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Analysis of heavy metal content of Cu, Pb, Hg and dissolved Sn in coastal of Banyuwangi district, Indonesia

Ervina Wahyu SETYANINGRUM[1], Agustina Tri Kusuma DEWI[1], Mega YUNIARTIK[1], and Endang Dewi MASITHAH[2]✉

[1]*Faculty of Agriculture and Fisheries, University of 17 Agustus 1945, Banyuwangi 68416, Indonesia*
[2]*Faculty of Fisheries and Marine, University of Airlangga, Surabaya 60115, Indonesia*

✉Corresponding author's Email: ervinawahyu@untag-banyuwangi.ac.id

ABSTRACT

Banyuwangi Regency has the longest coast in East Java of Indonesia with sandy beaches and corals and there are various types of coastal and marine resources that can be utilized both in terms of economics and environment. But in the current era of industrialization, coastal areas in Banyuwangi have become a top priority for industrial development, agribusiness, agro-industry, housing, transportation, ports and tourism. The purpose of this study was to analyze the content of copper (Cu), lead (Pb), mercury (Hg), and tin (Sn) and the effect of water quality on the heavy metal content in the coast of Banyuwangi Regency. The method in this study uses descriptive. Data taken along the coast of Banyuwangi Regency include water quality (alkalinity, NH4, PO4, DO, pH, NO3, water temperature and salinity), copper (Cu), lead (Pb), mercury (Hg), and tin (Sn). Data analysis using multiple linear regression analysis, followed by F test and t-test. The results showed that there was an influence between the quality of the water on the value of heavy metal of copper (Cu), and the value of R-Square 0.681 which means that it has an influence proportion on the value of copper (Cu) of 68.1%. Likewise, for the quality of water for tin (Sn), there is an influence with the value of R-Square of 0.700, which means that the effect is as high as 70%. While the quality of the waters against Lead, heavy metal (Pb) and mercury (Hg) has no significant effect. Based on the results of the study, Banyuwangi district government needs to take serious actions in controlling heavy metal pollution through the implementation of law No. 23 of 1997 concerning to environmental management, and the application of environmental quality standards more strictly.

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INTRODUCTION

Like other coastal waters, the Coastal of Banyuwangi District has the potential to accumulate anthropogenic loads carried from several rivers. This is compounded by the misuse of the river as a waste disposal site so that the pollutant load will be distributed to the river estuary also to the sea. The input of waste from land to estuary generally comes from human activities such as industry, shipping, anthropogenic and others [1]. This makes estuary and coastal areas vulnerable to contamination [2].

Like fresh water, sea water also has a great ability to dissolve various substances, both in the form of gases, liquids, and solids. A sea is a place where the rivers transport various types of substances, which can be beneficial nutrients for fish and aquatic organisms, can also be materials that are not useful, even disrupt the growth and development of fish and aquatic organisms or can cause a decrease in water quality [3].

This decrease in water quality is caused by the presence of contaminants, both in the form of organic and inorganic components. Inorganic components include dangerous heavy metals. Darmono [4], explained that the definition of heavy metals is a metal element with a high molecular weight, which is specific gravity greater than 5 g/cm^3. However metalloid elements which have dangerous properties are also included in the group. Thus, currently elements included in heavy metals reach approximately 40 types of elements.

One of the pollutants that has the potential to be found in the coastal district of Banyuwangi is heavy metal. Pollution of heavy metals is categorized as pollution which causes harmful effects on the environment and the organisms in it. Heavy metals have non-degradable properties. In addition, heavy metals will accumulate in the environment such as water and sediment columns and be absorbed into marine biota [5].

Heavy metals can enter the environment in various ways, such as weathering of rocks containing heavy metals, volcanic activity and disposal of waste from mining, industry and transportation. The main source of heavy metal contaminants comes from air and water that pollute the soil. Certain metals in high concentrations will be very dangerous if found in the environment. The main cause of heavy metals being dangerous pollutants is because they are non-degradable by living organisms in the environment. As a result, these metals accumulate into the environment. Heavy metals are dangerous if they enter the metabolic system in amounts exceeding the threshold. The threshold varies for each type of heavy metal [4]. Some of them are widely used in various daily needs; therefore they are produced regularly on an industrial scale. The use of these heavy metals in various daily needs, either directly or indirectly, or intentionally or unintentionally, has polluted the environment. Some heavy metals that are dangerous and often pollute the environment are mainly mercury (Hg), lead (Pb), arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), and nickel (Ni) [6].

