Journal Home Page:
https://e-journal.unair.ac.id/JKL

Jurnal Kesehatan Lingkungan
Journal of Environmental Health
Vol. 17 No. 1
DOI: 10.20473/jkl.v17i1.2025.1-11
ISSN: 1829 - 7285 | E-ISSN: 2040 - 881X

ORIGINAL RESEARCH Open Access

MICROPLASTIC CONTAMINATION IN WELL WATER IN COASTAL AREA OF JEMBER REGENCY: STUDY OF CHARACTERISTICS, ABUNDANCE AND POTENTIAL CAUSAL FACTORS

Amanda Agustine Arwikana[1], Isa Ma'rufi[1], Globila Nurika[1]

[1]Department of Public Health, Faculty of Public Health, Jember University, Jember 68121, Indonesia

Corresponding Author:
*) nurikaglobila@unej.ac.id

Article Info

Submitted : 30 July 2024
In reviewed : 23 September 2024
Accepted : 7 January 2025
Available Online : 31 January 2025

Keywords : *Dug well consumption, Dug wells microplastics, Microplastics contamination*

Published by *Faculty of Public Health Universitas Airlangga*

Abstract

Introduction: *Sand-textured soil such as coastal makes it easier for microplastics to migrate over longer distances. Kalimalang Hamlet, a coastal area, has a sandy soil texture and most of its people consume untreated dug well water. This condition if it occurs in the long term can cause health problems, such as oxidative stress, metabolic changes, immune dysfunction, and cancer. This study is aimed at analyzing the content, abundance, and causative factors of microplastics in the well water of the community of Kalimalang Hamlet.* ***Methods:*** *This study is a quantitative-research with a descriptive method. Thirty samples of people who consumed water were selected by accidental sampling. Ten wells location was determined using cluster random sampling followed by proportional random sampling. Data analysis used was univariate with crosstab.* ***Results and Discussion:*** *The results showed that 10 dug wells were polluted with microplastics with a total of 188 particles with a size of 0.13-7.24 mm and identified forms of fibers, fragments, filaments. It is estimated that there are 235 microplastic particles per day consumed by the community through dug well water. Well depth, floor, sewerage, and distance from the waste management site have the potential to increase the abundance of microplastics.* ***Conclusion:*** *The distance of the dug well from the sea was not a major factor. This shows the need to implement plastic waste management such as 3R, boiling, and multistage filtration in the dug well water that will be consumed.*

INTRODUCTION

Microplastics are one of the pollutants in waters that have become a global problem because of their impact that threatens the environment and public health (1). Microplastics are pieces or fibers with a size of less than 5 mm (2). Global data on marine plastic waste disposal is one million metric tonnes per year, while Indonesia is the fifth largest producer of marine plastic waste at 56 thousand metric tonnes per year (3). Based on the KLHK performance report in 2022, plastic waste is the most common waste found in Indonesian seas at 105,946.98 gr/m^2 (4).

Microplastics can contaminate groundwater because they enter through pores with vertical and horizontal distribution properties (5-6). Groundwater flow velocity depends on soil type, which affects the movement and distribution of microplastics in groundwater (7). Microplastics can migrate longer distances in sand-textured aquifers than alluvial textures (8). Microplastics have an impact on human health in the form of oxidative damage, cytotoxicity, neurotoxicity, damaging the immune system which results in the onset of autoimmune disorders or immunosuppression. Another impact is to cause genomic instability of peripheral lymphocytes which has an impact on the onset of disease, especially cancer (9).

SIPSN waste generation data in 2022, Jember Regency produces the second highest waste generation in East Java at 370,362.43 tonnes of annual waste and 1,014.69 tonnes of daily waste. Based on data from the Jember District Environment Office in 2022, Puger Sub-district is one of the sub-districts with waste generation

Cite this as :
Arwikana AA, Ma'rufi I, Nurika G. Microplastic Contamination in Well Water in Coastal Area of Jember Regency: Study of Characteristics, Abundance and Potential Causal Factors. *Jurnal Kesehatan Lingkungan*. 2025;17(1):1-11. https://doi.org/10.20473/jkl.v17i1.2025.1-11

of 35 m^3 per day. This is reinforced by the findings of microplastics in the estuary along the Puger Coast (10).

Kalimalang Hamlet is one of the hamlets in Mojomulyo Village located on the Puger Coast. Kalimalang Hamlet has several characteristics such as sandy soil texture, plastic waste found along the beach, seaside, and the environment around residents' homes. The results of the preliminary study showed that the people of Kalimalang Hamlet still consume dug well water even though it sometimes has a salty taste, thus indicating that there has been a process of seawater intrusion that allows microplastic pollution. This is supported by the results of the preliminary study that microplastics were found in three community well water samples that were directly consumed without treatment, so that if consumed in the long term there will be accumulation that has an impact on health problems such as immune system dysfunction, neurotoxicity, metabolic changes, and others (11-12). Therefore, it is important to conduct research to analyse the content and abundance of microplastics in dug well water consumed by the community in Puger Coastal Kalimalang Hamlet.

METHODS

Research Design

This study uses a type of quantitative research with descriptive methods. The design of this study is a cross sectional study with data collection at one time. Descriptive research is carried out by observing the environment without intervention in the environment and research respondents. This research has gone through an ethical test from the KEPK Faculty of Public Health, University of Jember No. No.465/KEPK/FKM-UNEJ/III/2024.

Research Location

This research was conducted on the Puger Coast with most of the population still using dug wells for consumption. Kalimalang Hamlet, Mojomulyo Village, Puger District, Jember Regency was chosen as the research location because it is within a radius of 0-500 meters from the Puger Sea. Laboratory tests of microplastic content were carried out at the Ecoton Laboratory in Wringinanom District, Gresik Regency. This research began to be carried out in September 2023 and sampling was carried out on March 8, 2024 at 10.00 AM-01.00 PM. March is included in the rainy season, where rainfall can affect the content and abundance of microplastics in groundwater.

Population and Sample

The population of dug wells in this study is all dug wells of the Kalimalang Hamlet community located in the coastal area within a radius of 0-500 meters from the Puger Sea that are consumed, which is as many as 85 dug wells (Figure 1). The researcher used this range because the Kalimalang Hamlet area closest to the sea was in that range. The community population in this study is people who are at risk of exposure to microplastics from dug well water consumed in the coastal area of Kalimalang Hamlet.

