Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 32s (2025)
https://www.jneonatalsurg.com

Environmental Health Risk Analysis of Exposure to Iron (Fe) and Manganese (Mn) in Dug Well Water in Banta-Bantaeng Sub-district, Makassar City

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Cite this paper as: A. Jihan Asyura Aprilyani Amri, Anwar Mallongi, Erniwati Ibrahim, Setiawan Kasim, (2025) Environmental Health Risk Analysis of Exposure to Iron (Fe) and Manganese (Mn) in Dug Well Water in Banta-Bantaeng Sub-district, Makassar City. *Journal of Neonatal Surgery*, 14 (32s), 3371-3383.

ABSTRACT

Clean water is one of the most important necessities of life it can be a primary means to improve public health. The purpose of this study was to analyze the health risks of exposure to iron (Fe) and manganese (Mn) in dug well water in Banta-Bantaeng Village, Makassar City. This study is an observational study with environmental health risk analysis (EHRA). The results showed that the level of risk of exposure to heavy metal iron for adults was 3×10^3 ml/L/day while for children it was 9×10^2 ml/L/day, which means that on average the community around the Banta-Bantaeng Village Area, Makassar City is at risk of experiencing health problems in children and adults because the THQ value is > 1. For the risk level of exposure to heavy metals manganese, the average for adults is 2×10^5 ml/L/day while for children it is 2×10^2 ml/L/day, which means that on average, the community around the Banta-Bantaeng Village Area, Makassar City is at risk of experiencing health problems in children and adults because the THQ value is > 1. The average level of health risk of exposure to iron (Fe) and manganese (Mn) in dug well water in Banta-Bantaeng Village, Makassar City, is at risk for health.

Keywords: *EHRA; Iron (Fe); Manganese (Mn); Hazard Quotient; Target Hazard Quotient; Risk Management*

1. INTRODUCTION

Global water quality continues to be a major concern as the need for clean water increases and the impact of human activities on the environment. One issue that often arises is metal contamination in water, especially iron (Fe) and manganese (Mn). Iron and manganese content that exceeds the threshold not only affects the taste, color, and odor of water, but also has an impact on human health and damages the pipeline network and water distribution system.

Clean water is a primary need in improving public health [1]. Good water quality meets health requirements and can be used for daily needs such as washing and cooking [2]. However, based on WHO data, 663 million people in the world still have difficulty accessing clean water, and it is estimated that two-thirds of the population will have difficulty accessing clean water by 2025 [3].

Iron and manganese are essential metals that the body needs in small amounts, but excessive exposure can have negative impacts on health. Consuming water with high levels of Fe and Mn can cause health problems, such as weakness, coughing, shortness of breath, bronchopneumonia, pulmonary edema, and cyanosis and methemoglobinemia [4].

In Indonesia, population growth is directly proportional to the increase in the need for clean water. In 2018, Indonesia's clean water production was recorded at 4,879,050 m^3 for 268 million people [5]. Good environmental quality is reflected in the availability of clean water, where one of the main sources is well water. However, the quality of well water in some areas does not always meet standards, often contaminated with iron (Fe) and manganese (Mn), making the water unfit for consumption [6]. In Banta-Bantaeng Village, many wells have Fe levels above the safe limit (2.4 mg/l), not in accordance with the Indonesian Minister of Health Regulation No. 32 of 2017 (1.0 mg/l). Well water pollution by heavy metals contributes to increased health risks such as hypertension and other diseases. Research shows that Fe, Cu, Zn, and Mn in well water are still below the quality standard, while Cd and Pb exceed the established limits [7]. Excessive exposure to iron and manganese can cause health problems, including insomnia, heart attacks, and liver cancer [8].

Makassar City, as one of the big cities in Indonesia, is not free from this problem. Banta-Bantaeng Village, which has a high population density, many residents still rely on dug wells as their main source of water. However, until now, data on the levels of Fe and Mn contamination and their potential health risks in this area are still limited. Environmental Health Risk Analysis (EHRA) is an effective method for identifying and assessing the potential hazards of environmental contaminants to human health. This approach allows for a quantitative assessment of the risks posed by exposure to contaminants, such as Fe and Mn, in drinking water. Thus, EHRA can be an important tool in formulating mitigation strategies and decision-making related to water quality management.

Based on these conditions, it is important to conduct an environmental health risk analysis of exposure to iron (Fe) and manganese (Mn) metals in dug well water in Banta-Bantaeng District, Makassar City. This study aims to identify the level of contamination, calculate the potential long-term health risks, and provide a scientific basis for public health mitigation and intervention efforts. By understanding the magnitude of the risk and the factors that influence it, it is hoped that the results of this study can be a reference for the government and stakeholders in designing safe, sustainable, and public health water source management policies.