Cu is a microelement is needed by organisms of both land and water, but in small amounts. The presence of Cu in general waters can come from industrial areas around the waters. This metal will be absorbed by aquatic biota sustainably if its presence in the water is always available, moreover, for aquatic biota with low mobility such as shellfish [7]. Lead (Pb) is gray metal, can be forged and can be formed. Pb has active chemical properties so that it can be used to coat metal to prevent corrosion. When mixed with other metals, lead can form better mixed metals than pure metal. In addition, lead also has a density exceeding other metals. This metal is widely used in the battery, cable, paint (as a coloring agent), gilding, pesticide industry and is the most widely used as an anti-dust agent in gasoline. Lead is also used as a constituent substance and as a pipe connecting formulation [4]. Tin (Sn) is a silvery white, shiny metal, can be forged and can be formed. Tin melting point is 231,930C. This metal is not easily oxidized in the air so it is often used as another metal coating to prevent rust. Tin is also often used as another metal coating to prevent rust. Tin is also often used as a mixture with other metals such as soft solder [8].

The presence of heavy metal at high concentration in the water column will endanger marine aquatic organisms from inhibiting metabolic process to causing the death of biota [9]. Therefore, this study aims to monitor the concentration of dissolved heavy metal along coastal of Banyuwangi district and analyze its association with aquatic environmental factors.

MATERIAL AND METHODS

This research was conducted in March - June 2018. Data collection methods used purposive sampling along the coast of Banyuwangi Regency. The location of the study can be seen in Figure 1.

The research method uses descriptive methods, which is data presented by explaining and describing the real situation. Measurement of water quality which includes temperature, salinity, pH, dissolved oxygen (DO) was measured directly at the temporary research location for observing alkalinity, NH_4, PO_4, NO_3 carried out at the faculty of agriculture and fisheries laboratory on university 17 August 1945 Banyuwangi. While taking water samples for heavy metals using dark glass bottles at each research location point along the coast of Banyuwangi Regency, then taken to the Surabaya to measure heavy metal levels.

Work procedure for analysis of heavy metal copper (Cu) content test method using Standar Nasional Indonesia (SNI) 6989.6: 2009, Mercury (Hg) using SNI 6989.78: 2011 test, Lead (Pb) using SNI 6989.46: 2009 test method, while Tin (Sn) using test method American Public Health Association (APHA) Ed. 21,311 B, 2005.

