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LAMPIRAN 1. ALUR PENELITIAN

Penelitian ini dilakukan selama tiga tahun yang dibagi dalam tiga tahapan penelitian, diantaranya:

PENELITIAN PROGRAM PENDIDIKAN MAGISTER MENUJU DOKTOR UNTUK SARJANA UNGGUL (PMDSU)

TAHAP 1

SAMPEL YANG DIUJI:
- Tanah
- Air sumur

TAHAP 2

SAMPEL YANG DIUJI:
- Air sungai
- Sedimen sungai
- Anadara granosa
- Chanos chanos
- Air sumur

PENGAMBILAN DATA MANUSIA

TAHAP 3

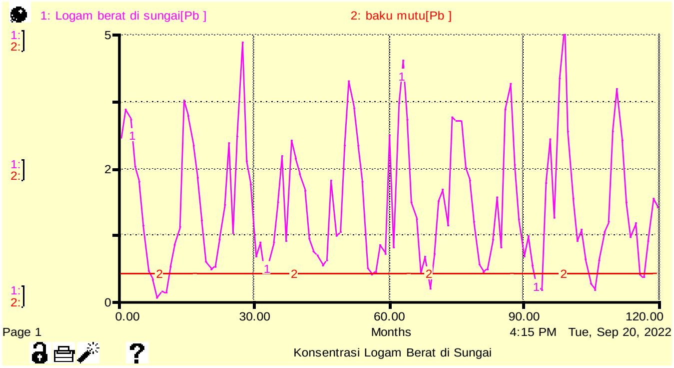
PEMBUATAN MODEL SISTEM DINAMIS.

Penelitian tahap 1 dilakukan penelitian kawasan terrestrial yaitu dengan menganalisis logam berat utama seperti Hg, Pb, Cr, Cd, Ni pada sampel tanah dan air sumur di sekitar wilayah DAS Pangkajene. Diketahui bahwa hanya Pb dan Cr yang terdeteksi di air sumur maka hanya Pb dan Cr yang masuk dalam pemodelan sistem dinamis sebagai logam berat utama yang akan memengaruhi perairan Pangkajene karena terdeteksi dalam fase larutan (air).

Penelitian tahap 2 dilakukan penelitian dengan menganalisis Pb dan Cr pada sampel air sungai, sedimen sungai, anadara granosa, chanos-chanos, dan air sumur di wilayah pesisir. Pengambilan sampel dilakukan sebanyak 8 kali mulai November 2020 – Juni 2021. Selain itu dilakukan pengambilan sampel manusia dengan cara wawancara untuk mengetahui pola pajanan dari ikan bandeng, kerang, dan air sumur. Wawancara hanya dilakukan satu kali (*cross-sectional)* pada 287 orang .

Penelitian tahap 3 dilakukan pembuatan model sistem dinamis dengan mengikutsertakan data yang telah dianalisis sebelumnya. Pembuatan model sistem dinamis dilakukan pada tahun terakhir penelitian akhir 2021 – 2022.

LAMPIRAN 2. DATA HASIL MODEL SISTEM DINAMIS



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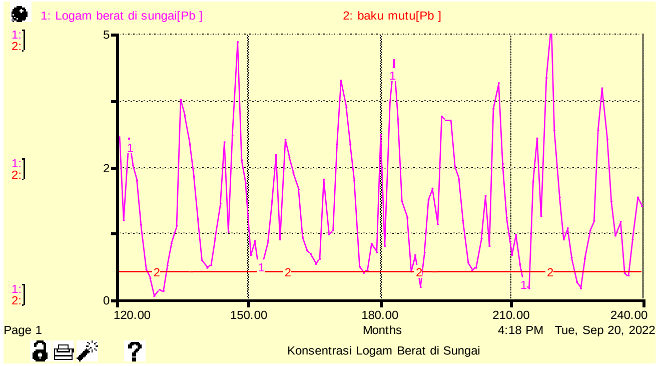
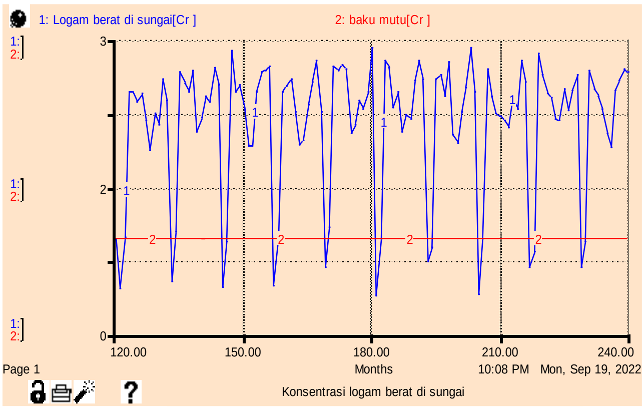
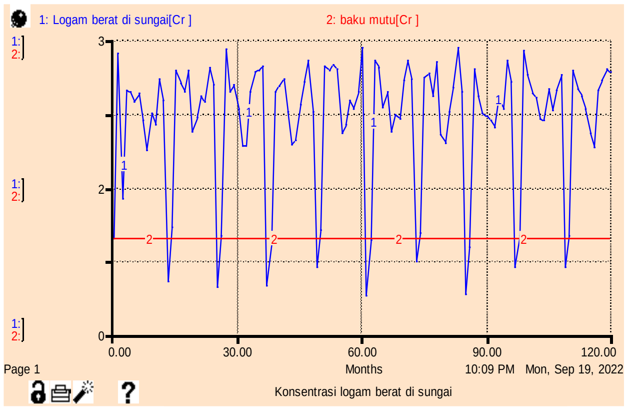


(b)

Gambar S1. Pola temporal konsentrasi Pb di sungai

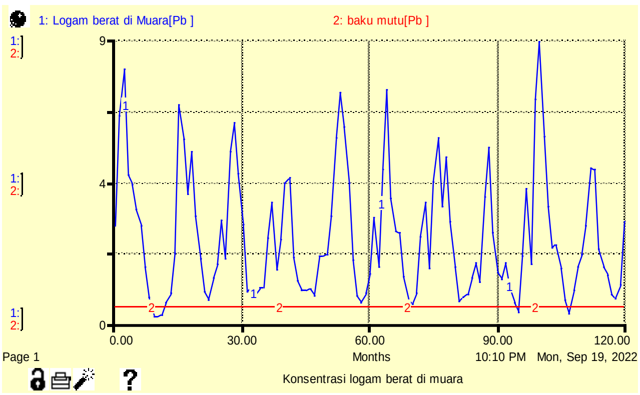


(a)

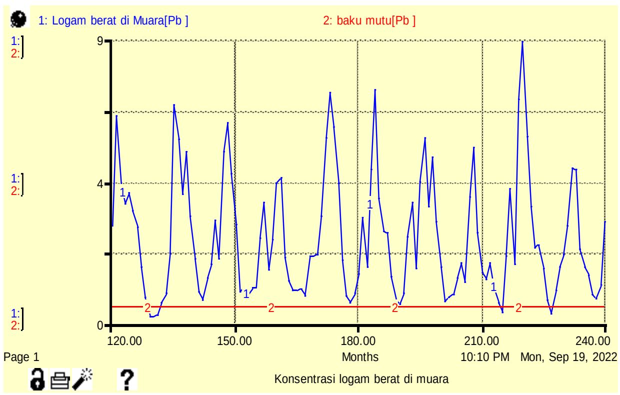


(b)

Gambar S2. Pola temporal konsentrasi Cr di sungai

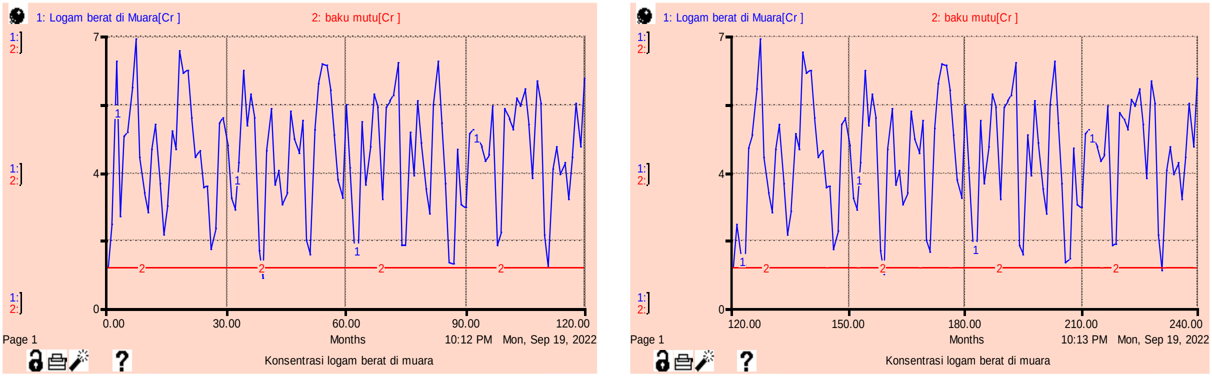


(a)



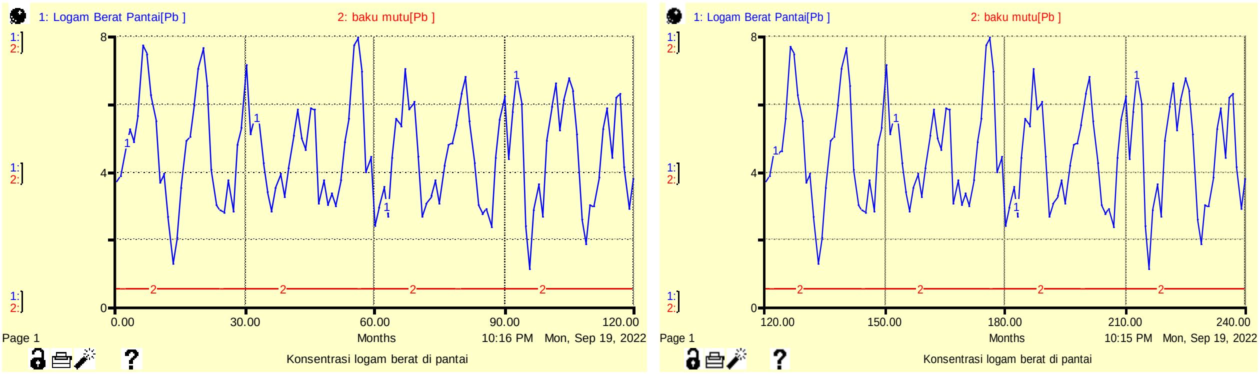
(b)