The sample of this study consisted of well water samples and respondents who consumed the well water. The well water samples in this study came from community-owned dug wells that were consumed in coastal areas with a radius of 0-500 meters from the Puger Sea, which was as many as 10 dug wells. The determination of the sample point of the community's dug wells in this study was determined using cluster random sampling based on the distance range. Sampling of each cluster was carried out by dividing the length of the administrative area of the research location, which was 2.5 km into 5 groups with a range of distances every 500 meters. The calculation of the determination of the sample of each cluster uses proportional random sampling (Table 1 and Figure 1). The procedure technique for sampling dug well water is guided by SNI 6989.58:2008 regarding water and wastewater: groundwater sampling method.

The community sample in this study uses an accidental sampling technique. The criteria for sample inclusion are the people of Kalimalang Hamlet who are willing to be respondents, productive age (15-64 years old) with male or female gender, able to answer interview questions, and people who are at risk of exposure to microplastics from the dug well water consumed. The community sample in this study is 30 people obtained from the results of a preliminary study that for every dug well consumed, there are an average of three people who use the well for consumption. Community sampling was carried out by visiting people who consumed dug well water which was used as a sample of well water in Kalimalang Hamlet, Puger District.

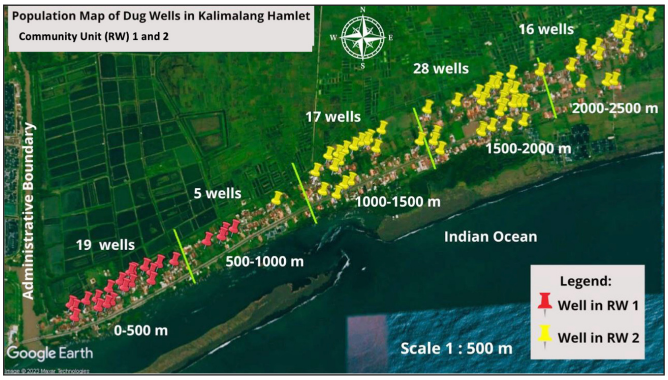

Figure 1. Location Mapping of Total Population of Dug Well in Kalimalang Hamlet

Table 1. Sample Calculation Using Proportional Random Sampling

Cluster (meter)	Number of Wells	Calculation	Number of Samples
Distance 0-500	19	$\frac{19}{85}x\ 10$	2
Distance 500-1000	5	$\frac{5}{85}x\ 10$	1
Distance 1000-1500	17	$\frac{17}{85}x\ 10$	2
Distance 1500-2000	28	$\frac{28}{85}x\ 10$	3
Distance 2000-2500	16	$\frac{16}{85}x\ 10$	2
Total			10

Data Collection

The variables of this study are microplastic content (size, color, and shape), abundance of microplastics, sources of household pollutants, distance of the well to the sea, well construction (depth, rings, well floor, well cover, drainage, and distance of the well to waste treatment), port of entry (water treatment, frequency of water consumption, duration, and amount of well water consumed). Primary data in this study were obtained from interviews with people who consumed dug well water, observation of the environment around dug wells and dug well construction, and also laboratory tests. The secondary data used consisted of data on waste generation, the amount of water from dug wells, and literature studies in the form of books, journals, theses, and so on related to this research. The instruments used are questionnaire sheets, observation sheets, tools and materials for sampling well water based on SNI 6989.58:2008 regarding water and wastewater.

Data Analysis

The data processing techniques used consist of editing, coding, data entry, and tabulating. The data analysis used by univariate statistical tests was used to identify the amount of microplastic content and abundance in dug well water samples based on the shape, size, and color obtained from the results of laboratory tests. Then, it was followed by crosstab tabulation to display the distribution of the frequency of the content, the abundance of microplastics with dug well construction, the distance of the dug well with pollutants, and port of entry in dug well consumption descriptively. The data in this study is presented in the form of tables and narratives.

RESULTS

Microplastic Content and Characteristics in Dug Wells

The content, size, and abundance of microplastics can be seen in Table 2. All dug well locations were contaminated with microplastics totalling 188 particles, with 5 particles classified as mesoplastic. The location with the highest microplastics was well A with 37 particles, while the lowest location was well C with 10 particles. The size of microplastics found was in the range of 0.13-7.24 mm.

The colour of the microplastics found consisted of 12 colours including grey, blue, brown, transparent brown, green, black, yellow, red, pink, white, transparent, and purple with the dominant colour being black with 58 particles. The forms of microplastics identified were fibers as many as 22 particles (11.7%), filaments which were dominantly found at 143 particles (76.10%), and fragments as many as 23 particles (12.2%). In detail, the colour distribution of microplastics in each dug well location is presented in Table 3.

Table 2. Size, Number, and Abundance of Microplastics in Dug Well Water

Well	Size (mm)	Size Category (Particles)		Number (particles)	Abundance (particles/ml)	Abundance
		Microplastics (<5 mm)	Mesoplastics (5-25 mm)			
A	0.13–5.25	36	1	37	0.185	0.115-0.185
B	0.24–4.32	13	0	13	0.065	0.060-0.114
C	1.01–5.19	9	1	10	0.050	0.050-0.059
D	0.23–4.21	34	0	34	0.170	0.115-0.185
E	0.26-5.97	14	1	15	0.075	0.060-0.114
F	0.28-4.25	11	0	11	0.055	0.050-0.059
G	0.19-4.29	23	0	23	0.115	0.115-0.185
H	0.36-6.09	11	1	12	0.060	0.060-0.114
I	0.14-1.28	15	0	15	0.075	0.060-0.114
J	0.20-7.24	17	1	18	0.090	0.060-0.114
	Total	183	5	188	$\bar{X} = 0.094$	