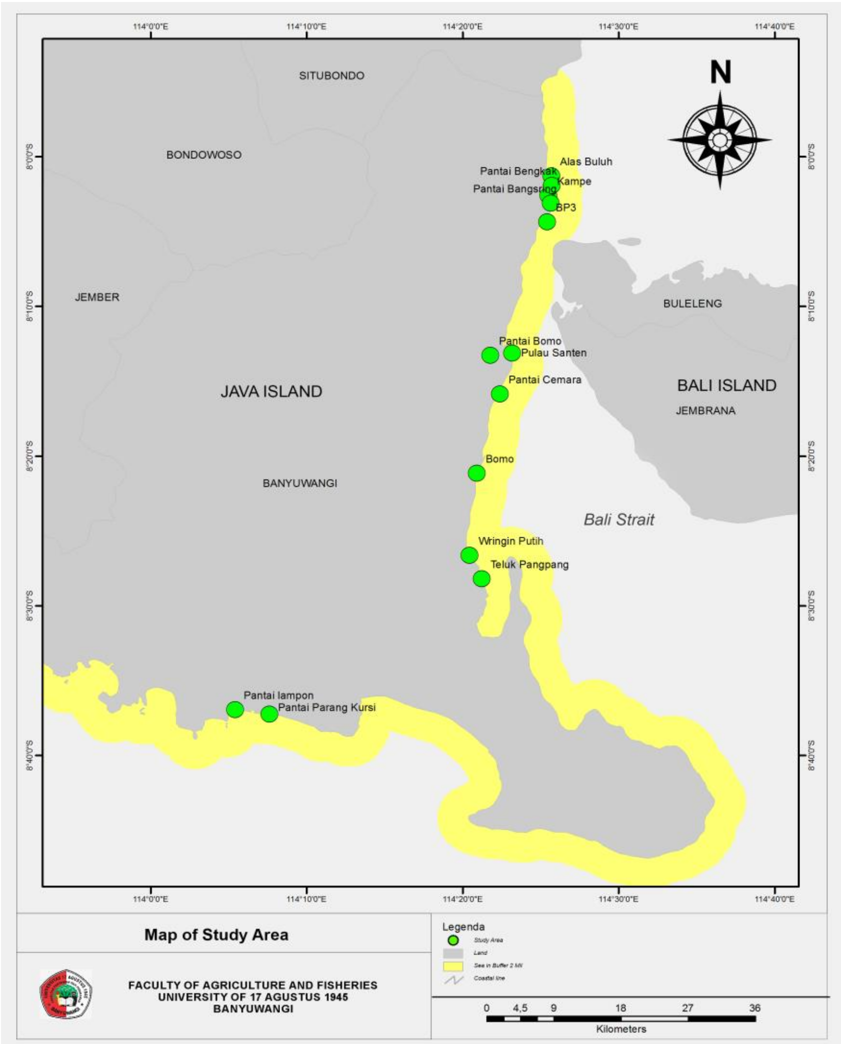

Figure 1. Banyuwangi Coastal Research Site Map.

Data analysis using multiple linear regression analysis to determine the degree of influence between variables of water quality and heavy metals. The statistical test results are presented in the form of mathematical equations, namely the multiple linear regression equation as follows:

$$Y = a+b1X1+b2X2+...+bnXn$$

Where:

Y: Dependent variable, a: Constanta, b1,b2: Regression coefficient, X1,X2: Independent variable

RESULTS AND DISCUSSION

Water quality parameters

Water quality data taken in the form of temperature, salinity, pH, DO and NH_4 in the waters of Banyuwangi coastal with the location of data collection in nine points representing all sub-districts along Banyuwangi coastal with twice replications.

Most of the water quality parameters can affect the concentration, distribution and toxicity of heavy metals in the waters referring to Hutagaol [10], which stated that temperature, turbidity, pH, salinity and DO are parameters that affect the toxicity of heavy metals in the waters. Environmental parameters are suspected affect heavy metal concentrations such as temperature, pH and salinity. The increase in temperature will reduce the adsorption of heavy metal compounds in particulates to settle to the bottom. The increase in pH can reduce the solubility of heavy metals in water because there is a change from the form of carbonate to hydroxide which forms a bond with particles in the water. Increasing salinity causes a decrease in toxic metals due to the desalination process. So, the existing heavy metal compounds can occur in the sedimentation process [11].

Table 1. Water quality data of Banyuwangi beach in 2018

Research Sites \ Water Quality	DO	Water Temperature	Water pH	Salinity	NH_4 (ppm)	NO_3 (ppm)	PO_4 (ppm)	Alkalinity CO_3 (ppm)	Alkalinity HCO_3 (ppm)
Alas Buluh	6.7	30.3	7.6	26	0	1	0	12	116
	6.5	29.7	7.3	25	0	0	0	36	112
Kampe	7.1	30.1	7.3	22	0	0	0	24	100
	7	28.8	7	23	0	0	0.1	12	144
BP3	8	27.3	7.2	20	0	0	0	24	116
	6.1	27.5	7.1	20	0	0	0.1	16	136
Cemara Beach	7.5	31	9	25	0	0	0.1	80	88
	6.4	29.3	8	25	0	0	0	32	100
Pakem Kertosari	7.7	31.6	7.2	24	0	0	0	12	112
	7.4	29.3	7.4	27	0	0	0	16	124
Santen Island	7.2	29.7	7.2	26	0	0	0	36	92
	6.5	29.2	7.4	26	0	0	0	36	100
Blimbingsari	6.1	30.3	8.9	27	0	0	0.1	12	120
	6.4	30.1	8.4	27	0	0	0.1	12	140
PangpangBay	7.04	30.3	6.9	23	0.7	0	0	24	98
	0.9	29.17	0	18	0.8	0	0	24	116
Lampon	6.9	30.6	7.1	25	0	0	3	44	84
	6.8	30.7	6.9	26	0	0	0	44	80

DO = dissolved oxygen; NH_4= ammonium; PO_4= phosphate; CO_3= carbonate; HCO_3= bicarbonate; BP3= Balai Pendidikan dan Pelatihan Perikanan (Fisheries Education and Training Center)

Heavy metals Cu, Hg, Pb and Sn in the coastal of Banyuwangi regency

The heavy metals analyzed in this study were types of Copper (Cu), Mercury (Hg), Lead (Pb) and tin (Sn). The following are the results of heavy metal tests carried out in the Surabaya Industrial Research and Standardization Center laboratory.

