MEDFARM: Jurnal Farmasi dan Kesehatan, Vol. 15, No. 1, 2026, Page 256-271

e-ISSN : 2715-9957

p-ISSN: 2354-8487

ANALYSIS OF HEAVY METAL IN REFILLED DRINKING WATER IN DEMAK REGENCY USING ATOMIC ABSORPTION SPECTROPHOTOMETRY

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ABSTRACT

Drinking water is a vital necessity which must meet the health standards because it directly impacts the body's biological functions. Increasing groundwater pollution has prompted people, especially in rural areas, to turn to refilled drinking water as a practical and economical option. However, the quality of refilled drinking water remains a concern, particularly regarding the potential for heavy metals such as Pb, Fe, Cd, and Cr, which are harmful to health. This study aimed to determine the levels of those heavy metals in refilled drinking water in Demak and analyze the effects of ozone, ultraviolet, and reverse osmosis disinfection methods on metal content. This study used a quantitative descriptive approach which used nine samples from drinking water refill station in Demak with three samples for each disinfection method. Metal content was analyzed by using Atomic Absorption Spectrophotometry (AAS), while pH and organoleptic tests were used to complete the water quality evaluation. All samples had Pb, Cd, and Cr levels below the thresholds stipulated in Regulation of the Minister of Health No. 492/2010 and SNI 3553:2015. However, Fe levels in several samples exceeded the standards (0.1 mg/L according to SNI and 0.3 mg/L according to the Minister of Health Regulation), with the highest value was 0.31 mg/L. Six samples had a pH below 6.5, indicating acidic properties that could potentially accelerate corrosion and release heavy metals. Most refilled drinking water in Demak met quality standards, but required special attention to Fe and pH levels approaching or exceeding the thresholds.

Keywords: Refilled drinking water, heavy metals, disinfection method, AAS

Introduction

Water is a chemical compound that is essential for life and cannot be replaced by other compounds. Its primary use is as drinking water to meet the biological needs of the human body (Ismayanti *et al*., 2019). Drinking water quality must meet the standards of the Ministry of Health of the Republic of Indonesia, as stipulated in Regulation of the Minister of Health No. 492 of 2010 (Pulungan & Wahyuni, 2021).

According to Basic Health Research data (2023), access to safe drinking water in Indonesia has increased to 96.02% in urban areas and 85.70% in rural areas. However, approximately 70% of household drinking water sources are still contaminated with fecal matter, which can cause diarrhea (UNICEF, 2022). Demak Regency is an example of a case where changes in the quality of water supplied by the local water utility (PDAM) have had a negative impact on public health, such as the occurrence of itching and sore throats due to its use (Anonymous, 2008).

The trend towards the use of refilled drinking water in rural communities is increasing, one of the factors is the increasing seriousness of groundwater pollution. Refilled drinking water is an alternative solution to meet the drinking water needs of the Indonesian public due to its convenience and relatively affordable price. These factors have led people to prefer using refilled drinking water (Fatimura *et al.,* 2021).

Drinking Water Refill Station or DAMIU are business entities that manage the supply of drinking water to meet the public's drinking water needs in large quantities at affordable prices. In term of price, refilled drinking water is cheaper than bottled water. In some areas, the cost can be as much as a quarter of the cost of bottled water (Marhamah *et al*., 2020). This makes refilled drinking water be a solution that meets the public's need for convenient and cost-effective drinking water.

One of the substances contained in wastewater is metal. Determining metal elements in refilled drinking water requires special attention to maintain its quality. Refilled drinking water obtained from various processing processes which may contain metal elements that can dissolve in water and increase its concentration. These substances in drinking water can be toxic to the human body (Amelia, 2021).