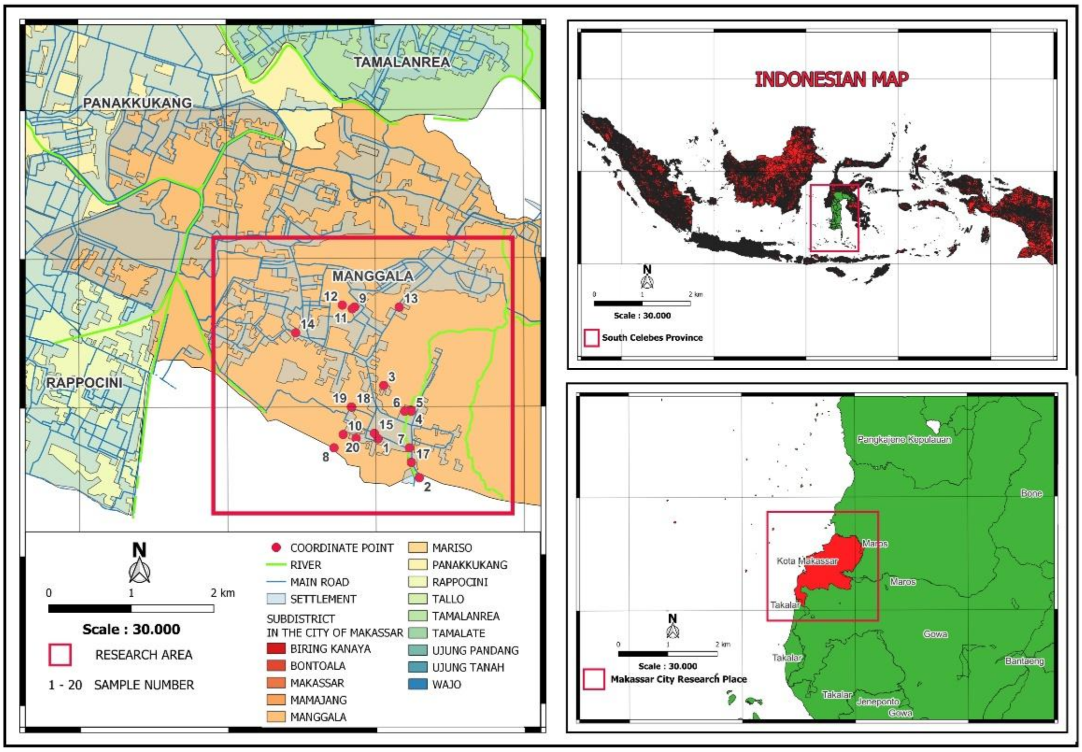

Figure 1. **Map of Research**

The selection of sampling locations in the Banta-Bantaeng District, Makassar City, was based on the characteristics of the area where most of the population still relies on dug well water as the main source of clean water for daily consumption. This area is also included in a densely populated area with quite rapid residential growth, but is not balanced by adequate sanitation systems and water resource management. In addition, based on initial data and reports from residents, there are indications of changes in the quality of well water, such as changes in color, taste, and odor, which lead to suspected heavy metal contamination, such as iron (Fe) and manganese (Mn). This condition makes the area relevant for a more in-depth environmental health risk study.

On the other hand, the geological and hydrological structures in Banta-Bantaeng allow for the natural dissolution of these metals into groundwater, especially in dug wells that are not equipped with good wall and cover protection. In addition to natural factors, human activities such as the disposal of domestic waste without treatment, the use of detergents, and agricultural activities around settlements also contribute to the potential for pollution. Therefore, the selection of this location not only takes into account the level of environmental vulnerability, but also its strategic value in providing a real picture of the health impacts that may arise due to exposure to heavy metals from daily drinking water in rapidly developing urban areas that do not yet have an optimal water management system.

2. MATERIALS AND METHODS

Research Design

This study used an observational method (field observation, laboratory analysis of iron and manganese concentrates in well water) with the Environmental Health Risk Analysis (EHRA) approach. Environmental Health Risk Analysis (EHRA) or also known as Environmental Health Risk Analysis, is a systematic approach used to assess and evaluate potential health risks associated with human exposure to environmental pollutants [9]. This analytical framework is used to determine the extent to which certain heavy metal contaminants, or various chemical compounds can have a negative impact on human health, taking into account the level of exposure and the toxicological properties of the substance in question, namely in the form of observations of samples to determine the description of the variables studied, namely the description of the Environmental Health Risk Analysis of the distribution of iron and manganese in the well water of the Banta-*bantaeng community, Makassar City.*

Sampling Technique

The sampling methodology used in the Environmental Health Risk Analysis of Detergent Contamination in Well Water used a purposeful sampling approach. This approach involves the deliberate selection of wells with a higher probability of contamination by pollutants, guided by specific environmental factors and community activities. The selected wells were mostly located near sources of contamination, locations characterized by inadequate sanitation infrastructure, and areas with high population density. Water samples from the wells were collected using a random sampling technique, which involves sampling at designated times to accurately reflect the conditions prevailing at the time of collection. In addition, samples were obtained from multiple locations to increase the reliability of the findings regarding the distribution of iron and manganese pollution within the study area. The collected samples were then subjected to laboratory analysis to measure iron and manganese levels, thereby facilitating the assessment of potential health risks to the community.