In general, the range of Cu concentration is 0.0104 mg/l, Hg 0 mg/l, Pb 0.0173 mg/l and Sn 1.3436 mg/l obtained from the coastal waters of Banyuwangi Regency. If referring to the Decree of the Minister of Environment No. 51 of 2004 concerning Sea Water Quality Standards, Mercury (Hg) 0.001 mg/l, Copper (Cu) and Lead (Pb) 0.008 mg/l, and Tin (Sn) 2 mg/l, then the value of heavy metals Hg and Sn is still below the threshold while Cu and Pb are above the threshold.

According to WHO, the highest desirable level in drinking water for Cu is 50 µg/L and the threshold for concentration for aquatic life tolerance (safe for most fishes) is 2×10^4 µg/L [12]. As for Pb, the WHO maximum permissible level of drinking water is 100 µg/L and the threshold of concentration for aquatic life tolerance (safe for most fishes) is 100 µg/L [12].

Table 2. Test results for heavy metals Cu, Hg, Pb and Sn in Coastal of Banyuwangi regency in 2018.

Parameter	Unit	Test Result						Test Methods
		P. 2169 Alas buluh	P. 2170 Alas buluh	P. 2171 Kampe	P. 2172 Kampe	P. 2173 BP 3	P. 2174 BP 3	
Copper (Cu)	mg/l	<0.0223	0.026	0.032	<0.0223	0.026	0.026	SNI 6989.6 : 2009
Mercury (Hg)	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	SNI 6989.78 : 2011
Lead (Pb)	mg/l	0.012	0.015	0.015	0.016	0.017	0.015	SNI 6989.46:2009
Tin (Sn)*	mg/l	<0.1050	<0.1050	0.469	<0.1050	<0.1050	<0.1050	APHA Ed.21.311 B.2005

Parameter	Unit	Test Results						Test Methods
		P. 2175 P. Santen	P. 2176 P. Santen	P. 2177 P. Pakem	P. 2178 P. Pakem	P. 2179 P. Cemara	P. 2180 P. Cemara	
Copper (Cu)	mg/l	<0.0223	<0.0223	0.026	<0.0223	0.03	<0.0223	SNI 6989.6 : 2009
Mercury (Hg)	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	SNI 6989.78 : 2011
Lead (Pb)	mg/l	0.017	0.018	0.017	0.022	0.018	0.018	SNI 6989.46:2009
Tin (Sn)*	mg/l	<0.1050	<0.1050	<0.1050	<0.1050	<0.1050	4.136	APHA Ed.21.311 B,2005

Parameter	Unit	Test Results				Test Methods
		P. 2181 Teluk Pampang	P. 2182 Lampon	P. 2183 Lampon	P. 2184 P. Blimbing Sari	
Copper (Cu)	mg/l	<0.0223	<0.0223	<0.0223	<0.0223	SNI 6989.6 : 2009
Mercury (Hg)	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	SNI 6989.78 : 2011
Lead (Pb)	mg/l	0.018	0.019	0.021	0.018	SNI 6989.46:2009
Tin (Sn)*	mg/l	4.703	4.791	3.743	3.656	APHA Ed.21.311 B,2005

Note: Parameters tested according to parameters; "<" shows the limit of quantity value from the test

Source of heavy metals on the coast can be divided into two, which enter naturally and artificially into marine waters. Heavy metals that enter the ocean waters can come from three sources, namely:

- Input from the coastal area, which originates from the river and the results of coastal abrasion due to wave activity.
- Inputs from the deep sea, including metals released as a result of volcanic activity in deep seas and metals released from particles through chemical processes.
- Inputs from nearshore land environments, including metals originating from the atmosphere as dust particles.

The source of artificial metals is metal that was released during the metal and rock industry process. Some industries only use certain heavy metals for their production activities. However, in general, most industries use various types of heavy metal elements, making it difficult to trace the origin of sources of pollution. Of the four heavy metals mentioned above, different concentrations of heavy metals are obtained in seawater. This difference in concentration is possible due to the variability of metals in water caused by currents, adsorption, tides, or deposition [13].

Effect of water quality to heavy metal

Based on the results of regression analysis of the four types of heavy metals namely Copper (Cu), Lead (Pb), Mercury (Hg) and Lead (Pb) on the coast of Banyuwangi Regency, it shows that there is no effect on water quality of Lead (Pb) and Mercury (Hg). Whereas two other types of heavy metals, namely Copper (Cu) and Tin (Sn) have influence.