Gambar S3. Pola temporal konsentrasi Pb di muara



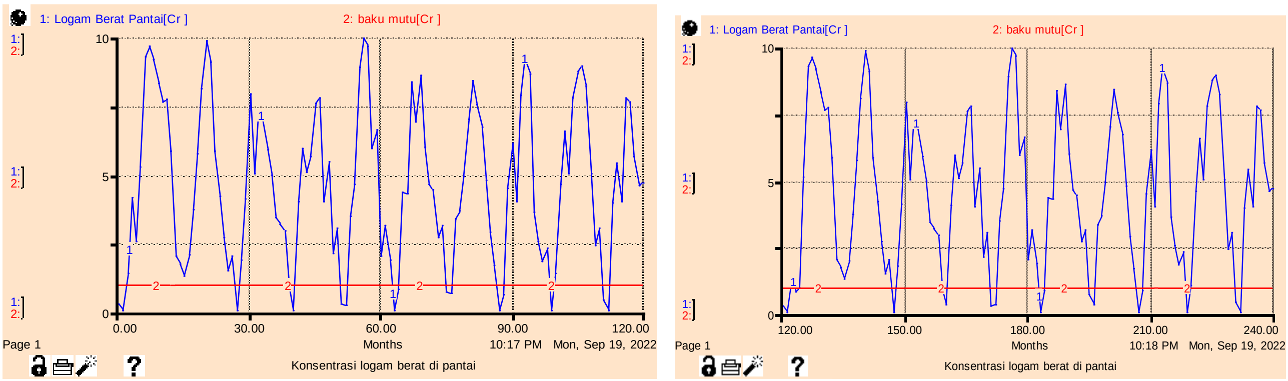
(a) (b)

Gambar S4. Pola temporal konsentrasi Cr di muara



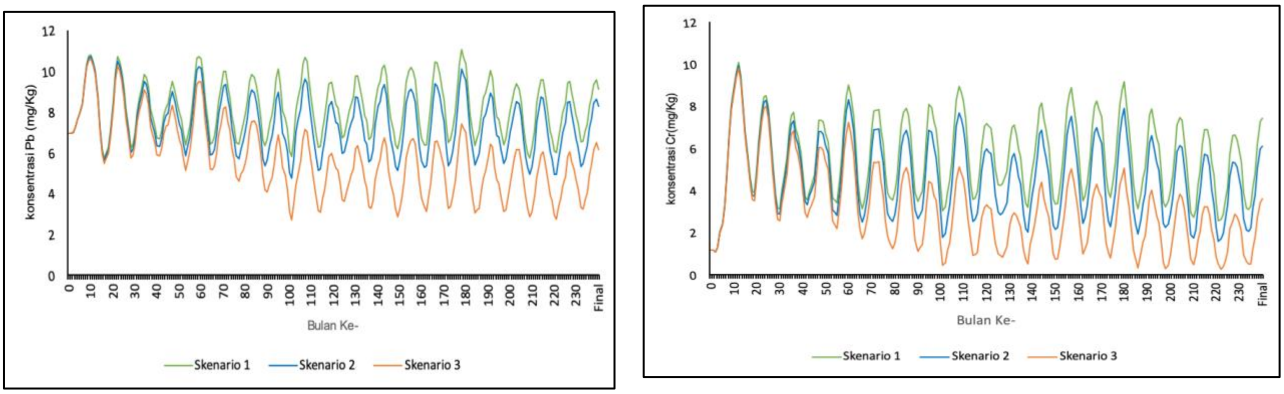
(a) (b)

Gambar S5. Pola temporal konsentrasi Pb di pantai



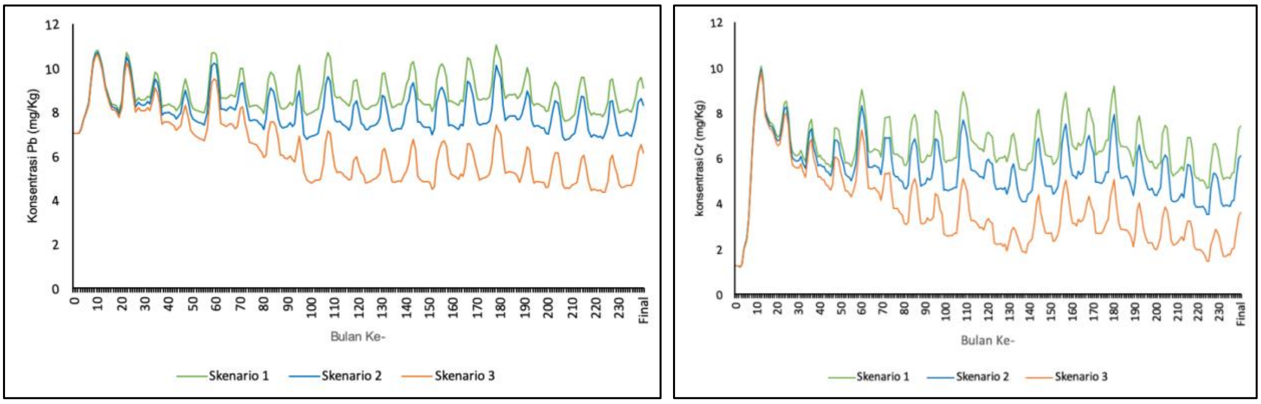
(a) (b)

Gambar S6. Pola temporal konsentrasi Cr di pantai



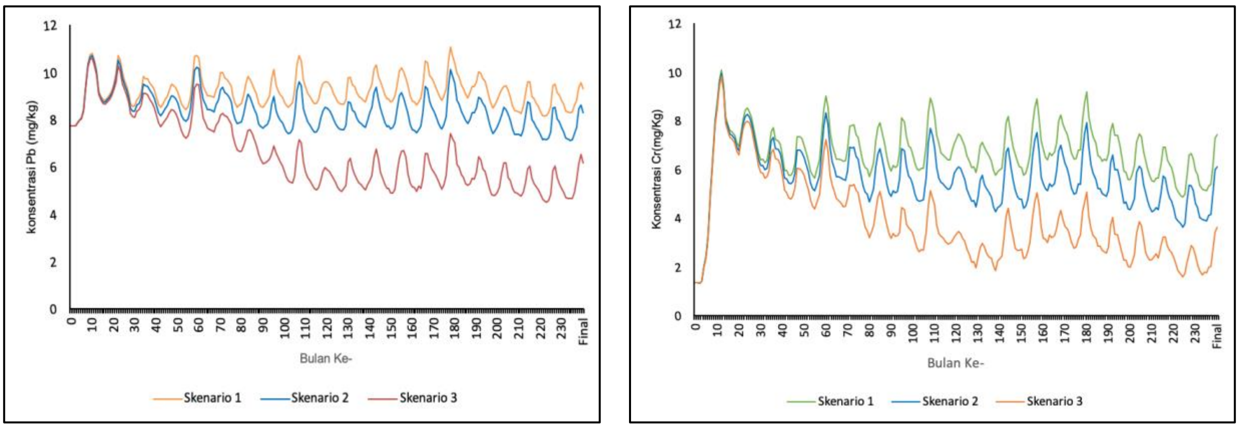
(a) (b)

Gambar S7. Penerapan skenario pengurangan penggunaan pupuk anorganik dan pestisida terhadap konsentrasi (a) Pb dan (b) Cr pada kerang *Anadara granosa* ukuran kecil di kawasan pesisir Pangkajene.



(a) (b)

Gambar S8. Penerapan skenario pengurangan penggunaan pupuk anorganik dan pestisida terhadap konsentrasi (a) Pb dan (b) Cr pada kerang *Anadara granosa* ukuran sedang di kawasan pesisir Pangkajene.

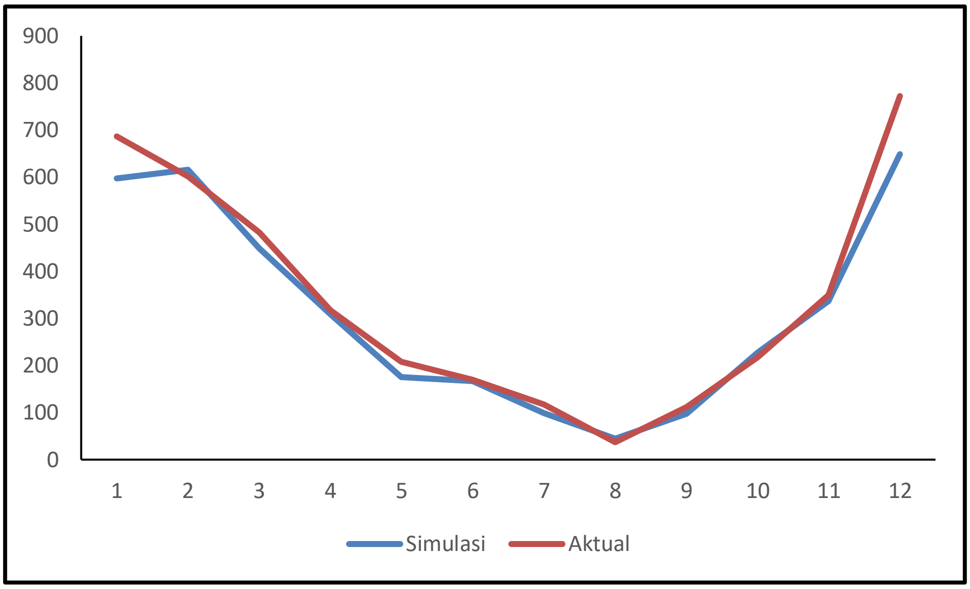


(a) (b)

