Health Risk Analysis of Nickel and Lead Exposure in Drinking Water at Kawasi Village, Obi Island, South Halmahera District, 2015

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ABSTRACT--- - *Nickel and lead poisoning in drinking water is a major public-health problem at Kawasi Village, as a result of a neglected nickel mining industry that contaminating the source of water in the village. A cross-sectional study was conducted to estimate the risk of exposure to lead via drinking water ingestion pathway for the population of Kawasi Village. The study included 984 respondents, with 328 men aged 18-65 years, 328 women of childbearing-aged 15-45 years, and 328 children aged 6-12 years. The results showed the excess cancer risk (ECR) for women, man, and children at Kawasi Village were $6.006x10^{-7}$, $4.103x10^{-7}$, and $2.641x10^{-7}$, respectively. None of the excess cancer risk (ECR) was found to be greater than $>10^{-4}$. In addition, the highest concentration intake (Cmax) were 176487491.8 for man, 350543611.7 for women, and 66205364.4 for children. In conclusion, non-carcinogenic risk attributed to ingestion of lead in the drinking water was found to be negligible.*

Keywords— Lead Poisoning, Drinking Water, Environmental Health Risk Analysis, Kawasi Village, Obi Island

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1. INTRODUCTION

Kawasi area is located in Obi sub-district, South Halmahera Regency, Province of North Maluku, Indonesia. In this region, Harita Nickel Group has exploited this mineral since 2010, however, it was suddenly stopped in early 2014 due to governmental policy change in energy and mineral resources, hence making Kawasi an inactive nickel mining area for now (PK2LI, 2015). Nickel deposit in this site varies from 0.5% in the ferricrete zone (top layer) to as much 3% in saprolite zone (lowest layer).

Nickel compounds and metallic nickel have many industrial and commercial applications, and are found in many objects of general use, such as coins, earrings, watches, belt buckles, bras, mobile phones, dental and orthopedic implants, and cardiovascular stents (Zambelli, Uversky and Ciurli, 2016). This non-ferrous metal has good physical, chemical, mechanical properties for those appliances, either as single metal or in alloy with other metals. In addition to stainless steel, nickel is also used as fine chemical for catalyst in many chemicals industries and electroplating. Therefore, nickel demand always increases resulting in intensive nickel exploitation globally.

Usually, mining companies export raw (wholly) nickel ores without prior extraction and purification. The government of Indonesia through the Ministry of Energy and Mineral Resources (No. 1/2014) had banned the export of raw minerals ores. By this, all minerals are mandated to build and operate metal smelter to refine metal ores before exported. In response to this, Harita Nickel, a holding company of nickel smelter at the mining in Obi Island, is planning to build a nickel smelter at the mining site in Obi Island (PK2LI, 2015).

In Indonesia, nickel mines must undertake rigorous environmental protection and management measures because the potential risks of their operations to the environment and human health are inevitably high (Amin *et al*., 2015). Not only that, nickel mining are also known to have deleterious effect on the quality of environment by degrading natural ecosystems, forest, and lagoon (Pasquet *et al*., 2016).

Therefore, it is mandatory to *PT Trimegah Bangun persada* (TBP), a nickel mining operator under Harita nickel, to carry out a baseline study on mineral contamination and community health consequences before the smelter is built and operated. As a result, in 2015 an environmental health risk analysis methods was conducted to measure the community health consequences before the smelter is built and operated, while also considering the characteristics of anthropometric exposure factors of the population in Kawasi village. This public health risk analysis is intended to obtain baseline data on lead contamination in groundwater extracted from dug wells for drinking water when nickel mining is not operating.

2. RESEARCH METHODS

This research was an analytical observational cross-sectional study using the Environmental Health Risk Analysis method, by calculating or predicting the risk of nickel and lead exposure in drinking water. A cross-sectional study was conducted to estimate the risk of exposure to lead via drinking water ingestion pathway for the population of Kawasi Village at Obi Island and Soligi Village, as a comparison of the research which located far enough from the nickel mining site. This research was conducted from 19 to 26 may 2015, and involving 11 personnel. Two research expert in environmental contamination and health effects, one field supervisor, two laboratory technicians, and six enumerators.