In connection with this, even though the Pb value is at the threshold, it is not caused by the value of water quality, but the presence of waste entering the coastal area. Whereas the Hg type value is below the threshold and the waste entering the coastal area means that it still contains Hg. According to Anggoro [14], heavy metal is one of the waste parameters as a source of impact in coastal waters. Probability value of calculated F (sig.) in the table above, the value 0,0001 is smaller than the significance level of 0.05 so it can be concluded that the linear regression model that was estimated is worth using to explain the effect of heavy metal copper (Cu) on alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, and salinity. Copper (Cu) is one of the heavy metals that can be found in the aquatic environment and in sediments [15]. Heavy metals naturally have low concentrations in waters. High or low concentrations of heavy metals are caused by the maximum amount of heavy metal waste into the waters. Heavy metals that enter the waters will experience precipitation, dilution and dispersion, then absorbed by organisms that live in the waters. Maslukah [16], states that the process of entering Cu in subsequent waters undergoes an adsorption process followed by a process of flocculation and desorption. The adsorption process by particles causes the precipitation of material in the sediment and makes the concentration near the bottom of the water column become high again.

From the Table 4, the R-Square value of 0.681, it shows that the proportion of the copper (Cu) variable influence to the variables of alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, and salinity is 68.1%. This means, that the value of the independent variable has an influence proportion on the value of copper (Cu) of 68.1% while the remaining 31.9% (100% - 68.1%) is influenced by other variables that are not in the linear regression model.

Table 3. F-Test: Water quality to copper (Cu) heavy metal

ANOVA [a]						
Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
1	Regression	0.0001	8	0.0001	8.265	0.000b
	Residual	0.0001	31	0.0001		
	Total	0.0001	39			

a. Dependent Variable: Tin (Cu); b. Predictors: (Constant), Alkalinity, NH_4, PO_4, DO, pH, NO_3, Water Temperature, Salinity

Table 4. R Square value: copper (Cu) heavy metal to water quality

Model Summary [b]					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	0.825a	0.681	0.598	0.0017955	2.587

a. Predictors: (Constant), Alkalinity, NH_4, PO_4, DO, pH, NO_3, Water Temperature, Salinity; **b.** Dependent Variable: Copper (Cu)

Table 5. t-Test: Heavy metal copper (Cu) towards water quality

Coefficients [a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity statistics**	
		B	**Std. Error**	**Beta**			**Tolerance**	**VIF**
1	(Constant)	-0.014	0.011		-1.289	0.207		
	DO	0.000	0.001	0.079	0.683	0.500	0.762	1.312
	water temperature	0.002	0.000	0.620	4.258	0.000	0.485	2.060
	pH	0.001	0.001	0.182	1.496	0.145	0.692	1.445
	Salinity	-0.001	0.000	-0.928	-5.907	0.000	0.417	2.396
	NH_4	-0.011	0.002	-0.688	-5.193	0.000	0.586	1.707
	NO_3	-0.004	0.001	-0.445	-3.387	0.002	0.597	1.674
	PO_4	-0.001	0.000	-0.202	-1.882	0.069	0.895	1.118
	Alkalinity	4.021E-005	0.000	0.231	1.711	0.097	0.567	1.764

a. Dependent variable: copper (Cu); DO= dissolved oxygen; NH_4= ammonium; NO_3 = nitrate ; PO_4= phosphate; VIF: Variance Inflation F=actor

The probability value of calculated t from the independent variables of dissolved oxygen (DO) is 0.50, pH of 1.45, PO_4, and alkalinity of 0.097 (greater than Sig. 0.05) indicates that the independent variable dissolved oxygen (DO) , pH, PO_4, and alkalinity have no significant effect on the dependent variable of copper (Cu). The probability value of calculated t from the independent variable water temperature of 0.00, salinity of 0.00, NH_4 of 0.00 and NO_3 of 0.02 (smaller than Sig. 0.05), indicating that the variable is independent of water temperature, salinity , NH4, and NO3 have a significant effect on the dependent variable of copper (Cu).

Based on the above values, the interpretation of the models of alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, and salinity of Copper (Cu) heavy metals is as follows:

Copper (Cu) = -0.14 + 0.00 DO + 0.002 Water Temperature + 0.001 pH - 0.001 salinity – 0.011 NH4 – 0.004 NO3 – 0.001 PO4 + 4.021 alkalinity

The regression coefficient of dissolved oxygen (DO) is positive, meaning that when the value of DO rises, the value of heavy metals Copper (Cu) will also increase. If the value of DO decreases, the value of Cu will decrease too. If the value of dissolved oxygen (DO) rises by 1 mg/l it will increase the total Cu value by 0,000 mg/l and conversely the decrease in DO by 1 mg/l will reduce the copper (Cu) value by 0,000 mg/l.