Gambar S9. Penerapan skenario pengurangan penggunaan pupuk anorganik dan pestisida terhadap konsentrasi (a) Pb dan (b) Cr pada kerang *Anadara granosa* ukuran besar di kawasan pesisir Pangkajene

Tabel 1. Hasil simulasi dan kondisi aktual dari curah hujan

Simulasi	Aktual
597	687
615	602
449	482
309	317
176	208
167	169
98	117
45	37
97	112
228	218
337	349
649	772



Gambar S10. Perbandingan antara hasil simulasi dan kondisi aktual curah hujan di wilayah studi

LAMPIRAN 3. SUMBER DATA DAN HASIL PENGUKURAN

Tabel S1. Sumber data perancangan model pencemaran logam berat di Sungai Pangkajene

Parameter	Sumber data	Periode pengambilan data	Metode pengambilan data
		Data lingkungan	
Konsentrasi Pb dan Cr air sungai	Data primer	8 kali (November 2020 – Juni 2021)	Grab sampling
Konsentrasi Pb dan Cr sedimen muara sungai	Data primer	8 kali (November 2020 – Juni 2021)	Grab sampling
Konsentrasi Pb dan Cr air sumur	Data primer	8 kali (November 2020 – Juni 2021)	Grab sampling
Konsentrasi Pb dan Cr pada daging kerang *Anadara granosa*	Data primer	8 kali (November 2020 – Juni 2021)	Grab sampling
Debit sungai	Data primer	8 kali (November 2020 – Juni 2021)	Metode pelampung
Data curah hujan	Data sekunder	Curah hujan 5 tahun (2016 – 2021)	BMKG https://dataonline.bmkg.go.id/home
Data produksi semen PT tonasa	Data sekunder	Produksi tonasa tahun 2016	Ratnawati. 2017. Analisis Pengendalian Kualitas Produk pada PT. Semen Tonasa di Kabupaten Pangkep. Skripsi: Fakultas Ekonomi dan Bisnis Universitas Muhammadiyah Makassar.
Dosis penggunaan pupuk dan pestisida	Data primer	1 kali	Wawancara
Luas lahan pertanian	Data sekunder	1 kali	Badan Pusat Statistik Kabupaten Pangkep tahun 2021
Konsentrasi logam berat (Pb dan Cr) dalam pupuk	Data sekunder	1 kali	Studi literatur
		Data Manusia	
Berat badan responden	Data primer	1 kali	Penimbangan berat badan dengan timbangan digital
Frekuensi pajanan	Data primer	1 kali	Wawancara
Durasi pajanan	Data primer	1 kali	Wawancara
Laju konsumsi	Data primer	1 kali	Wawancara

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai	Unit	Sumber
		Sub-model logam berat di sungai		
Input dari hulu	Total konsentrasi logam berat (Pb dan Cr) di air yang berasal dari wilayah industri dan pertanian	-	mg/L	Perhitungan
Curah hujan	Jumlah curah hujan yang terkumpul per bulan	-	mm/bulan	Badan Meteorologi Klimatologi dan Geofisika (BMKG)
Konsentrasi dari hulu	Konsentrasi logam berat (Pb dan Cr) di air yang berasal dari wilayah sebelum wilayah industri (PT semen Tonasa) selama 8 bulan (November 2020 – Juni 2021)	-	mg/L	Observasi lapangan
Konsentrasi di limbah tonasa	Konsentrasi logam berat (Pb dan Cr) di air yang diambil dari wilayah industri (PT semen Tonasa) selama 8 bulan (November 2020 – Juni 2021)	-	mg/L	Observasi lapangan
Produksi semen	Jumlah semen yang dihasilkan oleh industri semen (PT semen Tonasa) per bulan	-	Ton/bulan	(Ratnawati, 2017)
Total limbah pertanian	Total logam berat (Pb dan Cr) per ha dengan referensi beban bulanan limbah pertanian	-	mg/ha/ tahun	Perhitungan
Luas ladang	Total luas ladang/kebun	0.5	ha	(BPS Kabupaten Pangkep, 2021)
Luas sawah	Total luas areal persawahan	253	ha	(BPS Kabupaten Pangkep, 2021)
Referensi beban bulanan limbah pertanian	Proporsi penggunaan pupuk kimia dan pestisida per bulan	-	No unit	Perhitungan
Total logam berat per ha	Total logam berat (Pb dan Cr) yang dihasilkan dari wilayah pertanian	-	mg/ha	Perhitungan

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai	Unit	Sumber
Konsentrasi logam berat pada pupuk urea	Konsentrasi logam berat pada pupuk urea	4 (Pb) 3 (Cr)	mg/Kg	(Rauf, Ikram and Akhter, 2002)
Konsentrasi logam berat pada pupuk Sp-36	Konsentrasi logam berat pada pupuk SP-36	3 (Pb) 90 (Cr)	mg/Kg	(Kratz, Schick and Schnug, 2016)
Konsentrasi logam berat di pestisida	Konsentrasi logam berat pada insektisida	27.08 (Pb) 8.68 (Cr)	mg/L	(Campos, 2003)
	Konsentrasi logam berat pada herbisida	33.33 (Pb) 2.56 (Cr	mg/L	
Pupuk anorganik per ha sawah	Hasil perkalian antara luas sawah dengan dosis penggunaan pupuk anorganik per ha	-	kg/ha	Perhitungan
Pupuk anorganik per ha ladang	Hasil perkalian antara luas ladang dengan dosis penggunaan pupuk anorganik per ha	-	kg/ha	Perhitungan
Pestisida per ha sawah	Hasil perkalian antara luas sawah dengan dosis penggunaan pestisida per ha	-	L/ha	Perhitungan
Pestisida per ha ladang	Hasil perkalian antara luas ladang dengan dosis penggunaan pestisida per ha	-	L/ha	Perhitungan
Sink ke sedimen dan konsumsi biota	Logam berat yang terendap ke dalam sedimen dan teradsorbsi oleh biota	-	mg/L	Perhitungan
Koefisien konsumsi biota	Koefisien adsorbsi logam berat pada biota perairan	0.3	No unit	(Souisa *et al.*, 2015)
Koefisien sink ke sedimen	Koefisien endapan logam berat dalam sedimen	0.4	No unit	(Souisa *et al.*, 2015)
Transportasi logam berat ke muara	Total logam berat yang ditransportasikan dari sungai menuju muara sungai	-	mg/L	Perhitungan

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai	Unit	Sumber
Proporsi konsentrasi transportasi ke muara	Proporsi logam berat yang ditransportasikan dari sungai ke muara	0.9	No unit	(Souisa *et al.*, 2015)
Logam berat di sungai	Total logam berat (Pb dan Cr) di air sungai	-	mg/L	Observasi
Sub-model logam berat di muara				
Loading dari sungai	Total logam berat yang ditransportasikan dari sungai ke muara	-	mg/L	Perhitungan
Koefisien pertambahan sungai ke muara	Koefisien pertambahan logam berat dari sungai ke muara	1.176	mg/L	Perhitungan
Logam berat di muara	Total logam berat (Pb dan Cr) di air muara	-	mg/L	Observasi
Konsentrasi di air tambak	Konsentrasi logam berat (Pb dan Cr) di air tambak	-	mg/L	Observasi
Konsentrasi di sedimen tambak	Konsentrasi logam berat (Pb dan Cr)	-	mg/Kg	Observasi
Konsentrasi logam di bandeng	Konsentrasi logam berat (Pb dan Cr) di daging ikan Bandeng	-	mg/Kg	Observasi
Konsentrasi logam berat air sumur	Konsentrasi logam berat (Pb dan Cr) pada air sumur selama 8 bulan (November 2020 – Juni 2021)	-	mg/L	Observasi
Proporsi transport ke pantai	Proporsi logam berat yang ditransportasikan ke pantai luar	0.5	No unit	(Souisa *et al.*, 2015)
Transportasi logam ke pantai	Total logam berat yang ditransmisikan ke pantai	-	mg/L	Perhitungan
Sub-model logam berat di pantai				
Transport dari muara	Total logam berat (Pb dan Cr) yang ditransportasikan dari muara	-	mg/L	Perhitungan

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai	Unit	Sumber
Debit aliran muara ke pantai	Debit aliran di muara	-	m^3/detik	Observasi
Logam berat di pantai	Total logam berat (Pb dan Cr) di air pantai	-	mg/L	Observasi
Transportasi ke perairan luar	Total logam berat (Pb dan Cr) yang ditransportasikan ke laut/perairan luar pantai	-	mg/L	Perhitungan
Konsentrasi logam berat sedimen pantai	Konsentrasi logam berat (Pb dan Cr) pada sedimen pantai	-	mg/Kg	Observasi
Rataan air pantai per periode	Rata-rata konsentrasi logam berat (Pb dan Cr) pada air pantai mengikuti periode umur kerang: 6 bulan (kerang kecil), 12 bulan (kerang sedang), 20 bulan (kerang besar)	-	mg/L	Perhitungan
Rataan sedimen pantai per periode	Rata-rata konsentrasi logam berat (Pb dan Cr) pada sedimen pantai mengikuti periode umur kerang: 6 bulan (kerang kecil), 12 bulan (kerang sedang), 20 bulan (kerang besar)	-	mg/L	Perhitungan
Konsentrasi logam berat di kerang	Total konsentrasi logam berat (Pb dan Cr) pada daging kerang *Anadara granosa*	-	mg/Kg	Perhitungan
Nilai referensi logam berat air pantai	Nilai rata-rata logam berat (Pb dan Cr) pada air pantai selama 8 bulan (November 2020 – Juni 2021)	-	mg/L	Observasi
Nilai referensi logam berat sedimen	Nilai rata-rata logam berat (Pb dan Cr) pada sedimen pantai selama 8 bulan (November 2020 – Juni 2021)	-	mg/Kg	Observasi
Nilai referensi logam berat di kerang	Nilai rata-rata logam berat (Pb dan Cr) pada daging kerang *Anadara granosa* selama 8 bulan (November 2020 – Juni 2021)	-	mg/Kg	Observasi