Table 3. Colour and Number by Particle Shape of Microplastics

Well	Shape of Microplastics	Number of Microplastics by Color (Particles)												Number (Particles)
		Grey	Blue	Brown	Brown-transparent	Green	Black	Yellow	Red	Pink	White	Transparent	Purple	
A	Fiber	0	1	0	0	0	1	0	0	0	0	0	0	2
	Filament	1	9	2	2	0	7	1	2	3	0	1	0	28
	Fragment	1	0	3	0	0	3	0	0	0	0	0	0	7
B	Fiber	0	0	0	0	0	0	1	0	0	0	0	0	1
	Filament	6	1	0	0	0	1	2	1	0	0	1	0	12
C	Fiber	0	1	1	0	0	0	0	0	0	0	0	0	2
	Filament	1	3	1	0	0	0	2	0	0	0	1	0	8
D	Fiber	2	0	0	0	0	0	0	0	0	0	0	0	2
	Filament	6	6	1	0	0	9	3	2	0	0	0	1	28
	Fragment	0	0	0	0	0	4	0	0	0	0	0	0	4
E	Fiber	1	0	0	0	0	1	0	0	0	0	0	0	2
	Filament	3	2	0	0	1	4	1	0	0	0	2	0	13
F	Fiber	0	1	0	0	0	1	0	0	0	0	0	0	2
	Filament	2	1	0	0	0	1	0	0	0	0	3	0	7
	Fragment	0	0	0	0	0	1	0	0	0	1	0	0	2
G	Fiber	0	1	0	0	0	3	1	0	0	0	0	0	5
	Filament	3	3	2	0	0	3	1	2	1	1	0	0	16
	Fragment	0	0	0	0	0	2	0	0	0	0	0	0	2
H	Fiber	0	0	0	0	0	0	0	1	0	0	0	0	1
	Filament	0	3	0	0	0	0	1	3	0	0	1	0	8
	Fragment	0	0	0	0	0	2	0	0	0	0	1	0	3
I	Fiber	0	0	0	0	0	2	0	0	0	0	0	0	2
	Filament	1	1	0	0	1	4	1	0	0	0	3	0	11
	Fragment	0	0	0	0	0	2	0	0	0	0	0	0	2
J	Fiber	0	0	0	0	0	3	0	0	0	0	0	0	3
	Filament	1	5	0	0	0	1	1	0	0	0	4	0	12
	Fragment	0	0	0	0	0	3	0	0	0	0	0	0	3
	Total	28	38	10	2	2	58	15	11	4	2	17	1	188
	Fiber													22 (11.70%)
	Filament													143 (76.10%)
	Fragment													23 (12.20%)
	Total													188 (100.00%)

Microplastic Abundance in Dug Wells

The abundance of microplastics identified was in the range of 0.050-0.185 particles/ml. The highest microplastic abundance in well A was 0.185 particles/ml and the lowest in well C was 0.050 particles/ml. Microplastic abundance is divided into three categories: 0.050-0.059 particles/ml, 0.060-0.114 particles/ml, and 0.115-0.185 particles/ml. The microplastic abundance categories can be seen in Table 2.

Distance of Dug Well from Pollutant Source

The distance between the respondents' well location and the Puger Sea is 121.60-398.18 metres. Based on the measurement results, it is known that the closest distance in dug well I is 121.60 m and the farthest distance in dug well D is 398.18 metres. Based on the measurement results, the distance between the dug wells and the Puger Sea is classified into 3 categories: close (121.60-131.94 metres), medium (131.95-362.34 metres), and far (362.35-398.18 metres).

Dug Well Construction

The construction condition of the respondents's dug wells is dominant, with a ring height of <80 cm in 9 wells (90%), a depth of 3.98-5.26 metres in 5 wells (50%), and no well floor in 6 wells (60%). In addition, the dominant respondent has dug wells with open conditions without a cover as many as 6 wells (60%), not equipped with sewerage as many as 7 wells (70%), and the distance between the location of waste processing and dug wells is at a distance of 1.5-2.9 metres as many as 6 wells (60%). A detailed description of the condition of the Kalimalang Hamlet community's dug wells is listed in Table 4.

Table 4. Construction of Dug Wells for the Kalimalang Hamlet

Category	Results	
	n	%
Upper Well Wall (ring)		
<80 cm	9	90
≥80 cm	1	10

Category	Results n	Results %
Lower Well Wall		
3.70-3.97 meter	2	20
3.98-5.26 meter	5	50
5.27-5.40 meter	3	30
Well Floor		
<1 meter from the outer upper well wall	1	10
≥1 meter from the outer upper well wall	3	30
Unavailable	6	60
Well Cover		
Available	4	40
None	6	60
Sewer		
Available	3	30
None	7	70
Distance to Waste Treatment Plant		
1-1.4 meter	1	10
1.5-2.9 meter	6	60
3-6 meter	3	30

Port of Entry (Ingestion) of Dug Well Water Consumption

The results of the interview obtained that there were 15 respondents (50%) who consumed untreated dug well water with the dominant consumption frequency in the always category as many as 12 respondents (40%). The dominant duration of respondents consumption were found to be 19-32 years as many as 17 people (56.7%) with the amount of well water consumption per day dominant at >2 litres as many as 17 respondents (56.7%). On average, the respondents consumes 2.5 litres of dug well water per day. The results of the interview with the Kalimalang Hamlet community in detail are presented in Table 5.

Table 5. Port of Entry through Ingestion in Dug Well Water Consumption

Category	Results n	Results %
Treatment of the Dug Well Water Consumed		
Cooked	15	50
Not cooked	15	50
Consumption Frequency		
Always	12	40
Often (4-6 glass)	3	10
Rarely (1-3 glass)	9	30
Never	6	20
Consumption Duration		
16-18 years	4	13.3
19-32 years	17	56.7
33-50 years	9	30.0
Amount of Water Consumed		
<1 liter	0	0.0
≥ 1 - <2 liter	2	6.7
2 liter	11	36.7
>2 liter	17	56.7

Factors Causing Microplastic Pollution in Dug Wells Related to Well Construction

Table 6 is the frequency distribution of microplastic abundance according to dug well construction, there are 9 dug wells that have a ring height of <80 cm and dominantly contain an abundance of microplastics of 0.060-0.114 particles/ml as many as 5 wells. The dominant respondents wells have a depth of 3.98-5.26 metres with 3 wells containing an abundance of 0.060-0.114 particles/ml. The dominant well does not have a floor with 3 wells having an abundance of 0.060-0.114 particles/ml, not equipped with a lid as many as 4 dug wells contain an abundance of 0.060-0.114 particles/ml. The dominant community well does not have a sewer, 3 wells with an abundance of 0.060-0.114 particles/ml and 3 wells 0.115-0.185 particles/ml. Meanwhile, the distance between the waste management site and the dug well was dominated by the distance category of 1.5-2.9 metres with an abundance of 0.060-0.114 and 0.115-0.185 particles/ml in 3 wells each.