Data Analysis

Hazard Identification

This stage aims to identify the dangers posed by the presence of iron and manganese in the environment. Excess iron in water can cause digestive disorders such as nausea, vomiting, and diarrhea, and has the potential to cause secondary hemochromatosis conditions that damage vital organs such as the liver and heart. Meanwhile, high levels of manganese are neurotoxic, especially for children, and can interfere with brain development, cause cognitive decline, and trigger central nervous system disorders with symptoms similar to Parkinson's disease. At this stage, data on the concentration of chemicals in the environment (such as drinking water or surface water) are collected and compared with safe limits set by international standards, such as WHO, EPA IRIS.

Dose-response analysis

This stage analyzes the relationship between the level of exposure to iron or manganese and the biological response it causes. The goal is to determine the threshold at which these chemicals begin to cause harmful effects. Toxicology data from laboratories or epidemiological studies are used to develop dose-response curves, which include values such as the No Observed Adverse Effect Level (NOAEL) and the Lowest Observed Adverse Effect Level (LOAEL). For example, high exposure to iron can cause more severe irritant effects, while low exposure can be considered safe. Dose-response analysis is carried out based on the standardization issued by the US-EPA Agency for the Reference Dose (RfD) value for iron, which is 0.3 (ml/L/d) and manganese, 0.14 (ml/L/d). The dose and concentration hereinafter referred to as RfD are values used as a reference for safe values for the non-carcinogenic effects of a risk agent. The RfD value is the result of research from various sources, both those conducted directly on human objects and extrapolations from the results of empirical research on human experimental animals related to environmental matrices, as well as from regulations or standards set for pollutant risk agents.

Exposure Duration Analysis

Duration of exposure refers to the length of time a person or population is exposed to a particular chemical. Exposure can be acute (short-term) or chronic (long-term). For iron and manganese, chronic exposure duration is usually more relevant because accumulation of chemicals in the ecosystem can lead to long-term impacts on human health. Factors such as frequency of use of contaminated water sources, water consumption habits, and vulnerable populations (children, elderly) are taken into account to determine the duration and intensity of exposure (USEPA).

$$ADD = \frac{C\ x\ IngR\ x\ ET\ x\ EF\ x\ ED}{BW\ x\ AT} \qquad \text{(equation 1)}$$

Information :

ADD : Average daily dose (ml/L/day)

C : Concentration of contaminant in water (ml/L)

IngR : Ingestion Rate (L/hour)

ET : Exposure time (hour/day)

EF : Frequency of exposure (day/year)

ED : Duration duration (year)

BW : Body Weight (kg)

AT : Averaging time (day) [10]

Hazard Quotient

Risk characterization is the final stage that integrates the results of the previous three steps to provide an overview of the level of risk faced. In this stage, the risk is calculated by comparing the actual chemical concentration (from the hazard identification stage) with the value considered safe (from the dose-response analysis). Hazard Quotient (HQ) is a ratio used in environmental health risk analysis to assess the potential impact of a hazardous substance on humans or ecosystems. HQ is calculated by comparing the level of exposure (Exposure Concentration, EC) of a substance with a threshold that is considered safe, such as the Reference Dose (RfD). Risk is usually expressed in the form of a hazard quotient (HQ) or the probability of a particular health effect occurring. If HQ > 1, it means that the health risk is significant and requires mitigation measures.

$$HQ = \frac{ADD}{RfD} \quad \text{(equation 2)}$$

Information:

HQ : *Hazard Quotient*

RfD : *Reference of Dose*

Target Hazard Quotient (THQ) is an indicator used in health risk analysis to assess the potential non-carcinogenic risk due to exposure to hazardous chemicals, such as heavy metals, pesticides, or other chemicals in the environment. THQ is calculated based on the comparison between the daily exposure dose and the reference value that is safe for humans.

$$\text{THQ} = \frac{\text{fE x Dt x R x C}}{\text{RfD x WB x Tvag}} 10^{-3} \quad \text{(equation 3)}$$

Information:

THQ : Target Hazard Quotient

fE : Frequensy Exposure

Dt : Exoosure Duration

R : Oral consumption rate

C : Consentration Risik Agent

RfD : Reference of Dose

Wb : Body Weight

Tavg : Time Average

Ethical Approval

Obtain ethical approval from the Ethics Committee of the Faculty of Public Health, Hasanuddin University, with number 5632/UN4.14.1/TP.01.02/2024 consent for environmental sample collection, data collection, and handling.