Water temperature regression coefficient is positive, meaning that when the water temperature rises, the copper (Cu) value will also increase. If the value of the water temperature drops, the value of copper (Cu) will decrease. If the value of the water temperature rises by 1 $^{\circ}$C, it will increase the value of Cu by 0.002 mg/l and conversely a decrease in water temperature of 1 $^{\circ}$C will reduce the value of Cu by 0.002 mg/l.

PH regression coefficient is positive, meaning that when the pH value rises, the value of copper (Cu) will also increase. If the pH value decreases, the copper (Cu) value will decrease. If the pH value rises by 1, it will increase the Cu value by 0.001 mg/l and conversely a decrease in pH of 1 will decrease the value of Cu by 0.001 mg/l.

Alkalinity regression coefficient has a positive value, meaning that when the alkalinity value rises, the copper (Cu) value will also increase. If the value of alkalinity decreases, the value of copper (Cu) will decrease. If the alkalinity value rises by 1, it will increase the Cu value by 4.021 mg/l and conversely a decrease in alkalinity of 1 will reduce the Cu value by 4.021 mg/l.

The salinity regression coefficient is negative, meaning that when the salinity value increases, the copper (Cu) value will decrease, whereas when the salinity value drops, the value of copper (Cu) will increase. If the salinity value increases by 1 then it will reduce the copper (Cu) value by 0.001 mg/l and conversely a decrease in the salinity value of 1 will increase the value of Cu by 0.001 mg/l.

This is confirmed also by Balasubramanian [17], that dissolve Cd and Pb in the coastal water indicated that salinity played a major role in the depletion of the dissolved metals during estuarine mixing. As salinity increased, the concentrations of dissolved Pb and Cd decreased. The data revealed that large quantum of metals was removed from the water column and precipitated as a suspended matter which may contaminate the bottom sediments. The decrease in the concentration of heavy metals with salinity showed the contribution from freshwater sources was insignificant which indicated that point sources and physical mixing of anthropogenic inputs injected by industrial, harbour activity, sewage etc. regulated the metal concentrations along these waters.

NH_4 regression coefficient is negative, meaning that when the value of NH_4 increases, the value of copper (Cu) will decrease, whereas when the value of NH_4 drops, the value of Cu will increase. If the value of NH_4 increases by 1 mg/l it will reduce the value of copper (Cu) by 0.011 mg/l and conversely the decrease in the value of NH_4 by 1 mg/l will increase the value of Cu by 0.011 mg/l.

NO_3 regression coefficient is negative, meaning that when the NO_3 value increases, the Cu value will decrease, whereas when the NO_3 value drops, the Cu value will increase. If the NO_3 value increases by 1 mg/l it will reduce the value of Cu by 0.004 mg/l and conversely a decrease in NO_3 value of 1 mg/l will increase the value of Cu by 0.004 mg/l.

PO_4 regression coefficient is negative, meaning that when the PO_4 value rises, the value of Cu will decrease, whereas when the PO_4 value drops, the value of Cu will increase. If the PO_4 value increases by 1 mg/l it will reduce the value of Cu by 0.001 mg/l and conversely the decrease in the value of PO_4 by 1 mg/l will increase the value of Cu by 0.001 mg/l.

According to Balasubramanian [17], Metals such as Zn, Mn, Cu, Cd, Hg, Pb, silt, clay, organic carbon (OC), pH and salinity with a strong factor loading (> 0.700) found to be a significant parameters contributing to the water quality of these coastal waters. High and positive scores of dissolved metals and sediment characteristic on variable 1 or 2 indicated high anthropogenic inputs from catchments. The presence of multiple variables present in the same factor suggested a close association among them and identical source.

The probability value of F count (Sig.) in the table above, the value is 0.270 greater than the significance level of 0.05 so it can be concluded that alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, salinity have no effect on lead (Pb) in coastal of Banyuwangi Regency.

The probability value of F count (Sig.) in the table above is 0.221 greater than the significance level of 0.05 so it can be concluded that alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, and salinity have no effect on mercury value (Hg) .

The concentration of mercury (Hg) at each sampling location when the research was carried out was the same i.e. <0.0005 mg/l. This value based on the Decree of the State Minister of Environment Number 51 of 2004 concerning Sea Water Quality Standards is classified as very low and does not interfere with aquatic biota, including fish; which has been determined the threshold value is 0.001 mg/l. Komarawidjaja [19], explained that the value of the measurement results is still far below the quality standards that apply to any designation so that coastal waters are safe to be used as ponds, ports or marine tourism.