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai		Unit	Sumber
Sub-model risiko ekologi dan kesehatan manusia					
PNEC	*Predicted no-effect concentration* untuk logam berat	Pb 0.02 (air tawar) 0.033 (air asin)	Cr 0.1058 (air asin) 0.019 (air tawar)	mg/L	Perhitungan dengan metode SSD model
eHQ sungai	Ecological Hazard Quotient atau risiko ekologis dari pencemaran logam berat (Pb dan Cr) di air sungai	-		No unit	Perhitungan
eHQ muara	Ecological Hazard Quotient atau risiko ekologis dari pencemaran logam berat (Pb dan Cr) di air muara	-		No unit	Perhitungan
eHQ pantai	Ecological Hazard Quotient atau risiko ekologis dari pencemaran logam berat (Pb dan Cr) di air pantai	-		No unit	Perhitungan
CR pantai	Cancer risk atau risiko karsinogenik yang didapatkan dari pajanan logam berat melalui ingesti air pantai ketika kegiatan rekreasi	-		No unit	Perhitungan
CR sumur	Risiko karsinogenik yang didapatkan dari pajanan logam berat melalui ingesti air sumur	-		No unit	Perhitungan
CR kerang	Risiko karsinogenik yang didapatkan dari pajanan logam berat melalui ingesti daging kerang *Anadara granosa*	-		No unit	Perhitungan
CR bandeng	Risiko karsinogenik yang didapatkan dari pajanan logam berat melalui ingesti ikan bandeng	-		No unit	Perhitungan
THQ air pantai	Target Hazard Quotient atau risiko non-karsinogenik yang didapatkan dari	-		No unit	Perhitungan

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai	Unit	Sumber
	pajanan logam berat melalui ingesti air pantai ketika kegiatan rekreasi			
THQ sumur	Target Hazard Quotient atau risiko non-karsinogenik yang didapatkan dari pajanan logam berat melalui ingesti air sumur	-	No unit	Perhitungan
THQ bandeng	Target Hazard Quotient atau risiko non-karsinogenik yang didapatkan dari pajanan logam berat melalui ingesti daging ikan bandeng	-	No unit	Perhitungan
THQ kerang	Target Hazard Quotient atau risiko non-karsinogenik yang didapatkan dari pajanan logam berat melalui ingesti daging kerang	-	No unit	Perhitungan
ADD kerang non karsi per periode	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari daging kerang per periode umur kerang 6 bulan (kerang kecil), 12 bulan (kerang sedang), 20 bulan (kerang besar) untuk risiko non-karsinogenik	-	mg/kg/hari	Perhitungan
ADD kerang non karsi	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari daging kerang untuk risiko non karsinogenik	-	mg/kg/hari	Perhitungan
ADD kerang karsi	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari daging kerang untuk risiko karsinogenik	-	mg/kg/hari	Perhitungan
ADD kerang karsi per periode	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari daging kerang per	-	mg/kg/hari	Perhitungan

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai	Unit	Sumber
	periode umur kerang 6 bulan (kerang kecil), 12 bulan (kerang sedang), 20 bulan (kerang besar) untuk risiko karsinogenik			
ADD sumur non-karsi ing	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari air sumur untuk risiko non-karsinogenik	-	mg/kg/hari	Perhitungan
ADD sumur karsi ing	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari air sumur untuk risiko karsinogenik	-	mg/kg/hari	Perhitungan
ADD bandeng karsi	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari daging ikan bandeng untuk risiko karsinogenik	-	mg/kg/hari	Perhitungan
ADD bandeng non-karsi	*Average daily dose* atau rata-rata dosis masing-masing logam berat (Pb/Cr) harian yang dikonsumsi dari daging ikan bandeng untuk risiko non-karsinogenik	-	mg/kg/hari	Perhitungan
CSF	*Cancer slope factor*	0.0085 (Pb) 0.42 (Cr)	mg/kg/hari	(Zakir *et al.*, 2020; USEPA, 2021a)
RfD	*Reference dose*	0.004 (Pb) 0.003 (Cr)	mg/kg/hari	(Barone *et al.*, 2018; Zakir *et al.*, 2020; USEPA, 2021a)
BW	*Body weight* atau berat badan	56 (dewasa) 31 (anak-anak)	Kg	Observasi
CF	*Conversion factor*	0.000001	Kg/mg	(USEPA, 1991, 2004)
ED	*Exposure duration* atau durasi pajanan	35 (Dewasa) 12 (anak-anak)	Tahun	Observasi
EF	*Exposure frequency* atau frekuensi pajanan	135 (kerang) 143 (143)	Hari/tahun	Observasi
AT	*Averaging time* untuk pajanan manusia	ED x 365 (non karsinogenik) 72 x 365 (karsinogenik)	hari	Observasi (World Bank, 2019)

Tabel S2. Ringkasan variabel yang digunakan dalam pembuatan model sistem dinamis

Variabel	Deskripsi	Nilai	Unit	Sumber
EV	*Event exposure*	1	Event/hari	(USEPA, 2021b)
IR	*Ingestion rate*	0.11 (air pantai rekreasi – dewasa) 0.12 (air pantai rekreasi – anak) 231875 (kerang, dewasa) 207000 (ikan bandeng, dewasa) 1.8 (air sumur, anak-anak) 2.6 (air sumur, dewasa) 179816 (kerang, anak-anak) 141436 (ikan bandeng, anak-anak)	L/hari Mg/hari	(USEPA, 2015, 2021b) Observasi
ET	*Exposure time rekreasi*	0.71 (dewasa) 0.54 (anak-anak)	Jam/hari	(USEPA, 2021b)

Debit sungai Pangkajene

Tabel S3. Debit sungai Pangkajene

Waktu pengambilan data	Debit sungai (m^3/detik)
November 2020	10.85
Desember 2020	42.65
Januari 2021	28.57
Februari 2021	24.81
Maret 2021	15.56
April 2021	16.66
Mei 2021	10.98
Juni 2021	18.97

Sumber data: data primer

Data terkait penggunaan pupuk dan pestisida di pertanian

Tabel S4. Dosis pupuk dan pestisida pada pertanian

Jenis	Dosis
Pupuk urea (kg/ha/tahun)	200
Pupuk Sp-36 (kg/ha/tahun)	100
Insektisida (L/ha/tahun)	4
Herbisida (L/ha/tahun)	1

Sumber data: data primer

Tabel S5. Luas lahan pertanian dan ladang

Luas lahan pertanian (ha)	253
Luas lading (ha)	0.5

Sumber: (BPS Kabupaten Pangkep, 2021)

Tabel S6. Konsentrasi logam berat pada pupuk dan pestisida

Jenis	Konsentrasi		Referensi
	Pb	Cr	
Pupuk Urea (mg/kg)	4	3	(Rauf, Ikram and Akhter, 2002)
Pupuk SP-36 (mg/kg)	3	90	(Kratz, Schick and Schnug, 2016)
Insektisida (mg/L)	27.08	8.68	(Campos, 2003)
Herbisida (mg/L)	33.33	2.56	

Data terkait penggunaan pupuk di tambak

Tabel S7. Dosis pupuk dan pestisida pada pertanian

Jenis	Dosis
Pupuk Sp-36 (kg/ha) – 1 kali pembenihan	75

Sumber data: data primer

DATA PRODUKSI SEMEN TONASA

Tabel S8. Data Produksi Semen Tonasa per Bulan

Bulan	Jumlah produksi semen tonasa (ton)
Januari	208187
Februari	212765
Maret	210178
April	211312
Mei	212465
Juni	205672
Juli	207123
Agustus	213875
September	212765
Oktober	216712
November	211654
Desember	215678
Total 1 tahun	2538377
Rata-rata per bulan	211531

Sumber data: (Ratnawati, 2017)

DATA CURAH HUJAN

Tabel S9. Curah Hujan di Kabupaten Pangkep tahun 2016 – 2021

Tahun	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt	Nov	Dec
2016	407	738	555	335	490	205	326	22	230	442	335	517
2017	716	665	463	517	153	340	97	75	313	224	558	1059
2018	613	884	617	278	208	205	140	4	12	236	277	911
2019	916	344	293	311	47	103	5	0	0	0	39	352
2020	633	567	338	147	261	71	34	8	33	141	347	933
2021	839	412	626	315	89	90	100	115	85	262	541	860
mean	687	602	482	317	208	169	117	37	112	218	349	772

Sumber data: BMKG (http://dataonline.bmkg.go.id/home)

KARAKTERISTIK FISIKOKIMIA SAMPEL LINGKUNGAN

1. Lingkungan sungai

Tabel S10. Nilai suhu air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel (^{o}C)

Bulan	Titik sampling				
	S1	S2	S3	S4	S5
November	29.0	29.0	29.9	31.0	31.0
Desember	27.0	27.0	27.1	27.7	27.7
Januari	28.0	28.0	28.7	30.0	30.0

Tabel S10. Nilai suhu air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel (ºC)

Bulan	**Titik sampling**				
	S1	**S2**	**S3**	**S4**	**S5**
Februari	28.3	28.5	29.2	30.2	30.2
Maret	28.4	28.4	28.8	29.0	29.0
April	29.2	30.0	30.0	30.2	30.2
Mei	29.8	29.8	30.0	30.2	30.2
Juni	28.2	28.2	29.7	31.0	31.0

Tabel S11. Nilai salinitas air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel (**‰)**

Bulan	**Titik sampling**				
	S1	S2	S3	S4	S5
November	0	0	3	30	30
Desember	0	0	0	0	10
Januari	0	0	0	0	18
Februari	0	0	0	0	20
Maret	0	0	0	0	25
April	0	0	0	0	20
Mei	0	0	5	30	30
Juni	0	0	5	30	30

Tabel S12. pH air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel

Bulan	**Titik sampling**				
	S1	S2	S3	S4	S5
November	7.85	7.91	7.67	8.18	8.18
Desember	7.95	7.84	7.66	7.93	8.08