Research by Ismayanti *et al*., (2019) analyzed three water refill stations near the campus of Islamic University of Indonesia (UII), Yogyakarta using atomic absorption spectrophotometry. The study used physical parameters including odor, taste, color, and pH. Chemical parameters included testing for Fe, Pb, Cr, and Cd. The results showed that Fe, Pb, and Cd levels exceeded drinking water quality standards. High levels of these metals in drinking water can be harmful to human health, especially when consumed over long periods.

Metal analysis in these samples used an Atomic Absorption Spectrometer (AAS) (SNI 6989-8-2009). The AAS method provides accurate analysis results due to the instrument's high sensitivity and selectivity (Marlina, 2019). Based on this background, an analysis of the Fe, Pb, Cd, and Cr metal content in refilled drinking water in Demak will be conducted using the Atomic Absorption Spectrophotometry (AAS) method

Methodology

Tools and Materials

The tools used in this study were an analytical balance, a volumetric flask, a dropper, a graduated cylinder, an Erlenmeyer flask, a beaker, a watch glass, a Whatman No. 40 paper funnel, a pH meter, and a BUCK SCIENTIFIC 205 Atomic Absorption Spectrophotometer.

The materials used in this study were refilled drinking water samples obtained from a drinking water refill station in Demak Regency, buffer solution, distilled water, 65% concentrated HNO3, diphenylcarbazide solution, deionized water, H_3PO_4, 0,2 N sulfuric acid, $K_2Cr_2O_7$, cadmium metal, iron metal, and $Pb(NO_3)_2$.

Research Procedures

1. Sample Population and Sampling Technique

   The population in this study included all objects to be studied. The population in this study was all drinking water refill station in Demak Regency. Nine samples were taken from different water refill station: 9 samples were treated using the ozone method, the next 3 used the ultraviolet light method, and the last 3 were treated using the reverse osmosis (RO) method. Sample selection was based on inclusion criteria: drinking water refill station in Demak Regency using ozone, ultraviolet light, and reverse osmosis (RO) disinfection methods. Exclusion criteria were drinking water refill station outside Demak Regency.

2. Physical Parameters

   Physical parameters in this study included odor, color, taste, and pH tests. Odor, color, and taste tests were conducted using the senses of smell, sight, and taste. The pH test involved calibrating the pH meter using buffer solutions (pH 4 and 7) before each test. Afterward, dipped the electrode which had been cleaned with deionized water, into the sample whose pH will be measured (BSN, 2019).

3. Chemical Parameters

   a. Ferro

      - Preparation of Fe solution: An approximately 0.100 g of Fe was accurately weighed and dissolved to prepare a 100 mg/L stock solution. The stock solution was subsequently diluted to obtain a 10 mg/L standard solution. A series of working solutions was then prepared for further analysis (BSN, 2009c).
      - Sample analysis: A 50 mL sample was homogenized, followed by the addition of 5 mL of concentrated HNO_3. The mixture was heated until a clear solution was obtained (the digestion process was repeated if necessary). The solution was then transferred into a 50 mL volumetric flask and diluted to the mark with distilled water. After homogenization, the absorbance was measured using AAS at a wavelength of 248.3 nm (BSN, 2009c).

   b. Plumbum

      - Preparation of Pb solution: An approximately 0.16 g of $Pb(NO_3)_2$ was accurately weighed and dissolved to prepare a 100 mg/L stock solution. The stock solution was then diluted to obtain a 10 mg/L standard solution. Subsequently, a series of working solutions, including one blank and at least three different concentrations, was prepared for analysis (BSN, 2009d).