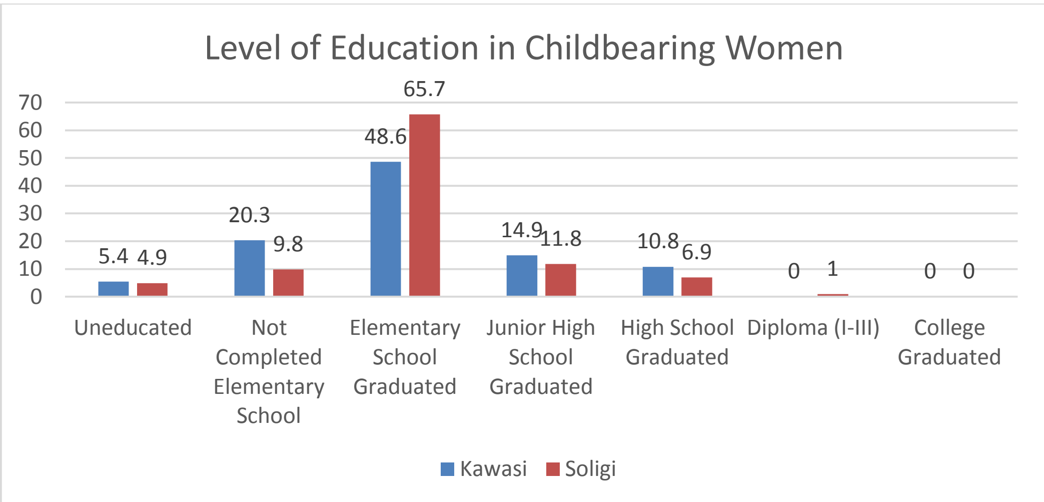
The study included 984 respondents, with 328 men aged 18-65 years, 328 women of childbearing-aged 15-45 years, and 328 children aged 6-12 years. They were subjected to survey and measurements of socio-demographic characteristic, and anthropometric exposure factors. In addition, the study also collected 20 sample of drinking water throughout both villages. In the Kawasi and Soligi Village, the experiment conducted two physical and 32 chemical parameters in 40 drinking samples, and two bacteriological parameters (*E. coli* and *coliform*) in 60 drinking water samples. Aforementioned biological agents were analyzed by Environmental Health Laboratory of Faculty of Public Health, at Universitas Indonesia, Depok. By this method and design, the present study is reported in two main parts. First, exposure evaluation of minerals contamination in environmental media that contact to human. Second, health risk estimates from exposure to mineral from inhalation of dust-containing minerals Ingestion of drinking water.

3. RESULTS

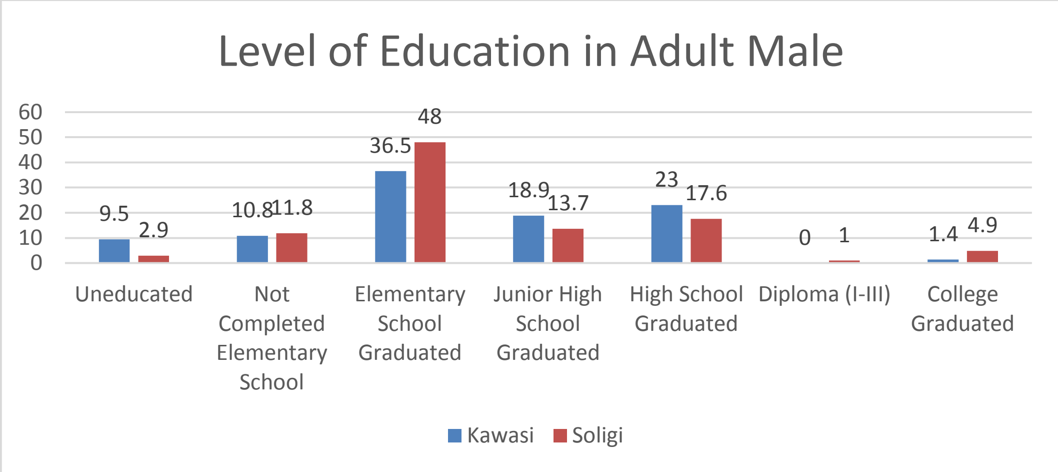
The results show that Kawasi and Soligi are the comparable village in socio-demographic characteristics, physical environment, exposure factors' characteristics. In general, the population of Kawasi and Soligi represents a typical resident in a small island that characterized by difficult communication and transportation. They largely depend on natural resources; mostly live on farming and fishing, low education level, inadequate sanitation, and bad personal hygiene. The major community concern is not only perceptible adverse health effects but also about air and water contamination. Dust in both villages with respect to mining activity.

