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**Lampiran 1. Konsentrasi Debu TSP dan Logam di Udara**

| Lokasi | Konsentrasi (μg/m³) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TSP | | Al | | As | | Cr | | Cu | | Ni | | Pb | | Zn | |
| | I | II | I | II | I | II | I | II | I | II | I | II | I | II | I | II |
| 1 | 42,90 | 94,78 | 689,69 | 14546,6 | 2,08 | 88,07 | 10,81 | 187,8 | 5,02 | 45,21 | 1,75 | *ttd | 5,54 | 543,3 | 16779,8 | 10790,6 |
| 2 | 37,74 | 191,9 | 11678,78 | 1017,46 | 1,51 | 82,02 | 10,71 | 9,41 | 3,59 | 98,04 | 1,44 | *ttd | 6,92 | *ttd | 30469,3 | 14632,5 |
| 3 | 133,2 | 392,6 | 1421,34 | 615,74 | 1,45 | 86,80 | 11,76 | 8,21 | 2,72 | 42,19 | 2,13 | *ttd | 6,23 | *ttd | 15139,4 | 8222,16 |
| 4 | 66,07 | 109,4 | 798,86 | 586,40 | 1,64 | 104,1 | 12,74 | 10,15 | 7,04 | 31,75 | 1,97 | *ttd | 7,44 | 130,3 | 17540,6 | 8026,9 |
| 5 | 18,48 | 87,93 | 675,34 | 780,11 | 1,47 | 51,94 | 13,95 | 122,7 | 5,04 | 12,98 | 2,05 | *ttd | 8,11 | 1968,1 | 28953,5 | 7956,78 |
| 6 | 12,09 | 64,28 | 87,23 | 620,72 | 1,50 | 136,8 | 11,29 | 148,6 | *ttd | 243,7 | 1,46 | *ttd | 7,16 | 1838,9 | 30600,1 | 9438,23 |
| Min-Max | 12,09-133,2 | 64,28-392,69 | 87,23-11678,78 | 586,40-14546,6 | 1,47-2,08 | 51,94-136,8 | 10,71-13,95 | 8,21-187,8 | 2,72-7,0 | 12,98-243,7 | 1,44-2,13 | - | 5,54-8,11 | 130,3-1968,1 | 15139,4 - 30600,1 | 7956,78 - 14632,5 |
| Mean | 51,75 | 156,8 | 2558,5 | 844,50 | 1,61 | 91,63 | 11,88 | 81,17 | 4,68 | 78,97 | 1,80 | - | 6,90 | 746,77 | 23247,1 | 9844,55 |
| Batas deteksi alat | - | | 0,05 | | 0,9 | | 0,07 | | 0,03 | | 0,2 | | 0,08 | | 0,2 | |
| WHO (WHO, 2000) | 150-230 μg/m³ (24 jam) 60-90 μg/m³ (Tahun) | | - | | 6,6 ng/m³ | | 0,001 μg/m³ | | - | | 25 ng/m³ | | 0,5 μg/m³ | | - | |
| USEPA | 150 μg/m³ (24 jam) 60 μg/m³ (Tahun) | | - | | 0,1 | | 0,05 | | 1,3 | | 2 | | 0,01 | | 5 | |
| Indonesia (Peraturan Pemerintah, 2021) | 230 μg/m³ (24 jam) 90 μg/m³ (Tahun) | | - | | - | | - | | - | | - | | 2 μg/m³ (24 jam) 1 μg/m³ (Tahun) | | - | |

Keterangan: *I= musim penghujan, II= musim kemarau.*

**Lampiran 2. Definisi Operasional Variabel Penelitian**

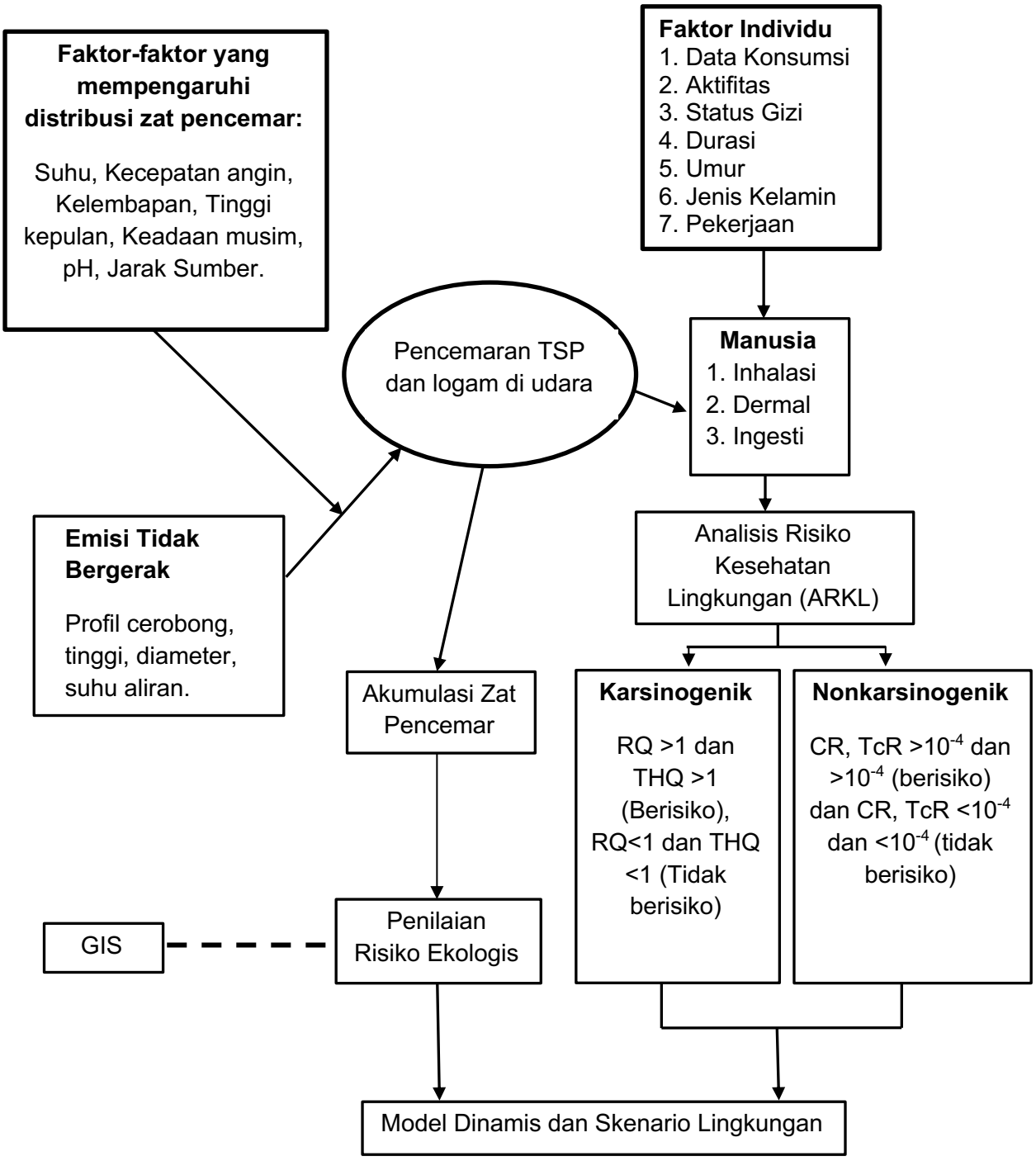
| No | Variabel | Defenisi operasional | Cara pengukuran | Alat ukur | Satuan | Skala |
|---|---|---|---|---|---|---|
| **1** | Tinggi Cerobong | Ukuran tinggi suatu cerobong adalah jarak yang diukur mulai dari ujung bawah permukaan cerobong hingga ke ujung paling atas | Data sekunder | Meteran | m | Rasio |
| **2** | Diameter Cerobong | Diameter dihitung sebagai jarak garis tengah yang diukur pada lubang atas cerobong yang berbentuk lingkaran. | Data sekunder | Meteran | m | Rasio |
| **3** | Data Emisi | Kuantitas zat pencemar yang diperoleh dari sisa hasil pembakaran bahan bakar yang berasal dari aktifitas cerobong. | Data sekunder | HAVS | $\mu g/cm^3$ | Rasio |
| **4** | Suhu Cerobong | Pengukuran kuantitatif pada temperatur yang dihasilkan di dalam cerobong saat beroperasi | Data sekunder | *Thermometer* | ℃ | Interval |
| **5** | Kecepatan Aliran Cerobong | Laju aliran zat pencemar yang diukur melalui cerobong ketika beroperasi dalam satuan mikrogram per meter kubik dengan skala rasio. | Data sekunder | Pipa pitot | m/detik | Interval |
| **6** | Suhu Udara | Ukuran kuantitatif pada temperatur udara. Pengukuran suhu ini dilakukan secara langsung di lapangan. | Data sekunder | *Thermometer* | ℃ | Interval |
| **7** | Radiasi Matahari | Intensitas ukuran lamanya pemancaran sinar matahari yang diperoleh melalui situs resmi BMKG Kelas 1 Maros di tahun 2016-2020. | Data sekunder | *Phyrometer* | jam/ hari | Rasio |
| **8** | Kecepatan Angin | Ukuran laju udara yang bergerak secara horizontal yang diperoleh melalui situs resmi BMKG Kelas 1 Maros di tahun 2016-2020. | Data sekunder | Anemometer | m/detik | Rasio |

| | | | | | | |
|---|---|---|---|---|---|---|
| **9** | Arah Angin | Arah angin bertiup di lokasi penelitian dan diidentifikasi dalam derajat searah jarum jam dari utara. Diperoleh dari situs resmi BMKG Kelas 1 Maros di tahun 2016-2020. | Data sekunder | Anemometer | derajat | Rasio |
| **10** | Tinggi kepulan asap (Δh) | Tinggi semburan asap atau kepulan asap yang keluar dari cerobong | Data perhitungan | - | m | Rasio |
| **11** | Kualitas plume lateral ($\sigma y$) | Parameter penyebaran *plume* secara horizontal yang merupakan fungsi dari jarax (x) | Data perhitungan | - | m | Interval |
| **12** | Kualitas plume vertikal ($\sigma z$) | Parameter penyebaran *plume* secara vertikal yang merupakan fungsi dari jarax (x) | Data sekunder | - | m | Interval |
| **13** | Jarak X | Kepulan vertikal dari arah permukaan | Data perhitungan | - | m | Interval |
| **14** | Jarak Y | Kepulan horizontal dari arah *centerline* | Data perhitungan | - | m | Interval |
| **15** | Percepatan gravitasi | Waktu rata – rata yang dibutuhkan partikel buat menarik partikel ke arahnya dalam jarah atau medan gravitasi tertentu | Data sekunder | - | $m/s^2$ | Rasio |
| **16** | Laju emisi (Q) | | Data perhitungan | - | $\mu g/s$ | Rasio |
| **17** | Tinggi efektif cerobong (H) | Ketinggian efektif dari cerobong yang diamati sehingga kepulan dapat terdispersi | Data perhitungan | - | m | Rasio |
| **18** | Konsentrasi Logam | Kuantitas zat pencemar di media lingkungan di lokasi penelitian. | Data primer | ICP/AAS | ppm | Rasio |
| **19** | Curah hujan | umlah air hujan yang jatuh selama periode waktu tertentu yang pengukurannya menggunakan satuan tinggi di atas permukaan tanah horizontal. | Data sekunder | Ombrometer/ mm | - | Interval |
| **20** | Jumlah hari hujan | Banyaknya jumlah hari yang mengalami hujan dalam satu bulan/tahun. | Data sekunder | - | - | Rasio |

| | | | | | | |
|---|---|---|---|---|---|---|
| **21** | *Total Hazard Index* (THI) | Karakteristik total risiko non karsinogenik yang dinyatakan dengan THI. Nilai dinyatakan sebagai perbandingan asupan *risk agent* dengan RfC/RfD | Data primer | Data Perhitungan | - | Rasio |
| **22** | Nilai asupan *(ADD)* | Jumlah konsentrasi agen risiko (mg/kg) yang masuk kedalam tubuh manusia dengan berat badan tertentu (kg) setiap harinya | Data primer | Data perhitungan | | |
| **23** | *Total Carcinogenic Risk* (TCR) | Nilai diperoleh dari mengalikan CSF (*Cancer Slope Factor*) dengan asupan karsinogenik *risk agent*. Risiko total karsinogenik merupakan jumlah dari beberapa nilai risiko karsinogenik | Data primer | Data Perhitungan | - | Rasio |
| **24** | Berat badan | Massa bobot tubuh responden yang diukur saat penelitian | Data primer | Timbangan | Kg | Rasio |
| **25** | Laju inhalasi (*InhRate*) | Banyaknya volume udara yang masuk setiap jamnya $m^3$/jam | Data sekunder | - | $m^3$/jam | Rasio |
| **26** | Referensi dosis (RfD) | Dosis pajanan harian dari agen risiko non-karsinogenik yang diestimasi tidak menimbulkan efek atau merupakan ambang batas timbulnya efek kesehatan pada manusia. | Data sekunder | - | mg/kg-day | Rasio |
| **27** | Referensi konsentrasi (RfC) | Konsentrasi pajanan harian dari agen risiko non-karsinogenik yang diestimasi tidak menimbulkan efek atau merupakan ambang batas timbulnya efek kesehatan pada manusia | Data sekunder | - | mg/kg-day | Rasio |
| **28** | Durasi pajanan (ED) | Lamanya atau jumlah tahun terjadi pajanan | Data primer | - | Tahun | Rasio |
| **29** | Frekuensi pajanan (EF) | Lamanya atau jumlah hari terjadi pajanan setiap tahunnya | Data primer | - | Tahun | Rasio |
| **30** | Area permukaan kulit yang terpapar (SA) | Ukuran area kulit yang terbuka dan memiliki kontak dengan agen pencemar dalam internsitas tertentu dalam setahun | Data primer | - | $cm^2$ | Rasio |

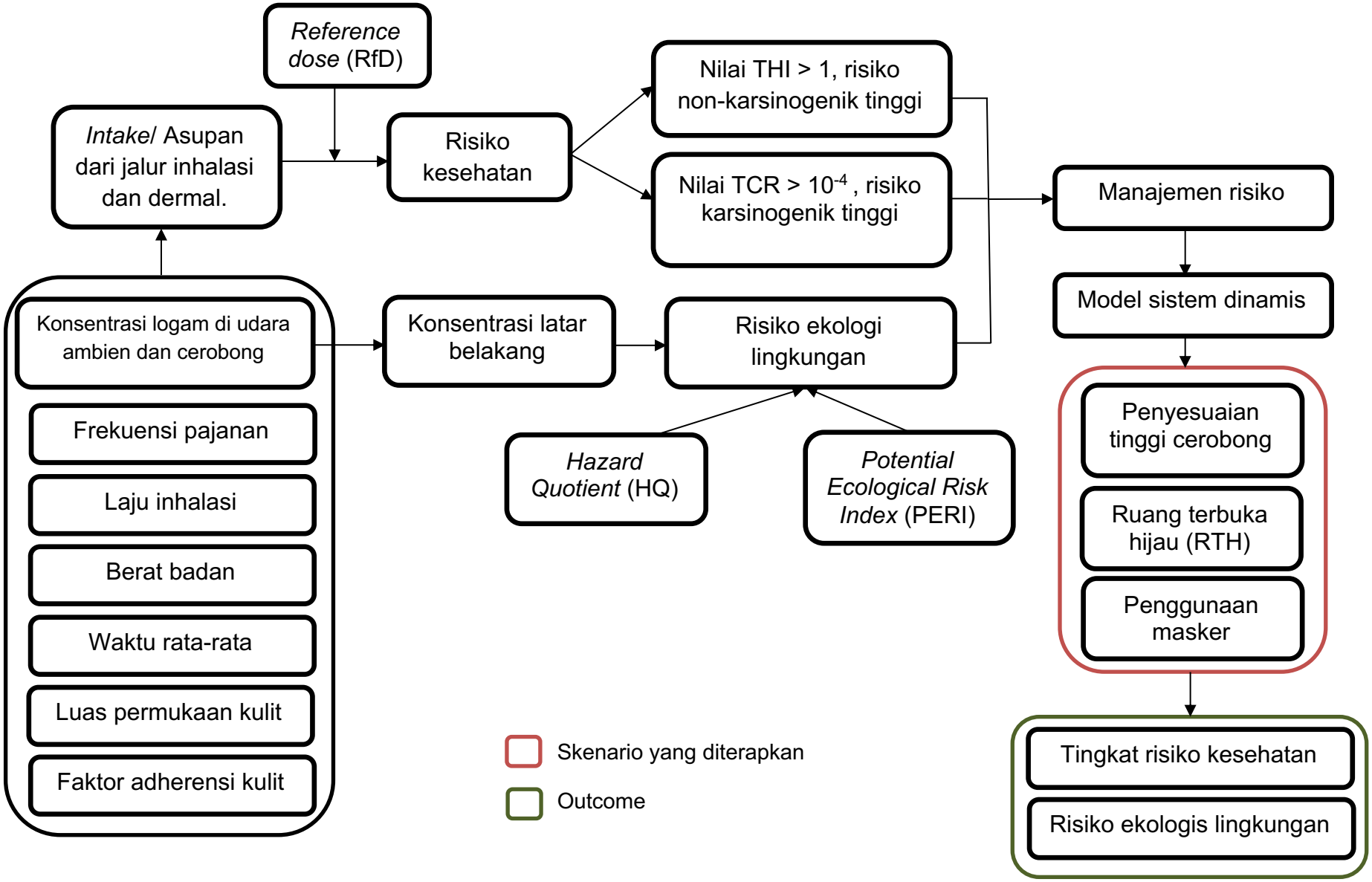
| | | | | | | |
|---|---|---|---|---|---|---|
| **31** | Waktu rata-rata (Tavg) | Banyaknya hari terjadi pajanan setiap tahun | Data sekunder | - | hari | Rasio |
| **32** | Fraksi serapan kulit (ABS) | Tetapan tingkat toleransi serapan kulit terhadap agen pencemar | Data sekunder | - | - | Rasio |
| **33** | Berat daun pohon lama/baru | Massa daun berdasarkan jenis pohon yang dipilih untuk menjadi penyerap partikulat logam dalam penelitian ini | Data sekunder | Timbangan | mg | Rasio |
| **34** | Total berat daun | Total massa daun dari pohon mangga dan akasia yang dipilih sebagai penyerap logam dalam penelitian ini | Data sekunder | Timbangan | mg | Rasio |
| **35** | Jumlah pohon | Kuantitas pohon yang menjadi penyerap partikulat logam melalui daun yang akan ditanam di sekitar lokasi penelitian | Data primer | - | - | Rasio |
| **36** | Koefisien absopsi daun | Kemampuan setiap helai daun untuk menyerap atau mengurangi partikulat logam di udara di sekitar lokasi penelitian | Data sekunder | | mg/kg | Rasio |
| **37** | Efektifitas masker | Salah satu parameter untuk mengukur kinerja penyaringan masker wajah terhadap polusi udara | Data sekunder | - | % | Rasio |
| **38** | Faktor kontaminasi (CF) | Tingkat risiko ekologi lingkungan untuk logam tunggal yang ada di udara sekitar wilayah penelitian | Data perhitungan | - | - | Rasio |
| **39** | Konsentrasi latar belakang | Level akumulasi logam di udara sekitar lokasi penelitian | Data primer | HVAS/ICP | mg/kg | Rasio |
| **40** | *Potential Ecological Risk Index* (PERI) | Tingkat risiko ekologi lingkungan untuk seluruh logam yang terakumulasi di udara sekitar wilayah penelitian | Data perhitungan | - | - | Rasio |

**Lampiran 3. Kerangka Teori**




Kerangka Teori Penelitian, (Soedomo, 2001), (Skerfving, 1993), (Ragazzi, 2016), (WHO Europe, 2007), (USEPA, 1989) yang dimodifikasi.

