulisan artikel ini untuk memberikan sudut pandang dalam bentuk studi komparasi database logam di dua negara yaitu Inggris dan Indonesia. Metode yang digunakan adalah telaah kritis dan analisis membandingkan kisah sukses dalam menyusun data logam menjadi database nasional. Indonesia sudah memiliki basis data publik yang dikelola Kementerian Lingkungan Hidup dan Kehutanan. Langkah selanjutnya adalah memperkuat kolaborasi antara Lembaga riset, universitas dan pemerintah untuk menyusun protokol standar terkait pengambilan, analisis dan laporan data logam ke dalam depositori nasional. Database ini akan sangat bermanfaat untuk menentukan status polusi di Indonesia dan data dasar untuk pengambilan berbagai keputusan lingkungan.*
***Kata Kunci:** basis data, Indonesia, logam, Inggris*

INTRODUCTION

Marine and coastal ecosystem is easily threatened by a contaminant that can reduce biodiversity, ecological and economic value, food security, affect livelihood, and also impacts human health (Ouali *et al*., 2018). The world's attention is focused on the ocean because of part of Sustainable Development Goals (SDGs) that target responsible consumption and production (SDG 12) and life below water (SDG 14) (United Nation, 2015). The ocean is also the main actor in the blue economy concept that a healthy ocean can support the food security and sustainability of fisheries (Vayer *et al*., 2020; Choudhary *et al*., 2021).

Indonesia is an archipelago with the world's fourth-longest coastline at 95,181 kilometers. As a result, Indonesia's coastline geomorphological traits are diverse and unique, particularly in northern Java (Bott *et al.,* (2021). Most of big cities in Indonesia located in coastal area and their topography is lowland deltas and high population city, which contribute to the high input land-based material to the ocean. Indonesia is predicted to receive a demographic bonus of 8% from 2020 to 2035 (Adyasari *et al*., 2021) resulting from the consequences of a decrease in environmental quality due to the influence of human activities such as increased sedimentation and contaminants from the mainland (Serrano *et al*., 2020). Ones of the chemicals discovered poses a risk to the ocean is heavy metal. Heavy metal is a toxic metal that can be sourced from natural or anthropogenic activities e. g. industrial and agricultural and provide a significant environmental and health risk to living organisms, particularly in aquatic environments (Khemis *et al*., 2017). Heavy metals are susceptible to being trapped by suspended particulate matter when they enter the water column then absorbed and deposited in the sediments (Zhang *et al*., 2021, Zhai *et al*., 2020). The ability of sediment to accumulate trace metal is well known, so they act the role as a carrier to an aquatic organism (Belabed *et al*., 2017; Franco-Fuentes *et al*., 2021, Ouali et al., 2018). Sediment-bounded heavy metals may be released again if there is a change of environment (Zhang *et al*., 2018; Liu *et al*., 2021). As a result, determining the level of heavy metal contamination in sediments is a critical point for ecological risk assessment and human risk assessment.

Maritime policies must be used to guarantee that human activities and a healthy ecosystem are harmonious. The use of contamination levels in abiotic environmental compartments, such as water and sediments, to monitor the water quality of marine ecosystems may aid in identifying the principal sources of pollution (la Colla *et al*., 2021). However, because metals in sediments have been increasing in recent years, water quality requirements are insufficient to preserve aquatic ecosystems. In Indonesia, (Adyasari *et al*., 2021) reported that the accumulation of heavy metals, organic pollutants, and other contaminants in sediments has increased in the last 20 years. Beside environmental database optimization, Adyasari *et al*. (2021) also recommend the requirement of Indonesia for plastics/microplastics, heavy metals, and organic contaminants regulation, due to they are found in higher concentrations in sediments than in water. Hereby, this review will reinforce the urgency to optimize the national database in Indonesia for further management coastal environment. The purposes of this article are to share viewpoints and those in a comparative study in terms of the metal database of both countries, the UK and Indonesia. The geology of the United Kingdom and Indonesia is the result of plate tectonic processes over a long period of time. Changing latitude and sea levels have influenced the nature of sedimentary sequences in both of countries. UK is chosen as a role model in this article because of their awareness and initiative to make a metal database for three decades. This is not a simple thing but no difficult to do if there are tight collaboration with the government and research institute.