3.1 The General Characteristics of The Population

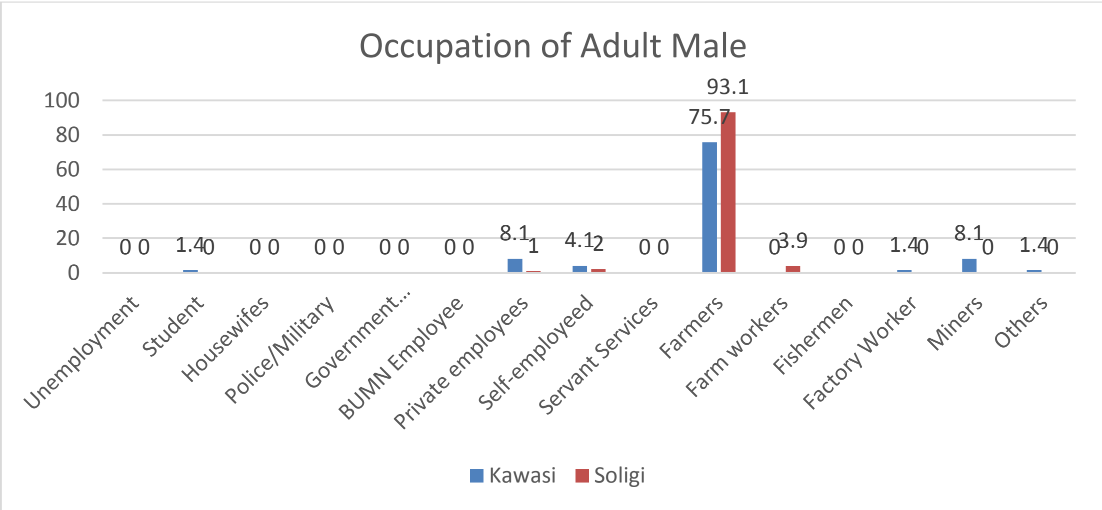
The general characteristics of the population of KawasiVillage and Soligi Village according to the level of education of adult men and women of childbearing age are listed in Figure 3.1 and figure 3.2, respectively, while the proportion of occupations is listed in Figure 3.3 and Figure 3.4. Educational achievement is categorized into seven levels of education unit, i.e. graduated from Elementary /Madrasah Ibtidaiyah (MI), completed primary school / junior high school, junior high school / Madrasah Tsanawiyah (MTS), graduated from Senior High School / Madrasah Aliyah (MA), completed diploma (1-3) and graduated from college.



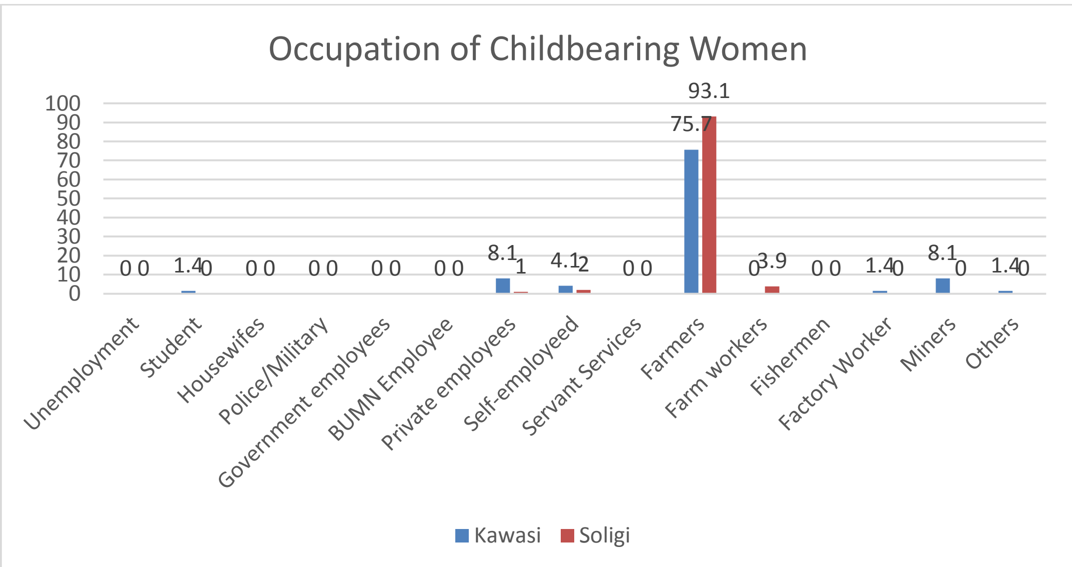
Picture 3.1 Proportion of educational outcomes of women of reproductive age of villagers of mining circles (Kawasi) and comparison villages (Soligi) of nickel mining areas on Obi island, South Halmahera District, North Maluku Province.