**Lampiran 4. Kerangka Konsep Penelitian**



**Lampiran 5. Tabel Konsentrasi Logam Hasil Simulasi**

1. Skenario Penambahan Tinggi Cerobong

   a. Logam Pb

*Simulasi konsentrasi Pb pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,002623 | 0,000044 | 0,012365 | 0,017782 | 0,011800 | 0,022473 |
| **13-24** | 0 | 0,000747 | 0,021809 | 0,000018 | 0,019446 | 0,017543 |
| **25-36** | 0 | 0,000264 | 0,020961 | 0,001801 | 0,013329 | 0,013355 |
| **37-48** | 0,000341 | 0,000014 | 0,010784 | 0,008610 | 0,009356 | 0,012970 |
| **49-60** | 0,001591 | 0,000389 | 0,021356 | 0,005905 | 0,018241 | 0,015574 |
| **61-72** | 0 | 0,000557 | 0,016884 | 0,004264 | 0,016423 | 0,017980 |
| **73-84** | 0 | 0,001004 | 0,020854 | 0,001493 | 0,014534 | 0,018470 |
| **85-96** | 0,000486 | 0,000407 | 0,022710 | 0,008306 | 0,025239 | 0,020861 |
| **97-108** | 0 | 0,000417 | 0,025282 | 0,001740 | 0,014138 | 0,019016 |
| **109-120** | 0,001404 | 0,000257 | 0,019353 | 0,015418 | 0,016857 | 0,009217 |
| **121-132** | 0,000944 | 0 | 0,047315 | 0,007197 | 0,030462 | 0,012182 |
| **133-144** | 0,001480 | 0 | 0,049047 | 0,015891 | 0,031091 | 0,013990 |
| **145-156** | 0,002086 | 0 | 0,040824 | 0,014474 | 0,014741 | 0,019828 |
| **157-168** | 0,003067 | 0 | 0,036534 | 0,021473 | 0,010412 | 0,024235 |
| **169-180** | 0,002265 | 0 | 0,036511 | 0,025121 | 0,011119 | 0,020753 |
| **181-192** | 0,001886 | 0 | 0,042854 | 0,013541 | 0,028591 | 0,022811 |
| **193-204** | 0,002897 | 0 | 0,047925 | 0,012874 | 0,018777 | 0,010647 |
| **205-216** | 0,002620 | 0 | 0,049371 | 0,016239 | 0,034462 | 0,010430 |
| **217-228** | 0,000861 | 0 | 0,048370 | 0,004991 | 0,026868 | 0,021547 |
| **229-240** | 0,000557 | 0 | 0,049092 | 0,009794 | 0,028807 | 0,016253 |

*Simulasi konsentrasi Pb pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,002535 | 0,000043 | 0,011976 | 0,017379 | 0,011430 | 0,021595 |
| **13-24** | 0 | 0,000734 | 0,021040 | 0,000018 | 0,018703 | 0,016967 |
| **25-36** | 0 | 0,000259 | 0,020274 | 0,001795 | 0,012917 | 0,012869 |
| **37-48** | 0,000323 | 0,000014 | 0,010482 | 0,008460 | 0,009075 | 0,012486 |
| **49-60** | 0,001451 | 0,000383 | 0,020681 | 0,005694 | 0,017714 | 0,015107 |
| **61-72** | 0 | 0,000545 | 0,016193 | 0,003857 | 0,015867 | 0,017518 |
| **73-84** | 0 | 0,000982 | 0,020064 | 0,001480 | 0,014012 | 0,017863 |
| **85-96** | 0,000463 | 0,000399 | 0,021843 | 0,008108 | 0,024366 | 0,020066 |
| **97-108** | 0 | 0,000410 | 0,024491 | 0,001737 | 0,013647 | 0,018122 |
| **109-120** | 0,001362 | 0,000252 | 0,018702 | 0,015083 | 0,016371 | 0,008964 |
| **121-132** | 0,000902 | 0 | 0,046071 | 0,007083 | 0,029686 | 0,011943 |
| **133-144** | 0,001409 | 0 | 0,047576 | 0,015604 | 0,030243 | 0,013705 |
| **145-156** | 0,001993 | 0 | 0,039447 | 0,014197 | 0,014450 | 0,019431 |
| **157-168** | 0,002996 | 0 | 0,035271 | 0,020957 | 0,010195 | 0,023743 |
| **169-180** | 0,002183 | 0 | 0,035201 | 0,024502 | 0,010916 | 0,020330 |
| **181-192** | 0,001846 | 0 | 0,041383 | 0,013242 | 0,027889 | 0,022311 |
| **193-204** | 0,002782 | 0 | 0,046806 | 0,012623 | 0,018391 | 0,010422 |
| **205-216** | 0,002503 | 0 | 0,048080 | 0,015869 | 0,033628 | 0,010222 |
| **217-228** | 0,000825 | 0 | 0,046960 | 0,004878 | 0,026168 | 0,021071 |
| **229-240** | 0,000533 | 0 | 0,047662 | 0,009587 | 0,028116 | 0,015915 |

*Simulasi konsentrasi Pb pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,002239 | 0,000002 | 0,009303 | 0,015627 | 0,010326 | 0,019162 |
| **13-24** | 0 | 0,000179 | 0,017669 | 0,000001 | 0,015746 | 0,015535 |
| **25-36** | 0 | 0,000045 | 0,017481 | 0,001704 | 0,010899 | 0,011608 |
| **37-48** | 0,000237 | 0,000001 | 0,008844 | 0,007534 | 0,008279 | 0,010837 |
| **49-60** | 0,000861 | 0,000104 | 0,017776 | 0,004290 | 0,016213 | 0,014066 |
| **61-72** | 0 | 0,000164 | 0,013555 | 0,002961 | 0,014281 | 0,016393 |
| **73-84** | 0 | 0,000314 | 0,016752 | 0,000590 | 0,012232 | 0,016191 |
| **85-96** | 0,000347 | 0,000062 | 0,017531 | 0,006982 | 0,021023 | 0,018131 |
| **97-108** | 6.17E-315 | 0,000076 | 0,020111 | 0,001505 | 0,011348 | 0,015669 |
| **109-120** | 0,001150 | 0,000041 | 0,015893 | 0,013387 | 0,015100 | 0,008425 |
| **121-132** | 0,000784 | 0 | 0,041700 | 0,006523 | 0,027816 | 0,011367 |
| **133-144** | 0,001172 | 0 | 0,043187 | 0,014389 | 0,028337 | 0,013027 |
| **145-156** | 0,001742 | 0 | 0,035977 | 0,013051 | 0,013472 | 0,018379 |
| **157-168** | 0,002649 | 0 | 0,032373 | 0,019689 | 0,009515 | 0,022155 |
| **169-180** | 0,001921 | 0 | 0,032324 | 0,023006 | 0,010263 | 0,019247 |
| **181-192** | 0,001657 | 0 | 0,037367 | 0,012385 | 0,025794 | 0,021035 |
| **193-204** | 0,002489 | 0 | 0,042797 | 0,011687 | 0,017383 | 0,009803 |
| **205-216** | 0,002196 | 0 | 0,043287 | 0,014931 | 0,031518 | 0,009761 |
| **217-228** | 0,000724 | 0 | 0,043050 | 0,004583 | 0,024568 | 0,019903 |
| **229-240** | 0,000413 | 0 | 0,043805 | 0,008825 | 0,026549 | 0,015096 |

b. Logam Cr

*Simulasi konsentrasi Cr pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000347 | 0,000023 | 0,005894 | 0,008330 | 0,004775 | 0,010850 |
| **13-24** | 0 | 0,000390 | 0,009609 | 0,000010 | 0,008214 | 0,007627 |
| **25-36** | 0 | 0,000140 | 0,009817 | 0,000444 | 0,005679 | 0,005594 |
| **37-48** | 0,000036 | 0,000007 | 0,005355 | 0,003461 | 0,004112 | 0,006303 |
| **49-60** | 0,000329 | 0,000203 | 0,010085 | 0,002495 | 0,007902 | 0,006517 |
| **61-72** | 0 | 0,000296 | 0,009385 | 0,001496 | 0,006503 | 0,007391 |
| **73-84** | 0 | 0,000514 | 0,009620 | 0,000783 | 0,005779 | 0,008225 |
| **85-96** | 0,000051 | 0,000208 | 0,010645 | 0,003826 | 0,010629 | 0,008738 |
| **97-108** | 0 | 0,000214 | 0,010902 | 0,000938 | 0,005900 | 0,008135 |
| **109-120** | 0,000144 | 0,000137 | 0,009592 | 0,007293 | 0,007642 | 0,004073 |
| **121-132** | 0,000160 | 0 | 0,020903 | 0,003662 | 0,014230 | 0,005211 |
| **133-144** | 0,000243 | 0 | 0,022913 | 0,007483 | 0,014338 | 0,005677 |
| **145-156** | 0,000391 | 0 | 0,020745 | 0,006008 | 0,006032 | 0,008891 |
| **157-168** | 0,000313 | 0 | 0,019729 | 0,010031 | 0,004186 | 0,011498 |
| **169-180** | 0,000384 | 0 | 0,019974 | 0,011753 | 0,004139 | 0,009066 |
| **181-192** | 0,000197 | 0 | 0,022157 | 0,006175 | 0,012052 | 0,008926 |
| **193-204** | 0,000601 | 0 | 0,020149 | 0,006083 | 0,009381 | 0,005556 |
| **205-216** | 0,000529 | 0 | 0,021796 | 0,007939 | 0,016559 | 0,004439 |
| **217-228** | 0,000133 | 0 | 0,022764 | 0,002521 | 0,011574 | 0,008263 |
| **229-240** | 0,000059 | 0 | 0,023079 | 0,004431 | 0,013171 | 0,006724 |

*Simulasi konsentrasi Cr pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000329 | 0,000022 | 0,005693 | 0,008131 | 0,004628 | 0,010403 |
| **13-24** | 0 | 0,000384 | 0,009265 | 0,000009 | 0,007872 | 0,007356 |
| **25-36** | 0 | 0,000138 | 0,009487 | 0,000445 | 0,005499 | 0,005372 |
| **37-48** | 0,000034 | 0,000007 | 0,005203 | 0,003408 | 0,003991 | 0,006048 |
| **49-60** | 0,000301 | 0,000200 | 0,009741 | 0,002414 | 0,007647 | 0,006292 |
| **61-72** | 0 | 0,000291 | 0,009010 | 0,001486 | 0,006234 | 0,007174 |
| **73-84** | 0 | 0,000505 | 0,009243 | 0,000776 | 0,005553 | 0,007938 |
| **85-96** | 0,000049 | 0,000204 | 0,010227 | 0,003737 | 0,010227 | 0,008372 |
| **97-108** | 0 | 0,000210 | 0,010550 | 0,000937 | 0,005716 | 0,007729 |
| **109-120** | 0,000140 | 0,000134 | 0,009255 | 0,007116 | 0,007395 | 0,003947 |
| **121-132** | 0,000149 | 0 | 0,020284 | 0,003595 | 0,013814 | 0,005100 |
| **133-144** | 0,000228 | 0 | 0,022136 | 0,007322 | 0,013883 | 0,005554 |
| **145-156** | 0,000367 | 0 | 0,019987 | 0,005875 | 0,005900 | 0,008694 |
| **157-168** | 0,000306 | 0 | 0,018984 | 0,009742 | 0,004105 | 0,011246 |
| **169-180** | 0,000367 | 0 | 0,019209 | 0,011402 | 0,004058 | 0,008865 |
| **181-192** | 0,000193 | 0 | 0,021331 | 0,006010 | 0,011699 | 0,008718 |
| **193-204** | 0,000572 | 0 | 0,019632 | 0,005953 | 0,009192 | 0,005434 |
| **205-216** | 0,000499 | 0 | 0,021157 | 0,007724 | 0,016106 | 0,004345 |
| **217-228** | 0,000124 | 0 | 0,022026 | 0,002455 | 0,011232 | 0,008070 |
| **229-240** | 0,000056 | 0 | 0,022332 | 0,004316 | 0,012805 | 0,006574 |

*Simulasi konsentrasi Cr pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000278 | 0,000001 | 0,004408 | 0,007381 | 0,004309 | 0,009331 |
| **13-24** | 0 | 0,000094 | 0,007817 | 0,000001 | 0,006584 | 0,006799 |
| **25-36** | 0 | 0,000024 | 0,008256 | 0,000426 | 0,004608 | 0,004882 |
| **37-48** | 0,000025 | 0 | 0,004430 | 0,003075 | 0,003730 | 0,005279 |
| **49-60** | 0,000129 | 0,000055 | 0,008418 | 0,001819 | 0,007018 | 0,005880 |
| **61-72** | 0 | 0,000088 | 0,007732 | 0,001089 | 0,005573 | 0,006746 |
| **73-84** | 0 | 0,000162 | 0,007761 | 0,000310 | 0,004896 | 0,007256 |
| **85-96** | 0,000037 | 0,000032 | 0,008274 | 0,003270 | 0,008801 | 0,007631 |
| **97-108** | 6,48E-316 | 0,000039 | 0,008623 | 0,000812 | 0,004841 | 0,006763 |
| **109-120** | 0,000118 | 0,000022 | 0,007914 | 0,006321 | 0,006840 | 0,003725 |
| **121-132** | 0,000122 | 0 | 0,018450 | 0,003312 | 0,012951 | 0,004865 |
| **133-144** | 0,000033 | 0 | 0,020244 | 0,006746 | 0,013016 | 0,005291 |
| **145-156** | 0,000307 | 0 | 0,018388 | 0,005399 | 0,005499 | 0,008266 |
| **157-168** | 0,000307 | 0 | 0,017480 | 0,009165 | 0,003905 | 0,010522 |
| **169-180** | 0,000318 | 0 | 0,017735 | 0,010707 | 0,003847 | 0,008431 |
| **181-192** | 0,000173 | 0 | 0,019465 | 0,005627 | 0,010777 | 0,008260 |
| **193-204** | 0,000502 | 0 | 0,017999 | 0,005530 | 0,008754 | 0,005115 |
| **205-216** | 0,000423 | 0 | 0,019135 | 0,007273 | 0,015106 | 0,004152 |
| **217-228** | 0,000102 | 0 | 0,020349 | 0,002308 | 0,010582 | 0,007652 |
| **229-240** | 0,000044 | 0 | 0,020666 | 0,003955 | 0,012111 | 0,006257 |

c. Logam Cu

*Simulasi konsentrasi Cu pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 9,288E-08 | 1,283E-08 | 2,253E-06 | 3,439E-06 | 1,447E-06 | 2,778E-06 |
| **13-24** | 0 | 2,991E-07 | 4,631E-06 | 8,329E-09 | 3,573E-06 | 2,917E-06 |
| **25-36** | 1,332E-90 | 1,290E-07 | 4,628E-06 | 4,374E-07 | 3,003E-06 | 2,424E-06 |
| **37-48** | 1,565E-08 | 5,568E-09 | 2,290E-06 | 1,928E-06 | 1,676E-06 | 2,378E-06 |
| **49-60** | 1,395E-07 | 1,533E-07 | 3,777E-06 | 1,612E-06 | 3,111E-06 | 2,467E-06 |
| **61-72** | 4,177E-17 | 2,971E-07 | 2,988E-06 | 1,116E-06 | 2,767E-06 | 3,458E-06 |
| **73-84** | 0 | 3,517E-07 | 4,533E-06 | 6,047E-07 | 2,515E-06 | 3,499E-06 |
| **85-96** | 2,367E-08 | 1,122E-07 | 4,196E-06 | 1,898E-06 | 4,047E-06 | 2,585E-06 |
| **97-108** | 2,08E-284 | 1,214E-07 | 5,767E-06 | 9,693E-07 | 2,700E-06 | 2,218E-06 |
| **109-120** | 5,133E-08 | 1,246E-07 | 4,326E-06 | 3,573E-06 | 3,508E-06 | 1,590E-06 |
| **121-132** | 4,865E-08 | 1,067E-26 | 8,813E-06 | 2,059E-06 | 6,433E-06 | 2,852E-06 |
| **133-144** | 7,586E-08 | 1,30E-26 | 7,98E-06 | 4,36E-06 | 5,52E-06 | 2,78E-06 |
| **145-156** | 1,091E-07 | 2,80E-20 | 6,99E-06 | 3,364E-06 | 2,92E-06 | 4,00E-06 |
| **157-168** | 1,034E-07 | 1,17E-21 | 5,87E-06 | 4,13E-06 | 1,95E-06 | 4,89E-06 |
| **169-180** | 1,134E-07 | 8,63E-42 | 6,03E-06 | 4,86E-06 | 2,04E-06 | 4,35E-06 |
| **181-192** | 8,480E-08 | 3,760E-58 | 7,10E-06 | 3,12E-06 | 5,42E-06 | 4,74E-06 |
| **193-204** | 8,89E-08 | 1,902E-21 | 1,10E-05 | 3,09E-06 | 4,71E-06 | 2,66E-06 |
| **205-216** | 1,316E-07 | 4,492E-45 | 1,03E-05 | 3,63E-06 | 7,99E-06 | 2,27E-06 |
| **217-228** | 4,38E-08 | 3,14E-23 | 8,80E-06 | 1,36E-06 | 4,70E-06 | 4,26E-06 |
| **229-240** | 2,710E-08 | 2,438E-21 | 9,32E-06 | 2,63E-06 | 5,46E-06 | 3,48E-06 |