METHODS

The methodology used in this paper is critical review and critical analysis to compare a success story about compiling metal data into a national database in the UK and Indonesia. A reputable and supportable journal was used for the literature review and be focused on Richir *et al*. (2021) as a main journal. UK has a database containing coastal and marine monitoring data that store in two databases: a) the Environment Agency (EA) and b) the MERMAN database managed by the British Oceanographic Data Centre (BODC) under the Clean Safe Seas Environmental Monitoring Programme (CSEMP) (CEFAS, 2012). This database consists of nine metals (As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, and Zn) in a lot of sites during three decades.

RESULTS

Success Story of UK

Based on these databases, the UK can perform data mining for their data. For example, the background concentration for uncontaminated sediment could be determine based on their long period data and calculate the sediment quality index (Richir *et al*., 2021). The following are the example analysis based on the existing database. The EA-MERMAN databases were created by overlaying two data sets (EA and MERMAN), resulting in 45,962 data points (334 sites) for 29 chemicals during a 31-years (1983–2013). The nine metals (As, Cd, Cr, Cu, Fe, Pb, Hg, Ni and Zn) that are most often monitored were chosen (about 87 percent of all data) derived from coastal and open sea sites. The protocol of sediment samples collected by EA and MERMAN must be clear and follow the guidelines provided by CEFAS (2012). The total number of sites monitored achieved 796 sites for As, 1.210 sites for Cd, 1.070 sites for Cu, 1.073 for Zn during three decades.

From this database, UK can conduct data mining to assess their environment based on historical data. Further, the UK determined the natural background concentration based on the 20th percentile value of historical data. If there is lack of historical data, non-contaminated data, sedimentary rock abundance, and crustal composition are required. The Geoaccumulation Index (Igeo) and Contamination factor (CF) as the sediment quality index were also calculated. Igeo is assessment of the pollution levels in sediment of individual heavy metal wheter CF is evaluation of sediment quality to describe toxic substance (Kowalska *et al*., 2018). Based on two parameters, the Nemerov Pollution Index (PI) (Richir *et al*., 2021; Ciarkowska, 2018) is used to classify sediment quality from unpolluted or excellent (PI ≤ 0.7); clean (PI=0.7-1); slight pollution (PI=1-2); moderate pollution (PI=2-3) and heavy pollution (PI≥ 3). Pollution indices can be used as a tool and guide for determining the state of the soil environment using a comprehensive geochemical investigation (Kowalska *et al*., 2018). Mining sediment contamination databases from national public sources is a valuable tool for assessing the trend of contamination at challenging scales. Managers will be able to link ecosystem management techniques with multiple contamination levels that have large cumulative effects if coastal observatory networks are combined. Another country also assigns a national database for example Scotland has Marine Scotland Data and Denmark development International Council for the Exploration of the Sea (ICES) database**.**

All sites together

Pollution Level	I_{geo}	Colour scale	CF	As (796)	Cd (1,210)	Cr (sad) (842)	Cr (td) (201)	Cu (1,070)	Fe (sad) (676)	Fe (td) (198)	Pb (1,064)	Hg (1,126)	Ni (1,066)	Zn (1,073)
Unpolluted	0		<1.5	53.9	14.6	43.9	76.1	28.7	58.9	82.3	36.2	25.7	38.5	33.6
Unpolluted - moderate pollution	0-1		1.5-3	27.9	18.0	49.2	20.4	25.8	39.6	17.7	34.4	15.0	51.3	39.1
Moderate pollution	1-2		3-6	6.8	22.6	6.9	3.5	22.6	1.3	0	20.8	23.0	9.3	19.2
Moderate - strong pollution	2-3		6-12	5.9	25.0	0	0	11.6	0.1	0	6.8	23.5	0.9	5.1
Strong pollution	3-4		12-24	2.8	14.4	0	0	6.4	0	0	1.7	9.9	0	1.3
Strong - very strong pollution	4-5		24-48	0.8	2.9	0	0	3.1	0	0	0.2	1.9	0	0.9
Very strong pollution	>5		>48	2.0	2.5	0	0	1.9	0	0	0	1.1	0	0.7

Coastal sites

Pollution Level	I_{geo}	Colour scale	CF	As (706)	Cd (1,121)	Cr (sad) (842)	Cr (td) (112)	Cu (980)	Fe (sad) (676)	Fe (td) (112)	Pb (974)	Hg (1,037)	Ni (976)	Zn (981)
Unpolluted	0		<1.5	52.3	12.6	43.9	65.2	28.5	58.9	74.1	36.0	21.2	41.1	33.8
Unpolluted - moderate pollution	0-1		1.5-3	27.8	17.0	49.2	28.6	23.0	39.6	25.9	32.2	14.7	48.2	36.8
Moderate pollution	1-2		3-6	7.1	22.3	6.9	6.2	24.0	1.3	0	22.5	24.9	9.7	20.6
Moderate - strong pollution	2-3		6-12	6.7	26.8	0	0	12.4	0.1	0	7.3	25.4	1.0	5.5
Strong pollution	3-4		12-24	3.1	15.5	0	0	6.7	0	0	1.7	10.7	0	1.4
Strong - very strong pollution	4-5		24-48	0.8	3.1	0	0	3.4	0	0	0.2	2.0	0	1.0
Very strong pollution	>5		>48	2.3	2.7	0	0	2.0	0	0	0	1.2	0	0.8