Picture 3.2 Proportion (%) Education achievement of male adult of mining circle village (Kawasi) and comparison village (Soligi) of nickel mining area on Obi island, South Halmahera District, North Maluku Province.



Picture 3.3 Proportion (%) type of employment of adult male villagers of mining circle (Kawasi) and comparison village (Soligi) nickel mining area on Obi island, South Halmahera District, North Maluku Province.



Picture 3.4 Proportion (%) type of employment of women of reproductive age of the villagers of the mining circle (Kawasi) and the comparison village (Soligi) of the nickel mining area on Obi island, South Halmahera District, North Maluku Province.

If achievement in the primary, secondary, and higher education is combined, education level in Soligi is better that than Kawasi. In soligi, adult males who completed all formal education (primary school to university) is 85,2% whereas in Kawasi is 79,8%. Similarly, fertile age woman who completed all formal education is 85,4% in Soligi and 74,3% in Kawasi. It is clear also that in both villages the formal education achievement among adult males adult females is similar.

3.2 Characteristics of Anthropometry and Activity Patterns

Table 3.1: Characteristics of Anthropometry and Respondent Activity Pattern (n = 984)

Characteristic	**Soligi village**			**Kawasi village**		
	Mean ± SD	Median	Distribution	Mean ± SD	Median	Distribution
Male						
Age, year	39,8 ± 8,6	40	Abnormal	37,5 ± 9,2	34,5	Abnormal
Weight, kg	58,8 ± 8,5	57,9	Abnormal	60,6 ± 8,1	60,2	Normal
Height, cm	162 ± 7	164	Normal	163 ± 5	164	Normal
Female						
Age, year	33,4 ± 7,3	33	Normal	33,2 ± 6,9	33	Normal
Weight, kg	60,5 ± 11,2	58,5	Abnormal	59,8 ± 11,2	58,5	Normal
Height, cm	157 ± 5	153	Normal	153 ± 5	153	Abnormal
Children						
Age, year	9,3 ± 1,8	9	Abnormal	9,5 ± 1,9	10	Abnormal
Weight, kg	23,9 ± 6,5	22,6	Abnormal	25,3 ± 7	24	Abnormal
Height, cm	126 ± 1	127	Normal	128 ± 1	129	Normal

Source: Primary Data of 2015

Table 3.1 summarizes the summary of inbound statistical values and data distribution of anthropometric exposure factors, adult male activity patterns, women of childbearing age and school-aged children. This table compares the mean, median, and data distribution values in the mining area (Kawasi Village) with the data in comparison with another areas (Soligi Village).

Table 3.2: Characteristics of Drinking Water Sample

Parameters, mg/L	**Nilai Rujukan (mg/L)**	**Kawasi**		**Soligi**	
		Mean ± SD	**Distribution**	**Mean ± SD**	**Distribution**
Physic					
Color	15	<5,2 ± 0,89	Abnormal	<12,05 ± 8,26	Abnormal
Turbidity	5	<0,85 ± 0,36	Abnormal	1,65 ± 1,26	Abnormal
Hardness	500	70,05 ± 42,12	Abnormal	136,55 ±75,97	Abnormal
Essential Logam					
Nickel	0,07	<0,001 ± 4,4E-19	Normal	<0,00165 ± 0.001	Abnormal
Iron	0,3	<0,0185 ± 0,0046	Abnormal	<0,0255 ± 0,0157	Abnormal
Cobalt	c	<0,001 ± 4,4E-19	Normal	<0,001 ± 4,45E-19	Normal
Manganese	0,4	<0,005 ± 8,9E-19	Normal	<0,00505 ± 0,0002	Abnormal
Chromium	0,05	<0,005 ± 8,9E-19	Normal	<0,005 ± 8,9 E-19	Normal
Calsium	c	11,86 ± 16,99			
Magnesium	c	9,84 ± 1,87	Abnormal	11,74 ± 7,051	Abnormal
Vanadium	c	<0,02 ± 3,56E-19	Normal	<0,0016 ± 0,00111	Abnormal
Molibden	0,07	<0,001 ± 4,4E-19	Normal	<0,0015 ± 0,0009	Abnormal
Choper	2	<0,005 ± 8,9E-19	Normal	< 0,005 ± 8,9 E-19	Normal
Zink	c	<0,0061 ± 0,0049	Abnormal	<0,0068 ± 0,00827	Abnormal
Heavy Metal					
Paladium	c	<0,02 ± 3,56E-19	Normal	<0,05 ± 7,12 E-18	Abnormal