3. RESULTS

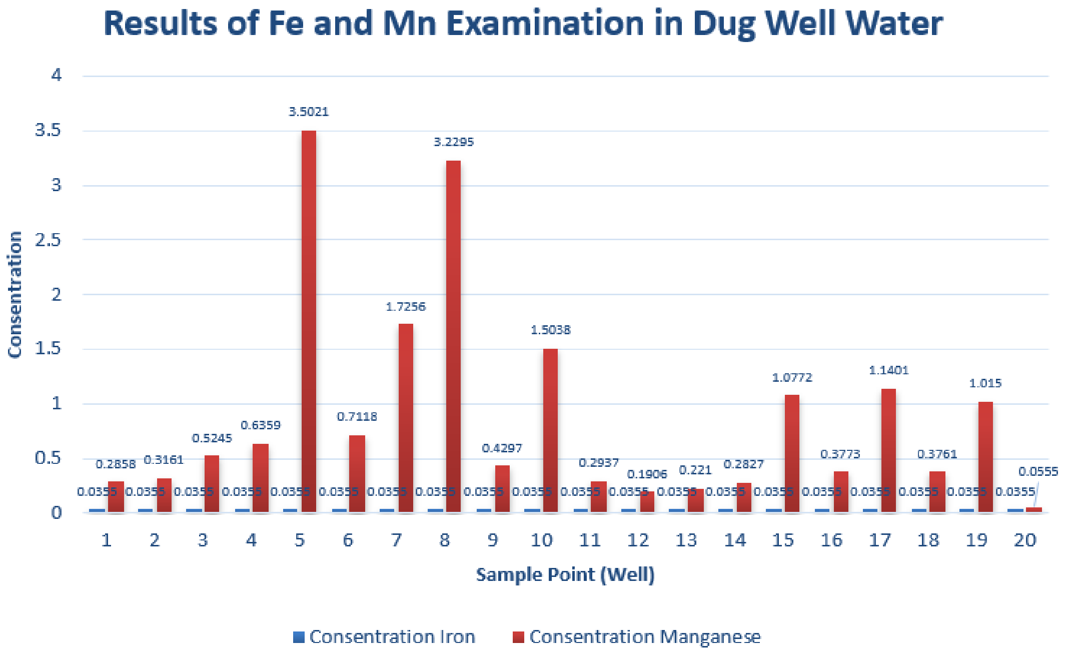

Figure 2. Results of Fe and Mn Examination In Dug Well Water

Based on Figure 2, it shows that there are 20 sampling points for dug well water used by the community. The Fe concentration at all points is 0.0555 mg/l, while the highest Mn concentration is at point 5, which is 3.5021 ml/L.

Table 1. Distribution of Respondent Characteristics in Banta-Bantaeng Village, Makassar City

Variable	Frequency (n)	Percentage (%)
Gender		
Male	67	67.0
Female	33	33.0
Age (Year)		
< 5	11	11.0
6 - 19	18	18.0
20 - 33	32	32.0
34 - 46	23	23.0
47- 60	12	12.0
> 60	4	4.0
Work		
Worker	2	2.0
Housewife	21	21.0
Trader	22	22.0
Scavenger	0	0.0

Variable	Frequency (n)	Percentage (%)
Farmer	1	1.0
Self-employed	25	25.0
Students	19	19.0
Does'nt Work	10	10.0
Weight		
<10	6	6.0
10 - 20	24	24.0
21 - 30	16	16.0
31-40	3	3.0
41-50	25	25.0
51-60	11	11.
>61	15	15.0

Source: Primary Data, 2024

Based on the data in table 1, it shows that there are more male respondents than female respondents, as many as 67 respondents, with the largest age range being 20-33 years, as many as 32 respondents. The majority of the community works as self-employed, as many as 25 respondents, with a body weight dominated by the 41-50 kg range, as many as 25 respondents.

Table 2. Respondent Characteristics Based on Body Weight and Community Activity Patterns in Banta-Bantaeng Village, Makassar City

Indicator	Min	Max	Mean	Information
Body Weight	3	82	40	Kg
Intake Rate (IR)	1	2	1.5	L/Day
Exposure Duration (ED)	12	67	38	Year
Average Time (AT)	2190	10950	6570	Day
Exposure Frequency (EF)	356	356	356	Day/Year

Source: Primary Data, 2024

Based on the data in table 2 shows that the respondents' body weight ranged from 3 kg to 82 kg and an average of 40 kg. The respondents' ingestion rate for children was 1 L/Day and for adults 2 L/Day. The respondents' exposure duration ranged from 12 to 67 years with an average of 38 years. The respondents' exposure frequency ranged from 356 days/year and an average of 356 days/year.

Table 3. Min, Max and Mean ADD Values of Respondents for Ingestion Path Iron Exposure in Banta-Bantaeng Village, Makassar City

Intake (ml/L/hari)	Minimum		Maximum		Average		Information	
	Child	Adult	Child	Adult	Child	Adult	Child	Adult
Realtime	2×10^{-4}	7×10^{-3}	2×10^{-3}	1×10^{-2}	1×10^{-3}	9×10^{-3}	MS	MS
Lifetime								
5	1×10^{-3}	3×10^{-2}	1×10^{-2}	6×10^{-2}	6×10^{-3}	4×10^{-2}	MS	MS

Intake (ml/L/hari)	Minimum		Maximum		Average		Information	
	Child	Adult	Child	Adult	Child	Adult	Child	Adult
10	2 x 10^{-3}	7 x 10^{-2}	2 x 10^{-2}	1 x 10^{-1}	1 x 10^{-2}	9 x 10^{-2}	MS	MS
15	3 x 10^{-3}	1 x 10^{-1}	4 x 10^{-2}	1 x 10^{-1}	2 x 10^{-2}	1 x 10^{-1}	MS	MS
20	4 x 10^{-3}	1 x 10^{-1}	5 x 10^{-2}	2 x 10^{-1}	2 x 10^{-2}	1 x 10^{-3}	MS	MS
25	5 x 10^{-3}	1 x 10^{-1}	6 x 10^{-2}	3 x 10^{-1}	3 x 10^{-2}	2 x 10^{-1}	MS	MS
30	6 x 10^{-3}	2 x 10^{-1}	8 x 10^{-2}	3 x 10^{-1}	4 x 10^{-2}	2 x 10^{-1}	MS	MS