- Sample analysis: A 50 mL sample was homogenized, followed by the addition of 5 mL of concentrated HNO_3. The mixture was heated until a clear solution was obtained (the digestion process was repeated if necessary). The solution was then transferred into a 50 mL volumetric flask and diluted to the mark with deionized water. After homogenization, the absorbance was measured using AAS at a wavelength of 283.3 nm or 217.0 nm (BSN, 2009d).

c. Cadmium

- Preparation of Cd solution: An approximately 0.100 g of Cd was accurately weighed and dissolved in HNO_3 to prepare a 100 mg/L stock solution. The stock solution was subsequently diluted to obtain a 10 mg/L standard solution. A series of working solutions, including one blank and at least three different concentrations, was then prepared for analysis (BSN, 2009b).
- Sample analysis: A 50 mL sample was homogenized, followed by the addition of 5 mL of concentrated HNO_3. The mixture was heated until a clear solution was obtained (the digestion process was repeated if necessary). The solution was then transferred into a 50 mL volumetric flask and diluted to the mark with deionized water. After homogenization, the absorbance was measured using AAS at a wavelength of 228.8 nm (BSN, 2009b).

d. Chromium

- Preparation of Cr solution: An approximately 0.1414 g of $K_2Cr_2O_7$ was dissolved to prepare a 500 mg/L stock solution, which was subsequently diluted to obtain 50 mg/L and 5 mg/L standard solutions. A series of working solutions, consisting of one blank and at least three different concentrations, was then prepared. To each solution, 0.25 mL of H_3PO_4 was added, and the pH was adjusted to approximately 2 using 0.2 N H_2SO_4. The volume was adjusted accordingly, followed by the addition of 2.0 mL of diphenylcarbazide reagent. The solution was shaken and allowed to stand for 5–10 minutes before measurement (BSN, 2009a).
- Analysis of the sample: A 0.25 mL aliquot of H_3PO_4 was added to the sample, and the pH was adjusted to approximately 2. The volume was then adjusted, followed by the addition of 2.0 mL of diphenylcarbazide reagent. The solution was shaken and allowed to stand for 5–10 minutes, and the absorbance was measured at 530–540 nm (BSN, 2009a).

4. Data Analysis

Analysis was conducted using a normality test to determine distribution of the data (a significance value >0.05 indicates normal data) and a homogeneity test to assess equality of variance among groups (a significance value >0.05 indicates homogeneous variance) (Hajaroh & Raehanah, 2015). Furthermore, a parametric test using One-Way ANOVA was conducted at a 95% confidence level. If a significant difference was detected, the analysis was followed by the Least

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p-ISSN: 2354-8487

Significant Difference (LSD) t-test as a post hoc test (Hidayah et al., 2021). In addition, the non-parametric Chi-Square test was applied to evaluate significant differences among more than two groups of variables (Jamco & Balami, 2022).

Result and Discussion

Physical Parameters

Physical parameters commonly used to assess water quality include temperature, turbidity, color, electrical conductivity (DHL), total dissolved solids (TDS), pH, taste, and odor (Mukarromah *et al.*, 2016). Measurement of these physical parameters was carried out in accordance with the Regulation of the Minister of Health of the Republic of Indonesia Number 492/MENKES/PER/IV/2010 concerning drinking water quality requirements.

a. Odor and Taste

Odor and taste testing is an organoleptic assessment conducted using the human senses, specifically taste evaluated by the sense of taste and odor evaluated by the sense of smell (Rusidah & Farikhah, 2021). The results of the organoleptic (odor) test on refilled drinking water in Demak Regency are presented in Table 1

Table 1 Organoleptic (Odor) Test Result

Sample	Method	Organoleptic (Odor) Test Result	Provisions		Description
			Minister of Health Regulation 2010	SNI 2015	
O1	Ozone	Odorless	Odorless	Odorless	Compliant
O2	Ozone	Odorless	Odorless	Odorless	Compliant
O3	Ozone	Odorless	Odorless	Odorless	Compliant
UV1	UV	Odorless	Odorless	Odorless	Compliant
UV2	UV	Odorless	Odorless	Odorless	Compliant
UV3	UV	Odorless	Odorless	Odorless	Compliant
RO1	RO	Odorless	Odorless	Odorless	Compliant
RO2	RO	Odorless	Odorless	Odorless	Compliant
RO3	RO	Odorless	Odorless	Odorless	Compliant

(Source: Personal Data, 2025)

The test results indicated that no odor was detected in any of the drinking water refill stations in Demak Regency. This indicated that all samples met the physical requirements for drinking water as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES/PER/IV/2010 and SNI 3553:2015, which state that drinking water must be odorless.