Tabel S12. pH air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel

Bulan	Titik sampling				
	S1	S2	S3	S4	S5
Januari	8.15	8.02	7.79	7.77	8.36
Februari	8.26	7.94	8.08	8.15	8.35
Maret	8.44	8.23	8.33	8.20	8.30
April	8.36	8.11	8.10	8.10	8.21
Mei	7.75	7.63	7.83	7.71	8.19
Juni	8.17	7.90	7.64	7.69	8.18

Tabel S13. Nilai total dissolved solid (TDS) air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel (mg/L)

Bulan	Titik sampling				
	S1	S2	S3	S4	S5
November	136	199	867	9020	9650
Desember	111	119	161	288	6511
Januari	111	98	116	122	6911
Februari	94	88	91	98	6565
Maret	90	136	201	156	7022
April	85	92	99	107	7440
Mei	165	125	260	7330	7745
Juni	159	315	3614	5602	7745

Tabel S14. Nilai konduktivitas elektrik atau *electrical conductivity (EC)* air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel (μS/cm)

Bulan	Titik sampling				
	S1	S2	S3	S4	S5
November	68	82	409	4908	5123
Desember	222	235	320	585	3010
Januari	223	201	233	244	13820
Februari	188	176	182	196	13130
Maret	180	273	203	312	14440
April	171	186	199	213	11500
Mei	329	1920	1255	14660	15490
Juni	247	319	631	10300	15490

Tabel S15. Nilai konsentrasi kromium (Cr) air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel (mg/L)

Bulan	**Titik sampling**				
	S1	**S2**	**S3**	S4	S5
November	ND	0.31	2.86	2.89	3.1
Desember	0.66	1.19	0.42	0.59	0.87
Januari	0.84	1.12	1.1	1.43	0.26
Februari	2.3	2.62	2.55	3.81	2.23
Maret	1.38	2.23	3.1	4.93	4.43
April	1.48	2.12	1.97	1.09	0.35
Mei	1.46	1.50	1.54	1.5	2.23
Juni	2.23	1.49	2.19	2.22	2.2

Tabel S16. Nilai konsentrasi timbal (Pb) air sungai Pangkajene selama masa pengambilan sampel per lokasi pengambilan sampel (mg/L)

Bulan	**Titik sampling**				
	S1	**S2**	**S3**	S4	S5
November	0.86	0.09	0.53	0.38	2.29
Desember	0.83	1.37	1.25	1.44	3.13
Januari	2.71	3.17	3.35	3.8	3.88
Februari	1.99	2.44	2.2	2.34	3.52
Maret	0.59	0.48	1.07	0.12	0.41
April	1.04	1.4	1.75	1.89	3.57
Mei	0.19	0.19	0.19	0.22	0.19
Juni	0.1	0.1	0.16	0.1	0.19

Tabel S17. Karakteristik fisikokimia sedimen muara sungai Pangkajene selama masa pengambilan sampel

Bulan	**pH**	**TOC**	**Pb**	**Cr**
November	7.77	1.28	8	41
Desember	7.59	0.53	13	30
Januari	7.40	1.41	8	50
Februari	7.25	2.65	16	54
Maret	6.84	1.41	12	58
April	6.53	2.04	12	62
Mei	6.56	0.48	8	68.33
Juni	6.77	3.14	16	77.12

2. Lingkungan tambak

Tabel S18. Konsentrasi logam berat (Pb dan Cr) di daging ikan bandeng

Lokasi sampel	Pb	Cr
Tekolabbua	0.17	1.73

Tabel S19. Konsentrasi logam berat (Pb dan Cr) pada air dan sedimen tambak di Tekolabbua

Waktu pengambilan	Air tambak		Sedimen tambak	
	Pb	Cr	Pb	Cr
November	2.02	3.48	52	62.86
Mei	0.19	1.57	21.74	29

3. Air sumur

Tabel S20. Konsentrasi logam berat (Pb dan Cr) air sumur di wilayah pesisir Pangkajene

Bulan	**Pb**	**Cr**
November	0.98	2.46

Tabel S20. Konsentrasi logam berat (Pb dan Cr) air sumur di wilayah pesisir Pangkajene

Bulan	Pb	Cr
Desember	1.63	1.3
Januari	2.89	1.73
Februari	1.72	2.93
Maret	0.45	5.22
April	1.2	1.68
Mei	0.1	1.39
Juni	0.22	2.14

DATA MANUSIA

Tabel S23. Distribusi responden berdasarkan umur, jenis kelamin, tingkat pendidikan, dan pekerjaan

Kelompok responden	Kategori	Lokasi penelitian			
		Kelurahan Mappasaile		Kelurahan Tekolabbua	
		N	%	N	%
Umur (tahun)					
Anak-anak	<8	9	17.6	7	19.4
	8 – 15	34	66.7	21	58.3
	>15	8	15.7	8	22.2
	Total	51	100.0	36	100.0
Dewasa	< 24	15	11.3	8	11.9
	24 – 47	101	75.9	49	73.1
	>47	17	12.8	10	14.9
	Total	133	100.0	67	100.0
Jenis kelamin					
Anak-anak	Laki-laki	22	43.1	15	41.7
	Perempuan	29	56.9	21	58.3
	Total	51	100	36	100.0
Dewasa	Laki-laki	51	38.3	24	35.8
	Perempuan	82	61.7	43	64.2
	Total	133	100	67	100.0
Tingkat pendidikan					
Anak-anak	Tidak sekolah	29	56.9	19	52.8
	SD	13	25.5	9	25.0
	SMP	7	13.7	6	16.7
	SMA	2	3.9	2	5.6
	Perguruan Tinggi	0	0	0	0.0
	Total	51	100	36	100.0
Dewasa	Tidak sekolah	8	6.0	8	11.9
	SD	32	24.1	15	22.4

Tabel S23. Distribusi responden berdasarkan umur, jenis kelamin, tingkat pendidikan, dan pekerjaan

Kelompok responden	Kategori	Lokasi penelitian: Kelurahan Mappasaile N	%	Kelurahan Tekolabbua N	%
	SMP	32	24.1	12	17.9
	SMA	58	43.6	30	44.8
	Perguruan Tinggi	3	2.3	2	3.0
	Total	133	100	67	100.0
	Pekerjaan				
Anak-anak	Pelajar/ mahasiswa	51	100.0	36	100.0
Dewasa	Pelajar/ mahasiswa	6	4.5	6	9.0
	PNS/ TNI/ Polri	5	3.8	2	3.0
	Swasta	8	3.8	4	6.0
	Petani	8	6.0	2	3.0
	Nelayan	17	12.8	7	10.4
	Pedagang	19	14.3	7	10.4
	Ibu rumah tangga	61	45.9	31	46.3
	Lainnya	17	12.8	8	11.9
	Total	133	100	67	100.0

Tabel S24. Distribusi responden berdasarkan riwayat penyakit dan gangguan kesehatan subjektif

Kelompok responden	Kategori	Kelurahan Mappasaile TM N	%	M N	%	Kelurahan Tekolabbua TM N	%	M N	%
	Riwayat penyakit terdiagnosis medis								
Anak-anak	Penyakit kardiovaskular	51	100	0	0	36	100	0	0
	Hipertensi	51	100	0	0	36	100	0	0
	Diabetes	51	100	0	0	36	100	0	0
	Anemia	51	100	0	0	36	100	0	0
	Kanker	51	100	0	0	36	100	0	0
	Osteoporosis	51	100	0	0	36	100	0	0
	Penyakit hati	51	100	0	0	36	100	0	0
	Penyakit ginjal	51	100	0	0	36	100	0	0
	Asma	51	100	0	0	35	97.2	1	2.8
Dewasa	Penyakit kardiovaskular	133	100	0	0	67	100	0	0
	Hipertensi	126	94.7	7	5.3	59	88.1	8	11.9
	Diabetes	131	98.5	2	1.5	67	100	0	0
	Anemia	133	100	0	0	67	100	0	0
	Kanker	133	100	0	0	67	100	0	0
	Osteoporosis	133	100	0	0	67	100	0	0
	Penyakit hati	133	100	0	0	67	100	0	0
	Penyakit ginjal	133	100	0	0	67	100	0	0
	Asma	133	100	0	0	65	97.0	2	3.0
	Gangguan kesehatan subjektif								
Anak-anak	Gatal-gatal	44	86.3	7	13.7	31	86.1	5	13.9
	Kemerahan kulit	44	86.3	7	13.7	31	86.1	5	13.9

Tabel S24. Distribusi responden berdasarkan riwayat penyakit dan gangguan kesehatan subjektif

Kelompok responden	Kategori	Kelurahan Mappasaile				Kelurahan Tekolabbua			
		TM		M		TM		M	
		N	%	N	%	N	%	N	%
	Luka pada kulit	49	96.1	2	3.9	34	94.4	2	5.6
	Luka pada rongga mulut	45	88.2	6	11.8	30	83.3	6	16.7
	Mual dan muntah	51	100	0	0	36	100	0	0
	Sakit perut	42	82.4	9	17.6	33	91.7	3	8.3
	Diare	42	82.4	9	17.6	33	91.7	3	8.3
	Nyeri tenggorokan	51	100	0	0	34	94.4	2	5.6
	Sakit kepala	46	90.2	5	9.8	35	97.2	1	2.8
	Konvulsi	51	100	0	0	36	100	0	0
	Somnolen	51	100	0	0	36	100	0	0
	Tremor	51	100	0	0	36	100	0	0
	Kebas	51	100	0	0	36	100	0	0
Dewasa	Gatal-gatal	116	87.2	17	12.8	51	76.1	16	23.9
	Kemerahan kulit	119	89.5	14	10.5	52	77.6	15	22.4
	Luka pada kulit	132	99.2	1	0.8	67	100	0	0
	Luka pada rongga mulut	125	94.0	8	6.0	55	82.1	12	17.9
	Mual dan muntah	131	98.5	2	1.5	62	92.5	5	7.5
	Sakit perut	109	82.0	24	18	39	58.2	28	41.8
	Diare	111	83.5	22	16.5	54	80.6	13	19.4
	Nyeri tenggorokan	131	98.5	2	1.5	61	91.0	6	9.0
	Sakit kepala	71	53.4	62	46.6	34	50.7	33	49.3
	Konvulsi	133	100	0	0	67	100	0	0
	Somnolen	132	99.2	1	0.8	66	98.5	1	1.5
	Tremor	133	100	0	0	67	100	0	0
	Kebas	130	97.7	3	2.3	67	100	0	0