*Simulasi konsentrasi Cu pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 8,979E-08 | 1,248E-08 | 2,214E-06 | 3,397E-06 | 1,426E-06 | 2,714E-06 |
| **13-24** | 0 | 2,948E-07 | 4,555E-06 | 8,101E-09 | 3,503E-06 | 2,864E-06 |
| **25-36** | 2,203E-91 | 1,268E-07 | 4,550E-06 | 4,377E-07 | 2,958E-06 | 2,373E-06 |
| **37-48** | 1,492E-08 | 5,396E-09 | 2,251E-06 | 1,913E-06 | 1,652E-06 | 2,329E-06 |
| **49-60** | 1,334E-07 | 1,513E-07 | 3,707E-06 | 1,596E-06 | 3,063E-06 | 2,423E-06 |
| **61-72** | 2,213E-17 | 2,933E-07 | 2,909E-06 | 1,110E-06 | 2,707E-06 | 3,407E-06 |
| **73-84** | 0 | 3,206E-07 | 4,456E-06 | 5,993E-07 | 2,470E-06 | 3,444E-06 |
| **85-96** | 2,253E-08 | 1,101E-07 | 4,115E-06 | 1,873E-06 | 3,973E-06 | 2,531E-06 |
| **97-108** | 4,190E-289 | 1,193E-07 | 5,689E-06 | 9,677E-07 | 2,666E-06 | 2,164E-06 |
| **109-120** | 4,973E-08 | 1,224E-07 | 4,250E-06 | 3,530E-06 | 3,454E-06 | 1,563E-06 |
| **121-132** | 4,628E-08 | 1,067E-26 | 8,671E-06 | 2,041E-06 | 6,329E-06 | 2,820E-06 |
| **133-144** | 7,208E-08 | 1,30E-26 | 7,82E-06 | 4,32E-06 | 5,43E-06 | 2,75E-06 |
| **145-156** | 1,039E-07 | 2,80E-20 | 6,85E-06 | 3,326E-06 | 2,88E-06 | 3,96E-06 |
| **157-168** | 1,010E-07 | 1,17E-21 | 5,72E-06 | 4,07E-06 | 1,93E-06 | 4,84E-06 |
| **169-180** | 1,093E-07 | 8,39E-42 | 5,88E-06 | 4,78E-06 | 2,02E-06 | 4,30E-06 |
| **181-192** | 8,296E-08 | 2,66E-58 | 6,94E-06 | 3,08E-06 | 5,34E-06 | 4,69E-06 |
| **193-204** | 8,53E-08 | 1,90E-21 | 1,08E-05 | 3,06E-06 | 4,66E-06 | 2,63E-06 |
| **205-216** | 1,255E-07 | 3,47E-45 | 1,01E-05 | 3,58E-06 | 7,88E-06 | 2,24E-06 |
| **217-228** | 4,18E-08 | 3,14E-23 | 8,65E-06 | 1,34E-06 | 4,63E-06 | 4,21E-06 |
| **229-240** | 2,594E-08 | 2,43E-21 | 9,15E-06 | 2,60E-06 | 5,38E-06 | 3,43E-06 |

*Simulasi konsentrasi Cu pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 7,900E-08 | 6,866E-10 | 1,570E-06 | 3,032E-06 | 1,332E-06 | 2,366E-06 |
| **13-24** | 0 | 7,268E-08 | 3,769E-06 | 5,075E-10 | 2,869E-06 | 2,656E-06 |
| **25-36** | 1,545E-97 | 2,155E-08 | 3,765E-06 | 4,196E-07 | 2,381E-06 | 2,162E-06 |
| **37-48** | 1,123E-08 | 2,183E-10 | 1,788E-06 | 1,722E-06 | 1,551E-06 | 1,923E-06 |
| **49-60** | 4,272E-08 | 4,125E-08 | 2,964E-06 | 1,240E-06 | 2,803E-06 | 2,281E-06 |
| **61-72** | 4,477E-19 | 9,054E-08 | 2,206E-06 | 7,925E-07 | 2,384E-06 | 3,217E-06 |
| **73-84** | 0 | 1,114E-07 | 3,694E-06 | 2,431E-07 | 2,186E-06 | 3,166E-06 |
| **85-96** | 1,687E-08 | 1,703E-08 | 3,180E-06 | 1,635E-06 | 3,370E-06 | 2,331E-06 |
| **97-108** | 2,875E-320 | 2,208E-08 | 4,636E-06 | 8,376E-07 | 2,281E-06 | 1,906E-06 |
| **109-120** | 4,177E-08 | 2,035E-08 | 3,467E-06 | 3,025E-06 | 3,201E-06 | 1,476E-06 |
| **121-132** | 3,992E-08 | 3,292E-26 | 7,559E-06 | 1,876E-06 | 5,871E-06 | 2,684E-06 |
| **133-144** | 5,973E-08 | 3,98E-26 | 6,84E-06 | 3,98E-06 | 5,06E-06 | 2,62E-06 |
| **145-156** | 9,023E-08 | 5,96E-20 | 6,14E-06 | 2,982E-06 | 2,61E-06 | 3,76E-06 |
| **157-168** | 8,976E-08 | 2,70E-21 | 5,18E-06 | 3,84E-06 | 1,84E-06 | 4,50E-06 |
| **169-180** | 9,682E-08 | 5,488E-41 | 5,33E-06 | 4,51E-06 | 1,92E-06 | 4,08E-06 |
| **181-192** | 7,423E-08 | 1,184E-73 | 6,06E-06 | 2,864E-06 | 4,87E-06 | 4,45E-06 |
| **193-204** | 7,60E-08 | 4,324E-21 | 9,71E-06 | 2,78E-06 | 4,42E-06 | 2,43E-06 |
| **205-216** | 1,09E-07 | 2,179E-47 | 8,82E-06 | 3,384E-06 | 7,30E-06 | 2,14E-06 |
| **217-228** | 3,64E-08 | 7,91E-23 | 7,76E-06 | 1,26E-06 | 4,38E-06 | 4,00E-06 |
| **229-240** | 2,01E-08 | 5,507E-21 | 8,32E-06 | 2,37E-06 | 5,10E-06 | 3,27E-06 |

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*Simulasi konsentrasi Ni pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,001693 | 0,000012 | 0,005210 | 0,008333 | 0,004897 | 0,011355 |
| **13-24** | 0,002066 | 0,000232 | 0,017402 | 0,011141 | 0,016406 | 0,022079 |
| **25-36** | 0,000934 | 0,000539 | 0,026157 | 0,005992 | 0,022200 | 0,022936 |
| **37-48** | 0,000644 | 0,000371 | 0,023279 | 0,007298 | 0,019307 | 0,022150 |
| **49-60** | 0,000978 | 0,000296 | 0,024774 | 0,008367 | 0,020648 | 0,021855 |
| **61-72** | 0,001505 | 0,000438 | 0,025971 | 0,008454 | 0,023992 | 0,024028 |
| **73-84** | 0,000681 | 0,000716 | 0,026098 | 0,005934 | 0,023308 | 0,026139 |
| **85-96** | 0,000722 | 0,000918 | 0,029367 | 0,007418 | 0,026930 | 0,026953 |
| **97-108** | 0,000465 | 0,000744 | 0,034374 | 0,006700 | 0,029613 | 0,027882 |
| **109-120** | 0,001049 | 0,000598 | 0,033614 | 0,010018 | 0,027121 | 0,025307 |
| **121-132** | 0,001797 | 0,000393 | 0,042284 | 0,013406 | 0,032845 | 0,022164 |
| **133-144** | 0,001695 | 0,000178 | 0,062328 | 0,015192 | 0,041491 | 0,023356 |
| **145-156** | 0,003223 | 0 | 0,063762 | 0,020997 | 0,038271 | 0,025176 |
| **157-168** | 0,003725 | 0,000036 | 0,059224 | 0,024447 | 0,029804 | 0,033293 |
| **169-180** | 0,005307 | 0,000016 | 0,054658 | 0,028703 | 0,026821 | 0,037357 |
| **181-192** | 0,003845 | 0,000007 | 0,055745 | 0,028035 | 0,028459 | 0,037444 |
| **193-204** | 0,003751 | 0,000003 | 0,066351 | 0,023146 | 0,036689 | 0,029752 |
| **205-216** | 0,004681 | 0,000002 | 0,069055 | 0,023242 | 0,040997 | 0,025368 |
| **217-228** | 0,004103 | 0,000001 | 0,068526 | 0,020291 | 0,041646 | 0,025716 |
| **229-240** | 0,002518 | 0 | 0,073585 | 0,016373 | 0,042544 | 0,027942 |

*Simulasi konsentrasi Ni pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,001644 | 0,000011 | 0,005056 | 0,008166 | 0,004771 | 0,011045 |
| **13-24** | 0,002002 | 0,000228 | 0,016886 | 0,010913 | 0,015915 | 0,021387 |
| **25-36** | 0,000905 | 0,000529 | 0,025327 | 0,005883 | 0,021514 | 0,022237 |
| **37-48** | 0,000621 | 0,000364 | 0,022532 | 0,007174 | 0,018735 | 0,021469 |
| **49-60** | 0,000914 | 0,000291 | 0,024042 | 0,008189 | 0,020093 | 0,021197 |
| **61-72** | 0,001388 | 0,000430 | 0,025143 | 0,008293 | 0,023336 | 0,023396 |
| **73-84** | 0,000628 | 0,000701 | 0,025201 | 0,005800 | 0,022629 | 0,025483 |
| **85-96** | 0,000679 | 0,000898 | 0,028320 | 0,007256 | 0,026106 | 0,026195 |
| **97-108** | 0,000438 | 0,000728 | 0,033238 | 0,006565 | 0,028698 | 0,026944 |
| **109-120** | 0,001011 | 0,000586 | 0,032536 | 0,009825 | 0,026322 | 0,024396 |
| **121-132** | 0,001736 | 0,000385 | 0,041058 | 0,013163 | 0,032011 | 0,021555 |
| **133-144** | 0,001630 | 0,000174 | 0,060698 | 0,014944 | 0,040509 | 0,022873 |
| **145-156** | 0,003098 | 0,000079 | 0,062039 | 0,020665 | 0,037431 | 0,024728 |
| **157-168** | 0,003608 | 0,000036 | 0,057464 | 0,024016 | 0,029238 | 0,032767 |
| **169-180** | 0,005153 | 0,000016 | 0,052998 | 0,028152 | 0,026359 | 0,036787 |
| **181-192** | 0,003740 | 0,000007 | 0,053932 | 0,027488 | 0,027949 | 0,036837 |
| **193-204** | 0,003647 | 0,000003 | 0,064526 | 0,022714 | 0,036022 | 0,029263 |
| **205-216** | 0,004524 | 0,000001 | 0,067372 | 0,022815 | 0,040246 | 0,024969 |
| **217-228** | 0,003959 | 0,000001 | 0,066857 | 0,019923 | 0,040813 | 0,025285 |
| **229-240** | 0,002425 | 0 | 0,071719 | 0,016076 | 0,041693 | 0,027467 |

*Simulasi konsentrasi Ni pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,001462 | 0,000001 | 0,004145 | 0,007443 | 0,004358 | 0,010096 |
| **13-24** | 0,001780 | 0 | 0,013950 | 0,009807 | 0,014083 | 0,019310 |
| **25-36** | 0,000805 | 0,000122 | 0,021393 | 0,005329 | 0,018624 | 0,020254 |
| **37-48** | 0,000522 | 0,000076 | 0,019018 | 0,006509 | 0,016217 | 0,019385 |
| **49-60** | 0,000623 | 0,000067 | 0,020590 | 0,007050 | 0,018020 | 0,019134 |
| **61-72** | 0,000844 | 0,000115 | 0,021427 | 0,006723 | 0,021209 | 0,021614 |
| **73-84** | 0,000382 | 0,000209 | 0,021302 | 0,004393 | 0,020368 | 0,023600 |
| **85-96** | 0,000468 | 0,000264 | 0,023632 | 0,005777 | 0,023203 | 0,024053 |
| **97-108** | 0,000310 | 0,000174 | 0,027572 | 0,005318 | 0,024989 | 0,024364 |
| **109-120** | 0,000823 | 0,000124 | 0,027059 | 0,008628 | 0,023047 | 0,021842 |
| **121-132** | 0,001480 | 0,000076 | 0,035563 | 0,011705 | 0,029246 | 0,019867 |
| **133-144** | 0,001364 | 0,000034 | 0,054705 | 0,013648 | 0,037697 | 0,021478 |
| **145-156** | 0,002701 | 0,000015 | 0,056152 | 0,019097 | 0,034964 | 0,023384 |
| **157-168** | 0,003180 | 0,000007 | 0,052382 | 0,022343 | 0,027377 | 0,030968 |
| **169-180** | 0,004565 | 0,000003 | 0,048531 | 0,026513 | 0,024708 | 0,034772 |
| **181-192** | 0,003324 | 0,000001 | 0,049278 | 0,025879 | 0,026195 | 0,034858 |
| **193-204** | 0,003246 | 0,000001 | 0,059004 | 0,021264 | 0,033823 | 0,027710 |
| **205-216** | 0,004046 | 0 | 0,061684 | 0,021485 | 0,037949 | 0,023663 |
| **217-228** | 0,003538 | 0 | 0,061089 | 0,018823 | 0,038460 | 0,023965 |
| **229-240** | 0,002104 | 0 | 0,065880 | 0,015066 | 0,039379 | 0,026058 |

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*Simulasi konsentrasi As pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000139 | 0,000139 | 0,000854 | 0,001505 | 0,000754 | 0,001631 |
| **13-24** | 0 | 0,000041 | 0,002052 | 0,000001 | 0,001682 | 0,001562 |
| **25-36** | 0 | 0,000018 | 0,002097 | 0,000199 | 0,001435 | 0,001307 |
| **37-48** | 0,000026 | 0,000001 | 0,001165 | 0,000826 | 0,000929 | 0,001215 |
| **49-60** | 0,000070 | 0,000021 | 0,001768 | 0,000321 | 0,001529 | 0,001407 |
| **61-72** | 0 | 0,000043 | 0,001487 | 0,000242 | 0,001391 | 0,001965 |
| **73-84** | 0 | 0,000048 | 0,001915 | 0,000083 | 0,001284 | 0,001797 |
| **85-96** | 0,000040 | 0,000014 | 0,001883 | 0,000842 | 0,002010 | 0,001378 |
| **97-108** | 0 | 0,000015 | 0,002521 | 0,000139 | 0,001368 | 0,001006 |
| **109-120** | 0,000084 | 0,000018 | 0,001945 | 0,001568 | 0,001717 | 0,000976 |
| **121-132** | 0,000067 | 0 | 0,004610 | 0,000805 | 0,003681 | 0,001766 |
| **133-144** | 0,000106 | 0 | 0,004421 | 0,001955 | 0,003138 | 0,001695 |
| **145-156** | 0,000141 | 0 | 0,003886 | 0,001622 | 0,001817 | 0,002312 |
| **157-168** | 0,000166 | 0 | 0,003589 | 0,002187 | 0,001373 | 0,002644 |
| **169-180** | 0,000154 | 0 | 0,003474 | 0,002788 | 0,001407 | 0,002545 |
| **181-192** | 0,000143 | 0 | 0,004076 | 0,001621 | 0,002898 | 0,002803 |
| **193-204** | 0,000093 | 0 | 0,005430 | 0,001044 | 0,002735 | 0,001506 |
| **205-216** | 0,000159 | 0 | 0,005106 | 0,002044 | 0,004250 | 0,001468 |
| **217-228** | 0,000063 | 0 | 0,004802 | 0,000717 | 0,002814 | 0,002547 |
| **229-240** | 0,000046 | 0 | 0,004885 | 0,001308 | 0,003218 | 0,002114 |