Description: MS (Eligible), TMS (Not Eligible)

**Note: RfD 0.30 ml/L/day*

Source: Primary Data, 2024

Based on the data in Table 3, the real-time ADD intake value of non-carcinogenic Iron exposure through the ingestion route (oral) of 100 respondents obtained the results that the average value for adults was 9 x 10^{-3} ml/L/day higher than children, which was 1 x 10^{-3} ml/L/day. While the lifetime ADD intake of non-carcinogenic Iron exposure projections for the 5th - 30th year, the average value for children was 4 x 10^{-2} - 2 x 10^{-1} ml/L/day, lower than adults, which was 6 x 10^{-3} - 4 x 10^{-2} ml /L/day.

Table 4. Min, Max, and Mean THQ Values of Ingestion Path Iron Levels in Banta-Bantaeng Village, Makassar City

THQ (ml/L/hari)	Min		Max		Average		Information	
	Child	Adult	Child	Adult	Child	Adult	Child	Adult
Realtime	1 x 10^{2}	2 x 10^{3}	1 x 10^{3}	4 x 10^{3}	9 x 10^{2}	3 x 10^{3}	Risk	Risk
Lifetime								
5	7 x 10^{2}	1 x 10^{4}	9 x 10^{3}	2 x 10^{4}	4 x 10^{3}	1 x 10^{4}	Risk	Risk
10	1 x 10^{3}	2 x 10^{3}	1 x 10^{4}	4 x 10^{4}	9 x 10^{3}	3 x 10^{4}	Risk	Risk
15	2 x 10^{3}	4 x 10^{3}	2 x 10^{4}	7 x 10^{4}	1 x 10^{4}	5 x 10^{4}	Risk	Risk
20	2 x 10^{3}	5 x 10^{3}	3 x 10^{4}	9 x 10^{4}	1 x 10^{4}	7 x 10^{4}	Risk	Risk
25	3 x 10^{3}	7 x 10^{3}	4 x 10^{4}	1 x 10^{5}	2 x 10^{4}	9 x 10^{4}	Risk	Risk
30	4 x 10^{3}	8 x 10^{3}	5 x 10^{4}	1x 10^{5}	2 x 10^{4}	1 x 10^{5}	Risk	Risk

Description: MS (Eligible), TMS (Not Eligible)

**Note: Risky if THQ > 1, no risk if THQ < 1*

Source: Primary Data 2024

Based on Table 4, it can be seen that the real-time non-carcinogenic hazard quotient (THQ) target value for Iron of 76 respondents (children and adults) is a mean value for adults of 3 x 10^{3} ml/L/day higher than for children of 9 x 10^{2} ml/L/day, which means that on average, the community around the Banta-bantaeng Village Area, Makassar City is at risk of experiencing health problems in children and adults because the THQ value is >1. While the THQ lifetime projection for the 5th - 30th year for children is around 4 x 10^{3} - 2 x 10^{4} ml/L/day and adults around 1 x 10^{4} - 1 x 10^{5} ml/L/day, so it can be concluded that in terms of lifetime 5 - 30 years, the community around the Banta-bantaeng Village Area, Makassar City is at risk of experiencing health problems.

Table 5. Min, Max, and Mean THQ Values of Manganese Ingestion Path in the Banta-bantaeng Subdistrict Area of Makassar City

THQ (mgl/L/hari)	Min		Max		Average		Information	
	Child	Adlt	Child	Adult	Child	Adult	Child	Adult
Realtime	9 x 10	1×10^4	1×10^3	7×10^5	2×10^2	2×10^5	Risk	Risk
Lifetime							Risk	Risk
5	4×10^1	5×10^4	5×10^3	3×10^6	1×10^3	1×10^6	Risk	Risk
10	9×10^1	1×10^5	1×10^4	7×10^6	2×10^3	2×10^6	Risk	Risk
15	1×10^2	1×10^5	1×10^4	1×10^7	3×10^3	3×10^6	Risk	Risk
20	2×10^2	2×10^5	2×10^4	1×10^7	4×10^3	5×10^6	Risk	Risk
25	2×10^2	2×10^5	2×10^4	1×10^7	5×10^3	6×10^6	Risk	Risk
30	2×10^2	3×10^5	3×10^4	2×10^7	6×10^3	6×10^6	Risk	Risk

Description: MS (Eligible), TMS (Not Eligible)

**Note: Risky if THQ > 1, no risk if THQ < 1*

Source: Primary Data 2024

Based on Table 5, it can be seen that the target value of the non-carcinogenic real-time hazard quotient (THQ) of manganese for 100 respondents (children and adults) is the average value for adults 2×10^5 ml/L/day higher than for children, which is 2×10^2 ml/L/day, which means that on average the community around the Banta-bantaeng Village Area, Makassar City is at risk of experiencing health problems in children and adults because the THQ value is > 1. While the THQ lifetime projection for the 5th - 30th year for children is around 1×10^3 - 6×10^3 ml/L/day and adults around 1×10^6 - 6×10^6 ml/L/day so it can be concluded that in terms of lifetime 5 - 30 years the community around the Banta-bantaeng Village Area, Makassar City is at risk of experiencing health problems.