Keterangan: TM: tidak mengalami; M: mengalami

Tabel S25. Jumlah kasus penyakit tidak menular di Kabupaten Pangkajene dan Kepulauan

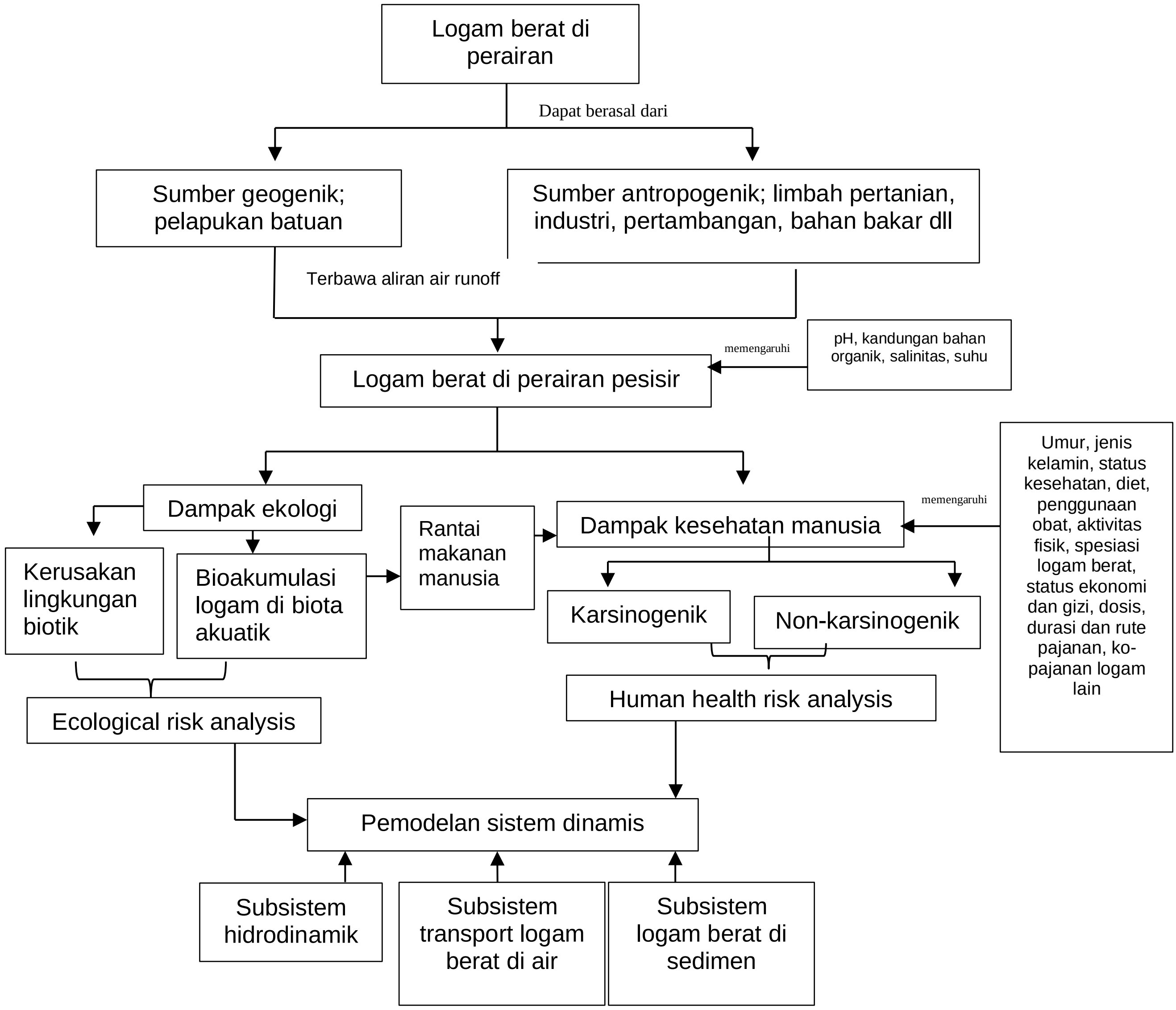
Penyakit tidak menular	Tahun				
	2017	2018	2019	2020	2021
Hipertensi	26213	19976	20402	22330	25045
Diabetes melitus	10295	6738	6340	7365	9952
Obesitas	1729	2978	2464	2195	1482
Struma	63	28	24	541	63
Thyrotoksikosis	13	4	14	8	13
Stroke	213	58	104	135	210
Asma	3579	1710	1384	1109	3407

Tabel S25. Jumlah kasus penyakit tidak menular di Kabupaten Pangkajene dan Kepulauan

Penyakit tidak menular	Tahun				
	2017	**2018**	**2019**	**2020**	**2021**
PPOK	691	611	484	559	691
Osteoporosis	241	112	66	60	241
Penyakit ginjal kronik	132	83	50	13	132
Kecelakaan lalu lintas	2893	2629	2170	959	2697
Tumor payudara	60	55	35	177	58
Tumor kulit	0	1	11	40	0
Tumor retina mata	1	1	0	0	1
Tumor pada bibir, rongga mulut	0	0	0	0	0
Tumor genitalia externa perempuan	2	1	3	2	2
Tumor serviks	2	1	0	2	2
Tumor genitalia interna perempuan (kecuali serviks)	15	2	0	3	15

Sumber data: Dinas Kesehatan Kab Pangkep Tahun 2022

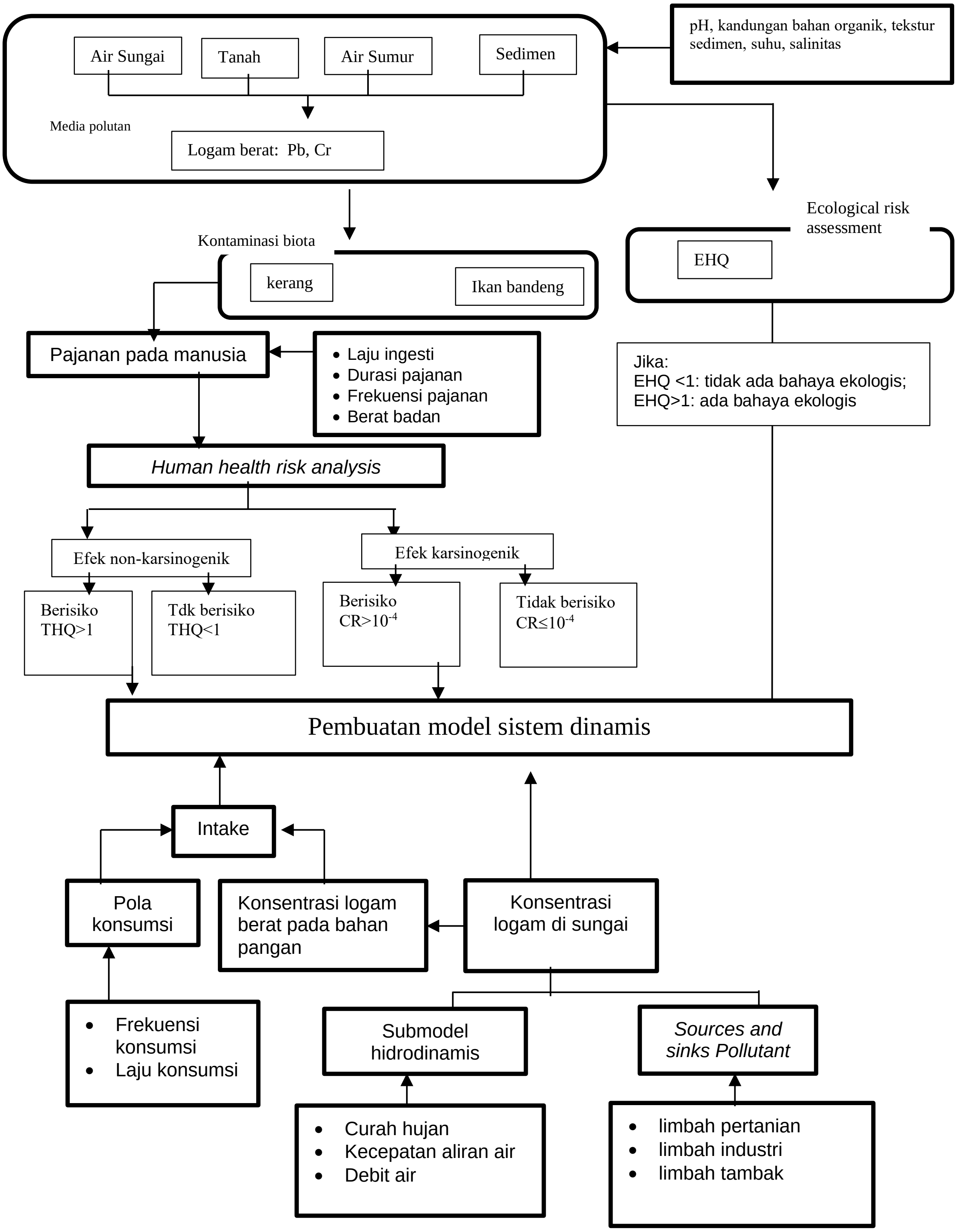
Lampiran 4. Kerangka teori penelitian



Gambar S11. Kerangka Teori Penelitian

Rujukan: (ATSDR, 2018; Christensen, 1995; European Commission, 2003; Gochfeld, 1997; Huisingh and Huisingh, 1974; Ji, 2008; Kakkar and Jaffery, 2005; Kristiansen et al., 1997; National Research Council (NRC), 2006, 1983; Scialabba, 1998; Siegel, 2002; Suter et al., 2005; U.S. Environmental Protection Agency (EPA), 2003; Vallero, 2014; Zukowska and Biziuk, 2008).