*Simulasi konsentrasi As pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000135 | 0,000002 | 0,000830 | 0,001478 | 0,000738 | 0,001586 |
| **13-24** | 0 | 0,000040 | 0,001999 | 0,000001 | 0,001634 | 0,001526 |
| **25-36** | 0 | 0,000018 | 0,002042 | 0,000198 | 0,001404 | 0,001270 |
| **37-48** | 0,000025 | 0,000001 | 0,001139 | 0,000814 | 0,000911 | 0,001181 |
| **49-60** | 0,000064 | 0,000021 | 0,001720 | 0,000310 | 0,001497 | 0,001378 |
| **61-72** | 0 | 0,000042 | 0,001430 | 0,000239 | 0,001348 | 0,001931 |
| **73-84** | 0 | 0,000047 | 0,001861 | 0,000082 | 0,001251 | 0,001759 |
| **85-96** | 0,000038 | 0,000014 | 0,001828 | 0,000825 | 0,001962 | 0,001343 |
| **97-108** | 0 | 0,000015 | 0,002469 | 0,000139 | 0,001343 | 0,000970 |
| **109-120** | 0,000081 | 0,000017 | 0,001892 | 0,001539 | 0,001680 | 0,000958 |
| **121-132** | 0,000065 | 0 | 0,004510 | 0,000793 | 0,003609 | 0,001744 |
| **133-144** | 0,000102 | 0 | 0,004309 | 0,001924 | 0,003077 | 0,001674 |
| **145-156** | 0,000136 | 0 | 0,003784 | 0,001596 | 0,001792 | 0,002282 |
| **157-168** | 0,000163 | 0 | 0,003485 | 0,002146 | 0,001357 | 0,002609 |
| **169-180** | 0,000149 | 0 | 0,003371 | 0,002736 | 0,001390 | 0,002512 |
| **181-192** | 0,000140 | 0 | 0,003954 | 0,001592 | 0,002844 | 0,002766 |
| **193-204** | 0,000090 | 0 | 0,005336 | 0,001029 | 0,002701 | 0,001485 |
| **205-216** | 0,000153 | 0 | 0,005002 | 0,002008 | 0,004175 | 0,001451 |
| **217-228** | 0,000061 | 0 | 0,004692 | 0,000705 | 0,002766 | 0,002512 |
| **229-240** | 0,000044 | 0 | 0,004993 | 0,001285 | 0,003164 | 0,002087 |

*Simulasi konsentrasi As pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000121 | 0 | 0,000708 | 0,001376 | 0,000683 | 0,001459 |
| **13-24** | 0 | 0,000010 | 0,001782 | 0 | 0,001445 | 0,001423 |
| **25-36** | 0 | 0,000003 | 0,001826 | 0,000191 | 0,001246 | 0,001162 |
| **37-48** | 0,000019 | 0 | 0,001042 | 0,000756 | 0,000850 | 0,001059 |
| **49-60** | 0,000038 | 0,000006 | 0,001544 | 0,000237 | 0,001396 | 0,001298 |
| **61-72** | 0 | 0,000013 | 0,001237 | 0,000185 | 0,001221 | 0,001826 |
| **73-84** | 0 | 0,000015 | 0,001660 | 0,000033 | 0,001138 | 0,001636 |
| **85-96** | 0,000029 | 0,000002 | 0,001620 | 0,000759 | 0,001795 | 0,001245 |
| **97-108** | 0 | 0,000003 | 0,002231 | 0,000120 | 0,001227 | 0,000864 |
| **109-120** | 0,000068 | 0,000003 | 0,001687 | 0,001416 | 0,001577 | 0,000907 |
| **121-132** | 0,000058 | 0 | 0,004175 | 0,000748 | 0,003413 | 0,001663 |
| **133-144** | 0,000086 | 0 | 0,003995 | 0,001812 | 0,002909 | 0,001597 |
| **145-156** | 0,000121 | 0 | 0,003507 | 0,001493 | 0,001694 | 0,002173 |
| **157-168** | 0,000145 | 0 | 0,003245 | 0,002037 | 0,001288 | 0,002475 |
| **169-180** | 0,000134 | 0 | 0,003131 | 0,002598 | 0,001319 | 0,002392 |
| **181-192** | 0,000125 | 0 | 0,003636 | 0,001506 | 0,002664 | 0,002630 |
| **193-204** | 0,000081 | 0 | 0,004980 | 0,000957 | 0,002578 | 0,001411 |
| **205-216** | 0,000137 | 0 | 0,004634 | 0,001910 | 0,003964 | 0,001387 |
| **217-228** | 0,000055 | 0 | 0,004386 | 0,000671 | 0,002630 | 0,002390 |
| **229-240** | 0,000034 | 0 | 0,004670 | 0,001203 | 0,003008 | 0,001987 |

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*Simulasi konsentrasi Pb pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,001303 | 0,000031 | 0,009498 | 0,012772 | 0,008904 | 0,019004 |
| **13-24** | 0,000633 | 0,000556 | 0,023149 | 0,000030 | 0,019477 | 0,017536 |
| **25-36** | 0 | 0,000404 | 0,030850 | 0,001397 | 0,021266 | 0,014965 |
| **37-48** | 0,000293 | 0,000019 | 0,016304 | 0,006635 | 0,011774 | 0,013663 |
| **49-60** | 0,000842 | 0,000290 | 0,024779 | 0,006864 | 0,017349 | 0,014308 |
| **61-72** | 0,000399 | 0,000438 | 0,028962 | 0,003940 | 0,017492 | 0,021029 |
| **73-84** | 0 | 0,000769 | 0,025643 | 0,001733 | 0,018597 | 0,021407 |
| **85-96** | 0,000418 | 0,000309 | 0,028760 | 0,006302 | 0,024312 | 0,021991 |
| **97-108** | 0 | 0,000336 | 0,035767 | 0,002796 | 0,020291 | 0,018416 |
| **109-120** | 0,000765 | 0,000301 | 0,035926 | 0,011563 | 0,022016 | 0,012642 |
| **121-132** | 0,001075 | 0 | 0,081071 | 0,006683 | 0,048771 | 0,021600 |
| **133-144** | 0,000638 | 0 | 0,096171 | 0,015877 | 0,044769 | 0,019309 |
| **145-156** | 0,002172 | 0 | 0,082322 | 0,018478 | 0,027838 | 0,026393 |
| **157-168** | 0,002067 | 0 | 0,081557 | 0,018330 | 0,020237 | 0,034796 |
| **169-180** | 0,002521 | 0 | 0,076504 | 0,021805 | 0,021938 | 0,033824 |
| **181-192** | 0,001712 | 0 | 0,093667 | 0,014766 | 0,033823 | 0,036755 |
| **193-204** | 0,001235 | 0 | 0,096050 | 0,016137 | 0,034465 | 0,018814 |
| **205-216** | 0,003034 | 0 | 0,098703 | 0,014508 | 0,065909 | 0,018725 |
| **217-228** | 0,000780 | 0 | 0,097362 | 0,005422 | 0,043553 | 0,028654 |
| **229-240** | 0,000533 | 0 | 0,104743 | 0,008893 | 0,047640 | 0,026255 |

*Simulasi konsentrasi Pb pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,001266 | 3,051E-05 | 0,009153 | 0,0124263 | 0,008669 | 0,0182098 |
| **13-24** | 6,08E-04 | 0,000547 | 0,022591 | 2,8864E-05 | 0,018768 | 0,0169352 |
| **25-36** | 1,29E-86 | 0,000398 | 0,029897 | 0,0013893 | 0,020633 | 0,0146481 |
| **37-48** | 0,00027 | 1,873E-05 | 0,015880 | 0,0065340 | 0,011387 | 0,0133626 |
| **49-60** | 0,00079 | 0,000285 | 0,024062 | 0,0066588 | 0,017017 | 0,0140029 |
| **61-72** | 3,39E-04 | 0,000428 | 0,028275 | 0,0038780 | 0,017176 | 0,0206312 |
| **73-84** | 0 | 0,000751 | 0,001718 | 0,0017185 | 0,017948 | 0,0210312 |
| **85-96** | 0,00039 | 0,000302 | 0,027786 | 0,0061211 | 0,023607 | 0,0211427 |
| **97-108** | 2,43E-284 | 0,000329 | 0,034756 | 0,0027783 | 0,019756 | 0,0175420 |
| **109-120** | 0,00073 | 0,000295 | 0,034563 | 0,0112722 | 0,021594 | 0,0123322 |
| **121-132** | 1,04E-03 | 6,828E-24 | 0,078820 | 0,006575 | 0,047861 | 0,0210803 |
| **133-144** | 0,000608 | 9,71E-24 | 0,092941 | 1,57E-02 | 0,043903 | 0,0188543 |
| **145-156** | 2,08E-03 | 2,11E-17 | 0,079427 | 0,0182971 | 0,027254 | 0,0258328 |
| **157-168** | 2,01E-03 | 8,80E-19 | 0,078549 | 1,80E-02 | 0,019755 | 3,41E-02 |
| **169-180** | 2,45E-03 | 8,89E-39 | 0,073609 | 0,0213954 | 0,021513 | 0,0329383 |
| **181-192** | 0,001677 | 9,28E-55 | 0,090133 | 0,0144328 | 0,033186 | 0,0357485 |
| **193-204** | 1,20E-03 | 1,43E-18 | 0,093356 | 0,0158477 | 0,033607 | 1,85E-02 |
| **205-216** | 2,91E-03 | 1,31E-41 | 0,095706 | 1,42E-02 | 0,064511 | 0,0182451 |
| **217-228** | 0,00075 | 2,35E-20 | 0,094170 | 0,005369 | 0,042445 | 2,81E-02 |
| **229-240** | 0,00051 | 1,83E-18 | 0,100312 | 0,008672 | 0,046625 | 2,57E-02 |

*Simulasi konsentrasi Pb pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,001126 | 1,679E-06 | 0,007039 | 0,011094 | 0,007761 | 0,016146 |
| **13-24** | 5,33E-04 | 0,000127 | 0,017586 | 1,834E-06 | 0,016084 | 0,015416 |
| **25-36** | 9,06E-93 | 7,476E-05 | 0,022543 | 0,001309 | 0,017209 | 0,013558 |
| **37-48** | 0,000207 | 0,000001 | 0,011656 | 0,005863 | 0,009874 | 0,012212 |
| **49-60** | 0,000366 | 0,000074 | 0,018804 | 0,005053 | 0,015700 | 0,012666 |
| **61-72** | 0,000277 | 0,000125 | 0,021834 | 0,002586 | 0,015728 | 0,019212 |
| **73-84** | 0 | 0,000237 | 0,019552 | 0,000837 | 0,015566 | 0,019632 |
| **85-96** | 0,000283 | 0,000049 | 0,020597 | 0,005190 | 0,019943 | 0,019341 |
| **97-108** | 1.66E-314 | 0 | 0,025929 | 0,002355 | 0,017581 | 0,015360 |
| **109-120** | 0,000595 | 0,000051 | 0,026493 | 0,009893 | 0,019159 | 0,011382 |
| **121-132** | 0,000920 | 0 | 0,066809 | 0,006029 | 0,043527 | 0,020001 |
| **133-144** | 0,000482 | 0 | 0,084613 | 0,014041 | 0,040753 | 0,017925 |
| **145-156** | 0,001836 | 0 | 0,072230 | 0,016123 | 0,025621 | 0,024538 |
| **157-168** | 0,001774 | 0 | 0,072161 | 0,016698 | 0,018487 | 0,032090 |
| **169-180** | 0,002128 | 0 | 0,066891 | 0,019995 | 0,020098 | 0,031176 |
| **181-192** | 0,001527 | 0 | 0,082052 | 0,013213 | 0,031210 | 0,033656 |
| **193-204** | 0,001050 | 0 | 0,084818 | 0,014321 | 0,031476 | 0,017607 |
| **205-216** | 0,002586 | 0 | 0,086462 | 0,013266 | 0,060599 | 0,017417 |
| **217-228** | 0,000666 | 0 | 0,086325 | 0,004993 | 0,040014 | 0,026744 |
| **229-240** | 0,000397 | 0 | 0,093016 | 0,007919 | 0,043993 | 0,024511 |

b. Logam Cr

*Simulasi konsentrasi Cr pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000347 | 0,000023 | 0,005894 | 0,008330 | 0,004775 | 0,010850 |
| **13-24** | 0 | 0,000390 | 0,009609 | 0,000010 | 0,008214 | 0,007627 |
| **25-36** | 0 | 0,000140 | 0,009817 | 0,000444 | 0,005679 | 0,005594 |
| **37-48** | 0,000036 | 0,000007 | 0,005355 | 0,003461 | 0,004112 | 0,006303 |
| **49-60** | 0,000329 | 0,000203 | 0,010085 | 0,002495 | 0,007902 | 0,006517 |
| **61-72** | 0 | 0,000296 | 0,009385 | 0,001496 | 0,006503 | 0,007391 |
| **73-84** | 0 | 0,000514 | 0,009620 | 0,000783 | 0,005779 | 0,008225 |
| **85-96** | 0,000051 | 0,000208 | 0,010645 | 0,003826 | 0,010629 | 0,008738 |
| **97-108** | 0 | 0,000214 | 0,010902 | 0,000938 | 0,005900 | 0,005900 |
| **109-120** | 0,000144 | 0,000137 | 0,009592 | 0,007293 | 0,007642 | 0,004073 |
| **121-132** | 0,000160 | 0 | 0,020903 | 0,003662 | 0,014230 | 0,005211 |
| **133-144** | 0,000243 | 0 | 0,022913 | 0,007483 | 0,014338 | 0,005677 |
| **145-156** | 0,000391 | 0 | 0,020745 | 0,006008 | 0,006032 | 0,008891 |
| **157-168** | 0,000313 | 0 | 0,019729 | 0,010031 | 0,004186 | 0,011498 |
| **169-180** | 0,000384 | 0 | 0,019974 | 0,010849 | 0,004139 | 0,009066 |
| **181-192** | 0,000197 | 0 | 0,022157 | 0,006175 | 0,012052 | 0,008926 |
| **193-204** | 0,000601 | 0 | 0,020149 | 0,006083 | 0,009381 | 0,005556 |
| **205-216** | 0,000529 | 0 | 0,021796 | 0,007939 | 0,016559 | 0,004439 |
| **217-228** | 0,000133 | 0 | 0,022764 | 0,002521 | 0,011574 | 0,008263 |
| **229-240** | 0,000059 | 0 | 0,023079 | 0,004431 | 0,013171 | 0,006724 |

*Simulasi konsentrasi Cr pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000329 | 0,000022 | 0,005693 | 0,008131 | 0,004628 | 0,010403 |
| **13-24** | 0 | 0,000384 | 0,009265 | 0,000009 | 0,007872 | 0,007356 |
| **25-36** | 0 | 0,000138 | 0,009487 | 0,000445 | 0,005499 | 0,005372 |
| **37-48** | 0,000034 | 0,000007 | 0,005203 | 0,003408 | 0,003991 | 0,006048 |
| **49-60** | 0,000301 | 0,000200 | 0,009741 | 0,002414 | 0,007647 | 0,006292 |
| **61-72** | 0 | 0,000291 | 0,009010 | 0,001486 | 0,006234 | 0,007174 |
| **73-84** | 0 | 0,000505 | 0,009243 | 0,000776 | 0,005553 | 0,007938 |
| **85-96** | 0,000049 | 0,000204 | 0,010227 | 0,003737 | 0,010227 | 0,008372 |
| **97-108** | 0 | 0,000210 | 0,010550 | 0,000937 | 0,005716 | 0,007729 |
| **109-120** | 0,000140 | 0,000134 | 0,009255 | 0,007116 | 0,007395 | 0,003947 |
| **121-132** | 0,000149 | 0 | 0,020284 | 0,003595 | 0,013814 | 0,005100 |
| **133-144** | 0,000228 | 0 | 0,022136 | 0,007322 | 0,013883 | 0,005554 |
| **145-156** | 0,000367 | 0 | 0,019987 | 0,005875 | 0,005900 | 0,008694 |
| **157-168** | 0,000306 | 0 | 0,018984 | 0,009742 | 0,004105 | 0,011246 |
| **169-180** | 0,000367 | 0 | 0,019209 | 0,011402 | 0,004058 | 0,008865 |
| **181-192** | 0,000193 | 0 | 0,021331 | 0,006010 | 0,011699 | 0,008718 |
| **193-204** | 0,000572 | 0 | 0,019632 | 0,005953 | 0,009192 | 0,005434 |
| **205-216** | 0,000499 | 0 | 0,021157 | 0,007724 | 0,016106 | 0,004345 |
| **217-228** | 0,000124 | 0 | 0,022026 | 0,002455 | 0,011232 | 0,008070 |
| **229-240** | 0,000056 | 0 | 0,022332 | 0,004316 | 0,012805 | 0,006574 |