Open sea sites

Pollution Level	I_{geo}	Colour scale	CF	As (90)	Cd (89)	Cr (sad) (0)	Cr (td) (89)	Cu (90)	Fe (sad) (0)	Fe (td) (86)	Pb (90)	Hg (89)	Ni (90)	Zn (92)
Unpolluted	0		<1.5	66.7	40.4	-	89.9	31.1	-	93	37.8	77.5	10	30.4
Unpolluted - moderate pollution	0-1		1.5-3	28.9	30.3	-	10.1	56.7	-	7	57.8	19.1	85.6	64.1
Moderate pollution	1-2		3-6	4.4	25.8	-	0	7.8	-	0	2.2	1.1	4.4	4.3
Moderate - strong pollution	2-3		6-12	0	3.4	-	0	2.2	-	0	1.1	2.2	0	1.1
Strong pollution	3-4		12-24	0	0	-	0	2.2	-	0	1.1	0	0	0
Strong - very strong pollution	4-5		24-48	0	0	-	0	0	-	0	0	0	0	0
Very strong pollution	>5		>48	0	0	-	0	0	-	0	0	0	0	0

I_{geo} = Geoaccumulation Index.
CF = Contamination Factor.
Number in brackets = number of sites monitored, on a yearly basis, over the 31-year time series.

Figure 1. An example the data mining of EA MERMAN database in UK.

Metal Contamination in Coastal Environment of Indonesia

Indonesia is an island nation located between the Pacific and Indian Oceans, with water covering 78 percent of its territory and more than 81,000 kilometers of coastlines (Adyasari *et al*., 2021). As a result of this phenomenon, Indonesia now possesses high biodiversity and is unique as a tropical coastal and marine habitat in the world. Unfortunately, the quality of Indonesian coastal water has been steadily degrading, especially in the densely populated coastal cities of Java. The heavy metal concentrations in Jakarta Bay are up to three times greater than in Bangkok (for sediment) and Manila (for seawater) when compared to other nations with similar environments (Adyasari *et al*., 2021; Velasques et al., 2002). The trend of Cu and Pb in Jakarta Bay, have increased 40 and 30 times between 1983 and 2014, respectively (Koropitan & Cordova, 2007). The most significant source of coastal water pollution in Indonesia is excess nutrients, organic compounds, and heavy metals from home wastewater, industry, mining, agriculture, aquaculture, and solid waste (Asian Development Bank, 2016). Based on Adyasari *et al*. (2021), nutrient pollution is the most pressing issue in Indonesia followed by heavy metals and organic pollutants during 1986 and 2021. As a result, the quality of Indonesia's coastal water is poor, and prompt action is required, such as restrictions for plastic debris, heavy metals, and organic contaminants, which are typically found in larger concentrations in sediments than in the water. The mining areas of Sulawesi, Papua, Buru Island (Maluku), and Sumbawa (Nusa Tenggara) are the source of pollution in Indonesia (Budianta, 2021). The hotspot area is Buyat Bay, Sulawesi that indicated the mercury level is 7 mg/kg in sediment and exceeds the safety limit of 2 mg/kg from WHO. The other possible source of metal pollution in the mining region is derived from natural factors such as volcanoes (Franco-Fuentes *et al*., 2021; Syakti *et al*., 2015), variability of the season (Siregar *et al*. 2016, Zhang *et al*., 2021), and interaction between contaminant (Purwiyanto *et al*., 2020), anthropogenic from marine or terrestrial source such as shipping activities, industry, wastewater discharge (Suteja *et al*., 2020; Amin *et al*., 2009; Sindern *et al*., 2016).