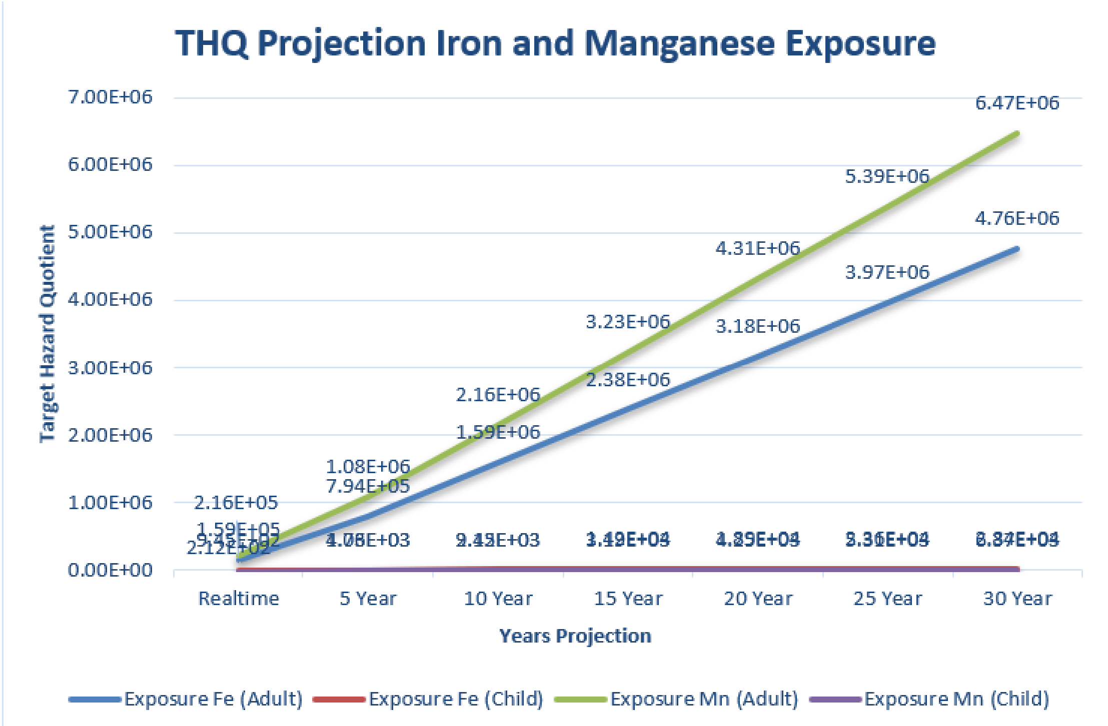

Figure 3. Projection of Target Hazard Quotient (THQ) for Fe and Mn Exposure in Banta-bantaeng Village, Makassar City

Based on Figure 3, it shows that real-time and lifetime exposure every year (5-30) in the future for children and adults tends to experience a significant increase. The projected increase in exposure to iron (Fe) and manganese (Mn) metals each year is caused by the gradual accumulation of contaminants in the environment, especially in groundwater sources such as dug wells that do not have adequate protection systems. Over time, these metals can continue to accumulate due to leaching from soil and rock layers, and are triggered by human activities such as the use of chemical fertilizers, domestic waste disposal, and industrialization around settlements. In addition, climate and seasonal changes also affect the dynamics of water quality, where metal concentrations tend to increase in the dry season due to decreasing groundwater volume. If there are no efforts to control or improve water quality, the level of community exposure to these heavy metals will increase every year, which ultimately has the potential to increase long-term health risks.

4. DISCUSSION

Intake Rate (IR)

Ingestion Rate (IR) is the amount of water consumed by an individual from a particular source in a certain period of time. Ingestion rate is the amount of groundwater consumed by respondents within 24 hours or every day. The intake rate value is used to calculate the level of risk of heavy metals contained in the groundwater consumed. In this context, IR is related to the amount of iron (Fe) and manganese (Mn) dissolved in well water drunk by a person. The respondent's ingestion rate for children is 1 L/Day and for adults 2 L/Day.

Higher ingestion rates are generally found in adults, while lower ingestion rates likely reflect children or individuals with lower activity. Ingestion is an important parameter in environmental health risk studies, especially related to exposure to pollution through ingestion. The longer a person is exposed to hazardous materials, the greater the intake value and the greater the potential health risks they will receive. The effects of consuming drinking water with high levels of iron and manganese are closely related to the level and duration of exposure. In general, the higher the levels of iron and manganese and the longer the exposure, the greater the toxic effects. The higher the intake of exposure, the higher the risk of health problems caused [11].

Exposure Duration

Exposure Duration (ED) is the period of time during which an individual is exposed to a chemical. The duration of exposure (years) used in this study is real-time and lifetime (non-carcinogenic exposure duration 5-30 years). The duration of exposure of respondents ranged from 12-67 years, with an average of 38 years. This shows that most respondents have lived in the study location for a long time, so exposure to pollutants may have occurred in the long term. Long duration of exposure can increase health risks associated with exposure to environmental contaminants. Duration of exposure affects the intake value, where the longer the consumption of drinking water (duration of exposure), the greater the intake value and the greater the risk of getting adverse health effects [12].