*Simulasi konsentrasi Cr pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 0,000278 | 0,000001 | 0,004408 | 0,007381 | 0,004309 | 0,009331 |
| **13-24** | 0 | 0,000094 | 0,007817 | 0,000001 | 0,006584 | 0,006799 |
| **25-36** | 0 | 0,000024 | 0,008256 | 0,000426 | 0,004608 | 0,004882 |
| **37-48** | 0,000025 | 0 | 0,004430 | 0,003075 | 0,003730 | 0,005279 |
| **49-60** | 0,000129 | 0,000055 | 0,008418 | 0,001819 | 0,007018 | 0,005880 |
| **61-72** | 0 | 0,000088 | 0,007732 | 0,001089 | 0,005573 | 0,006746 |
| **73-84** | 0 | 0,000162 | 0,007761 | 0,000310 | 0,004896 | 0,007256 |
| **85-96** | 0,000037 | 0,000032 | 0,008274 | 0,003270 | 0,008801 | 0,007631 |
| **97-108** | 6.4E-316 | 0,000039 | 0,008623 | 0,000812 | 0,004841 | 0,006763 |
| **109-120** | 0,000118 | 0,000022 | 0,007914 | 0,006321 | 0,006840 | 0,003725 |
| **121-132** | 0,000122 | 0 | 0,018450 | 0,003312 | 0,012951 | 0,004865 |
| **133-144** | 0,000184 | 0 | 0,020244 | 0,006746 | 0,013016 | 0,005291 |
| **145-156** | 0,000307 | 0 | 0,018388 | 0,005399 | 0,005499 | 0,008266 |
| **157-168** | 0,000270 | 0 | 0,017480 | 0,009165 | 0,003905 | 0,010522 |
| **169-180** | 0,000318 | 0 | 0,017735 | 0,010707 | 0,003847 | 0,008431 |
| **181-192** | 0,000173 | 0 | 0,019465 | 0,005627 | 0,010777 | 0,008260 |
| **193-204** | 0,000502 | 0 | 0,017999 | 0,005530 | 0,008754 | 0,005115 |
| **205-216** | 0,000423 | 0 | 0,019135 | 0,007273 | 0,015106 | 0,004152 |
| **217-228** | 0,000102 | 0 | 0,020349 | 0,002308 | 0,010582 | 0,007652 |
| **229-240** | 0,000044 | 0 | 0,020666 | 0,003955 | 0,012111 | 0,006257 |

c. Logam Cu

*Simulasi konsentrasi Cu pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 9,28E-08 | 1,28E-08 | 2,25E-06 | 3,43E-06 | 1,44E-06 | 2,77E-06 |
| **13-24** | 0 | 2,991E-07 | 4,631E-06 | 8,329E-09 | 3,573E-06 | 2,917E-06 |
| **25-36** | 1,332E-90 | 1,290E-07 | 4,628E-06 | 4,374E-07 | 3,003E-06 | 2,424E-06 |
| **37-48** | 1,565E-08 | 5,568E-09 | 2,290E-06 | 1,928E-06 | 1,676E-06 | 2,378E-06 |
| **49-60** | 1,395E-07 | 1,533E-07 | 3,777E-06 | 1,612E-06 | 3,111E-06 | 2,467E-06 |
| **61-72** | 4,177E-17 | 2,971E-07 | 2,988E-06 | 1,116E-06 | 2,767E-06 | 3,458E-06 |
| **73-84** | 0 | 3,517E-07 | 4,533E-06 | 6,047E-07 | 2,515E-06 | 3,499E-06 |
| **85-96** | 2,367E-08 | 1,122E-07 | 4,196E-06 | 1,898E-06 | 4,047E-06 | 2,585E-06 |
| **97-108** | 2,08E-284 | 1,214E-07 | 5,767E-06 | 9,693E-07 | 2,700E-06 | 2,218E-06 |
| **109-120** | 5,133E-08 | 1,246E-07 | 4,326E-06 | 3,573E-06 | 3,508E-06 | 1,590E-06 |
| **121-132** | 4,865E-08 | 1,067E-26 | 8,813E-06 | 2,059E-06 | 6,433E-06 | 2,852E-06 |
| **133-144** | 7,586E-08 | 1,30E-26 | 7,98E-06 | 4,36E-06 | 5,52E-06 | 2,78E-06 |
| **145-156** | 1,091E-07 | 2,80E-20 | 6,99E-06 | 3,36E-06 | 2,92E-06 | 4,00E-06 |
| **157-168** | 1,034E-07 | 1,17E-21 | 5,87E-06 | 4,13E-06 | 1,95E-06 | 4,89E-06 |
| **169-180** | 1,134E-07 | 8,63E-42 | 6,03E-06 | 4,86E-06 | 2,04E-06 | 4,35E-06 |
| **181-192** | 8,480E-08 | 3,76E-58 | 7,10E-06 | 3,12E-06 | 5,42E-06 | 4,74E-06 |
| **193-204** | 8,89E-08 | 1,90E-21 | 1,10E-05 | 3,09E-06 | 4,71E-06 | 2,66E-06 |
| **205-216** | 1,31E-07 | 4,49E-45 | 1,03E-05 | 3,63E-06 | 7,99E-06 | 2,27E-06 |
| **217-228** | 4,38E-08 | 3,14E-23 | 8,80E-06 | 1,36E-06 | 4,70E-06 | 4,26E-06 |
| **229-240** | 2,71E-08 | 2,43E-21 | 9,32E-06 | 2,63E-06 | 5,46E-06 | 3,48E-06 |

*Simulasi konsentrasi Cu pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 8,979E-08 | 1,248E-08 | 2,214E-06 | 3,397E-06 | 1,426E-06 | 2,714E-06 |
| **13-24** | 0 | 2,948E-07 | 4,555E-06 | 8,101E-09 | 3,503E-06 | 2,864E-06 |
| **25-36** | 2,203E-91 | 1,268E-07 | 4,550E-06 | 4,377E-07 | 2,958E-06 | 2,373E-06 |
| **37-48** | 1,492E-08 | 5,396E-09 | 2,251E-06 | 1,913E-06 | 1,652E-06 | 2,329E-06 |
| **49-60** | 1,334E-07 | 1,513E-07 | 3,707E-06 | 1,596E-06 | 3,063E-06 | 2,423E-06 |
| **61-72** | 2,213E-17 | 2,933E-07 | 2,909E-06 | 1,110E-06 | 2,707E-06 | 3,407E-06 |
| **73-84** | 0 | 3,473E-07 | 4,456E-06 | 5,993E-07 | 2,470E-06 | 3,444E-06 |
| **85-96** | 2,253E-08 | 1,101E-07 | 4,115E-06 | 1,873E-06 | 3,973E-06 | 2,531E-06 |
| **97-108** | 4,19E-289 | 1,193E-07 | 5,689E-06 | 9,677E-07 | 2,666E-06 | 2,164E-06 |
| **109-120** | 4,973E-08 | 1,224E-07 | 4,250E-06 | 3,530E-06 | 3,454E-06 | 1,563E-06 |
| **121-132** | 4,628E-08 | 1,067E-26 | 8,671E-06 | 2,041E-06 | 6,329E-06 | 2,820E-06 |
| **133-144** | 7,208E-08 | 1,30E-26 | 7,82E-06 | 4,32E-06 | 5,43E-06 | 2,75E-06 |
| **145-156** | 1,039E-07 | 2,80E-20 | 6,85E-06 | 3,326E-06 | 2,88E-06 | 3,96E-06 |
| **157-168** | 1,010E-07 | 1,17E-21 | 5,72E-06 | 4,07E-06 | 1,93E-06 | 4,84E-06 |
| **169-180** | 1,093E-07 | 8,39E-42 | 5,88E-06 | 4,78E-06 | 2,02E-06 | 4,30E-06 |
| **181-192** | 8,296E-08 | 2,66E-58 | 6,94E-06 | 3,08E-06 | 5,34E-06 | 4,69E-06 |
| **193-204** | 8,53E-08 | 1,90E-21 | 1,08E-05 | 3,06E-06 | 4,66E-06 | 2,63E-06 |
| **205-216** | 1,25E-07 | 3,47E-45 | 1,01E-05 | 3,58E-06 | 7,88E-06 | 2,24E-06 |
| **217-228** | 4,18E-08 | 3,14E-23 | 8,65E-06 | 1,34E-06 | 4,63E-06 | 4,21E-06 |
| **229-240** | 2,594E-08 | 2,43E-21 | 9,15E-06 | 2,60E-06 | 5,38E-06 | 3,43E-06 |

*Simulasi konsentrasi Cu pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 7,900E-08 | 6,866E-10 | 1,570E-06 | 3,032E-06 | 1,332E-06 | 2,366E-06 |
| **13-24** | 0 | 7,268E-08 | 3,769E-06 | 5,075E-10 | 2,869E-06 | 2,656E-06 |
| **25-36** | 1,545E-97 | 2,155E-08 | 3,765E-06 | 4,196E-07 | 2,381E-06 | 2,162E-06 |
| **37-48** | 1,123E-08 | 2,183E-10 | 1,788E-06 | 1,722E-06 | 1,551E-06 | 1,923E-06 |
| **49-60** | 4,272E-08 | 4,125E-08 | 2,964E-06 | 1,240E-06 | 2,803E-06 | 2,281E-06 |
| **61-72** | 4,477E-19 | 9,054E-08 | 2,206E-06 | 7,925E-07 | 2,384E-06 | 3,217E-06 |
| **73-84** | 0 | 1,114E-07 | 3,694E-06 | 2,431E-07 | 2,186E-06 | 3,166E-06 |
| **85-96** | 1,687E-08 | 1,703E-08 | 3,180E-06 | 1,635E-06 | 3,370E-06 | 2,331E-06 |
| **97-108** | 2.875E-320 | 2,208E-08 | 4,636E-06 | 8,376E-07 | 2,281E-06 | 1,906E-06 |
| **109-120** | 4,177E-08 | 2,035E-08 | 3,467E-06 | 3,025E-06 | 3,201E-06 | 1,476E-06 |
| **121-132** | 3,992E-08 | 3,292E-26 | 7,559E-06 | 1,876E-06 | 5,871E-06 | 2,684E-06 |
| **133-144** | 5,973E-08 | 3,98E-26 | 6,84E-06 | 3,98E-06 | 5,06E-06 | 2,62E-06 |
| **145-156** | 9,023E-08 | 5,96E-20 | 6,14E-06 | 2,982E-06 | 2,61E-06 | 3,76E-06 |
| **157-168** | 8,976E-08 | 2,70E-21 | 5,18E-06 | 3,84E-06 | 1,84E-06 | 4,50E-06 |
| **169-180** | 9,682E-08 | 5,488E-41 | 5,33E-06 | 4,516E-06 | 1,92E-06 | 4,08E-06 |
| **181-192** | 7,423E-08 | 1,184E-73 | 6,06E-06 | 2,864E-06 | 4,87E-06 | 4,45E-06 |
| **193-204** | 7,60E-08 | 4,324E-21 | 9,71E-06 | 2,78E-06 | 4,42E-06 | 2,43E-06 |
| **205-216** | 1,095E-07 | 2,179E-47 | 8,82E-06 | 3,384E-06 | 7,30E-06 | 2,14E-06 |
| **217-228** | 3,64E-08 | 7,91E-23 | 7,76E-06 | 1,26E-06 | 4,38E-06 | 4,00E-06 |
| **229-240** | 2,01E-08 | 5,50E-21 | 8,32E-06 | 2,37E-06 | 5,10E-06 | 3,27E-06 |

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*Simulasi konsentrasi Ni pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 5,82E-06 | 3,36E-08 | 1,75E-05 | 2,82E-05 | 1,56E-05 | 3,83E-05 |
| **13-24** | 8,83E-06 | 7,12E-07 | 6,52E-05 | 4,76E-05 | 6,21E-05 | 8,70E-05 |
| **25-36** | 3,99E-06 | 2,20E-06 | 1,03E-04 | 2,48E-05 | 8,89E-05 | 9,25E-05 |
| **37-48** | 2,56E-06 | 1,58E-06 | 9,51E-05 | 2,77E-05 | 7,83E-05 | 8,89E-05 |
| **49-60** | 3,39E-06 | 1,12E-06 | 9,70E-05 | 3,33E-05 | 8,05E-05 | 8,70E-05 |
| **61-72** | 6,43E-06 | 1,67E-06 | 1,05E-04 | 3,47E-05 | 9,61E-05 | 9,51E-05 |
| **73-84** | 2,91E-06 | 2,69E-06 | 1,03E-04 | 2,48E-05 | 9,33E-05 | 1,04E-04 |
| **85-96** | 2,81E-06 | 3,77E-06 | 1,16E-04 | 2,84E-05 | 1,05E-04 | 1,07E-04 |
| **97-108** | 1,99E-06 | 3,02E-06 | 1,36E-04 | 2,80E-05 | 1,20E-04 | 1,12E-04 |
| **109-120** | 3,68E-06 | 2,46E-06 | 1,36E-04 | 3,67E-05 | 1,09E-04 | 1,04E-04 |
| **121-132** | 7,21E-06 | 1,68E-06 | 1,61E-04 | 5,45E-05 | 1,28E-04 | 8,90E-05 |
| **133-144** | 6,50E-06 | 7,59E-07 | 2,46E-04 | 5,86E-05 | 1,65E-04 | 9,34E-05 |
| **145-156** | 1,27E-05 | 3,43E-07 | 2,56E-04 | 8,32E-05 | 1,56E-04 | 9,82E-05 |
| **157-168** | 1,42E-05 | 1,55E-07 | 2,39E-04 | 9,59E-05 | 1,21E-04 | 1,30E-04 |
| **169-180** | 2,15E-05 | 7,02E-08 | 2,20E-04 | 1,13E-04 | 1,08E-04 | 1,50E-04 |
| **181-192** | 1,54E-05 | 3,17E-08 | 2,21E-04 | 1,14E-04 | 1,10E-04 | 1,50E-04 |
| **193-204** | 1,47E-05 | 1,44E-08 | 2,63E-04 | 9,36E-05 | 1,47E-04 | 1,22E-04 |
| **205-216** | 1,88E-05 | 6,49E-09 | 2,75E-04 | 9,27E-05 | 1,61E-04 | 1,03E-04 |
| **217-228** | 1,71E-05 | 2,94E-09 | 2,73E-04 | 8,47E-05 | 1,66E-04 | 1,00E-04 |
| **229-240** | 1,04E-05 | 1,33E-09 | 2,94E-04 | 6,61E-05 | 1,69E-04 | 1,12E-04 |

*Simulasi konsentrasi Ni pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 5,65E-06 | 3,26E-08 | 1,70E-05 | 2,76E-05 | 1,52E-05 | 3,73E-05 |
| **13-24** | 8,56E-06 | 6,98E-07 | 6,33E-05 | 4,66E-05 | 6,03E-05 | 8,42E-05 |
| **25-36** | 3,87E-06 | 2,16E-06 | 1,00E-04 | 2,44E-05 | 8,62E-05 | 8,97E-05 |
| **37-48** | 2,47E-06 | 1,55E-06 | 9,20E-05 | 2,72E-05 | 7,60E-05 | 8,62E-05 |
| **49-60** | 3,18E-06 | 1,10E-06 | 9,41E-05 | 3,26E-05 | 7,83E-05 | 8,44E-05 |
| **61-72** | 5,93E-06 | 1,64E-06 | 1,01E-04 | 3,38E-05 | 9,35E-05 | 9,26E-05 |
| **73-84** | 2,68E-06 | 2,63E-06 | 9,97E-05 | 2,42E-05 | 9,06E-05 | 1,01E-04 |
| **85-96** | 2,64E-06 | 3,69E-06 | 1,12E-04 | 2,78E-05 | 1,02E-04 | 1,04E-04 |
| **97-108** | 1,87E-06 | 2,96E-06 | 1,32E-04 | 2,74E-05 | 1,16E-04 | 1,08E-04 |
| **109-120** | 3,55E-06 | 2,41E-06 | 1,32E-04 | 3,60E-05 | 1,06E-04 | 1,00E-04 |
| **121-132** | 6,97E-06 | 1,65E-06 | 1,56E-04 | 5,35E-05 | 1,24E-04 | 8,65E-05 |
| **133-144** | 6,25E-06 | 7,45E-07 | 2,39E-04 | 5,76E-05 | 1,61E-04 | 9,14E-05 |
| **145-156** | 1,23E-05 | 3,37E-07 | 2,50E-04 | 8,19E-05 | 1,52E-04 | 9,65E-05 |
| **157-168** | 1,37E-05 | 1,52E-07 | 2,32E-04 | 9,42E-05 | 1,19E-04 | 1,28E-04 |
| **169-180** | 2,09E-05 | 6,88E-08 | 2,13E-04 | 1,11E-04 | 1,07E-04 | 1,48E-04 |
| **181-192** | 1,49E-05 | 3,11E-08 | 2,14E-04 | 1,12E-04 | 1,08E-04 | 1,48E-04 |
| **193-204** | 1,43E-05 | 1,41E-08 | 2,56E-04 | 9,18E-05 | 1,44E-04 | 1,20E-04 |
| **205-216** | 1,82E-05 | 6,37E-09 | 2,68E-04 | 9,10E-05 | 1,58E-04 | 1,02E-04 |
| **217-228** | 1,65E-05 | 2,66E-04 | 2,66E-04 | 8,32E-05 | 1,63E-04 | 9,87E-05 |
| **229-240** | 1,01E-05 | 1,30E-09 | 2,87E-04 | 6,49E-05 | 1,66E-04 | 1,10E-04 |