Table 6. Frequency Distribution of Microplastic Abundance by Construction of Dug Wells in Kalimalang Hamlet

Construction Components of Dug Wells	Abundance of Mikroplastics (particles/ml) in Well Water						Total	
	0.050-0.059		0.060-0.114		0.115-0.185			
	n	%	n	%	n	%	N	%
Upper Well Wall (ring)								
<80 cm	2	22.2	5	55.6	2	22.2	9	100
≥80 cm	0	0.0	0	0.0	1	100.0	1	100
Lower Well Wall								
3.70-3.97 m	0	0.0	0	0.0	2	100.0	2	100
3.98-5.26 m	1	20.0	3	60.0	1	20.0	5	100
5.27-5.40 m	1	33.3	2	66.7	0	0.0	3	100
Well Floor								
<1 meter from the outer upper well wall	1	100.0	0	0.0	0	0.0	1	100
≥1 meter from the outer upper well wall	0	0.0	2	66.7	1	33.3	3	100
Unavailable	1	167.0	3	50.0	2	33.3	6	100
Well cover								
Available	1	25.0	1	25.0	2	50.0	4	100
Unavailable	1	16.7	4	66.7	1	16.7	6	100
Sewer								
Available	1	33.3	2	66.7	0	0.0	3	100
Unavailable	1	14.3	3	42.9	3	42.9	7	100
Distance to Waste Treatment Plant								
1-1.4 m	0	0.0	1	100.0	0	0.0	1	100
1.5-2.9 m	0	0.0	3	50.0	3	50.0	6	100
36 m	2	66.7	1	33.3	0	0.0	3	100

Factors Causing Microplastic Pollution in Dug Wells Related to the Distance between Dug Wells and Pollutant Sources

Based on Table 6, the distribution of microplastic abundance according to the distance between the dug wells to the Puger Sea, it is known that the dominant is in the medium category, namely 5 wells (50%) and 3 of them have microplastic abundance of 0.060-0.114 particles/ml. In the near distance category, 2 wells contained an abundance of 0.060-0.114 particles/ml. In the long distance category, 2 wells contained an abundance of 0.115-0.185 particles/ml.

Factors Causing Microplastic Pollution in Dug Wells related to Port of Entry (Ingestion) in Consumption of Dug Well Water

Based on Table 7, it was found that out of 30 respondents, 24 respondents (80%) still consume untreated dug well water with 12 respondents classified as always consuming. In that category, 9 people consumed water with an abundance of 0.060-0.114 particles/ml. Meanwhile, the dominant respondents had a consumption duration of 19-32 years with 8 people consuming well water with an abundance of 0.060-0.114 particles/ml. The amount of dug well water consumed was dominantly >2 litres with 8 people consuming dug well water with an abundance of 0.060-0.114 particles/ml. Based on the average amount of well water consumed by the community per day of 2.5 litres and with an average microplastic abundance of 0.094 particles/ml, it can be seen that the Kalimalang Hamlet community is estimated to consume as many as 235 particles/day of microplastics through the dug well water consumed.

Table 7. Frequency Distribution of Microplastic Abundance According to the Distance Between the Dug Well to the Puger Sea in Kalimalang Hamlet

Distance between Dug Well and Puger Sea (m)	Abundance of Mikroplastics (particles/ml) in Well Water						Total	
	0.050-0.059		0.060-0.114		0.115-0.185			
	n	%	n	%	n	%	N	%
Near (121.60-131.94)	0	0.0	2	100	0	0.0	2	100
Medium (131.95-362.34)	1	20.0	3	60	1	20.0	5	100
Far (362.35-398.18)	1	33.3	0	0	2	66.7	3	100

Table 8. Frequency Distribution of Microplastic Abundance by Port of Entry in Kalimalang Hamlet Community

Variables	Abundance of Mikroplastics (particles/ml) in well Water						Total	
	0.050-0.059		0.060-0.114		0.115-0.185			
	n	%	n	%	n	%	N	%
Consumption Frequency								
Always	0	0.0	9	75.0	3	25.0	12	100
Often (4-6 glass)	0	0.0	0	0.0	3	100.0	3	100
Rarely (1-3 glass)	3	33.3	6	66.7	0	0.0	9	100
Never	3	50.0	0	0.0	3	50.0	6	100
Consumption Duration								
16-18 years	0	0.0	1	25.0	3	75.0	4	100
19-32 years	4	23.5	8	47.1	5	29.4	17	100
33-50 years	2	22.2	6	66.7	1	11.1	9	100
Amount of Water Consumed								
≥ 1 - < 2 liter	0	0.0	2	100.0	0	0.0	2	100
2 liter	3	27.3	5	45.5	3	27.3	11	100
> 2 liter	3	17.6	8	47.1	6	35.3	17	100

DISCUSSION

Microplastic Content and Characteristics in Dug Wells

Well A has the highest amount of microplastics with 37 particles, while well C has the lowest amount with 10 particles. The difference in microplastic content and characteristics is due to the surrounding environmental conditions, distance to pollutant sources, community behaviour, construction of dug wells, and climate (13–15). The results of observations in wells classified as high in microplastics found a lot of plastic waste around dug wells, while in locations classified as low are more maintained cleanliness, so that one of the evidences of the cause of microplastics can come from the behaviour of people throwing garbage. Microplastic pollution in groundwater comes from plastic waste on the surface of the soil that is carried in through the pores of the soil (16).