DISCUSSION

The Proposed of National Database in Indonesia

The literature study using was conducted by searching for keywords “Indonesia”, “metal, “sediment” in “abstract, keywords and title“ from Scopus database and Googlescholar. The most reported of heavy metal in keywords in Scopus Database is Pb (33 articles), Cu (32 articles), Zn (23 articles), Cd and Cr (19 articles), Fe (18 articles), Hg (14 articles) and Ni (11). From the 193 papers identified in the initial search results, limitation on journals published in the last 10 years (2011-2021) generated 145 articles, which were then subjected to a content analysis to determine the topic's eligibility. Data from Google Scholar related to non-essential metal is appended in Table 1 to resume research has been done in Indonesia and useful as a baseline data. Anthropogenic metal accumulation in sediments of Jakarta Bay (Zn, Cu, and Pb) began in the 1920s and intensified significantly from the 1970s until the end of the 1990s. Zn and Pb accumulation rates near the coastal industrialized area were consistent or decreased from the end of the 1990s to 2006 (Hosono *et al*., 2011). Harmesa *et al.* (2021) reported that the Cd concentration in Dasun estuary, Rembang was relatively high, and the source was presumed to be waste from the batik industry. Pb concentration ranged from 7.6 to 15.40 mg kg^{-1} dw in shrimp aquaculture in Central Java and showed moderate contamination, according to the ecological risk (geoaccumulation index (Igeo), contamination factor (CF), pollution load index (PLI), and potential ecological risk index (PERI)) determined in the sediments (Hidayati *et al.,* 2020). The average Cd compositions ranged from 0.13 to 0.89 mg/kg, while the average Cr compositions ranged from 0.09 to 96.0 mg/kg, according to the studies. Furthermore, average Cu compositions ranged from 3.00 to 148 mg/kg, whereas average Ni compositions varied from 1.00 to 37.4 mg/kg. Furthermore, Pb compositions ranged from 1.00 to 111 mg/kg on average. Finally, Zn compositions ranged from 4.00 to 595 mg/kg on average. The average highest metal of Ni was found in East Asia, whereas the highest metals of Cd, Cr, Cu, Pb, and Zn were found in Southeast Asian countries, according to the study's metal distribution areas (Fang *et al*., 2011). Cordova *et al*. (2016) reported that the concentration of Pb, Hg and Cd in Jakarta Bay sediments reached 21,77; 0,36 and 0,19 mg/kg, respectively. The study of metal levels in sediments is not as extensive as that of metal levels in water. Metal levels in water are positively correlated with metal levels in sediments (Franco-fuentes *et al*., 2021), so if it follows a pattern of heavy metal study trends in water that are high in hotspot areas due to industrial and mining, the study should be concentrated several locations.

As operational suggestion, it recommended to focus on heavy metal such as cadmium, copper, mercury, and chromium because of nonessential metal. Non-essential metals (e.g., Cd, Cr, Pb, Hg) play an unknown role in the biological system, are toxic, persistent, and tend to accumulate in organisms (Fatima *et al*., 2020). The first step to initiate the preparation of sediment quality standards is the collection of baseline data on metal contamination sediments (Table 1). As we know that Indonesia is an archipelago with diverse characteristic, we recommended for initial project, the location can be concentrated on coastal area because this region is economically important and highly dense population especially Jakarta and Semarang. For specific sites with high risk i.e mining and aquaculture also get high priority. Heavy-mining sites in Buyat Bay (Sulawesi), Buru islands (Maluku), Aijkwa estuary (Papua), and Sumbawa (Nusa Tenggara) are the focus of study on coastal heavy metal pollution in Indonesia (Adyasari *et al*., 2021).

A national database is urgently needed for collecting data related to contamination in Indonesia. The fact that Indonesia has various coastal characterization will be a consequence of the dynamic data will be very diverse (Tussadiah *et al*., 2021). The form of data not only primary data like concentration of metal in water, sediment, and organism but also the water quality like pH, DO, salinity, TSS, temperature. Further analysis of these data will be useful for monitoring, direction for the policymaker, a comprehensive study for students, and for compiling water and sediment quality standard. Principally, Indonesia has a competency to compile a national database because of the method, equipment like Atomic Absorption Spectrophotometer (AAS), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) and human resources are available. The challenge comes from the availability of accredited personnel and laboratory to make sure the data is accurate and valid, and the availability of Certified Reference Material (CRM) for quality of assurance and quality of control. This project needs collaboration between research institutes, universities, local government, and national government as a leader. Standard Operational Procedures (SOP) must be arranged to make sure the data is reliable and accurate as a depository database.

Based on current trends in big data storing and archiving worldwide, we recommend optimizing the environmental database. Indonesia already has an open public access database contain environmental data (water, air, waste) issued by the Ministry of Environment and Forestry (https://dataalam.menlhk.go.id/). It is a good initiative to make open public data source. This database has the potential to facilitate and expedite future

Table 1. Baseline data of metal contamination in sediment.