Silver	c	<0,0001 ± 1,4E-20	Normal	<0,0001 ± 1,4E-20	Normal
Cadmium	0,003	<0,0001 ± 1,4E-20	Normal	< 0,0001 ± 1,4 E-20	Normal
Mercury	0,001	<0,0005 ± 7E-21	Normal	<5E-5 ± 6,9 E-21	Normal
Lead	0,01	<0,001 ± 4,4E-19	Normal	<0,001 ± 4,45E-19	Normal

Source: Primary Data of 2015

From the characteristics of drinking water sample comparation (table 3.2) as a summary of the statistical values of inhabitants, distribution and percentage of mineral contamination in the mine area (Kawasi Village) and comparator areas (Soligi Village). The water quality parameters consisted of two physical parameters (color and turbidity), one aggregate parameter (hardness), 10 transitional elemental metal elements (nickel, iron, cobalt, manganese, chromium, magnesium, vanadium, molybdenium, copper, zinc), and five heavy metals (palladium, silver, cadmium, mercury, lead).

In this table, the mean difference of mineral contamination of mine ring area with mineral contamination in the comparative region. Differences in both regions contamination were tested by different statistical tests of two mean. In calculating the mean, standard deviation or standard deviation (SD), standard error, skewness, and minimum and maximum numbers '<' (less than the limit of dedication (LOD) of laboratory analysis instruments) are excluded (considered zero or no value), so that only samples whose mineral concentrations are detected are calculated.

3.3 CDI Calculation (Daily Intake)

Table 3.3: Result of CDI/LADD, RQ/ECR

Contaminant and Population Group	**CDI/LADD**		**RQ/ECR**	
	Kawasi	**Soligi**	**Kawasi**	**Soligi**
Essential Logam				
Lead				
Male	8.32381E-6	8.32381E-6	4.10364E-7	4.10364E-7
Female	1.21835E-5	1.21835E-5	6.00645E-7	6.00645E-7
Children	5.35714E-6	5.35714E-6	2.64107E-7	2.64107E-7
Nickel				
Male	3.75914E-5	3.75914E-5	0.001879569	0.001879569
Female	3.34448E-5	3.34448E-5	0.001672241	0.001672241
Children	4.16667E-5	4.16667E-5	0.002083333	0.002083333

The estimation of Chronic Daily Intake (CDI) from drinking water ingestion for all population groups (adult men, women of childbearing age, school-aged children) are listed in table 3.3.

The results showed the excess cancer risk (ECR) for women, man, and children at Kawasi Village were 6.006×10^{-7}, 4.103×10^{-7}, and 2.641×10^{-7}, respectively. None of the excess cancer risk (ECR) was found to be greater than $>10^{-4}$.

3.4 Risk Management Intake Maximum Concentration (Cmax).

Table 3.4: Result of Cmax

Contaminant and Population Group	**Cmax (μg/M^3)**	
	Kawasi	**Soligi**
Essential Logam		
Lead		
Male	176487491.8	176487491.8
Female	350543611.7	350543611.7
Children	66205364.4	66205364.4
Nickel		
Male	176487491.8	15853701.09
Female	350543611.7	51804474.64
Children	66205364.4	3453192

The estimation of maximum Concentration (Cmax) from drinking water ingestion for all population groups (adult men, women of childbearing age, school-aged children) are listed in aforementioned table 3.4.