The dominant form of microplastics identified was filaments with 143 particles, while fibers with 22 particles, and fragments with 23 particles. Previous research, microplastics in the Puger Sea were only in the form of fibers and fragments (10). Thin, flexible filaments are sourced from larger plastic waste fragments that degrade under UV light into fine fibers (17-18). Other contributing factors include ocean waves, wind speed, animal bites, and human activity that breaks plastic into fragments (19). The observation results show that plastic waste such as plastic bags, food packaging, detergents, nets, fishing strings, and plastic bottles are most widely distributed in the dug well environment, so the filament form is dominant. Filament microplastics have the lowest density compared to other forms, so they are more abundant and easy to find (20).

Microplastic fibers were found in every dug well water sample, because the research location is around the coast. Polluted seawater can contaminate groundwater through pores with horizontal distribution properties influenced by ocean currents and wind pushes (6). Another cause is the behaviour of people who still throw nets, fishing ropes, and used water from washing clothes directly to the ground (21). This is in accordance with research that showed fiber microplastics originate from the activities of fishermen in the use of nets and fishing lines in the sea and coastal environment, as well as the activity of throwing used clothes washing water on the ground. Fragment microplastics have an irregular shape and come from plastics with strong polymer properties that experience decomposition or fragmentation into broken fragments (22).

Kalimalang Hamlet community dug wells not only found microplastics but found 5 mesoplastic particles. The variation in the size of microplastics found indicates that there is a degeneration process with a long time in the sea which is influenced by pH, temperature, depth, microorganisms, salinity, and UV radiation (13,23). The results showed that the dominant microplastics were <5 mm in size with 183 particles. This is in line with previous research that microplastics found in dug wells around Tamangapa landfill have a size of <5 mm (24). The smaller the size of microplastics, the greater the danger to the human body (25).

The colour of microplastics can indicate the source of the polymer type and more precise identification of microplastics (26). This study found 12 different colours due to the duration of sun exposure, so that microplastics will be oxidised, discoloured, softer in texture, and easily destroyed (13,19,27). The dominant colour found was black 58 particles, so it is in accordance with previous research which states if the dominant black colour is found in the wells of coastal residents of Bantul Regency (28). The black colour indicates that many contaminants are incorporated in microplastics and other organic particles due to their high ability to absorb pollutants, indicating that the environment is polluted (29). The intense colour of the microplastics proves that they have not yet shown any significant discolouration (30).

Microplastic Abundance in Dug Wells

The abundance of microplastics in the Kalimalang Hamlet dug well water is in the range of 0.050-0.185 particles/ml. The highest abundance of microplastics is owned by well A at 0.185 particles/ml and the lowest in well C at 0.050 particles/ml. Previous research stated that the abundance in the Puger Sea, especially the Getem Estuary, was 0.05 particles/litre (10). Differences in abundance are caused by the location of the dug well, well construction, the surrounding environment, community behaviour, seawater currents, and wind speed (31). Climate or rainfall can also affect abundance because it can increase water discharge or current velocity, so that microplastics can move quickly and if microplastics are on the soil surface, they will enter the soil pores through infiltration with rainwater (27,32).

Distance of the Dug Well to the Pollutant Source

The distance that allows microplastic pollution through seawater intrusion is not the main factor in the amount of microplastic content. This is in accordance with that showed the distance of the well with the number of microplastics has a relatively low relationship (33). This study is not in line with another research in dug wells around the Payungan landfill, that the highest number of microplastics was found at the closest distance (0-1 km) from the landfill (34). Other causative factors that can support the presence of microplastic content include the behaviour of people who still litter, the construction of dug wells, and climatic factors or rainfall.

Construction of Dug Wells

Dug wells must have a construction that is in accordance with the standards to prevent pollution. The rings of respondents dug wells are dominantly <80 cm in height, ≥3 metres deep from the floor surface, do not have well floors, covers, and drains, and the dominant distance of waste management sites is 1.5-2.9 metres. Based on the observation, the ring, floor, cover, sewerage, and distance from the waste treatment site did not meet the standard. The results showed that well construction can be one of the factors of microplastic content in the dug wells of the Kalimalang Hamlet community because microplastics were found in all well locations. The construction of dug wells can have an influence on the presence of contaminants contained in dug wells (35).

Port of Entry Dug Well Water Consumption

Microplastics can enter the human body, one of which is through the consumption of water contaminated with microplastics. Based on the interview results, 15 respondents (50%) directly consume well water without being treated. Respondents stated that well water is fresher to drink directly even though it sometimes tastes salty. Boiling water at 25-100˚C for 5 minutes in hard water can reduce the microplastic content by ±80-90%, while in low-mineralised water it can reduce microplastics by more than 25% (36). The multistage filtration process can also reduce microplastic particles by 75.5% (37).

Frequency of consumption is the amount of time people consume dug well water in one day, namely out of 30 respondents, 12 people always consume untreated dug well water. Duration of consumption is the period of time the respondents consumes dug well water, which is dominant in 19-32 years as many as 17 people (56.7%). The amount of dug well water consumed is dominant >2 litres as many as 17 people (56.7%), where people generally work as fishermen, so they need a lot of water consumption every day. On average, respondents consumed 2.5 litres of dug well water per day. When consuming dug well water with microplastic content for a long period of time, it can potentially have an impact on health such as accumulation in the body, oxidative stress, cytotoxicity, and trigger the onset of diseases such as cancer (38). However, the impact of the dangers of microplastics is still in the research development stage. Ingestion of polyethylene microplastics in rats can result in impaired nephron function through the process of increasing levels of particles in microplastics and Ox-LDL in the blood (39).

Factors Causing Microplastic Pollution Related to Dug Well Construction

The ring height of respondents dug wells is dominant at <80 cm with a microplastic abundance category of 0.060-0.114 particles/ml in 5 wells. Well lips that are not up to standard can increase the chances of a dug well being contaminated (35). The dominant respondents dug well has a depth of 3.98-5.26 with an abundance of microplastics of 0.060-0.114 particles/ml as many as 3 wells. The depth of the dug well supported by the condition of the dug well that does not meet the standards will make it easier for pollutants to enter the dug well (35). Respondents' dug wells are dominantly not equipped with covers with a large abundance of microplastics, namely 0.060-0.114 particles / ml as many as 4 wells. Observations show that people use covers that may affect the abundance of microplastics such as asbestos, plastic, tarpaulin, and rubber. Community dug wells were predominantly not equipped with a drain as many as 3 wells and had the largest abundance. Observations showed that people directly dispose of wastewater to the ground because there are no sewers, so that wastewater can seep into the ground and pollute the environment. Dominantly, respondents have a dug well with a distance of 1.5-2.9 metres from the waste management site with 3 wells having the highest abundance of microplastics, while the well with the furthest distance dominantly has the lowest abundance of microplastics. The distance between the dug well and the waste management site that is in accordance with the standard will prevent pollution (35). Some aspects that have the potential to influence the abundance of microplastics such as depth, well floor, the presence of sewerage, and the distance of the well to the waste processing site. This study is in line with a research which states that microplastic concentrations are influenced by well cover and depth (14).