Generally, odors in water result from the presence of certain substances, such as iron (Fe) at concentrations exceeding 10 mg/L, which may produce an unpleasant odor (Ismayanti *et al.*, 2019). Odors may also originate from biological sources, including algae, hydrogen sulfide (H_2S) formed under anaerobic (oxygen-deficient) conditions, and various organic compounds present in the water (Muthmainnah *et al.*, 2022).

Taste was also one of the parameters examined in this study to determine water quality. The results of the organoleptic (taste) test on refilled drinking water in Demak Regency can be seen in Table 2.

Table 2 Organoleptic (Taste) Test Result

Sample	Method	Organoleptic (Taste) Test Result	Provisions		Description
			Minister of Health Regulation 2010	SNI 2015	
O1	Ozone	Tasteless	Tasteless	Tasteless	Compliant
O2	Ozone	Tasteless	Tasteless	Tasteless	Compliant
O3	Ozone	Tasteless	Tasteless	Tasteless	Compliant
UV1	UV	Tasteless	Tasteless	Tasteless	Compliant
UV2	UV	Tasteless	Tasteless	Tasteless	Compliant
UV3	UV	Tasteless	Tasteless	Tasteless	Compliant
RO1	RO	Tasteless	Tasteless	Tasteless	Compliant
RO2	RO	Tasteless	Tasteless	Tasteless	Compliant
RO3	RO	Tasteless	Tasteless	Tasteless	Compliant

(Source: Personal Data, 2025)

Based on the test results presented in Table 1.2, no taste was detected in the drinking water from any of the water stations. No contaminants were identified that could pose a health risk or affect the taste of the water. Therefore, the drinking water met the health standards stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES/PER/IV/2010 and SNI 3553:2015.

The taste of water can serve as an indicator of the presence of contaminants that may pose health risks, including those associated with anaerobic conditions resulting from the microbial decomposition of organic compounds (Gafur *et al*., 2017). Elevated concentrations of Ferro (Fe) are known to produce an unpleasant metallic taste, stain equipment and laundry, and reduce the physical quality of drinking water (Ahmad *et al*., 2024). High levels of dissolved metals may also impart a bitter or astringent taste to drinking water (Mirlohi, 2022). Furthermore, if the Fe concentration exceeds 1 mg/L, it may cause skin and eye irritation and damage to the intestinal wall, which can be potentially fatal (Ismayanti *et al*., 2019).

b. Color

Changes in water color may indicate the presence of contaminants such as heavy metals or organic compounds. Therefore, water color can serve as an indicator of pollution or specific chemical reactions occurring in the water (Munggaran *et al*., 2024). The results of the organoleptic (color) test on refilled drinking water in Demak Regency are presented in Table 3.

Table 3 Organoleptic (Color) Test Result

Sample	Method	Organoleptic (Color) Test Result	Provisions		Description
			Minister of Health regulation 2010	SNI 2015	
O1	Ozone	Colorless	Colorless	Colorless	Compliant

e-ISSN : 2715-9957

p-ISSN: 2354-8487

O2	Ozone	Colorless	Colorless	Colorless	Compliant
O3	Ozone	Colorless	Colorless	Colorless	Compliant
UV1	UV	Colorless	Colorless	Colorless	Compliant
UV2	UV	Colorless	Colorless	Colorless	Compliant
UV3	UV	Colorless	Colorless	Colorless	Compliant
RO1	RO	Colorless	Colorless	Colorless	Compliant
RO2	RO	Colorless	Colorless	Colorless	Compliant
RO3	RO	Colorless	Colorless	Colorless	Compliant

(Source: Personal Data, 2025)

Based on the test results, no color was detected in the refilled drinking water samples. These results indicated that the drinking water complied with the maximum permissible limits stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES/PER/IV/2010 regarding drinking water quality requirements and SNI 3553:2015 for mineral water quality standards.