Lampiran 5. Kerangka Konsep Penelitian



Gambar S12. Kerangka konsep penelitian

Lampiran 6. Dokumentasi Kegiatan Selama Penelitian

Pra-penelitian

Gambar S13. Pengambilan sampel tanah

Gambar S14. Pengambilan sampel dan pemeriksaan parameter in-situ air sumur

Pengambilan sampel rutin

Gambar S15. Peralatan sampling dan sampel penelitian

Gambar S16. Pengambilan air sumur, air sungai, sedimen dan kerang

Gambar S17. Pengukuran parameter air in situ (salinitas, TDS, pH, EC, Suhu)

Gambar S18. Pengukuran panjang kerang

Gambar S19. Pengambilan data penampang sungai dan arus sungai

Gambar S20. Pengambilan sampel manusia

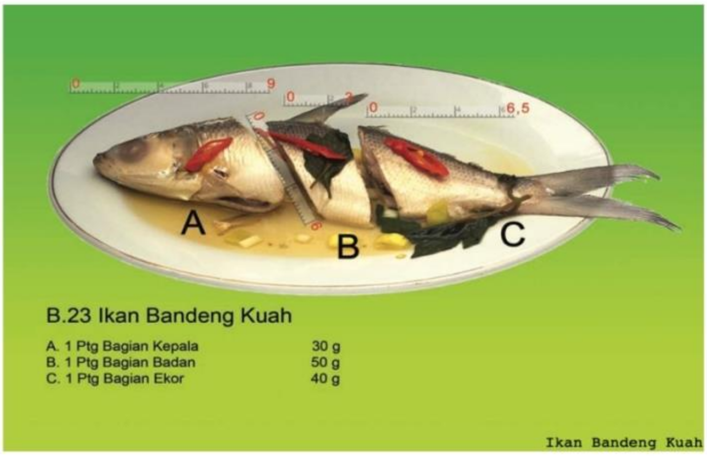
Lampiran 7. Model makanan dan minum

***Food model* konsumsi air dan biota akuatik untuk masyarakat di Kawasan Pesisir Pangkajene**

(sumber: Buku foto makanan, Kementerian kesehatan RI, 2014)

- Air minum

- Ikan bandeng (*Chanos-chanos)*



A. Ikan bandeng kuah

B. Ikan bandeng goreng

- Kerang (*Anadara granosa)*
  sumber: primer

A. Sendok kecil : 15 gram

B. Sendok besar/sayur : 44 gram

Lampiran 8. Etik Penelitian

KEMENTERIAN PENDIDIKAN DAN KEBUDAYAAN
UNIVERSITAS HASANUDDIN
FAKULTAS KESEHATAN MASYARAKAT
KOMITE ETIK PENELITIAN KESEHATAN
Sekretariat :
Jl. Perintis Kemerdekaan Km. 10 Makassar 90245, Telp. (0411) 585658, 516-005,
Fax (0411) 586013E-mail : kepkfkmuh@gmail.com, website : www.fkm.unhas.ac.id

REKOMENDASI PERSETUJUAN ETIK
Nomor **9209/UN4.14.1/TP.01.02/2020**

Tanggal : 23 November 2020

Dengan ini Menyatakan bahwa Protokol dan Dokumen yang Berhubungan dengan Protokol berikut ini telah mendapatkan Persetujuan Etik :

No.Protokol	28920093024	No. Sponsor Protokol	
Peneliti Utama	Ratna Dwi Puji Astuti	Sponsor	**DIKTI**
Judul Peneliti	Model Dinamis Dampak Pencemaran Logam Berat berbasis Analisis Risiko Kesehatan Lingkungan Pada Masyarakat di Kawasan Pesisir Pangkajene		
No.Versi Protokol	1	Tanggal Versi	28 September 2020
No.Versi PSP	1	Tanggal Versi	28 September 2020
Tempat Penelitian	Kabupaten Pangkajene dan Kepulauan		
Judul Review	☐ Exempted ☐ Expedited ☒ Fullboard	Masa Berlaku **23 November 2020 sampai 23 November 2021**	Frekuensi review lanjutan
Ketua Komisi Etik Penelitian	Nama : Prof.dr.Veni Hadju,M.Sc,Ph.D	Tanda tangan	Tanggal 23 November 2020
Sekretaris komisi Etik Penelitian	Nama : Nur Arifah,SKM,MA	Tanda tangan	Tanggal 23 November 2020

Kewajiban Peneliti Utama :

1. Menyerahkan Amandemen Protokol untuk persetujuan sebelum di implementasikan
2. Menyerahkan Laporan SAE ke Komisi Etik dalam 24 Jam dan dilengkapi dalam 7 hari dan Lapor SUSAR dalam 72 Jam setelah Peneliti Utama menerima laporan
3. Menyerahkan Laporan Kemajuan (progress report) setiap 6 bulan untuk penelitian resiko tinggi dan setiap setahun untuk penelitian resiko rendah
4. Menyerahkan laporan akhir setelah Penelitian berakhir
5. Melaporakn penyimpangan dari protocol yang disetujui (protocol deviation/violation)
6. Mematuhi semua peraturan yang ditentukan

Lampiran 9. Artikel yang sudah terbit

Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2020 Aug 15; 8(F):143-154.
https://doi.org/10.3889/oamjms.2020.4395
eISSN: 1857-9655
Category: *F - Review Articles*
Section: *Systematic Review Article*

OPEN ACCESS

Using System Dynamic Modeling for Improving Water Security in the Coastal Area: A Literature Review

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Keywords: System dynamic model; Water security; Coastal area
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Abstract

BACKGROUND: Water is one of the basic materials of human existence. In respect this, many countries have been focused on water security agenda as one of the national strategic security. One of water security domains is coastal water security. Water security, due to the myriad of factors influencing water quantity and quality in coastal area, can be considered as a complex system. Due to the complexity and dynamic characteristic, system dynamic model (SDM) is needed to implement in coastal area to integrate all subsystem.

AIM: This study aims to analyse the subsystems relating to coastal water security. The subsystem determination used to develop future policy-making relating to coastal water security.

METHODS: For this purpose, a systematic literature review was conducted and a set of 12 papers was selected from 2009 – 2019.

RESULTS: The papers' analysis shows the applicability of SDM to solve complex problems. Water scarcity has been identified as a major problem in the coastal area, identified in eight papers. Three papers are related to water quality and only one paper relating to both. There are four major subsystems relating to coastal water security: environment, economic, social, and politic. Information about the aquaculture activities, the mechanism of coastal water pollution and water relating human health risk is still limited.

CONCLUSION: We recommend use of SDM in the coastal water security to be extended to aquaculture, coastal water pollution and human health risk aspect in order to promote a holistic understanding of the complex issues and to develop more effective policies.

Introduction

Many countries in the world have been focused on water security agenda as one of the national strategic securities agenda [1]. As one of the most urgent topics facing humanity in the 21st century, water security can affect people's lives, property, and ecology [2], [3], [4], [5]. As one of the basic materials in human existence, the purposes of water are to support the development of human health, economic activities, and cultural lives [6]. In the last decade, human society facing serious water problems such as water scarcity, water pollution, and especially water damage caused by floods [7].

Lack of water security will impact to individual, city, countries, region, and global, which 80% world's population will be threatened by serious problem [1], [8]. In developing countries, an estimated 1 billion people lack access to safe affordable drinking water, 2.7 billion lack access to sufficient sanitation, and millions die each year from the preventable water-borne disease [3]. Contaminated water is one of the main environmental mediums of mortality and morbidity worldwide [9], [10], and evaluation of the quality of drinking water is one of the high priorities to avoid any health problems [11].

Water security context has diverse domain such as agricultural water security, domestic water security, urban water security, coastal water security, urban water supply, and demand system security, water resources security, and integrated water resources security [2], [3], [12], [13], [14], [15], [16]. Therefore, we conclude there are three domains of water security system: (1) Water resources security which has been focused to freshwater scarcity issue, which continue to gain urgency in science and policy term, (2) water environmental security refers to protect water from degradation and pollution for guaranteeing public health to maintain a good ecological status (GES) and sustainable functioning, and (3) water disaster aims to eliminate threats of water-related hazards and water emergency to solve water damage issues [2], [13], [16].

The problems existing in current water development and utilization include water deficit, serious waste of water, deterioration of water ecological environment due to the excessive exploration of water, disrepair, and aging of small water conservancy projects, and less enough attention paid to water management [6]. The coastal region is one of the areas vulnerable to water insecurities. The aquifer in coastal areas is linked to sea; an extraction of water from the reservoir is partly balanced by influx of saline

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Risk identification of Hg and Pb in soil: a case study from Pangkep Regency, Indonesia

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Keywords

Mercury
Lead
Ecological risk
Soil enrichment

Abstract

Lithogenic and anthropogenic activities can increase the concentration of heavy metals in the soil and degradation of environmental quality. Pangkajene dan kepulauan (Pangkep) regency is one of the areas in South Sulawesi Province which has severe environmental pressure. Twenty two surface soils of Pangkajene dan Kepulauan (Pangkep) regency, South Sulawesi, Indonesia were collected in order to determine the contamination status and potential ecological risks. The geo-accumulation index (I_{geo}) and potential ecological risk index (RI) were used to evaluate the contamination and risk level. The metal content in soils was determined using cold vapor atomic absorption spectrophotometer (CV-AAS) for Hg and flame atomic absorption spectrophotometer (F-AAS) for Pb. The results showed that the concentration of Hg and Pb ranged from 20.81- 223.47 mg kg^{-1} and 25.98-108.68 mg kg^{-1} respectively. Pb concentration in studied soil was below the quality standard for soil, whereas the Hg concentration was exceeded the soil quality standard. Agriculture field in Bungoro sub-district has the highest Hg concentration. The I_{geo} value showed that the soil in Pangkajene was extremely enriched with Hg and moderately enriched by Pb. The ecological risk index showed comprehensively the watershed area was at extreme risk level in need of effective monitoring and pollution control, and Hg is the important risk factor of Pangkajene watershed area.