The high frequency of respondents is because all respondents live in the study location and use groundwater or well water as a source of drinking water consumed daily, which can increase the risk of health problems for respondents because respondents are continuously exposed to drinking water containing iron and manganese. As concluded by previous researchers [11] that the magnitude of the risk obtained by respondents is determined by one of the frequency of exposure received, where the greater the frequency of a person being exposed to hazardous substances in one year, the greater the health risk that will be received. The longer the duration of the frequency of exposure, the greater the risk of health problems due to exposure to the agent.

Frequent Exposure

Frequency of exposure is the number of days of exposure to respondents at the research location. This high frequency of exposure indicates that respondents experience continuous exposure to environmental pollutants, which can have a significant impact on their long-term health. Frequency of exposure is the number of days respondents are exposed at the research location. The frequency of exposure for each person is determined by the length of the year (365 days). Frequency of exposure affects the absorption of iron and manganese into the body and the level of a person's exposure to hazardous substances. The main route of entry of iron and manganese in groundwater into the human body is through drinking water consumption or through the ingestion route so that the calculation of intake/intake of iron and manganese exposure is influenced by the concentration of iron and manganese in groundwater, rate of consumption (intake), frequency of exposure, duration of exposure and body weight. For the exposure frequency variable, the default value is 350 days/year (the default value in residential areas for drinking water exposure pathways based on US-EPA 1997), while the consumption rate, exposure duration and body weight variables are based on information obtained during interviews with 100 respondents [14]. According to the survey conducted, the frequency of exposure to iron and manganese at the research location was 350 days per year (stand exposure). Risks associated with exposure to iron and manganese. The fact that the frequency of exposure of all respondents was 350 days means that all respondents are very likely to have relatively high intake values. The more often and longer a person is polluted or in a polluted environment, the more hazardous substances enter the body and the greater the risk of health problems [15].

Target Hazard Quotient

Exposure to iron through the ingestion route is a critical factor that must be considered in assessing public health risks, especially in the area around the research location. Target Hazard Quotient (THQ) is an indicator used to assess non-carcinogenic risks, where a THQ value> 1 indicates a health risk that needs to be managed [16]. The real-time non-carcinogenic target hazard quotient (THQ) value of Iron 76 respondents (children and adults) is a mean adult value of 3 x 10^3 ml/L/day higher than children, namely 9 x 10^2 ml/L/day, which means that the average community around the Banta-bantaeng Village Area, Makassar City is at risk of experiencing health problems in children and adults because the THQ value is> 1. Meanwhile, the THQ lifetime projection for the 5th - 30th year for children is around 4 x 10^3 - 2 x 10^4 ml/L/day and adults around 1 x 10^4 - 1 x 10^5 ml/L/day. These figures indicate that long-term exposure to iron can increase the risk of serious health problems, including nervous system damage, digestive disorders, and cardiovascular disease [17].

Risk assessment using THQ shows that preventive measures are needed to reduce iron exposure in the community around the study site. These actions can include improving waste management systems to reduce iron exposure to the environment, as well as improving drinking water quality through better treatment [18]. Implementation of stricter regulations is also needed to control iron levels in the environment. The government and relevant authorities must set clear limits for iron concentrations in water, and carry out strict monitoring to ensure that these limits are not exceeded. The very high THQ value indicates that the non-carcinogenic risk posed by this exposure is very serious and requires immediate action [19].

Exposure to manganese through ingestion in the research location area has serious implications for the health of the local community, both for children and adults. Based on the table presented, the Target Hazard Quotient (THQ) value shows that the community around this area is at high non-carcinogenic health risk. THQ is an indicator used to measure health risks due to exposure to chemicals, with a THQ value> 1 indicating a risk that requires mitigation action [20].

The target value of the real-time non-carcinogenic hazard quotient (THQ) of manganese for 100 respondents (children and adults) is an average adult value of 2 x 10^5 ml/L/day higher than that of children, which is 2 x 10^2 ml/L/day, which means that on average the community around the Banta-bantaeng Village Area, Makassar City is at risk of experiencing health problems in children and adults because the THQ value is > 1. While the THQ lifetime projection for the 5th - 30th year for children is around 1 x 10^3 - 6 x 10^3 ml/L/day and adults around 1 x 10^6 - 6 x 10^6 ml/L/day so it can be concluded that in terms of lifetime 5 - 30 years the community around the Banta-bantaeng Village Area, Makassar City is at risk of experiencing health problems. The very high THQ value in adults indicates that this age group is more exposed to manganese through the consumption of contaminated water. Adults consume more water from contaminated sources and have higher cumulative exposure over time. Meanwhile, for children, although the THQ value is lower than that of adults, the health risk remains significant because the absorption of some chemicals, such as manganese, through the digestive tract in children makes them more susceptible to exposure to environmental pollutants due to the low body weight of children and having a higher metabolic rate and immature detoxification system [21]. This is in line with research conducted by Liu [22]· which stated that the average HQ of children was 1.39, exceeding the non-carcinogenic risk threshold and confirming that groundwater manganese poses a health risk to children. These results indicate that manganese contamination of groundwater in the study area poses a risk to human health, and long-term consumption of groundwater as drinking water can pose a threat to human health.