*Simulasi konsentrasi Ni pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 5,02E-06 | 1,80E-09 | 1,42E-05 | 2,52E-05 | 1,40E-05 | 3,43E-05 |
| **13-24** | 7,61E-06 | 1,45E-07 | 5,22E-05 | 4,19E-05 | 5,36E-05 | 7,59E-05 |
| **25-36** | 3,44E-06 | 5,03E-07 | 8,43E-05 | 2,20E-05 | 7,46E-05 | 8,17E-05 |
| **37-48** | 2,10E-06 | 3,25E-07 | 7,77E-05 | 7,77E-05 | 6,56E-05 | 7,80E-05 |
| **49-60** | 2,24E-06 | 2,49E-07 | 8,05E-05 | 2,84E-05 | 7,00E-05 | 7,60E-05 |
| **61-72** | 3,61E-06 | 4,29E-07 | 8,64E-05 | 8,57E-05 | 8,50E-05 | 8,54E-05 |
| **73-84** | 1,63E-06 | 7,77E-07 | 8,44E-05 | 1,86E-05 | 8,17E-05 | 9,38E-05 |
| **85-96** | 1,80E-06 | 1,11E-06 | 9,38E-05 | 2,19E-05 | 9,07E-05 | 9,55E-05 |
| **97-108** | 1,33E-06 | 7,15E-07 | 1,09E-04 | 2,22E-05 | 1,01E-04 | 9,78E-05 |
| **109-120** | 2,86E-06 | 5,15E-07 | 1,09E-04 | 3,15E-05 | 9,23E-05 | 8,97E-05 |
| **121-132** | 5,92E-06 | 3,24E-07 | 1,34E-04 | 4,74E-05 | 1,13E-04 | 7,96E-05 |
| **133-144** | 5,23E-06 | 1,46E-07 | 2,16E-04 | 5,25E-05 | 1,50E-04 | 8,58E-05 |
| **145-156** | 1,07E-05 | 6,61E-08 | 2,26E-04 | 7,57E-05 | 1,42E-04 | 9,12E-05 |
| **157-168** | 1,21E-05 | 2,99E-08 | 2,11E-04 | 8,75E-05 | 1,12E-04 | 1,21E-04 |
| **169-180** | 1,85E-05 | 1,35E-08 | 1,95E-04 | 1,04E-04 | 1,06E-04 | 1,39E-04 |
| **181-192** | 1,33E-05 | 6,12E-09 | 1,96E-04 | 1,06E-04 | 1,02E-04 | 1,40E-04 |
| **193-204** | 1,27E-05 | 2,77E-09 | 2,34E-04 | 8,60E-05 | 1,35E-04 | 1,13E-04 |
| **205-216** | 1,62E-05 | 1,25E-09 | 2,45E-04 | 8,57E-05 | 1,49E-04 | 9,65E-05 |
| **217-228** | 1,47E-05 | 5,65E-10 | 2,43E-04 | 7,86E-05 | 1,54E-04 | 9,36E-05 |
| **229-240** | 8,76E-06 | 2,56E-10 | 2,63E-04 | 6,08E-05 | 1,57E-04 | 1,04E-04 |

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*Simulasi konsentrasi As pada skenario I*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 2,66E-06 | 1,43E-08 | 1,53E-05 | 2,81E-05 | 1,12E-05 | 3,21E-05 |
| **13-24** | 3,61E-06 | 4,21E-07 | 6,24E-05 | 4,08E-05 | 4,94E-05 | 6,51E-05 |
| **25-36** | 1,63E-06 | 1,43E-06 | 1,04E-04 | 2,20E-05 | 8,20E-05 | 8,10E-05 |
| **37-48** | 1,19E-06 | 1,12E-06 | 1,01E-04 | 2,74E-05 | 7,67E-05 | 8,61E-05 |
| **49-60** | 1,53E-06 | 7,62E-07 | 1,01E-04 | 3,04E-05 | 7,69E-05 | 8,40E-05 |
| **61-72** | 2,53E-06 | 1,17E-06 | 1,03E-04 | 2,50E-05 | 8,90E-05 | 9,64E-05 |
| **73-84** | 1,15E-06 | 2,05E-06 | 1,07E-04 | 1,70E-05 | 8,78E-05 | 1,12E-04 |
| **85-96** | 1,45E-06 | 2,30E-06 | 1,17E-04 | 2,76E-05 | 9,90E-05 | 1,06E-04 |
| **97-108** | 1,10E-06 | 1,58E-06 | 1,37E-04 | 2,60E-05 | 1,09E-04 | 9,05E-05 |
| **109-120** | 1,76E-06 | 1,25E-06 | 1,41E-04 | 4,02E-05 | 1,01E-04 | 7,72E-05 |
| **121-132** | 3,58E-06 | 1,02E-06 | 1,74E-04 | 6,12E-05 | 1,45E-04 | 8,77E-05 |
| **133-144** | 3,61E-06 | 4,62E-07 | 2,57E-04 | 7,24E-05 | 1,95E-04 | 1,10E-04 |
| **145-156** | 7,53E-06 | 2,09E-07 | 2,59E-04 | 1,04E-04 | 1,79E-04 | 1,17E-04 |
| **157-168** | 7,60E-06 | 9,45E-08 | 2,53E-04 | 1,12E-04 | 1,32E-04 | 1,42E-04 |
| **169-180** | 1,06E-05 | 4,27E-08 | 2,39E-04 | 1,32E-04 | 1,16E-04 | 1,60E-04 |
| **181-192** | 7,89E-06 | 1,93E-08 | 2,48E-04 | 1,31E-04 | 1,23E-04 | 1,78E-04 |
| **193-204** | 7,49E-06 | 8,74E-09 | 2,98E-04 | 1,07E-04 | 1,71E-04 | 1,43E-04 |
| **205-216** | 8,07E-06 | 3,95E-09 | 3,16E-04 | 1,03E-04 | 2,02E-04 | 1,26E-04 |
| **217-228** | 8,66E-06 | 1,79E-09 | 3,05E-04 | 1,06E-04 | 2,06E-04 | 1,29E-04 |
| **229-240** | 5,60E-06 | 8,08E-10 | 3,28E-04 | 8,94E-05 | 2,01E-04 | 1,39E-04 |

*Simulasi konsentrasi As pada skenario II*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 2,59E-06 | 1,39E-08 | 1,49E-05 | 2,76E-05 | 1,10E-05 | 3,14E-05 |
| **13-24** | 3,51E-06 | 4,13E-07 | 6,09E-05 | 4,01E-05 | 4,83E-05 | 6,34E-05 |
| **25-36** | 1,59E-06 | 1,41E-06 | 1,02E-04 | 2,17E-05 | 8,00E-05 | 7,89E-05 |
| **37-48** | 1,15E-06 | 1,10E-06 | 9,84E-05 | 2,71E-05 | 7,49E-05 | 8,38E-05 |
| **49-60** | 1,45E-06 | 7,49E-07 | 9,88E-05 | 3,00E-05 | 7,53E-05 | 8,19E-05 |
| **61-72** | 2,36E-06 | 1,15E-06 | 1,00E-04 | 2,45E-05 | 8,69E-05 | 9,43E-05 |
| **73-84** | 1,07E-06 | 2,01E-06 | 1,04E-04 | 1,67E-05 | 8,55E-05 | 1,10E-04 |
| **85-96** | 1,37E-06 | 2,26E-06 | 1,13E-04 | 2,71E-05 | 9,65E-05 | 1,04E-04 |
| **97-108** | 1,05E-06 | 1,55E-06 | 1,33E-04 | 2,56E-05 | 1,06E-04 | 8,83E-05 |
| **109-120** | 1,70E-06 | 1,23E-06 | 1,38E-04 | 3,95E-05 | 9,90E-05 | 7,50E-05 |
| **121-132** | 3,46E-06 | 1,00E-06 | 1,70E-04 | 6,01E-05 | 1,42E-04 | 8,59E-05 |
| **133-144** | 3,47E-06 | 4,54E-07 | 2,50E-04 | 7,13E-05 | 1,92E-04 | 1,09E-04 |
| **145-156** | 7,25E-06 | 2,05E-07 | 2,53E-04 | 1,02E-04 | 1,76E-04 | 1,15E-04 |
| **157-168** | 7,35E-06 | 9,28E-08 | 2,46E-04 | 1,10E-04 | 1,30E-04 | 1,40E-04 |
| **169-180** | 1,03E-05 | 4,20E-08 | 2,33E-04 | 1,29E-04 | 1,14E-04 | 1,57E-04 |
| **181-192** | 1,90E-08 | 7,68E-06 | 2,40E-04 | 1,29E-04 | 1,21E-04 | 1,75E-04 |
| **193-204** | 7,30E-06 | 8,58E-09 | 2,90E-04 | 1,05E-04 | 1,69E-04 | 1,41E-04 |
| **205-216** | 7,81E-06 | 3,88E-09 | 3,09E-04 | 1,01E-04 | 1,99E-04 | 1,25E-04 |
| **217-228** | 8,37E-06 | 1,75E-09 | 2,98E-04 | 1,05E-04 | 2,02E-04 | 2,01E-04 |
| **229-240** | 5,40E-06 | 7,93E-10 | 3,21E-04 | 8,79E-05 | 1,98E-04 | 1,37E-04 |

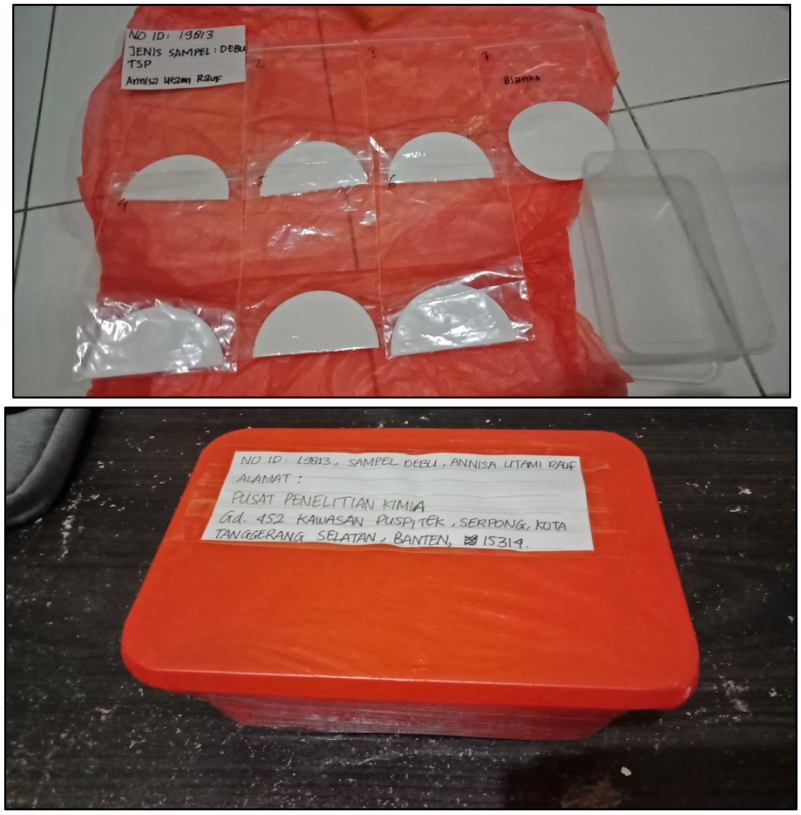
*Simulasi konsentrasi As pada skenario III*

| Bulan | Mattiro Deceng | Ammasangeng | Bunga Eja | Mattoangin | Tukamasea | Balleangin |
|---|---|---|---|---|---|---|
| **1-12** | 2,30E-06 | 7,70E-10 | 1,32E-05 | 2,58E-05 | 1,03E-05 | 2,94E-05 |
| **13-24** | 3,12E-06 | 9,06E-08 | 5,42E-05 | 3,72E-05 | 4,43E-05 | 5,85E-05 |
| **25-36** | 1,41E-06 | 3,31E-07 | 9,07E-05 | 2,02E-05 | 7,17E-05 | 7,31E-05 |
| **37-48** | 9,69E-07 | 2,27E-07 | 8,73E-05 | 2,54E-05 | 6,68E-05 | 7,69E-05 |
| **49-60** | 1,03E-06 | 1,66E-07 | 8,85E-05 | 2,73E-05 | 6,89E-05 | 7,50E-05 |
| **61-72** | 1,40E-06 | 3,07E-07 | 8,93E-05 | 2,08E-05 | 8,01E-05 | 8,80E-05 |
| **73-84** | 6,34E-07 | 6,03E-07 | 9,19E-05 | 1,32E-05 | 7,81E-05 | 1,03E-04 |
| **85-96** | 9,53E-07 | 6,87E-07 | 1,01E-04 | 2,33E-05 | 8,84E-05 | 9,71E-05 |
| **97-108** | 7,49E-07 | 3,99E-07 | 1,19E-04 | 2,23E-05 | 9,74E-05 | 8,18E-05 |
| **109-120** | 1,36E-06 | 2,74E-07 | 1,24E-04 | 3,61E-05 | 9,10E-05 | 6,88E-05 |
| **121-132** | 2,94E-06 | 1,99E-07 | 1,53E-04 | 5,52E-05 | 1,33E-04 | 8,06E-05 |
| **133-144** | 2,90E-06 | 9,00E-08 | 2,31E-04 | 6,64E-05 | 1,80E-04 | 1,03E-04 |
| **145-156** | 6,34E-06 | 4,07E-08 | 2,33E-04 | 9,57E-05 | 1,66E-04 | 1,09E-04 |
| **157-168** | 6,50E-06 | 1,84E-08 | 2,28E-04 | 1,04E-04 | 1,23E-04 | 1,33E-04 |
| **169-180** | 9,22E-06 | 8,32E-09 | 2,16E-04 | 1,22E-04 | 1,08E-04 | 1,50E-04 |
| **181-192** | 6,87E-06 | 3,76E-09 | 2,23E-04 | 1,22E-04 | 1,14E-04 | 1,67E-04 |
| **193-204** | 6,50E-06 | 1,70E-09 | 2,69E-04 | 9,86E-05 | 1,59E-04 | 1,35E-04 |
| **205-216** | 7,00E-06 | 7,69E-10 | 2,87E-04 | 9,55E-05 | 1,89E-04 | 1,19E-04 |
| **217-228** | 7,50E-06 | 3,48E-10 | 2,77E-04 | 9,93E-05 | 1,92E-04 | 1,21E-04 |
| **229-240** | 4,69E-06 | 1,57E-10 | 2,99E-04 | 8,29E-05 | 1,88E-04 | 1,30E-04 |

**Lampiran 6. Dokumentasi Kegiatan Selama Penelitian**


Gambar 1. Pengambilan Sampel Debu Tahap I

Gambar 2. Pengambilan Sampel Debu Tahap  II




Gambar 3. Pengiriman Sampel Debu ke Laboratorium LIPI Serpong

Gambar 4. Wawancara, pengukuran tinggi dan berat badan responden di Desa Salenrang

Gambar 5. Wawancara, pengukuran tinggi dan berat badan responden di Desa Tukamasea

Gambar 6. Wawancara, pengukuran tinggi dan berat badan responden di Desa Baruga

Gambar 7. Wawancara, pengukuran tinggi dan berat badan responden di Desa Ammasangeng

Gambar 8. Wawancara, pengukuran tinggi dan berat badan responden di Desa Bungaeja

## Lampiran 7. Artikel yang Terbit di Jurnal Internasional Bereputasi

1. *Community Health Risk Assessment of Total Suspended Particulates near a Cement Plant in Maros Regency, Indonesia* (Scopus, Q2). Journal of Health and Pollution (2021) 11 (30): 210616. https://doi.org/10.5696/2156-9614-11.30.210616

J|H&P Research

# Community Health Risk Assessment of Total Suspended Particulates near a Cement Plant in Maros Regency, Indonesia

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***Background.*** Cement plants generate particulate matter (PM) across processes from raw material preparation to packaging. The presence of total suspended particulates (TSP) coming out of the stack causes a high accumulation of dust in residential areas. Human exposure to TSP could affect human health and wellbeing.
***Objectives.*** The present study aims to evaluate concentrations of TSP and to estimate the health risks of TSP exposure through the inhalation pathway in communities surrounding a private cement industry in Maros regency, Indonesia.
***Methods.*** Total suspended particulates were collected using a high-volume air sampler (HVAS) at five locations. Samples were taken by grab sampling for 24 hours. The SCREEN3 program was used to view the maximum range and distribution of pollutants based on the geographical, stack profiles and meteorological factors in the study area. Hazard quotient (HQ) was used to estimate non-carcinogenic risks of TSP in surrounding communities.
***Results.*** Total suspended particulate concentrations were measured with a maximum value of 133.24 μg/m$^3$ and a minimum value of 18.48 μg/m$^3$. This maximum value exceeds the minimum acceptable level from Canadian National Ambient Air Quality Objectives (C-NAAQOs). The non-carcinogenic risks from the inhalation pathway were low except for location 3 (HQ>1) across all locations.
***Conclusions.*** The cement plant may significantly contribute to total TSP concentrations in air and may potentially have adverse effects on human health. Communities near the cement plant are vulnerable to TSP exposure and measures are needed to reduce TSP in Maros regency, Indonesia.
***Participant Consent.*** Obtained
***Ethics Approval.*** This study was approved by the Health Research Ethics Committee of Hasanuddin University with protocol number 28920093022.
***Competing Interests.*** The authors declare no competing financial interests.
***Keywords.*** air pollution, cement plant, hazard quotient, total suspended particulates
Received February 16, 2021. Accepted April 17, 2021.
*J Health Pollution 30: (210616) 2021*