Changes in water color to brown or black may indicate the presence of chemicals such as iron, manganese, or cyanide originating from industrial wastewater. It can also be influenced by microorganisms, suspended particles, and organic compounds that potentially pose health risks (Muthmainnah *et al*., 2022). Iron in water may exist in both dissolved and insoluble forms; dissolved ferrous iron appears clear but forms reddish-brown precipitates upon exposure to air. Its concentration is influenced by the water source, water station location, and distribution pipes (Fadhilla *et al*., 2022). The presence of heavy metals such as Fe may reduce the physical quality of refilled drinking water, as elevated Fe concentrations can cause brown discoloration and a rusty odor. Therefore, it is essential to ensure that Fe levels remain below the established permissible limits (Alimby & Triajie, 2021).

c. pH

pH is a crucial parameter, as it may influence the growth and activity of microorganisms in water (Saadah *et al*., 2017). The results of the pH analysis of refilled drinking water in Demak Regency are presented in Table 4.

Table 4 pH Test Result

Sample	Method	pH Test Result	Provisions		Descriptions
			Minister of Health Regulation 2010	SNI 2015	
O1	Ozon	7,94	6,5-8,5	6,5-8,5	C
O2	Ozon	7,54	6,5-8,5	6,5-8,5	C
O3	Ozon	6,92	6,5-8,5	6,5-8,5	C
UV1	**UV**	**5,91**	**6,5-8,5**	**6,5-8,5**	**NC**
UV2	**UV**	**6,43**	**6,5-8,5**	**6,5-8,5**	**NC**
UV3	**UV**	**5,41**	**6,5-8,5**	**6,5-8,5**	**NC**
RO1	**RO**	**5,32**	**6,5-8,5**	**6,5-8,5**	**NC**
RO2	**RO**	**6,39**	**6,5-8,5**	**6,5-8,5**	**NC**
RO3	**RO**	**6,18**	**6,5-8,5**	**6,5-8,5**	**NC**

(Source: Personal Data, 2025)

Description:

C = Compliant

NC = Not Compliant

The results indicated that only three samples treated using the ozonation method met the permissible pH range (6.5–8.5) established by the Regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES/PER/IV/2010 and SNI 3553:2015, they were O1 (7.94), O2 (7.54), and O3 (6.92). In contrast, the pH values of the other samples were below the required standards, including RO1 (5.32), UV3 (5.41), UV1 (5.91), RO3 (6.18), RO2 (6.39), and UV2 (6.43).

Water with a pH below 6.5 is considered acidic and may accelerate metal corrosion, produce an unpleasant taste, and transform certain chemical substances into toxic compounds that are harmful to health (Suminar, 2019). The ozonation process met the standards established by the Regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES/PER/IV/2010 and SNI 3553:2015, as ozone play role as an environmentally friendly disinfectant that can decompose organic compounds and remove color, odor, and taste. Its effectiveness was influenced by ozone concentration, contact time, and the sensitivity of the target organisms (Nabih *et al*., 2021). The pH of water tended to decrease after ozonation due to an increase in H^+ ions; however, a sufficiently high initial pH helped maintain the final pH within the permissible range. Furthermore, higher pH conditions facilitated the formation of hydroxyl radicals which were effective in degrading contaminants (Sari *et al*., 2013).