Health Risk

Based on the results of field observations, it was found that most of the physical structures of dug well walls already use ring walls made of cement and are waterproof, with an average well wall height of 3.8 meters, but there are also cracks or gaps found in each joint of the well wall ring. And there are still dug wells that do not have walls at all, so they go directly to the ground. This condition, of course, will pose a risk of groundwater pollution.

Exposure to heavy metals such as iron (Fe) and manganese (Mn) in well water can pose significant health risks to the community. Both are elements commonly found in groundwater, especially in areas with intensive industrial or agricultural activities. Research shows that high levels of Fe and Mn can cause various health problems, including digestive disorders and irritation to the skin and eyes [23,24].

Environmental health risk analysis shows that Fe levels in well water in several areas are still below the threshold set by the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017, which sets the maximum limit for Fe at 1 mg/L and Mn at 0.5 ml/L [23]. However, although the risk quotient for Fe and Mn in several locations shows a figure of less than 1, which means no risk in the short term, it is important to carry out regular monitoring to prevent an increase in the levels of these heavy metals [4,13].

One study in an industrial area showed that although the RQ for Fe exposure was below 1, people were advised to filter well water before consuming it to reduce the health risks that may arise from long-term exposure [23]. This is in line with other findings showing that long-term exposure to high levels of Fe and Mn can cause more serious health problems, including disorders of the nervous and cardiovascular systems [24,26].

On the other hand, research in Depok City shows that manganese levels in well water do not pose a health risk in the next

30 years, with an RQ value also less than 1 [27]. However, although these results indicate that manganese in well water in the area is not at risk, it is important to continue to carry out routine water quality testing, especially in areas that are potentially exposed to contaminants from industrial or agricultural activities [28]. The RQ value (health risk) is influenced by the intake value, where the greater the intake value, the greater the possibility of health problems. The intake value for each population group shows that adult intake is greater than that of children, where the intake value is influenced by exposure factors. The amount of intake value is directly proportional to the concentration value of iron and manganese exposure, and in drinking water, consumption rate, frequency of exposure, and duration of stay, so that the greater the value of these variables, the greater the intake value. However, the intake value is inversely proportional to body weight, where the smaller a person's weight, the smaller the intake received, because body weight is the divisor. In this condition, the intake value of adults is greater than that of children because children consume less water per kilogram of their body weight. The results of the health risk assessment can be associated with age, where the risk of adults is higher than that of children. Gender affects the RQ value, where the health risk assessment in adult women is higher than that of adult men. These results are in line with Zhai's research [29] in China, which showed that age and gender factors are considered the main factors influencing the results of human health risk assessments.

5. RESEARCH OF LIMITATIONS

Data collection on iron and manganese levels in dug well water can vary depending on location, season, and sampling method. There is limited epidemiological data on the long-term impacts of iron and manganese exposure on human health, especially in specific local populations. Without robust data, risk estimates may be inaccurate.

Suggestions for the Future

First, efforts are needed to manage the quality of dug well water by implementing filtration technology such as aeration and the use of zeolite or activated carbon-based filters to reduce Fe and Mn levels that exceed the threshold. Second, the community needs to be educated about the dangers of long-term exposure to these substances and is encouraged to routinely test the quality of well water to ensure it is suitable for consumption. Third, local governments and related agencies need to conduct regular monitoring and provide access to alternative sources of clean water for affected communities. In addition, environmental management policies, such as controlling pollution from industrial and domestic activities, must also be tightened to prevent further contamination of groundwater sources.

6. CONCLUSIONS

Based on the results of the environmental health risk analysis of exposure to iron (Fe) and manganese (Mn) metals in dug well water in Banta-Bantaeng District, Makassar City, it was found that most water samples had Fe and Mn concentrations that exceeded the threshold set by the Ministry of Health and WHO. This condition indicates that dug well water in the area does not meet the standards for clean water quality that is suitable for consumption, especially in terms of heavy metal content. The presence of these metals in high concentrations is thought to originate from local geological conditions, domestic activities, and the lack of a well protection system against environmental pollution.

The results of the health risk calculations show that the Intake and Hazard Quotient (HQ) values for Fe and Mn metals at several sampling points exceed the safe threshold value ($HQ > 1$), which indicates the potential for chronic health risks for people who consume the water in the long term. This risk mainly affects digestive system disorders, metal accumulation in the body, and central nervous system disorders, especially due to exposure to neurotoxic manganese. The groups most vulnerable to this exposure are children and pregnant women, given its impact on brain and nervous system development.

Therefore, comprehensive public health management and intervention measures are needed. Local governments together with related agencies need to routinely monitor the quality of dug well water, provide socialization to the community about the dangers of heavy metal exposure, and provide alternative sources of safer clean water. Simple water treatment efforts such as filtration and aeration can also be a short-term solution to reduce Fe and Mn levels. These findings emphasize the importance of environmental monitoring and protection of water resources to ensure sustainable public health.

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