## Introduction

Air pollution has been identified as a major environmental problem associated with respiratory disease and reduced life expectancy.[1] One indicator of reduced air quality is the presence of particulate matter (PM) which is commonly found around industrial activities, such as the cement industry.[1,2] In China, the second-largest source emitter of air pollution, a cement factory contributed about 15% $CO_2$ and 14% of PM <2.5 μm ($PM_{2.5}$).[3] In Romania, the cement industry released about 1 500 000 tons of municipal waste in 18 cities in 2004-2013, including carbon dioxide ($CO_2$), hydrogen chloride (HCl) and hydrogen fluoride (HF) emission.[4] From grinding to packaging, the entire process greatly contributes to the accumulation of total suspended particulates (TSP) inside the plant and outside the cement factory. In addition, most of the cement factory still uses coal as fuel.[5] Emissions of total suspended particulates contain harmful pollutants, such as heavy metals, polycyclic aromatic hydrocarbons, silica, and toxic gases that easily accumulate near the cement factory.[6,7,8]

Total suspended particulate exposure is associated with respiratory infections, skin damage, and digestion problems.[9,10] The accumulation of particulate matter (PM), which generally contains metals in surface plants, air, and water bodies is attributed to ecological damage.[11] A

2. *Potentially Toxic Element Levels in Atmospheric Particulates and Health Risk Estimation around Industrial Areas of Maros, Indonesia* (Scopus, Q1).
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https://doi.org/ 10.3390/toxics9120328

toxics

MDPI

*Article*

# Potentially Toxic Element Levels in Atmospheric Particulates and Health Risk Estimation around Industrial Areas of Maros, Indonesia

**Annisa Utami Rauf [1], Anwar Mallongi [1,*], Kiyoung Lee [2], Anwar Daud [1], Muhammad Hatta [3], Wesam Al Madhoun [4] and Ratna Dwi Puji Astuti [1]**

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[2] Department of Environmental Health Sciences, Graduate School of Public Health, Seoul National University, Seoul 08826, Korea; cleanair@snu.ac.kr
[3] Marine Science Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar 90245, Indonesia; hattaikl9@yahoo.com
[4] Faculty of Engineering, Gaza University, Gaza, Palestine; wsah79@gmail.com
* Correspondence: rawnaenvi@gmail.com

**Abstract:** Air quality deterioration is a major environmental problem in Indonesia. This study evaluated the levels and health risks of potentially toxic elements (PTEs) in Maros Regency, Indonesia. Total suspended particulate matter was collected from industrial areas for PTE (Al, Pb, Cr, Cu, Ni, As and Zn) analysis using inductively coupled plasma optical emission spectrometry (ICP-OES). Samples were collected from six critical areas in the Bantimurung region as that is where marble, cement and limestone industries are located. A calculation of the non-carcinogenic and cancer risks was performed to determine the potential health exposures in adults and children. A Monte Carlo simulation with 10,000 iterations and a sensitivity analysis was carried out to identify the risk probability and the most sensitive variable contributing to cancer risk from PTE exposure in humans. The results showed that the concentration of PTEs decreased in the order of Zn > Al > Cr > Pb > Cu > Ni > As in the wet season, and Zn > Al > Pb > As > Cr > Cu > Ni in the dry season. The hazard index (HI) value for children was 2.12, indicating a high non-carcinogenic risk for children. The total cancer risk (TCR) values in adults and children were $3.11 \times 10^{-5}$ and $1.32 \times 10^{-4}$, respectively, implying that both are at risk for developing cancer. The variables with the most contribution to cancer risk from As, Cr and Pb exposure in adults and children were As concentration (33.9% and 41.0%); exposure duration (ED) (34.3%) and SA (40.7%); and SA (98.7 % and 45.4%), respectively. These findings could be used as the scientific basis for public health intervention and to raise awareness of the harmful health effects of particulate bound PTEs

**Keywords:** air pollution; industrial waste; risk assessment; Maros



**Citation:** Rauf, A.U.; Mallongi, A.; Lee, K.; Daud, A.; Hatta, M.; Al Madhoun, W.; Astuti, R.D.P. Potentially Toxic Element Levels in Atmospheric Particulates and Health Risk Estimation around Industrial Areas of Maros, Indonesia. *Toxics* **2021**, *9*, 328. https://doi.org/10.3390/toxics9120328

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Published: 2 December 2021



## 1. Introduction

Air pollution is one of the greatest environmental problems faced by developing countries. Globally, air pollution is the world's largest environmental health risk and is responsible for 3.1% of the loss of disability-adjusted life years (DALYs) [1]. According to the Environment and Social Development Organization (ESDO), at least 200,000 people in Bangladesh could die from respiratory disease and long-term exposure to high concentrations of contaminated air [2]. Air pollution from industrial sources is associated with low birth weight and the severity of sleep disorders among the elderly in China [3]. In Indonesia, the air quality has decreased over the last two decades, and it fails to meet the World Health Organization (WHO) standard for fine particulate matter ($PM_{2.5}$) concentration. Indonesians lose 1.2 years of life expectancy as a result of the current pollution levels [4].

3. *Spatial Distribution and Ecological Risk of Potentially Toxic Elements in Maros Regency, Indonesia* (Scopus, Q2).
Carpathian Journal of Earth and Environmental Sciences (2022) 17,1.
10.26471/cjees/2022/017/203

Carpathian Journal of Earth and Environmental Sciences, February 2022, Vol. 17, No. 1, p. 93 – 100; DOI:10.26471/cjees/2022/017/203

# SPATIAL DISTRIBUTION AND ECOLOGICAL RISK OF POTENTIALLY TOXIC ELEMENTS IN MAROS REGENCY, INDONESIA

**Annisa Utami RAUF[1*], Anwar MALLONGI[1], Anwar DAUD[1], Muhammad HATTA[2], Ridwan AMIRUDDIN[3], Stang STANG[4], Atjo WAHYU[5] & Ratna Dwi Puji ASTUTI[1]**

*[1]Environmental Health Department, Faculty of Public Health, Hasanuddin University, Indonesia, *corresponding author: annisautamirauf@gmail.com*
*[2]Marine Science Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Indonesia.*
*[3]Epidemiology Department, Faculty of Public Health, Hasanuddin University, Indonesia*
*[4]Biostatistic Department, Faculty of Public Health, Hasanuddin University, Indonesia.*
*[5]Occupational Health and Safety Department, Faculty of Public Health, Hasanuddin University, Indonesia.*

**Abstract:** Air pollution is a major environmental problem in Indonesia. Potentially toxic elements (PTEs) which bounded to particulate matter (PM) samples were collected from Maros karst area, the second largest karst in the world. The seasonal levels of PTEs and ecological risk assessment were used to investigate the pollution levels near the residential areas using pollution load index (PLI) and potential ecological risk index (PERI). Spatial distributions of ecological risks based on the PTEs concentration have been explored with Empirical Bayesian Kriging method. The result indicated the mean concentration of PTEs (Cr, Pb, Cu, As and Zn) were significantly higher in dry season than wet season. Based on the PERI and PLI values, the PTEs accumulation are more severe near industrial activities and traffic roads. Hotspots of the PTEs were located in the East and Southeast area. The implications of this study could be used to optimize the management strategies in controlling the PTEs pollution and become a scientific reference for taking environmental protection policies.

**Keywords:** air pollution, ecological risk, Maros karst, pollution index, trace metals

## 1. INTRODUCTION

Air pollution is caused by the accumulation of pollutants released into the atmosphere (Manisalidis et al., 2020). These pollutants are generated from natural events such as volcanoes, wildfires and dust storms or human activities including coal combustion, vehicle emissions and waste burning (Yin et al., 2021; Jelea, et al., 2007a; Rauf et al., 2020). The problem of particulate matter (PM) in ambient air has received a lot of attention as the social economy, industrialization, and urbanization have grown. The PM can reduce visibility and have a severe negative impact on climate change in global and regional areas (Lertxundi et al., 2010). The trace elements represent a small fraction of the total PM mass. Among the trace elements, arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr) and mercury (Hg) are classified as potentially toxic elements (PTEs) or poisonous even at low concentrations. Moreover, nickel (Ni), iron (Fe), and zinc (Zn) are micronutrients, but at certain concentrations and exceeding the specified limits, they can cause adverse impact on human health and organisms (Pourret & Hursthouse, 2019; Vitó et al., 2020). Thus, these elements are also included as PTEs. Several studies have proved that PTEs are associated with adverse health effects (Ziyaee et al., 2019).

Increasing anthropogenic activities in Indonesia, which elevated the number of vehicles, fossil fuel combustion, construction, and stone crushing, has been reported to produce PM that possibly contains PTEs (Kurniawan et al., 2021; Santoso et al., 2020). These activities potentially degrade the environment, resulting the decreased environmental quality and human health problems (Jelea, et al., 2007b). Some reports confirmed the high levels of PTEs that accumulated in ambient air around anthropogenic activities such as road dust and industrial processes (Celo et al., 2021; Mallongi et al., 2021). Tehran, the most industrialized city in Iran, had

## Lampiran 8. Persuratan dan Perizinan Penelitian

1202019300755 8

**PEMERINTAH PROVINSI SULAWESI SELATAN**
**DINAS PENANAMAN MODAL DAN PELAYANAN TERPADU SATU PINTU**
**BIDANG PENYELENGGARAAN PELAYANAN PERIZINAN**

Nomor : **7084/S.01/PTSP/2020**
Lampiran :
Perihal : **Izin Penelitian**

**KepadaYth.**
1. Bupati Maros
2. Kepala Dinas Pengelolaan Lingkungan Hidup Prov. Sulsel
3. Pimpinan PT. Semen Bosowa Maros
4. Balai GAKKUM Wilayah Sulawesi

di-
**Tempat**

Berdasarkan surat Dekan Fak. Kesehatan Masyarakat UNHAS Makassar Nomor : 7593/UN4.14/PT.01.05/2020 tanggal 05 Oktober 2020 perihal tersebut diatas, mahasiswa/peneliti dibawah ini:

| | |
|---|---|
| N a m a | : **ANNISA UTAMI RAUF** |
| Nomor Pokok | : K013191032 |
| Program Studi | : Ilmu Kesehatan Masyarakat |
| Pekerjaan/Lembaga | : Mahasiswa(S3) |
| Alamat | : Jl. P. Kemerdekaan Km. 10, Makassar |

Bermaksud untuk melakukan penelitian di daerah/kantor saudara dalam rangka penyusunan Disertasi, dengan judul :

**" MODEL SISTEM DINAMIS RISIKO PENCEMARAN LOGAM TERHADAP LINGKUNGAN DAN KESEHATAN MASYARAKAT DI SEKITAR WILAYAH INDUSTRI SEMEN KABUPATEN MAROS "**



Yang akan dilaksanakan dari : Tgl. ***15 Oktober 2020 s/d 15 Januari 2021***

Sehubungan dengan hal tersebut diatas, pada prinsipnya kami ***menyetujui*** kegiatan dimaksud dengan ketentuan yang tertera di belakang surat izin penelitian.
Dokumen ini ditandatangani secara elektronik dan Surat ini dapat dibuktikan keasliannya dengan menggunakan ***barcode***,
Demikian surat izin penelitian ini diberikan agar dipergunakan sebagaimana mestinya.

Diterbitkan di Makassar
Pada tanggal : 06 Oktober 2020

**A.n. GUBERNUR SULAWESI SELATAN**
**KEPALA DINAS PENANAMAN MODAL DAN PELAYANAN TERPADU**
**SATU PINTU PROVINSI SULAWESI SELATAN**
Selaku Administrator Pelayanan Perizinan Terpadu

**Dr. JAYADI NAS, S.Sos., M.Si**
Pangkat : Pembina Tk.I
Nip : 19710501 199803 1 004

Tembusan Yth
1. Dekan Fak. Kesehatan Masyarakat UNHAS Makassar di Makassar;
2. *Pertinggal.*

# PEMERINTAH KABUPATEN MAROS
# KECAMATAN BONTOA

**SURAT REKOMENDASI**
Nomor : 070/381/Bontoa

Yang bertanda tangan di bawah ini :

| | | |
|---|---|---|
| Nama | : | ANDI ARMANSYAH AMIRUDDIN, SH |
| NIP | : | 19710930 199803 1 004 |
| Pangkat/Gol. | : | Pembina, IV/a |
| Jabatan | : | Camat |
| Instansi | : | Kantor Camat Bontoa |

Berdasarkan Izin Penelitian yang dikeluarkan oleh Kepala Dinas Penanaman Modal dan Pelayanan Terpadu Satu Pintu, Nomor 289/X/IP/DPMPTSP/2020 Tanggal. 12 Oktober 2020 Perihal Izin Penelitian dalam rangka penulisan desertasi, maka dengan ini disampaikan kepada :

| | | |
|---|---|---|
| Nama | : | ANNISA UTAMI RAUF |
| Tempat, Tanggal Lahir | : | Ujung Pandang, 26 Juni 1994 |
| Alamat/Hp. | : | Jl. Nurul Hidayah No.21 B Makassar/082343495674 |
| Jenis Kelamin | : | Perempuan |
| Pekerjaan | : | Mahasiswa (S3) |
| No. KTP | : | 7371126606940013 |
| Jenis Kegiatan | : | Penelitian dalam rangka penulisan Desertasi |
| Waktu Pelaksanaan | : | 15 Oktober s/d 31 Oktober 2021 |
| Lokasi Kegiatan | : | Desa Salenrang dan Kelurahan Bontoa Kecamatan Bontoa |

bahwa pada perinsipnya kami tidak keberatan atas permohonan Izin dimaksud, dengan memperhatikan hal – hal sebagai berikut :

1. Tidak menyimpan dari ketentuan yang berlaku, semata-mata untuk kepentingan akademik, tidak mengganggu keamanan dan ketertiban Umum, serta menjaga kebersihan lingkungan.
2. Segala Biaya yang berhubungan dengan pelaksanaan kegiatan tersebut ditanggung oleh yang bersangkutan.
3. Surat Persetujuan ini tidak dapat digunakan untuk permintaan bantuan dan berlaku sejak tanggal dikeluarkan sampai Tanggal 30 Juni 2020.
4. Melaporkan hasil kegiatannya kepada Kepala Desa dan Camat, selambat-lambatnya 1 (satu) minggu setelah berakhirnya kegiatan.
5. Kegiatan yang dilaksanakan memberi nilai tambah terhadap pelayanan masyarakat.
6. Penyelenggara bersedia menerima sanksi atau denda apabila dikemudian hari ditemukan penyalahgunaan atau pelanggaran dari ketentuan yang berlaku.

Demikian Persetujuan ini kami buat dengan sesungguhnya agar maklum dan dapat dipergunakan sebagaimana mestinya.

Bontoa, 23 Oktober 2020

CAMAT

ANDI ARMANSYAH AMIRUDDIN, SH
Pangkat : Pembina/IV.a
NIP. 19710930 199803 1 004

***Tembusan : Yth,***
1. Bupati Maros (sebagai Laporan)
2. Kepala DPMPTSP Kab. Maros di Maros
3. Dekan FKM Unhas di Makassar
4. Kepala Desa dan Lurah lokasi kegiatan.
5. Arsip,-

Jl. Andi Radja Panjallingan Kel. Bontoa, Kab.Maros Prov. Sul-Sel. Telp. (0411) 388 3485 Kode Pos 90554
Email : bontoa@maroskab.go.id,Website : www.maroskab.go.id

**PEMERINTAH KABUPATEN MAROS**
**DINAS PENANAMAN MODAL DAN PELAYANAN TERPADU SATU PINTU**
Jl. Asoka No. 1 Telp. (0411)373884 Kabupaten Maros
email :admin@dpmptsp.maroskab.go.id Website : www.dpmptsp.maroskab.go.id

# IZIN PENELITIAN

Nomor: 289/X/IP/DPMPTSP/2020

**DASAR HUKUM :**

1. Undang-Undang Republik Indonesia Nomor 18 tahun 2002 tentang Sistem Nasional Penelitian, Pengembangan, dan Penerapan Ilmu Pengetahuan Teknologi;
2. Peraturan Menteri Dalam Negeri Nomor 7 Tahun 2014 tentang Perubahan Peraturan Menteri Dalam Negeri Nomor 64 Tahun 2011 tentang Pedoman Penerbitan Rekomendasi Penelitian;
3. Rekomendasi Tim Teknis Izin Penelitian Dinas Penanaman Modal dan Pelayanan Terpadu Satu Pintu Kabupaten Maros Nomor : 290/X/REK-IP/DPMPTSP/2020

Dengan ini memberikan Izin Penelitian Kepada :

| | |
|---|---|
| N a m a | : ANNISA UTAMI RAUF |
| Nomor Pokok | : K013191932 |
| Tempat/Tgl.Lahir | : UJUNG PANDANG / 26 Juni 1994 |
| Jenis Kelamin | : Perempuan |
| Pekerjaan | : MAHASISWA ( S3) |
| Alamat | : JL. NURUL HIDAYAH NO.21 B MAKASSAR |
| Tempat Meneliti | : KECAMATAN LAU, KECAMATAN BONTOA, KECAMATAN BANTIMURUNG, DINAS KESEHATAN MAROS, DINAS LINGKUNGAN HIDU |

Maksud dan Tujuan mengadakan penelitian dalam rangka Penulisan Disertasi dengan Judul :

**"MODEL SISTEM DINAMIS RISIKO PENCEMARAN LOGAM TERHADAP LINGKUNGAN DAN KESEHATAN MASYARAKAT DI SEKITAR WILAYAH INDUSTRI SEMEN KABUPATEN MAROS"**

Lamanya Penelitian : 15 Oktober 2020 s/d 31 Oktober 2021

Dengan ketentuan sebagai berikut :

1. Mentaati semua peraturan perundang-undangan yang berlaku, serta menghormati Adat Istiadat setempat.
2. Penelitian tidak menyimpang dari maksud izin yang diberikan.
3. Menyerahkan 1 ( satu ) examplar Foto Copy hasil penelitian kepada Dinas Penanaman Modal dan Pelayanan Terpadu Satu Pintu Kabupaten Maros.
4. Surat Izin Penelitian ini dinyatakan tidak berlaku, bilamana pemegang izin ternyata tidak mentaati ketentuan-ketentuan tersebut diatas.