The probability value of counted F (Sig.) in the table above is 0.00 less than the significance level of 0.05, so that it can be concluded that the multiple linear regression model that is estimated is feasible to use to explain the effect of tin (Sn) on Alkalinity, NH_4, PO_4 , DO, pH, NO_3, Water Temperature, and salinity.

From Table 8, the value of R-Square which is 0.700, it shows that the proportion of the influence of the variable tin (Sn) on the variables Alkalinity, NH_4, PO_4, DO, pH, NO_3, Water Temperature, and salinity by 70%. That is, the value of Sn has a proportional effect on Alkalinity, NH_4, PO_4, DO, pH, NO_3, Water Temperature, and salinity by 70% while the remaining 30% (100% - 70%) is influenced by other variables that do not exist in a linear regression model.

Table 6. F-Test: Water quality for lead metal (Pb)

ANOVA [a]						
Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
1	Regression	0.0001	8	0.0001	1.322	.270[b]
	Residual	0.0001	31	0.0001		
	Total	0.0001	39			

a. Dependent Variable: Lead (Pb); b. Predictors: (Constant), Alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, salinity

Table 7. F-Test: Water quality against mercury (Hg)

ANOVA [a]						
Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
1	Regression	0.0001	8	0.0001	1.437	0.221[b]
	Residual	0.0001	31	0.0001		
	Total	0.0001	39			

a. Dependent Variable: Mercury (Hg); b. Predictors: (Constant), Alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, salinity

Table 8. F-Test: Heavy metal tin (Sn) towards water quality

ANOVA [a]						
Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
1	Regression	113.151	8	14.144	9.049	0.0001[b]
	Residual	48.452	31	1.563		
	Total	161.603	39			

a. Dependent Variable: Tin (Sn); b. Predictors: (Constant), Alkalinity, NH_4, PO_4, DO, pH, NO_3, water temperature, salinity

Table 9. R Square value: heavy metal of tin (Sn) against water quality

Model Summary [b]					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	0.837a	0.700	0.623	1.2501901	1.453

a. Predictors: (Constant), Alkalinity, NH_4, PO_4, DO, pH, NO_3, Water Temperature, Salinity; **b.** Dependent Variable: Tin (Sn)

Table 10. t Test: Heavy metal of tin (Sn) against water quality

Coefficients [a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity statistics**	
		B	**Std. Error**	**Beta**			**Tolerance**	**VIF**
1	(Constant)	7.143	7.425		0.962	0.343		
	DO	-1.147	0.454	-0.285	-2.527	0.017	0.762	1.312
	water temperature	0.264	0.264	0.141	0.998	0.326	0.485	2.060
	pH	0.527	0.388	0.160	1.356	0.185	0.692	1.445
	Salinity	-0.056	0.115	-0.074	-0.483	0.632	0.417	2.396
	NH_4	4.329	1.520	0.366	2.848	0.008	0.586	1.707
	NO_3	-1.352	0.773	-0.222	-1.748	0.090	0.597	1.674
	PO_4	0.904	0.322	0.292	2.806	0.009	0.895	1.118
	Alkalinity	-0.063	0.016	-0.499	-3.822	0.001	0.567	1.764

a. Dependent variable: tin (Sn); DO= dissolved oxygen; NH_4= ammonium; NO_3 = nitrate ; PO_4= phosphate; VIF: Variance Inflation F=actor

The probability value of counted t from the independent variable of water temperature is 0.326, pH is 0.185, salinity is 0.632, and NO3 is 0.09 (greater than Sig. 0.05) indicating that the independent variables of water temperature, pH, salinity and NO3 are not significant effect on the dependent variable tin (Sn). The probability value of t count variable dissolved oxygen (DO) is 0.017, NH_4 is 0.08, PO_4 is 0.009, and alkalinity is 0.01 ($p< 0.05$), indicating that the independent variable DO, NH_4, PO_4, and alkalinity have a significant effect on the dependent variable tin (Sn). Based on the above values, the interpretation of the models of alkalinity, NH_4, PO_4, DO, pH, NO_3, Water Temperature, and Salinity for tin heavy metal (Sn) are as follows:

Tin (Sn) = 7,143 – 1,147 DO + 0,264 Water Temperature + 0,527 pH – 0,56 Salinity + 4,329 NH_4– 1,352 NO_3 + 0,904 PO_4 – 0,063 alkalinity.