Location	Cd	Pb	Hg	Cr	References
Kahayan estuary (2005)	69.87	46.87	7.41	-	Siregar & Murtini, (2008)
Barito Estuary (2005)	73.9	90.94	21.46	-	Siregar & Murtini, (2008)
Perairan Ngemboh, Gresik, East Java	0.46	1.71	-	-	Eshmat *et al.* (2014)
Jakarta Bay (2010)	0.012-0.75	-	-	45.32-139.18	Permanawati *et al.,* (2013)
Teluk Jakarta	0.312-0.425	12.49-23.60	0,774-0.855	-	Barokah *et al.* (2019)
Teluk Jakarta	-	-	0,009-0,38	-	Murtini & Ariyani, 2005
Semarang (2010)	0.09	13.69	-	-	Rositasari & Lestari, (2013)
Semarang (2016)	0.24	8.16	-	-	Rositasari & Puspitasari, (2021)
Estuary Jakarta (2015)	0.28	28.8	0.47	-	Cordova *et al.* (2016)
Semarang	-	25.6		-	Widianarko *et al.* (2000)
Wonorejo estuary, East Java	-	4.22	-	70.8	Titah *et al.* (2020); Lutfthansa *et al.* (2021)
Dasun estuary, Rembang	0.21	5.36	-	3.39	Harmesa & Cordova, (2021)
Benoa Bay	-	-	-	1-24.6	Suteja *et al.* (2020)
Trimulyo, Semarang	-	-	-	20.4–45.8	Nuraini *et al.* (2017)
Segara anakan	-	-	-	17-73	Syakti *et al.* (2015)
Dumai	0.88	32.43	-	-	Amin *et al.* (2009)
Buru islands (2011)	-	-	>3	-	Male *et al.* (2013)
Buru islands (2013)	-	-	8.05-82.39	-	Reichelt-Brushett *et al.* (2017)
Ratatotok, North Sulawesi	-	-	40	-	Limbong *et al.* (2005)

ecological investigations by providing easy access to already investigated.

CONCLUSIONS

From a case study in the UK, it is important to prepare a database of metals in sediment in Indonesia as national basis data. The database contains a history of baseline information of metals and helps the manager to choose best practices based on an environmental framework. As an initial step, it is recommended to explore the Java Sea especially Jakarta and Semarang, and several hotspots of mining because of the high risk of heavy metal contamination for collecting the database. This would facilitate the monitoring and utilization of data for various purposes. A government agency, the Ministry of Environment and Forestry, and National Research and Innovation Agency (NRIA) should take a lead that can coordinate the database update mechanism to other sectors.

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REFERENCES

Asian Development Bank. 2016. *Indonesia: Country Water Assessment*. Manila. Asian Development Bank, Philippines.

Adyasari, D., Pratama, M. A., Teguh, N. A., Sabdaningsih, A., Kusumaningtyas, M. A., & Dimova, N. 2021. Anthropogenic impact on Indonesian coastal water and ecosystems: Current status and future opportunities. *Marine Pollution*

Bulletin, 171. https://doi.org/10.1016/j.marpolbul.2021.112689

Amin, B., Ismail, A., Arshad, A., Yap, C.K., Kamarudin, M.S. 2009. Anthropogenic impacts on heavy metal concentrations in the coastal sediments of Dumai, Indonesia. *Environmental Monitoring Assessment*. 148 (1–4): 291–305.

Barokah, G. R., Dwiyitno, & Nugroho, I. 2019. Kontaminasi Logam Berat (Hg, Pb, dan Cd) dan Batas Aman Konsumsi Kerang Hijau (*Perna viridis*) dari Perairan Teluk Jakarta di Musim Penghujan. *Jurnal Pasccapanen dan Bioteknologi Kelautan dan Perikanan*. 14(2): 95-106.

Belabed, B.E., Meddour, A., Samraoui, B., Chenchouni, H. 2017. Modeling seasonal and spatial contamination of surface waters and upper sediments with trace metal elements across industrialized urban areas of the Seybouse watershed in North Africa. *Environmental Monitoring Assessment*. 189 (6): 265. https://doi.org/10.1007/s10661-017-5968-5.