Factors Causing Microplastic Pollution in relation to the Distance of the Dug Well to the Pollutant Source

The farthest distance of the dug wells from the Puger Sea dominated the largest microplastic abundance. The distance category of wells with the closest pollutant source has a microplastic abundance of 0.060-0.114 particles/ml. This shows that the farther distance has a greater abundance of microplastics, thus proving that the distance of the dug well to the pollutant source is not the main cause of microplastic abundance. This study is in line with research that showed the distance between the pollutant source and the dug well does not affect the abundance of microplastics in the dug well. Microplastic abundance is not proportional to the distance between the groundwater sample location and the landfill site (40). However, this study is not comparable with another study that found the distance between the dug well and the landfill has an influence on the abundance of microplastics. The abundance of microplastics in dug wells is not only caused by the distance between the dug well and the pollutant source, but can also be caused by other factors such as community behaviour in disposing of waste, well construction, climate, and other factors. This is supported by the community's habit of managing waste by dumping and burning it around the house or around the well and there is still a lot of rubbish scattered in the neighbourhood.

Factors Causing Microplastic Pollution related to Port of Entry (Ingestion) in Dug Well Water Consumption

The frequency of consumption of untreated dug well water in the category of always and has the highest abundance is 3 people. The duration of consumption of dug well water in respondents is dominant in the 19-32 year category by consuming microplastic abundance of 0.060-0.114 particles/ml as many as 8 people. The dominant amount of water consumed by the respondents are >2 litres with an abundance of 0.060-0.114 particles/ml. The average respondent consumes 2.5 litres of dug well water per day with an average abundance of 0.094 particles/ml, so it is estimated that per day there are 235 microplastic particles that enter the human body from the consumption of dug well water.

The greater the amount of microplastic consumption, the negative impact on health, influenced by the size, shape, and abundance. Microplastics can impact neurotoxicity, cytotoxicity, metabolic disorders, oxidative stress, immune disorders, and trigger cancer (41). Microplastics exert neurotoxic effects that impact neural functions such as impaired cognitive function (thought process, memory, concentration), and increase the risk of inflammation (41). Oxidative stress then triggers the production of free radicals that result in the destruction of body cells, which in the long run will potentially trigger the onset of Parkinson's disease or Alzheimer's disease. Immune disorders such as impaired macrophage function due to the accumulation of microplastics in tissues that result in localised inflammation and impaired immune response to disease (9,42). Polystyrene (PS) microplastics with smaller sizes can affect red blood cells and have an impact on haemolysis (25). In addition, microplastics can also act as carriers of toxic compounds and absorb contaminants from the environment, resulting in increased damage to the body (43).

ACKNOWLEDGEMENTS

Acknowledgement was addressed to all respondents to this study, namely the community Kalimalang Hamlet which has given permission to sample well water and took the time to conduct interviews with researchers.

AUTHORS' CONTRIBUTION

AAA: Conceptualization, Methodology, Data Collection, and Writing- Original draft preparation. IM: Validation and Writing- Reviewing. GN: Validation, Writing- Reviewing, and Editing

CONCLUSION

The total content of microplastics found in the Kalimalang Hamlet dug wells was 188 particles, the forms of microplastics found were filaments, fragments, and fibers with 12 different colours, and particle sizes that had a range of 0.13-7.24 mm. The abundance of microplastics is in the range of 0.050-0.185 particles/ml, while the distance between the dug well and the Puger Sea has a range of 121.60-398.18 metres. The construction of dug wells in Kalimalang Hamlet predominantly has a ring <80 cm, has a depth of 3.98-5.26 metres, has no well floor, well cover, and drain, and has a distance of 1.5-2.9 metres from the waste management site. Half of the respondents consumed untreated dug well water, the dominant frequency of consumption was always untreated, the dominant duration of consumption was 19-32 years, and the amount of water consumed per day was >2 litres. Aspects of depth, floor, sewerage, and distance to waste management sites have the potential to increase microplastic abundance. The distance of the dug well from the pollutant source is not a major factor in the abundance of microplastics and the highest abundance of microplastics is dominated by respondent who always consume well water without treatment with a duration of 19-32 years, and with an amount of >2 litres per day.

The Jember District Health Office is advised to provide education to the community regarding waste management in the community such as reduce, reuse, recycle (3R) because the habits of the respondents are still not managing waste properly and correctly, and also an introduction to microplastics including the dangers, impacts, and prevention methods. For the community to be able to carry out proper waste management, especially plastic waste such as 3R and waste processing locations that are not around dug wells. The community, especially respondents who still consume dug well water can filter the well water using multistage filtration and boil the water to minimize the presence of microplastic contaminants.