The results of UV disinfection indicated that the pH values were below the permissible limits established by the Regulation of the Minister of Health of the Republic of Indonesia 2010 and SNI 2015. The refilled drinking water filtration system utilizing UV consisted of eight components, including a semi-jet pump and filter media containing silica sand and activated carbon which eliminated impurities, odor, taste, and color (Indra & Sutanto, 2016). Contact between activated carbon, zeolite, silica sand, and water contributed to a decrease in pH due to increased dissolved carbon dioxide, which subsequently formed hydrogen ions (Sappewali *et al*., 2024). Reverse Osmosis (RO) technology also reduced water pH to approximately 6.0–6.5 because alkaline minerals that neutralize acidity were removed during the filtration process (Twadigmark, 2025). The pH could further decline to 5.0–5.5 upon exposure to air as a result of carbonic acid formation from dissolved CO_2 (Qin et al., 2005). In addition, prolonged storage of refilled drinking water (1–4 weeks) was reported to decrease pH, total dissolved solids (TDS), hardness, and Fe concentration, while increasing the risk of bacterial growth (Saadah *et al*., 2017).

Chemical Parameter

a. Ferro

Ferro (Fe) is one of the elements commonly found in groundwater and surface water, both naturally and as a result of human activities. In drinking water, the presence of Fe requires careful consideration because, at certain concentrations, it may affect the physical quality of water, including color, taste, and clarity. (Sappewali *et al*., 2024).

Table 5 Atomic Absorption Spectrophotometry (Fe) Test Result

Method	Unit of Measure ment	AAS **(Fe) Test result**	Averange ±SD	Requirements of the Ministry of health Regulation 2010	Desc	Requirements of SNI 2015	Desc
Ozone 1	mg/L	0,22		<0,3	C	<0,1	NC
Ozone 2	mg/L	0,25	0,20±0,06	<0,3	C	<0,1	NC
Ozone 3	mg/L	0,12		<0,3	C	<0,1	NC
RO 1	mg/L	0,06		<0,3	C	<0,1	C
RO 2	mg/L	0,12	0,09±0,03	<0,3	C	<0,1	C
RO 3	mg/L	0,09		<0,3	C	<0,1	NC
UV 1	mg/L	0,31		<0,3	C	<0,1	NC
UV 2	mg/L	0,15	0,21±0,09	<0,3	C	<0,1	NC
UV 3	mg/L	0,18		<0,3	NC	<0,1	NC

(Source: Personal Data, 2025)

Description:
C = Compliant
NC = Not Compliant

Ferro (Fe) concentrations in the water varied across disinfection and purification methods. One of UV samples (UV1) had an Fe concentration of 0.31 mg/L, exceeding the maximum limit of 0.3 mg/L stipulated in the Regulation of the Minister of Health of the Republic of Indonesia 2010, while two of ozone samples (O1: 0.22 mg/L and O2: 0.25 mg/L) approached the threshold. Moreover, according to the SNI 2015 (0.1 mg/L), there were only two of RO samples (RO1: 0.06 mg/L and RO3: 0.09 mg/L) met the standard, whereas the other samples exceeded the permissible limit, O3 (0.12 mg/L), RO2 (0.12 mg/L), UV3 (0.18 mg/L), and UV2 (0.15 mg/L).

Ferro in water might originate from the corrosion of iron pipes as well as from groundwater sources. Although the body requires only small amounts of Fe, high concentrations could lead to hemochromatosis, liver disorders, and pancreatic damage (Ismayanti *et al*., 2019). The body could tolerate Fe intake up to 40–45 mg/day; however, drinking water quality standards limit the maximum Fe concentration to 0.3 mg/L to prevent potential health risks (Fadhilla *et al*., 2022).

Reverse Osmosis demonstrated the highest effectiveness in reducing Fe concentrations, with values ranging from 0.06 to 0.12 mg/L. This technology used a semi-permeable membrane with a pore size of 0.0001 microns, which was capable of removing up to 98% of heavy metals such as Fe (Gusnawati, 2023). However, the effectiveness of RO did not reach 100%, as it was influenced by membrane fouling, scaling, and operational conditions (Kapepula & Luis, 2024).