Bott, L. M., Schöne, T., Illigner, J., Haghshenas Haghighi, M., Gisevius, K., & Braun, B. 2021. Land subsidence in Jakarta and Semarang Bay – The relationship between physical processes, risk perception, and household adaptation. *Ocean and Coastal Management*, *211*. https://doi.org/10.1016/j.ocecoaman.2021.105775

Brady, J.P., Ayoko, G.A., Martens, W.N., Goonetilleke, A. 2015. Development of a hybrid pollution index for heavy metals in marine and coastal sediments. *Environmental Monitoring Assessment*. 187, 306. https://doi.org/10.1007/s10661-015-4563-x

Budianta, W. 2021. Heavy metal pollution and mobility of sediment in Tajum River caused by artisanal gold mining in Banyumas, Central Java, Indonesia. *Environmental Science and Pollution Research,* 28. https://doi.org/10.1007%2Fs11356-020-11157-5

Cefas, 2012. *CSEMP Green Book*. http://cefas.defra.gov.uk/media/510362/greenbookv15.pdf.

Cole, M., Lindeque, P., Halsband, C., & Galloway, T.S. 2011. Microplastics as contaminants in the marine environment: a review. *Marine Pollution Bulletin.* 62 (12): 2588–2597.

Choudhary, P., Subhash, V., Khade, M., Savant, S., Musale, A., Kumar, R. K., Chelliah, M. S., & Dasgupta, S. 2021. Empowering blue economy: From underrated ecosystem to sustainable industry. *Journal of Environment Management,* 291, https://doi.org/10.1016/j.jenvman.2021.112697

Ciarkowska, K., 2018. Assessment of heavy metal pollution risks and enzyme activity of meadow soils in urban area under tourism load: a case study from Zakopane (Poland). *Environmental Science and Pollution Research*. 25, 13709–13718 https://doi.org/10.1007/s11356-018-1589-y

Cordova, M. R., Purbonegoro, T., Puspitasari, R. & Hindarti, D. Purbonegoro. 2016. Assessing Contamination Level of Jakarta Bay Nearshore Sediments Using Green Mussel (*Perna viridis*) Larvae. *Marine Research in Indonesia*, 41(2), 67-76

Eshmat, M. E., Mahasri, G. & Rahardja, B. S. 2014. Analisis Kandungan Logam Berat Timbal (Pb) dan Cadmium (Cd) Pada Kerang Hijau (*Perna viridis* L.) di Perairan Ngemboh Kabupaten Gresik Jawa Timur. *Jurnal Ilmiah Perikanan dan Kelautan.* 6(1): 101-108

Fatima, S., Muzammal, M., Ismail Khan, D., Aqsa Rehman, P., Saqib Ali Rustam, P., Khan, I., Zainab Shehzadi, P., Mehmood, A., Waqar, M., Rehman, A., Ali Rustam, S., & Shehzadi, Z. (2020). Water pollution of heavy metals and its effects on fishes. *International Journal of Fisheries and Aquatic Studies*, 8(3), 06-14. http://www.fisheriesjournal.com

Franco-Fuentes, E., Moity, N., Ramirez-Gonzales, J., Andrade-vera, S., Hardisson, A., Gonzales-Weller, D., Paz, S., Rubio, C., & Gutierrez, A. J. 2021. Metals in commercial fish in the Galapagos Marine reserve: Contribution to food security and toxic a risk assessment. *Journal of Environmental management*, 286. https://doi.org/10.1016/j.jenvman.2021.112188

Harmesa & Cordova, M. R. 2021. A preliminary study on heavy metal pollutants chrome (Cr), cadmium (Cd), and lead (Pb) in sediments and beach morning glory vegetation (*Ipomoea pescaprae*) from Dasun Estuary, Rembang, Indonesia. *Marine Pollution Bulletin*, 162, 111819. https://doi.org/10.1016/j.marpolbul.2020.111819

Hosono T., Su C.C., Delinom R., Umezawa Y., Toyota T., Kaneko S., & Taniguchi, M. 2011. Decline in heavy metal contamination in marine sediments in Jakarta Bay, Indonesia due to increasing environmental. Regulations. *Estuarine, Coastal and Shelf Science*, 92, 297-306

Hidayati, N. V., Prudent, P., Asia, L., Vassalo, L., Torre F., Widowati, I., Sabdono, A., Syakti, A. G. & Doumenq, P. 2020. Assessment of the ecological and human health risks from metals in shrimp aquaculture environments in Central Java, Indonesia. *Environmental Science and Pollution Research*, 27, 41668-41687. https://doi.org/10.1007/s11356-020-09967-8

Khemis, I.B., Aridh, N.B., Hamza, N., M'Hetli, M., Sadok, S. 2017. Heavy metals and minerals contents in pikeperch (*Sander lucioperca*), carp (*Cyprinus carpio*) and flathead grey mullet (*Mugil cephalus)* from Sidi Salem reservoir (Tunisia): health risk assessment related to fish consumption. *Environmental Science Pollution Research*. 24 (24), 19494–19507. https://doi.org/10.1007/s11356-017-9586-0.