Demikian Izin Penelitian ini diberikan untuk dipergunakan sebagaimana mestinya.

Maros, 12 Oktober 2020
**a.n. KEPALA DINAS,**

**ANDI ROSMAN, S. Sos, MM**
Pangkat: Pembina Utama Muda
Nip : 19721108 199202 1 001

Tembusan Kepada Yth.:
1. Dekan FKM UNHAS di Makassar
2. Arsip

PEMERINTAH KABUPATEN MAROS
KECAMATAN BANTIMURUNG
**KELURAHAN LEANG-LEANG**
*JL.POROS LEANG-LEANG KODE POS 90561*

# SURAT REKOMENDASI PENELITIAN

Nomor : 30 / KLL/BTM /III/ 2020

Yang bertanda tangan dibawah ini Kepala Kelurahan Leang-Leang Kecamatan Bantimurung Kabupaten Maros, Menerangkan Bahwa :

| | | |
|---|---|---|
| Nama | : | **ANNISA UTAMI RAUF** |
| Nim | : | K013191032 |
| Pekerjaan | : | Mahasiswa |
| Alamat Sekretariat | : | JL.Nurul hudaya No.21 B Kel.Bangkala Kec.Mangkala kota Makassar |
| Waktu Pelaksanaan | : | 01 April 2020 s/d 31 Desember 2020 |

Atas dasar surat Rekomendasi Penelitian dari Camat Bantimurung Nomor : 070/21/BTM/III/2020 tanggal 19 Maret 2020, maka kami merekomendasikan Pengambilan data kepada Masyarakat terkait sampel lingkungan ( Air sumur Tanah,Udara, Tanaman pangan ) dan data Kepala Keluarga dalam rangka persiapan penulisan disertasi yang berjudul :

***"MODEL SISTEM DINAMIS RISIKO PENCEMARAN LOGAM TERHADAP LINGKUNGAN DAN KESEHATAN MASYARAKAT DI SEKITAR WILAYAH INDUSTRI SEMEN KABUPATEN MAROS"***

Dengan ketentuan mentaati segala aturan perundang-undangan yang berlaku, serta menghormati adat istiadat setempat.

Demikian surat keterangan Rekomendasi ini dibuat dan untuk dipergunakan sebagaimana mestinya.

Leang-Leang, 19 Maret 2020
**Lurah,**

**SARIPUDDIN TALLI, SE**
Pangkat : Penata
Nip. : 19770612 200701 1 012

# PEMERINTAH KABUPATEN MAROS
# KECAMATAN BANTIMURUNG

*Jalan Poros Bantimurung-Maros Maros( 90561 ) Telp. 388 4021*
Email : bantimurung@maroskab.go.id Website :www.bantimurung.maroskab.go.id

Pakalu, 19 Maret 2020
Kepada
Yth. Para Kepala Desa dan Lurah
Se- Kec. Bantimurung

Nomor : 070 / 81 / Btm/III/2020
Lamp. : -
Perihal : Rekomendasi Penelitian

Berdasarkan Surat dari Dinas Kementrian Pendidikan dan Kebudayaan Universitas Hasanuddin Program Studi Doktor (S3) Ilmu Kesehatan Masyarakat UNHAS Tamalanrea Makassar, Nomor 3098/UN4.14.8/PT.01.04/2020 Tanggal 16 Maret 2020 Perihal Permohonan Izin Pengambilan Data, maka dengan ini memberikan Rekomendasi kepada :

| | | |
|---|---|---|
| Nama | : | **ANNISA UTAMI RAUF** |
| NIM | : | K013191032 |
| Tempat / Tgl. Lahir | : | Ujung Pandang, 26 Juni 1994 |
| Jenis Kelamin | : | Perempuan |
| Pekerjaan | : | Mahasiswi |
| Alamat | : | Jl. Nurul Hudaya No.21 B Kel. Bangkala Kec. Mangkala Kota Makassar |
| Waktu Pelaksanaan Kegiatan | : | 01 April 2020 s/d 31 Desember 2020 |
| Tempat Pelaksanaan | : | Kecamatan Bantimurung |

Bermaksud akan mengadakan Pengambilan Data kepada Masyarakat Kecamatan Bantimurung terkait Sampel Lingkungan ( Air Sumur, Tanah, Udara, Tanaman Pangan ) dan Data Kepala Keluarga dalam rangka persiapan penulisan disertasi yang berjudul :

**"MODEL SISTEM DINAMIS RISIKO PENCEMARAN LOGAM TERHADAP LINGKUNGAN DAN KESEHATAN MASYARAKAT DI SEKITAR WILAYAH INDUSTRI SEMEN KABUPATEN MAROS"**

Bahwa pada prinsipnya Pemerintah Kecamatan Bantimurung memberikan izin dimaksud dengan memperhatikan hal – hal sebagai berikut :

1. Sebelum dan sesudah melaksanakan kegiatan tersebut melaporkan diri kepada Camat Bantimurung.
2. Survey / Penelitian / Pengambilan Data dimaksud tidak menyimpang dari ketentuan yang berlaku dan semata – mata untuk kepentingan Ilmiah serta dapat memberi nilai tambah terhadap peningkatan kesejahteraan masyarakat.
3. Menyesuaikan dengan adat istiadat setempat, tidak mengganggu keamanan dan
4. Ketertiban Umum, serta menjaga kebersihan lingkungan
5. Tidak bertentangan dengan peraturan perundang – undangan yang berlaku.
6. Menyerahkan 1 (Satu ) rangkap Hasil Laporan Pelaksanaan Kegiatan kepada Camat
7. Segala Biaya dan akibat yang ditimbulkan dari perlaksanaan kergiatan tersebut ditanggung oleh yang bersangkutan.

Demikian Rekomendasi ini diberikan untuk dipergunakan sebagaimana mestinya.

CAMAT

**ASRUL RIFAI RACHMAN, S.STP**
Pangkat : Pembina Tk.I
NIP. 19800112 200012 1 001

Tembusan :
1. Bupati Maros (Sebagai Laporan )
2. Kapolsek Bantimurung di Pakalu
3. Danramil Bantimurung di Pakalu
4. Arsip

**PEMERINTAH KABUPATEN MAROS**
KECAMATAN BONTOA
**DESA SALENRANG**

Alamat : Jalan Poros Maros – Pangkep, Kilometer 9,5, Desa Salenrang Kode pos 90554

## SURAT IZIN PENELITIAN

Nomor : 77/120/DS/BT/2020

Menindaklanjuti surat Izin Dinas Penanaman Modal dan Pelayanan Terpadu satu Pintu Nomor : 289/X/IP/DPMPTSP/2020 tertanggal 12 Oktober dan Surat Rekomendasi Camat Bontoa Nomor : 070/381/Bontoa, maka dengan ini Pemerintah Desa Salenrang memberikan Izin/Rekomendasi kepada saudari :

| | |
|---|---|
| Nama | : **Annisa Utami Rauf** |
| Tempat/Tgl Lahir | : Ujungpandang, 26 Juni 1994 |
| Nomor Pokok | : K013191932 |
| Fakultas | : Kesehatana Masyarakat |
| Program Studi | : Kesehatan Lingkungan |
| PT/Universitas | : Universitas Hasanuddin Makassar |
| Lokasi Penelitian | : Kecamatan Lau, Bontoa, Bantimurung, Dinas Kesehatan Maros dan Dinas Lingkungan Hidup kabupaten Maros |

Untuk mengadakan penelitian dalam rangka penulisan Disertasi penyelesaian studi selama 1 (satu) Tahun, terhitung mulai tanggal 15 Oktober 2020 – 31 Oktober 2021 dengan judul :

**"MODEL SISTEM DINAMIS RISIKO PENCEMARAN LOGAM TERHADAP LINGKUNGAN DAN KESEHATAN MASYARAKAT DI SEKITAR WILAYAH INDUSTRI SEMEN KABUPATEN MAROS"**

Dengan ketentuan sebagai berikut :

1. Mentaati semua peraturan perundang-undangan yang berlaku, serta mentaati adat istiadat masyarakat setempat.
2. Penelitian tidak menyimpang dari maksud izin yang diberikan
3. Menyerahkan 1 (satu) examplar Foto Copy hasil Penelitian kepada Pemerintah Desa Salenrang.
4. Surat izin penelitian ini dinyatakan tidak berlaku apabila pemegang izin ternyata menyalahi ketentuan-ketentuan tersebut di atas.

Demikian Surat Izin Penelitian ini diberikan kepada yang bersangkutan untuk dipergunakan sebagaimana mestinya.

Salenrang, 23 oKTBER 2020

Kepala Desa Salenrang,

SYAHRIR

**Tembusan Kepada Yth. :**

1. Kepala Dinas PMD kabupaten Maros di Maros
2. Ketua LPPM Universitas Muslim Maros di Maros
3. Camat Bontoa di Panjallingan
4. Ketua BPD Salenrang di Salenrang
5. Kepala Dusun se-Desa Salenrang di Salenrang
6. Arsip

# *CURRICULUM VITAE*

**A. Data Pribadi**

1. Nama : Annisa Utami Rauf
2. Tempat, tanggal lahir : Ujungpandang, 26 Juni 1994
3. Alamat : Jalan Nurul Hudayah No. 21 B, Antang, Makassar
4. Kewarganegaraan : Indonesia

**B. Riwayat Pendidikan**

1. Tamat SD Tahun 2006 di SD INPRES Perumnas Antang II
2. Tamat SMP tahun 2009 di SMPN 23 Makassar
3. Tamat SMA tahun 2013 di Sekolah Menengah Analis Kimia (SMAK) Makassar
4. Sarjana (S1) tahun 2017 di Universitas Negeri Makassar, Jurusan Kimia
5. Magister (S2) tahun 2019 di Universitas Hasanuddin, Jurusan Kesehatan Lingkungan

**C. Pekerjaan dan Riwayat Pekerjaan**

1. Jenis Pekerjaan : Mahasiswa
2. NIP atau identitas lain (NIK) : 7371126606940013
3. Pangkat/Jabatan : -

**D. Karya Ilmiah (artikel) yang telah dipublikasikan:**

1. **Rauf, A.U.,** Mallongi, A., Daud, A., Hatta, M., Amiruddin, R., Rahman, S.A., Wahyu, A., Astuti, R.D.P. (2021). Spatial Distribution and Ecological Risk of Potentially Toxic Elements in Maros Regency, Indonesia. *Carpathian Journal of Earth and Environmental Sciences*, Vol. 17, No. 1, p. 93 – 100. doi:10.26471/cjees/2022/017/203.
2. **Rauf A.U,** Mallongi A., Lee K., Daud A., Hatta M., Al Madhoun W., Astuti RDP. Potentially Toxic Element Levels in Atmospheric Particulates and Health Risk Estimation around Industrial Areas of Maros, Indonesia. (2021). *Toxics*. 9(12):328. doi: 10.3390/toxics9120328.
3. **Rauf, A.U**., Mallongi, A., Daud, A., Hatta, M., Al-Madhoun, W., Amiruddin, R., Rahman, S.A., Wahyu, A., Astuti, R.D.P. (2021). Community Health Risk Assessment of Total Suspended Particulates near a Cement Plant in Maros Regency, Indonesia. *Journal of Health and Pollution* 17 June 2021; 11 (30): 210616. doi: 10.5696/2156-9614-11.30.21066.
4. Mallongi A., Astuti RDP., Amiruddin, R., Hatta M., **Rauf A.U**. (2021). Identification Source and Human Health Risk Assessment of Potentially Toxic Metal in Soil Samples around Karst Watershed of Pangkajene, Indonesia. *Environmental Nanotechnology, Monitoring & Management*. doi: 10.1016/j.enmm.2021.100634.
5. Mallongi A., **Rauf A.U**., Daud A., Hatta M., Al-Madhoun W., Amiruddin R., Stang S., Wahyu A., Astuti RDP. (2022). Health risk assessment of

potentially toxic elements in Maros karst groundwater: a Monte Carlo simulation approach, *Geomatics, Natural Hazards and Risk*, 13:1, 338-363. doi: 10.1080/19475705.2022.2027528.

6. Astuti, R.D.P, Mallongi, A., **Rauf, A.U**. (2021). Natural enrichment of chromium and nickel in the soil surrounds the karst watershed. *Global Journal of Environmental Science and Management*, 7(3), -. doi: 10.22034/gjesm.2021.524891.3622.
7. Astuti, R.D.P.; Mallongi, A.; Choi, K.; Amiruddin, R.; Hatta, M.; Tantrakarnapa, K.; **Rauf, A.U**., (2022). Health risks from multiroute exposure of potentially toxic elements in a coastal community: A probabilistic risk approach in Pangkep Regency, Indonesia. Geomatics, Nat. Hazards Risk., 13(1): 705 -735 (32 pages).
8. Astuti, R.D.P, Mallongi, A., **Rauf, A.U.** (2021). Risk identification of heavy metals in well water surrounds watershed area of Pangkajene, Indonesia. *Gaceta Sanitaria (35),* doi: 10.1016/j.gaceta.2020.12.010.
9. **Rauf, A. U.,** Mallongi, A., & Astuti, R. D. P. (2020). Ecological risk assessment of hexavalent chromium and silicon dioxide in well water in Maros Regency, Indonesia. *Gaceta Sanitaria* (35), doi: 10.1016/j.gaceta.2020.12.002
10. Astuti, R., Mallongi, A., **Rauf, A.U.** (2021). Risk identification of Hg and Pb in soil: a case study from Pangkep Regency, Indonesia. *Soil Science Annual*, 72(1), doi: 10.37501/soilsa/135394.
11. **Rauf, A. U.,** Mallongi, A., & Astuti, R. D. P. (2020). Mercury and Chromium Distribution in Soil near Maros Karst Ecosystem. *Carpathian Journal of Earth and Environmental Sciences*, *15*(2), 453-460, doi: 10.26471/cjees/2020/015/144.
12. **Rauf, A. U.,** Mallongi, A., & Astuti, R. D. P. (2020). Heavy Metal Contributions on Human Skin Disease near Cement Plant: A Systematic Review. *Open Access Maced J Med* Sci. 2020 Jul 25; 8 (F): 117-122, doi: 10.3889/oamjms.2020.4396.
13. Mallongi, A., Stang, S., Astuti, R.D.P, **Rauf, A.U**, Natsir, M.F. (2022). 'Risk assessment of fine particulate matter exposure attributed to the presence of the cement industry', *Global Journal of Environmental Science and Managemen*t, 9(1), pp. 1-16. doi: 10.22034/gjesm.2023.01.05
14. Mallongi, A., Natsir, M. F., Astuti, R. D. P., **Rauf, A. U**., Rachmat, M., & Muhith, A. (2020). Potential Ecological Risks of Mercury Contamination Along Communities Area in Tonasa Cement Industry Pangkep, Indonesia. *Enfermeria clinica*, *30*, 119-122.
15. Ishak, H., Syafar, M., Mallongi, A., & **Rauf, A. U**. (2020). Effectiveness of mosquito nests eradication abatezation for elimination of Aedes aegypti. *Enferm Clin*, 473-476.
16. Luwu, A. B. T., Mallongi, A., Syam, A., Yanti, I. H., Gafur, A., & **Rauf, A.U.** (2020). Air germ numbers in Bougenville's care room at H. Andi Sulthan Daeng Radja Bulukumba Hospital. *Enfermería Clínica*, *30*, 415-418.
17. Rini, A., Amiruddin, R., , Mallongi, M., & **Rauf, A.U.** (2020). Social Media and Simulation Game on Literation HIV and AIDS TKBM in Makassar Port. *Enfermeria clinica*, *30*, 357-361.
18. Mallongi, A., Natsir, M. F., Astuti, R. D. P., & **Rauf, A. U.** (2020). Assessment of Ecological and Target Hazard Risks of Mercury Contaminated Water Along Makassar Coastal Areas, Indonesia. *Open Access Maced J Med* Sci, Feb. 5 ;8(T2):229-35.

19. Mallongi, A., Manyullei, S., Natsir, M. F., Astuti, R. D. P., & **Rauf, A. U.** (2019). Risks Assessment of Silica Contamination on the Communities Living Surround the Cement Industry, Pangkep Indonesia. *Indian Journal of Public Health Research & Development*, *10*(10).
20. Mallongi, A., Rauf, A., Astuti, R., Palutturi, S., & Ishak, H. (2023). Ecological and human health implications of mercury contamination in the coastal water. *Global Journal of Environmental Science and Management*, 9(2), 261-274. doi: 10.22034/gjesm.2023.02.06

## E. Makalah pada Seminar/Konferensi Ilmiah Nasional dan Internasional

1. Rauf AU et al 2020. The 1st International Conference on Safety and Public Health, Presenter (Hasanuddin University, Makassar, Indonesia).
2. Rauf AU et al 2021. The 52nd Asia-Pacific Academic Consortium for Public Health Conference 2021, Presenter (Airlangga University, Surabaya, Indonesia).
3. Rauf AU et al 2022. The 13th International Nursing Conference, Continuous Innovation for Sustainable Health and Climate-resilience, Presenter (Airlangga University, Surabaya, Indonesia).

## 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, SKM, M.Sc, PhD).
2. Riset dan kolaborasi artikel, Program Peningkatan Kualitas Publikasi Internasional/ Sandwich Like Program. Durasi 2021-2022. (Supervisor: Prof. Kiyoung Lee, ScD, Dean of Graduate School of Public Health, Seoul National University).