REFERENCES

1. Liu K, Wang X, Wei N, Song Z, Li D. Accurate Quantification and Transport Estimation of Suspended Atmospheric Microplastics in Megacities: Implications for Human Health. *Environment International*. 2019;132(1):1-10. https://doi.org/10.1016/j.envint.2019.105127
2. National Oceanic and Atmospheric Administration. Microplastics. United States: National Oceanic and Atmospheric Administration; 2023. https://marinedebris.noaa.gov/what-marine-debris/microplastics
3. Meijer LJJ, van Emmerik T, van der Ent R, Schmidt C, Lebreton L. More than 1000 Rivers Account for 80% of Global Riverine Plastic Emissions Into the Ocean. *Science Advances*. 2021;7(18):1–13. https://doi.org/10.5327/Z2176-94781900
4. The Ministry of Environment and Forestry of Republic Indonesia. Performance Report of 2022. Jakarta: The Ministry of Environment and Forestry of Republic Indonesia; 2023.
5. Gong X, Tian L, Wang P, Wang Z, Zeng L, Hu J. Microplastic Pollution in the Groundwater Under a Bedrock Island in the South China Sea. *Environment Research*. 2023;239(117277). https://doi.org/10.1016/j.envres.2023.117277
6. Du S, Zhu R, Cai Y, Xu N, Yap PS, Zhang Y, et al. Environmental Fate and Impacts of Microplastics in Aquatic Ecosystems: A Review. *RSC Advances*. 2021;11(26):15762–15784. https://doi.org/10.1039/D1RA00880C
7. Abdullah TO, Ali SS, Al-Ansari NA, Knutsson S, Laue J. Magnitude and Direction of Groundwater Seepage Velocity in Different Soil and Rock Materials. *Engineering*. 2020;12(04):242–253. https://doi.org/10.4236/eng.2020.124020
8. Goeppert N, Goldscheider N. Experimental Field Evidence for Transport of Microplastic Tracers Over Large Distances in an Alluvial Aquifer. *Journal of Hazardous Materials*. 2020;408(1):1–32. https://doi.org/10.1016/j.jhazmat.2020.124844
9. Çobanoğlu H, Belivermiş M, Sıkdokur E, Kılıç Ö, Çayır A. Genotoxic and Cytotoxic Effects of Polyethylene Microplastics on Human Peripheral Blood Lymphocytes. *Chemosphere*. 2021;272(129805):1-6. https://doi.org/10.1016/j.chemosphere.2021.129805
10. Ariyunita S, Dhokhikah Y, Subchan W. The First Investigation of Microplastics Contamination in Estuarine Located in Puger District, Jember Regency, Indonesia. *Jurnal Riset Biologi dan Aplikasinya*. 2021;3(1):7–13. https://doi.org/10.26740/jrba.v3n1.p7-12
11. Bhuyan MS. Effects of Microplastics on Fish and

in Human Health. *Front in Environmental Science*. 2022;10(2022):1–17. https://doi.org/10.3389/fenvs.2022.827289

12. Li Y, Tao L, Wang Q, Wang F, Li G, Song M. Potential Health Impact of Microplastics: A Review of Environmental Distribution, Human Exposure, and Toxic Effects. *Environment and Health*. 2023;1(4):249–257. https://doi.org/10.1021/envhealth.3c00052
13. Azizah P, Ridlo A, Suryono CA. Mikroplastik pada Sedimen di Pantai Kartini Kabupaten Jepara Jawa Tengah. *Journal of Marine Research*. 2020;9(3):326–332. https://doi.org/10.14710/jmr.v9i3.28197
14. Cha J, Lee JY, Chia RW. Microplastics Contamination and Characteristics of Agricultural Groundwater in Haean Basin of Korea. *Science of the Total Environment*. 2023;864(2023):1-11. https://doi.org/10.1016/j.scitotenv.2022.161027
15. Samandra S, Johnston JM, Jaeger JE, Symons B, Xie S, Currell M, et al. Microplastic Contamination of an Unconfined Groundwater Aquifer in Victoria, Australia. *Science of the Total Environment*. 2022;802(1):1-9. https://doi.org/10.1016/j.scitotenv.2021.149727
16. Chia RW, Lee JY, Kim H, Jang J. Microplastic Pollution in Soil and Groundwater: A Review. *Environmental Chemistry Letters*. 2021;19(6):4211–4224. https://doi.org/10.1007/s10311-021-01297-6
17. Argiandini DM. Identifikasi Kelimpahan Mikroplastik di Sekitar Perairan Provinsi Gorontalo. *Environmental Pollution Journal*. 2023;3(1):582–588. https://doi.org/10.58954/epj.v3i1.106
18. Wienardy AE, Fitriyah F, Syarifah U. Identifikasi Tipe dan Kelimpahan Mikroplastik pada Ikan Nila (Oreochromis niloticus) di Waduk Lahor Kabupaten Malang, Jawa Timur. *Biology Natural Resources Journal*. 2023;2(2):68–74. https://doi.org/10.55719/binar.v2i2.693
19. Fachrul MF, Rinanti A, Tazkiaturrizki T, Agustria A, Naswadi DA. Degradasi Mikroplastik pada Ekosistim Perairan oleh Bakteri Kultur *Campuran Clostridium sp*. dan *Thiobacillus sp*. *Jurnal Penelitian dan Karya Ilmiah Lembaga Penelitian Universitas Trisakti*. 2021;6(2):304–316. https://doi.org/10.25105/pdk.v6i2.9935
20. Hanif KH, Suprijanto J, Pratikto I. Identifikasi Mikroplastik di Muara Sungai Kendal, Kabupaten Kendal. *Journal of Marine Research*. 2021;10(1):1–6. https://doi.org/10.14710/jmr.v9i2.26832
21. Gaylarde C, Baptista-Neto JA, da Fonseca EM. Plastic Microfibre Pollution: How Important Is Clothes' Laundering?. *Heliyon*. 2021;7(5):1-10. https://doi.org/10.1016/j.heliyon.2021.e07105
22. Sandra SW, Radityaningrum AD. Kajian Kelimpahan Mikroplastik di Biota Perairan. *Jurnal Ilmu Lingkungan*. 2021;19(3):638–648. https://doi.org/10.14710/jil.19.3.638-648
23. Ningrum IP, Sa'adah N, Mahmiah. Jenis dan Kelimpahan Mikroplastik Pada Sedimen di Gili Ketapang, Probolinggo. *Journal of Marine Research*. 2022;11(4):785–793. https://doi.org/10.14710/jmr.v11i4.35467
24. Natsir MF, Selomo M, Ibrahim E, Arsin AA, Alni NC. Analysis on Microplastics in Dug Wells Around Tamangapa Landfills, Makassar City, Indonesia. *Gaceta Sanitaria*. 2021;35(S1):S87–S89. https://doi.org/10.1016/j.gaceta.2020.12.024
25. Hwang J, Choi D, Han S, Jung SY, Choi J, Hong J. Potential Toxicity of Polystyrene Microplastic Particles. *Scientific Reports*. 2020;10(739):1–12. https://doi.org/10.1038/s41598-020-64464-9
26. Seftianingrum B, Hidayati I, Zummah A. Identifikasi Mikroplastik pada Air, Sedimen, dan Ikan Nila (*Oreochromis niloticus*) di Sungai Porong, Kabupaten Sidoarjo, Jawa Timur. *Jurnal Jeumpa*. 2023;10(1):68–82. https://doi.org/10.33059/jj.v10i1.7408
27. Laksono OB, Suprijanto J, Ridlo A. Kandungan Mikroplastik pada Sedimen di Perairan Bandengan Kabupaten Kendal. *Journal of Marine Research*. 2021;10(2):158–164. https://doi.org/10.14710/jmr.v10i2.29032
28. Lukman NA. Identifikasi Keberadaan Mikroplastik pada Air Sumur Penduduk Wilayah Pesisir Pantai Kabupaten Bantul. Yogyakarta: Universitas Islam Indonesia; 2022.
29. Wahdani A, Yaqin K, Rukminasari N, Inaku DF, Fachruddin L. Konsentrasi Mikroplastik pada Kerang Manila Venerupis philippinarum di Perairan Maccini Baji, Kecamatan Labakkang, Kabupaten Pangkajen Kepulauan, Sulawesi Selatan. *Marine Science Research*. 2020;12(2):1–14. https://doi.org/10.56064/maspari.v12i2.12809
30. Kapo FA, Toruan LNL, Paulus CA. Jenis dan Kelimpahan Mikroplastik pada Kolom Permukaan Air di Perairan Teluk Kupang. *Jurnal Bahari Papadak*. 2020;1(1):10–21. https://garuda.kemdikbud.go.id/journal/view/25881
31. Fitriyah A, Syafrudin S, Sudarno S. Identifikasi Karakteristik Fisik Mikroplastik di Sungai Kalimas, Surabaya, Jawa Timur. *Jurnal Kesehatan Lingkungan Indonesia*. 2022;21(3):350–357. https://doi.org/10.14710/jkli.21.3.350-357
32. Susanti S, Pratiwi FD, Nugraha MA. Analisis Kandungan Logam Berat Pb dan Kelimpahan Mikroplastik di Estuari Sungai Baturusa Provinsi Kepulauan Bangka Belitung. *Journal of Fisheries and Marine Research*. 2022;6(1):104-114. https://doi.org/10.21776/ub.jfmr.2022.006.01.12
33. Norindra DN, Budi Setyorini H, Prasetiyowati SH. Sebaran Mikroplastik di Pantai Sepanjang, Kabupaten Gunungkidul. *Journal of Marine Research*. 2023;12(2):336–342. https://doi.org/10.14710/jmr.v12i2.37442
34. Utami I, Liani M. Identifikasi Mikroplastik pada Air Sumur Gali di sekitar TPA Piyungan Yogyakarta. *Jurnal Riset Daerah*. 2021;21(3):4003–4014. https://ojs.bantulkab.go.id/index.php/jrd/article/view/57