Water temperature regression coefficient is positive, meaning that when the water temperature rises, the value of tin (Sn) will also increase. If the value of the water temperature drops, the value of Sn will decrease. If the value of the water temperature rises by 1 °C, it will increase the value of tin (Sn) by 0.264 mg/l and conversely a decrease in water temperature of 1 °C will reduce the value of Sn by 0.264 mg/l. The pH regression coefficient is positive, meaning that when the pH value rises, the value of tin (Sn) will also increase. If the pH value drops, the value of tin (Sn) will decrease. If the pH value increases by 1, it will increase the value of Sn by 0.527 mg/l and conversely a decrease in pH of 1 will decrease the value of Sn by 0.527 mg/l.

NH_4 regression coefficient is positive, meaning that when the value of NH_4 rises, the value of tin (Sn) will also increase. If the value of NH_4 drops, the value of tin (Sn) will decrease. If the value of NH_4 rises by 1 mg/l, it will increase the value of Sn by 4.329 mg/l and conversely the decrease in NH_4 by 1 mg/l will reduce the value of tin (Sn) by 4.329 mg/l.

PO_4 regression coefficients are positive, meaning that when the PO_4 value rises, the value of tin (Sn) will also increase. If the PO_4 value drops, the value of Sn will decrease. If the value of PO_4 rises by 1 mg/l, it will increase the value of Sn by 0.904 mg/l and conversely a decrease in PO_4 of 1 mg/l will decrease the value of Sn by 0.904 mg/l. The regression coefficient of dissolved oxygen (DO) is negative, meaning that when the dissolved oxygen value rises, the value of Sn will decrease, whereas when the DO value drops, the value of Sn will increase. If the value of DO increases by 1 mg/l it will reduce the value of Sn by 1.147 mg/l and conversely a decrease in DO of 1 mg/l will increase the tin value by 1,147 mg/l. The salinity regression coefficient is negative, meaning that when the salinity value rises, the value of tin (Sn) will decrease, whereas when the salinity value drops, the value of tin (Sn) will increase. If the salinity value increases by 1 ppt it will reduce the value of Sn by 0.056 mg/l and conversely a decrease in the salinity value of 1 ppt will increase the value of Sn by 0.056 mg/l. NO_3 regression coefficient is negative, meaning that when the NO_3 value rises, the value of Sn will decrease, whereas when the NO_3 value drops, the value of Sn will increase. If the NO_3 value increases by 1 mg/l it will reduce the value of Sn by 1.352 mg/l and conversely a decrease in NO_3 value of 1 mg/l will increase the value of Sn by 1.352 mg/l.

The regression coefficient of alkalinity is negative, meaning that when the alkalinity value rises, the value of Sn will decrease, whereas when the value of alkalinity decreases, the value of Sn will increase. If the alkalinity value increases by 1 mg/l it will reduce the value of Sn by 0.063 mg/l and vice versa the decrease in the value of alkalinity by 1 mg/l will increase the value of Sn by 0.063 mg/l. The high pH and low dissolved oxygen content in this sampling site can contribute towards this situation. Hot Spring waters of Lake Bogoria (BG1), Lake Elementaita (EL1) contained lower concentrations of heavy metals. High pH and temperature and very low oxygen can encourage solubilization processes and subsequent precipitation [18].

CONCLUSION

The concentrations of Cu, Hg, Pb and Sn obtained in the coastal waters of Banyuwangi Regency were Cu 0.0104 mg/l, Hg 0 mg/l, Pb 0.0173 mg/l and Sn 1.3436 mg/l. If referring to the Keputusan Menteri Lingkungan Hidup (Decree of the Minister of Environment) No. 51 of 2004 concerning Sea Water Quality Standards, Mercury (Hg) 0.001 mg/l, Copper (Cu) and Lead (Pb) 0.008 mg/l, and Tin (Sn) 2 mg/l, then the value of heavy metals Hg and Sn is still below the threshold while Cu and Pb are above the threshold. Whereas based on the results of regression analysis, of the four types of heavy metals Copper (Cu), Lead (Pb), Mercury (Hg) and Lead (Pb) on the coast of Banyuwangi Regency, indicating water quality that there is no effect on Lead specific gravity metals (Pb) and Mercury (Hg); whereas two other types of heavy metals Cu and Sn had influence.

Based on the results of the study, Banyuwangi district government needs to take serious actions in controlling heavy metal pollution through the implementation of law No. 23 of 1997 concerning to environmental management, and the application of environmental quality standards more strictly.

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Authors' contributions
All authors contributed equally to this work.

Competing interests
The authors declare that they have no competing interests.

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