Koropitan, A.F., Cordova, M.R. 2017. Study of heavy metal distribution and hydrodynamic simulation in green mussel culture net, Cilincing water-Jakarta Bay. *Makara Journal of Science*. 89–96.

Kowalska, J. B., Mazurek, R., Gasiorek, M., & Zalesk. T. 2018. Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination–A review. *Environmental Geochemical Health*. 40: 2395–2420. https://doi.org/10.1007/s10653-018-0106-z(0123456789().,-volV)(0123456

La Colla, N. S., Botté, S. E., Simonetti, P., Negrin, V. L., Serra, A. V., & Marcovecchio, J. E. 2021. Water, sediments and fishes: First multi compartment assessment of metal pollution in a coastal environment from the SW Atlantic. *Chemosphere*, 282. https://doi.org/10.1016/j.chemosphere.2021.131131

Liu, H., Liu, G., Yuan, Z., Ge, M., Wang, S., Liu, Y., & Da, C. 2019. Occurrence, potential health risk of heavy metals in aquatic organisms from Laizhou Bay, China. *Marine Pollution Bulletin*, *140*, 388–394. https://doi.org/10.1016/j.marpolbul.2019.01.067

Liu, J., Peng, A., Deng, S., Liu, M., Liu, G., & Li, C. 2021. Distribution of heavy metals and radionuclides in the sediments and their environmental impacts in Nansha Sea area, South China Sea. *Marine Pollution Bulletin*, 166. http://dx.doi.org/10.1016/j.marpolbul.2021.112192

Limbong, D., Kumampang, J., Ayhuan, D., Arai, T & Miyazaki, N. Mercury Pollution Related to Artisanal Gold Mining in North Sulawesi Island, Indonesia. *Bulletin of Environmental Contamination and Toxicology*.75: 989-996

Lutfthansa, U. M., Titah, H. S., & Pratikno, H. 2021. The Ability of Mangrove Plant on Lead Phytoremediation at Wonorejo Estuary, Surabaya, Indonesia. *Journal Ecological Engineering*. 22(6): 253–268. DOI: https://doi.org/10.12911/22998993/137675

Male, Y. T., Reichelt-Brushett, A. J., Pocock, M., & Nanlohy, A. 2013. Recent mercury contamination from artisanal gold mining on Buru Island, Indonesia – Potential future risks to environmental health and food safety. *Marine Pollution Bulletin*, 77: 428-433

Murtini, J.T. dan Ariyani, F. 2005a. Kandungan logam berat kerang darah (*Anadara granosa*) dan kualitas perairan di Tanjung Pasir, Jawa Barat. *Jurnal Penelitian Perikanan Indonesia*. 11 (8): 39–45.

Nuraini, R. A. T., Endrawati, H., & Maulana, I. R. 2017. Analisis Kandungan Logam Berat Kromium (Cr) pada Air, Sedimen dan Kerang Hijau (*Perna viridis*) di Perairan Trimulyo Semarang. *Jurnal Kelautan Tropis*. 20(1): 48–55

Ouali, N., Belabed, B. E., & Chenchouni, H. 2018. Modelling environment contamination with heavy metals in flathead grey mullet *Mugil cephalus* and upper sediments from north African coasts of the Mediterranean Sea. *Science of the Total Environment*, 639: 156–174. https://doi.org/10.1016/j.scitotenv.2018.04.377

Permanawati, Y., Zuraida, R., & Ibrahim, A. 2013. Heavy Metal Content (Cu, Pb, Zn, Cd, and Cr) In Sea Water and Sediment in Jakarta Bay. *Jurnal Geologi Kelautan*, 11 (1): 9-16

Purwiyanto, A.I.S., Suteja, Y., Trisno, Ningrum, P.S., Putri, W.A.E., & Rozirwan. 2020. Concentration and adsorption of Pb and Cu in microplastics: case study in aquatic environment. *Marine Pollution Bulletin*. 158, 111380.