35. Baktiar S, Sahdan M, Setyobudi A. Gambaran Konstruksi dan Letak Sumur Gali dengan Kandungan Pestisida dalam Air Sumur Gali di Area Persawahan Kelurahan Oesao Kabupaten Kupang. *Media Kesehatan Masyarakat*. 2022;4(1):100–107. https://doi.org/10.35508/mkm.v4i2.3272
36. Yu Z, Wang JJ, Liu LY, Li Z, Zeng EY. Drinking Boiled Tap Water Reduces Human Intake of Nanoplastics and Microplastics. *Environmental Science and Technology Letters*. 2024;11(3):273–279. https://doi.org/10.1021/acs.estlett.4c00081
37. Junardi J, Yudasti YG, Claudia GP, Aldin, Mahapati WOSW, Irwan AF. Simulasi Penyisihan Mikroplastik Pada Limbah Laundry Menggunakan Proses Filtrasi Bertingkat. *Jurnal Ilmiah Teknik Sipil*. 2022;14(2):188-191. http://dx.doi.org/10.55679/jts.v10i1.27911
38. Chiang CC, Yeh H, Shiu RF, Chin WC, Yen TH. Impact of Microplastics and Nanoplastics on Liver Health: Current Understanding and Future Research Directions. *World Journal of Gastroenterology*. 2024;30(9):1011–1017. http://dx.doi.org/10.3748/wjg.v30.i9.1011
39. Apriliani IM, Purba NP, Dewanti LP, Herawati H, Faizal I. Analisis Jalur: Gangguan Fungsi Nefron Tikus (Rattus Norvegicus) Akibat Mengkonsumsi Partikel Mikroplastik Politilena. *Media Publikasi Promosi Kesehatan Indonesia*. 2021;2(1):134-143. https://doi.org/10.56338/mppki.v7i1.4240
40. Thao LXT, Duc Long H, Thi Linh N, Anh Thu V, Tuan Manh D, Minh Tuan P, et al. Microplastics Occurrence in Groundwater of Da Nang City, Viet Nam. *Vietnam Journal of Science and Technology*. 2022;60(5B):39–49. https://dx.doi.org/10.15625/2525-2518/17352
41. Segovia-Mendoza M, Nava-Castro KE, Palacios-Arreola MI, Garay-Canales C, Morales-Montor J. How Microplastic Components Influence the Immune System and Impact on Children Health: Focus on Cancer. *Birth Defects Research*. 2020;112(17):1341–1361. https://doi.org/10.1002/bdr2.1779
42. Yang W, Jannatun N, Zeng Y, Liu T, Zhang G, Chen C, et al. Impacts of Microplastics on Immunity. *Frontiers in Toxicology*. 2022;4(956885):1–14. https://doi.org/10.3389/ftox.2022.956885
43. Wu P, Lin S, Cao G, Wu J, Jin H, Wang C, et al. Absorption, Distribution, Metabolism, Excretion and Toxicity of Microplastics in the Human Body and Health Implications. *Journal of Hazardous Materials*. 2022;437(129361):1-18. https://doi.org/10.1016/j.jhazmat.2022.129361