Based on the measurement of concentration intake maximum(Cmax) in Kawasi Village found that the value of metal essential Lead for Male is 176487491.8 μg/M^3, female 350543611.7 μg/M^3, and Children 662053664.4 μg/M^3. While Soligi Village found that Male value is 176487491.8 μg/M^3, female 350543611.7 μg/M^3 and children 66205364.4

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4. DISCUSSION

4.1. Anthropometry

Basic education is an education that provides the basis of life, both for personal and for the community. From graphs 3.1 and 3.2 show that Soligi village has a bigger proportion of childbearing woman who graduated at the level of formal education more than Kawasi village, that is 85.4% in Soligi village while 74.3% in the village kawasi. Similarly, the proportion of adult male in Soligi village who graduated at the level of formal education is larger than in the kawasi village, that is 85.2% in Soligi village and 79.8% in Kawasi village.In the type of work in both villages, the farmer as the work that has the largest proportion. Soligi village has a larger proportion of farmers workers than Kawasi village, which is 93.1% in Soligi village while 75.7% is in Kawasi villag. The rate of drinking water consumption of the mine ring population and the comparison area is not much different from the numbers used in the regulation or guideline of 2 L / day, (Levallois et al, 1998). The rate of drinking water consumption of adult men in mining areas around 9% more than the consumption of adult men in the region of comparison. Similarly, in women of childbearing age, kawasi population consumption is about 5% more than the consumption of soligi population. However, the rate of drinking water consumption of school-aged children in both areas is exactly the same. The rate of drinking water consumption of adult population ranging from 1.8 L / day (women of reproductive age in Soligi) to 2.4 L / day (Adult male in Kawasi) is only 10 to 20% with the default value of US-EPA as much as 2 L/ day, but the rate of consumption of school-age children in the kawasi and soligi 50% greater than the default value of US-EPA is only 1 L / day, (US-EPA 1997). Minister of Health RI Regulation no. 492 / menkes / Per / IV / 2010 on drinking water quality requirements is used as 'reference value' of mineral contamination in drinking water to determine CL. For contaminants not regulated by Permenkes 492/2010, the reference value is derived from the value of quantitative toxicity (Rfd) as a maximum contaminant level goal (MCLG) that indicates the limits of contaminant health. (US EPA)

4.2. Charakteristic of Drinking Water Sample

Based on the measurement of characteristic of drinking water sample in kawasi village it was found that the essential value of nickel metal mean ± SD was <0.001 ± 4.4 E-19 with Normal distribution While Soligi village found that Mean ± SD value was <0,00165 ± 0.001 with distribution Abnormal.

Measurement of characteristic of drinking water sample in kawasi village found that the value of heavy metal Lead mean ± SD is <0.001 ± 4.4 E-19 with Normal distribution while Soligi desan found that Mean ± SD is <0.001 ± 4.45E-19 with distribution Normal.

4.3. Excessive Cancer Risk (ECR) and Risk Quotient (RQ)

The level of health risks for non-carcinogenic effects of nickel and lead expressed in risk quotient (RQ) is estimated by comparing daily chronic daily dose (CDI) intake to nickel and lead reference doses (RfD). CDI is calculated according to equation (1), whereas RfD is obtained from the Integrated Risk Information database. Risk is considered to exist and must be controlled if RQ> 1. For carcinogenic effects, the risk level is expressed as excess cance risk (ECR). The ECR is estimated by multiplying the daily average dose of lifesime (LADD) with the cancer slop factor (CSF). Inhaled CSF is obtained from the IRIS database . Risk is considered to exist and must be controlled if RQ> 1. For carcinogenic effects, the risk level is expressed as excess cance risk (ECR). The ECR is estimated by multiplying the daily average dose of lifesime (LADD) with the cancer slop factor (CSF). Inhaled CSF is obtained from the IRIS database, (Rahman, 2017).

In this study, it is found that RQ of nickel in water at both villages is not any different if it's compared to each population group. But if the RQ was compared to population group in each village, then the order from high to low was children as the highest with 0,00208333 followed by the adult male with 0,001879569 and the lowest was the childbearing women with 0,0016722.

Meanwhile the ECR of lead in both village are the same situation like RQ of Nickel that not have any different if its compared to each population group. But if the ECR was compared to all population group in each village, then the order from high to low was childbearing women as the highest with 6.00645E-7 followed by the adult male with 4.10364E-7and the lowest was the childbearing women with 2.64107E-7. None of the excess cancer risk (ERC) was found to be grater than $>10^{-4}$ in addition.