Rositasari, R., & Lestari. 2013. Evaluasi Lingkungan Perairan Pesisir Semarang. *Jurnal Ilmu dan Teknologi Kelautan Tropis*. 5(1):112-121

Reichelt-Brushett, A. J., Stone, J., Howe, P., Thomas, B., Clark, M., Male, Y., Nanlohy, A., Butcher, P.2017. Geochemistry and mercury contamination in receiving environments of artisanal mining wastes and identified concerns for food safety. *Environmental Research*. 152: 407-418

Rositasari, R., & Puspitasari, R. 2021. The ecological vulnerability of Semarang's coastal waters, a brief review. The 4th International Symposium on Marine and Fisheries Research IOP Conf. Series: Earth and Environmental Science 919 (2021) 012028. doi:10.1088/1755-1315/919/1/012028

Richir, J., Bray, S., McAleese, T., & Watson, G. J. 2021. Three decades of trace element sediment contamination: The mining of governmental databases and the need to address hidden sources for clean and healthy seas. *Environment International*, 149. https://doi.org/10.1016/j.envint.2020.106362

Sindern, S., Tremohlen, M., Dsikowitzky, L., Gronen, L., Schwarzbauer, J., & Siregar, T.H. 2016. Heavy metals in river and coast sediments of the Jakarta Bay region (Indonesia)—Geogenic versus anthropogenic sources. *Marine Pollution Bulletin*. 110 (2): 624–633.

Siregar, T.H., Priyanto, N., Putri, A.K., Rachmawati, N., Triwibowo, R., & Dsikowitzky, L. 2016. Spatial distribution and seasonal variation of the trace hazardous element contamination in Jakarta Bay, Indonesia. *Marine Pollution Bulletin*. 110 (2): 634–646.

Siregar, T. H & Murtini, J. T. 2008. Kandungan Logam Berat pada Beberapa Lokasi Perairan Indonesia pada tahun 2001 sampai dengan 2005. *Squalen*. 3(1):7-15

Suteja, Y., Dirgayusa, I.G.N.P., & Purwiyanto, A.I.S. 2020. Chromium in Benoa Bay, Bali-Indonesia. *Marine Pollution Bulletin*. 153, 111017.

Syakti, A., Demelas, C., Hidayati, N., Rakasiwi, G., Vassalo, L., & Kumar, N. 2015. Heavy metal concentrations in natural and human-impacted sediments of Segara Anakan Lagoon, Indonesia. *Environmental Monitoring Assessment*. 187 (1), 4079.

Titah, H. T. & Pratikno, H. 2020. Copper Accumulation by *Avicennia marina* at Mangrove Eco-forest in Wonorejo, Surabaya. The 5th International Conference on Energy, Environmental and Information System (ICENIS 2020) E3S Web of Conferences 202, 05004.

Tussadiah, A., Sujiwo, A. S., Andesta, I., & Daeli, W. 2021. Assessment of coastal ecosystem services and its condition for policy management plan in East Nusa Tenggara, Indonesia. *Regional Studies in Marine Sciences*, 47. https://doi.org/10.1016/j.rsma.2021.101941

United Nations. 2015. *Transforming our world: the 2030 Agenda for Sustainable Development*

Widianarko, B., Verweij, R. A., Van Gestel, C. A. M., & Van Straalen, N. M. 2000. Spatial Distribution of Trace Metals in Sediments from Urban Streams of Semarang, Central Java, Indonesia. *Ecotoxicology and Environmental Safety.* 46, 95-100

Velasquez, I.B., Jacinto, G.S., Valera, F.S. 2002. The speciation of dissolved copper, cadmium and zinc in Manila Bay, Philippines. *Marine Pollution Bulletin*. 45 (1), 210–217.

Voyer, M., Farmery, A. K., Kajlich, L., Vachette, A., & Quirk, G. 2020. Assessing policy coherence and coordination in the sustainable development of a Blue Economy. A case study from Timor Leste. *Ocean and Coastal management*, 192, https://doi.org/10.1016/j.ocecoaman.2020.105187

Zhai, B., Liu, Z., Wang., X., Bai, F., Wanga, L., Chen, Z., & Zhang, X. 2020. Assessment of heavy metal contaminations in surface sediments in the western Taiwan Straits. *Marine Pollution Bulletin,* 159. https://doi.org/10.1016/j.marpolbul.2020.111492

Zhang, H., Liu, S., Wu, K., Cui, J., Zhu, A., Zhang, Y., Mohamed, A. A., R., & Shi, X. 2021. Distribution and assessment of heavy metal contents in surface sediments of the wetern sediments Sunda Shelf. *Marine Pollution Bulletin*, 168. https://doi.org/10.1016/j.marpolbul.2021.112433

Zhang, Z., Lu, Y., Li, H., Tu, Y., Liu, B., Yang, Z. 2018. Assessment of heavy metal contamination, distribution and source identification in the sediments from the Zijiang River, China. *Science of Total Environment*. 645, 235e243.