1. Introduction

Heavy metals pollution in the soil is the severe problem worldwide which attracts public attention, especially concerning food security. Hg and Pb are the trace elements which may persist and accumulate in the soil. Its contamination does not only reduce the quality of the soil but also affects the growth of crop. Moreover, it can possibly transmit to the human body via dust and water resources by direct contact and ingestion (Chen and Zheng, 1996; Christoforidis and Stamatis, 2009; Li et al., 2016; Suryawanshi et al., 2016; Tchounwou et al., 2012; Wuana and Okieimen, 2011). Also, it can penetrate the food chain through bio-uptake by plants (Dowdy and Volk, 1983) and therefore affects animal and human health. Transfer of Hg and Pb to soil includes wet and dry deposition from atmosphere and direct discharge of pollutant (Ebinghaus et al., 1999). Waste incineration, mining, mineral processing, coal combustion, industries (electronics, pharmaceutical, caustic soda, petrochemical, cement), sewage sludges irrigation and application of fertilizer and pesticides are sources of Hg emission to the soil (Higueras et al., 2014; Li et al., 2016; Tangahu et al., 2011; Wang et al., 2020; Zhong et al., 2016). While, the Pb sources may come from leaded gasoline, mining, manufacturing, industry (paint, batteries, ammunition, metal production) and agriculture (fertilizer, manure, and pesticides) (Atafar et al., 2010; Tchounwou et al., 2012).

Hg and Pb are classified as the second and third highly toxic heavy metals, which are substances prioritize for control by U.S Agency for Toxic Substances and Disease Registry (ATSDR) in 2019 (U.S. Department of Health & Human Services, 2019). Like other heavy metals, Hg and Pb can accumulate in the soil and are bioaccumulated through food chain, which may pose a risk to ecological and human health (Masindi and Muedi, 2018; Rzymski et al., 2015; Wijayawardena et al., 2016). There is no level of exposure to Hg and Pb which is known to be without harmful effects (Bjørklund et al., 2019; Wani et al., 2015; World Health Organization (WHO), 2019). The high concentration of mercury or methylmercury primarily will affect to the neurological and renal system (Agency for Toxic Substances and Disease Registry (ATSDR), 1999; Bjørklund et al., 2019; El-Ansary et al., 2017; Fields et al., 2017; Jackson, 2018). Mercury also produces teratogenicity, especially in organic form (Methylmercury) (Bose-O'Reilly et al., 2010b; Inouye, 1989; Manduca et al., 2014; Mobarak, 2008). While the high concentration of Pb will affect to the nervous system, reproductive system and bone (Agency for Toxic Substances and Disease Registry (ATSDR), 2007; El-Ansary et al., 2017; Jackson

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ORIGINAL RESEARCH PAPER

Natural enrichment of chromium and nickel in the soil surrounds the karst watershed

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Hazard index
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Pollution load index
Surface soil enrichment
Weathering carbonate rocks

ABSTRACT

BACKGROUND AND OBJECTIVES: As a public concern, monitoring and controlling toxic metals pollution is needed worldwide. Due to the ability of poisonous metals in biomagnification and bioaccumulation, they can cause several adverse impacts on ecological and human health. The study aims to assess chromium and nickel enrichment levels and estimate the soil's ecological risk surrounds the Pangkajene watershed.

METHODS: The total concentrations of chromium and nickel were determined using the Flame Atomic Absorption Spectrophotometer. This study used contamination factor, geo-accumulation index, and pollution load index to evaluate soil enrichment status. The ecological hazard index is used to estimate the potential hazard that may occur due to contamination.

FINDINGS: The mean concentrations of chromium and nickel were 92.9 and 43.18 mg/kg, respectively. Chromium concentration exceeded the soil quality guideline for the protection of environment and human health, while Ni still below the standards. The geo-accumulation index value indicated no human-made-derived contamination in the soil. Weathering of carbonate rocks is the chromium and nickel major enrichment factor in the Pangkep regency. Contamination factor and pollution load index values showed low pollution in the studied soil. However, all study sites exceeded the ecological hazard index value (Ecological hazard index>1), which indicates a considerable ecological risk in the Pangkajene watershed area..

CONCLUSION: These findings may provide baseline information related to chromium and nickel enrichment in the soil for Pangkep regency municipality. The Pangkep regency municipality must highlight the importance of strengthening environmental standards and monitoring mechanism as the priority to maintain a healthy environment.

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NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
70	6	5

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Gac Sanit. 2021;35(S1):S33–S37

Risk identification of heavy metals in well water surrounds watershed area of Pangkajene, Indonesia☆

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ARTICLE INFO

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Keywords:
Heavy metals
Risk assessment
Water pollution

ABSTRACT

Objective: This study wants to evaluate heavy metals pollution and ecological risk level of well water in Pangkajene watershed area.
Methods: The total concentration of Cd, Cr(VI), Pb and Ni were determined using AAS. We used heavy metal pollution index (HPI), metal index (MI), hazard quotient (HQ) used to estimate metals pollution and ecological risk level. Pearson correlation analysis is executed to evaluate the relationship between all measured parameters.
Result: The concentration of Cd, Ni and Pb are below detection limit value. The mean concentration of Cr(VI) 0.0017 ± 0.0006 mg L^{-1}. The mean of HPI and MI value are 3.06 and 0.06, respectively. The upstream area of Pangkajene has HQ value for Cr(VI) is higher than 1, it indicates that exposure of Cr(VI) may cause adverse effects to the ecological system and human health.
Conclusion: The Cr(VI) is the main risk factor for well water contamination surrounds Pangkajene watershed area.

Introduction

Maros and Pangkajene regency have the second beautiful karst area in the world. Whereas, karst areas are vulnerable to an environmental problem than any other areas.[1,2] It may cause by special hydrogeological properties of karst areas.[3] Human activities may discharge many pollutants to the environment such as organic and inorganic pollutants (heavy metals). Pollutants are not only come from anthropogenic activities but also it may come from natural phenomena.

The high concentration of heavy metals in aquatic habitat is not only affected by the aquatic organism but it may affect to the quality of human life. High exposure of hexavalent chromium (Cr(VI)) from drinking water is related to carcinogenic effects.[4] The cancer formulation caused by chromium exposures is related to activating MAPK which enhances proliferation cell.[5] At low doses 0.3–520 mg.L^{-1} in drinking water it may enhance DNA damaging at mice.[6] The lead (Pb) may accumulate in bones and cause central nervous system disorders.[7] Cd, Pb, and Ni are also classified as carcinogenic metals.[5,8] This present study aims to assess heavy metals pollution and the ecological risk level of well water in Pangkajene watershed area.

Methods

Sampling procedures

This study focused on the assessment of heavy metal contamination and the estimation of ecological risk related to heavy metal contamination in well water surrounds Pangkajene watershed area. A total number of 18 shallow well water samples distributing from the upstream area to the downstream area of Pangkajene river (Bungoro, Minasatene, and Pangkajene sub-district) were collected using 500 ml HDPE bottle and following standard procedures (Fig. 1). Showed the location of sampling sites. Temperature, pH, total dissolved solids (TDS) and electrical conductivity (EC) were directly determined in the sampling field. Temperature was determined using a thermometer. pH, TDS and EC were determined by digital electrode meter. All samples were stored at a cool box with cubed ice.

Sample analysis

Heavy metals in water samples were determined using Indonesian Standard Procedures for Heavy metals Analysis (SNI 6989,16:2009 for Cd; SNI 6989.71:2009 for Cr(VI); SNI 06-6989.8-2009 for Pb; and SNI 6989.18:2009 for Ni). All samples were digested using 5 ml of HNO_3 and then filtered the solution using filter paper. We used flame atomic absorption spectrophotometry (F-AAS, PerkinElmer, pinAAcle 900H) to determine the total concentration of metals. To assure quality of measurement in the laboratory, three blank samples and U.S NIST reference material 1646a estuary sediment were used.

☆ Peer-review under responsibility of the scientific committee of the 1st International Conference on Safety and Public Health (ICOS-PH 2020). Full-text and the content of it is under responsibility of authors of the article.

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CURRICULUM VITAE

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1. Tamat SLTA tahun 2012 di SMAN 5 Kota Bekasi
2. Tamat Sarjana (S1) tahun 2016 di Universitas Indonesia
3. Magister (S2) tahun 2019 di Universitas Hasanuddin
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C. Pekerjaan dan Riwayat Pekerjaan

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3. Pangkat/Jabatan: -

D. Karya ilmiah yang telah dipublikasikan

1. **Astuti, R.D.P.,** Mallongi, A., 2020. Using system dynamic modelling for improving water security in the coastal area: a literature review. Open access Macedonia journal of medical sciences. 8, 143-154. https://doi.org/10.3889/oamjms.2020.4395
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E. Makalah pada Seminar/Konferensi Ilmiah Nasional dan International

1. Ratna Dwi Puji Astuti et al 2020. The 1st International Conference on Safety and Public Health 2020. As Presenter and Participant
2. Ratna Dwi Puji Astuti et al 2021. 52nd Asia-Pacific Academic Consortium for Public Health (APACPH) conference as Presenter and Participant
3. Ratna Dwi Puji Astuti et al 2021. 2nd International Modern Scientific Research Congress, Turkey as Presenter
4. Ratna Dwi Puji Astuti et al 2022. The 13th International Nursing Conference. As Presenter and Participant

F. Hibah dan Pendanaan

1. Kementerian Riset dan Teknologi Republik Indonesia (Ristek-BRIN), Beasiswa Pendidikan Magister menuju Doktor untuk Sarjana Unggul (PMDSU) batch 4 durasi 2018 – 2022 (Supervisor/promotor: Prof. Anwar Mallongi, S.K.M., M.Sc., Ph.D)
2. Riset dan kolaborasi artikel, program peningkatan kualitas publikasi internasional/Sandwich like program. Durasi 2021 – 2022 (Supervisor: Prof. Kyungho Choi, Ph.D – Graduate School of Public Health, Seoul National University).