4.4. Concentration Maximum (Cmax)

Based on the measurement of risk management Maximum Consentration (Cmax) in kawasi village found that the value of metal essential Lead for Male is 176487491.8, female 350543611.7, and Children 662053664.4 While Soligi village found that Male value is 176487491.8, female 350543611.7 and children 66205364.4.

Measurement of risk management Maximum Consentration in kawasi village found that the value of metal essential Nickel for Male is 176487491.8, female 350543611.7, and Children 662053664.4 While the village of Soligi found that the value of Male is 15853701.09, female 51804474.64 and children 3453192.

5. CONCLUSION AND SUGGESTION

5.1 Conclusion

Basic on the aforementioned results, it can be concluded:

1. The Excess Cancer Risk (ECR) for childbearing women, man, and children at Kawasi Village were 6.006×10^{-7}, 4.103×10^{-7}, and 2.641×10^{-7}, respectively. None of the excess cancer risk (ECR) was found to be greater than $>10^{-4}$.
2. The highest concentration intake (Cmax) in Kawasi Village were 176487491.8 for man, 350543611.7 for women, and 66205364.4 for children.
3. In conclusion, non-carcinogenic risk attributed to ingestion of lead in the drinking water was found to be negligible.

5.2 Suggestion

1. Boil drinking water in 100^{o} Celcius temperature as a sterilization way to prevent water borne disease.
2. As a prevention measure, do not drink water from the sources of the mining industry near Kawasi Village.

6. BIBLIOGRAPHY

[1]. Levallois, P., Guevin, N., Gingras, S., Levesque, B., Weber, J. & Letarte, R. 1998 *New patterns of drinking-water consumption: results of a pilot study*. Sci. Total Environ. 209, 233–241.

[2]. U.S. EPA (U.S. Environmental Protection Agency). (1997b). *Guiding principles for Monte Carlo analysis.* (EPA/630/R-97/001). Washington, DC.

[3]. US EPA. (n.d.). Comparison of Cal / EPA and US EPA Toxicity Values Report of the Risk Assessment Advisory Committee.

[4] PK2LI. (2015). *Analisis Risiko Kesehatan Berbasis Lingkungan & Komunitas Pertambangan Nikel di Pulau Obi.* Jakarta. Pusat Kajian Kesehatan Lingkungan dan Industri

[5] Zambelli, B., Uversky, V. and Ciurli, S. (2016). Nickel impact on human health: An intrinsic disorder perspective. *Biochimica et Biophysica Acta (BBA) - Proteins and Proteomics*, 1864(12), pp.1714-1731.

[6] Amin, R., Edraki, M., Mulligan, D. and Gultom, T. (2015). Chromium and nickel accumulation in the macrophytes of the Kawasi wetland on Obi Island, North Maluku Province, Indonesia. *Australian Journal of Botany*, 63(7), p.549.

[7] Pasquet, C., Le Monier, P., Monna, F., Durlet, C., Brigaud, B., Losno, R., Chateau, C., Laporte-Magoni, C. and Gunkel-Grillon, P. (2016). Impact of nickel mining in New Caledonia assessed by compositional data analysis of lichens. *SpringerPlus*, 5(1)

[8] Rahman, Abdurahman. 2017. *Analisis Risiko Kesehatan Lingkungan* (ARKL) : Buku Rancangan Pengajaran. Program Studi Sarjana Kesehatan Lingkungan Fakultas Kesehatan Masyarakat, Universitas Indonesia

[9] Clesceri, L.S., Greenberg, A.E., & Eaton, A. D (Eds.). (1998a). Standard Methods for the Examination of Water and Wastewater 20th Ed. Washington, DC: American Publik Health Association/American Water Works Association/Water Environment Federation.

[10] Lee,. J.-S., Chon,H. -T., Kim, K. -W. (2005) Human Risk Assessment of As, Cd, Cu, and Zn in the abandoned metal mine site. Environtrmental Geochemistry and Health, 27, 185 - 191

[11] Muzenda, C., Pumure, I. (2001). *Effects of Nickel mining Activities on water Quality*. Paper presented at the national meeting of the American Society of Mining ang Reclamation. Lexington , KY, June 9-13, 2002