Water treatment using ozone met the requirements of the Minister of Health Regulation 2010, but didn’t comply the SNI 2015 regarding drinking water standard. Ozone was effective in sterilizing water from microorganisms and decomposing complex organic compounds, however, it was unable to remove all heavy metals such as Fe (Fitri & Prarikeslan, 2019).

e-ISSN : 2715-9957

p-ISSN: 2354-8487

Fluctuations in Fe content in soil are strongly influenced by environmental parameters, including water depth, temperature, acidity (pH), microorganism activity, and aggressive CO_2 and rainwater content. Through the infiltration process, rainwater that seeps into the soil reacts with FeO and carbon dioxide (CO_2). This reaction triggers an increase in iron concentration, so water from deeper wells generally has higher levels of Fe contamination (Salisna *et al.,* 2021).

According to Wes Byrne in his book Reverse Osmosis: A Practical Guide for Industrial Users, disinfection using UV light is an effective method for deactivating microorganisms, although it is not capable of removing chemical contaminants. UV light works by damaging the DNA of microorganisms, preventing them from multiplying and causing disease. This method has been proven effective against various types of bacteria, viruses, and some chlorine-resistant protozoa. Another advantage is that UV light does not change the taste, odor, or chemical composition of water, and does not leave chemical residues.

However, it is important to understand that the use of UV light is only one component of a comprehensive water treatment system. For optimal results, UV light is usually combined with other filtration methods such as sediment filtration, activated carbon, and sometimes RO.

This is in line with research conducted by Wahyudin et al. (2013), which showed that the combination of ozonation, ultraviolet irradiation, and zeolite can effectively reduce metal content such as iron and manganese, total dissolved solids (TDS), and eliminate E. coli bacteria from groundwater.

Ultraviolet disinfection effectively inactivated microorganisms by damaging their DNA, thereby preventing replication; however, it did not remove chemical contaminants, including Fe (Byrne, 2000). UV light did not alter the taste, odor, or chemical composition of water and did not leave chemical residues, but it typically needed to be combined with sediment filtration, activated carbon, or Reverse Osmosis (RO) for optimal results. The research showed that the combination of ozonation, UV irradiation, and zeolite filtration effectively reduced Fe, Mn, and TDS levels, as well as eliminated E. coli bacteria in groundwater (Wahyudin *et al*., 2013).

The data obtained from heavy metal testing of refilled drinking water in Demak Regency were subsequently analyzed using statistical methods, beginning with hypothesis testing through a normality test. The results of the normality test are presented in Table 6.

Table 6 Normality Test Result

Result	Sig	Conclusion
Heavy Metal (Fe) based on disinfection method	0,200	Data was normally distributed

Description:
Sig > 0,05 = Data was normally distributed
Sig < 0,05 = Data was not normally distributed

Table 7 *ANOVA* Test Result

Result	Sig	Conclusion
Heavy Metal (Fe) analysis result based on disinfection method	0,783	There was no a significant difference

e-ISSN : 2715-9957

p-ISSN: 2354-8487

Description:

Sig > 0,05	=	H0 was accepted, this indicated that there was no a significant difference between the heavy metals with the disinfection method.
Sig < 0,05	=	H0 was rejected, this indicated that there was a significant difference between the heavy metals with the disinfection method.

In the normality test, the data from the heavy metal (Fe) analysis were normally distributed, as indicated by a significance value greater than 0.05, which was 0.200. Subsequently, the statistical analysis using the parametric ANOVA test showed a significance value greater than 0.05 which was 0.783, indicating that there was no significant difference among the disinfection methods. This indicated that the type of disinfection method was not the sole factor determining the concentration of heavy metals (Fe) in refilled drinking water.

b. Plumbum

Groundwater pollution could occur due to inadequate waste management, particularly waste containing heavy metals such as Plumbum (Pb). Plumbum originating from human activities could enter water sources and eventually settle as sediment. The results of the atomic absorption spectrophotometry (AAS) analysis of Pb are presented in Table 8.

Table 8 Atomic Absorption Spectrophotometry (Pb) Test Result

Sample	Method	Unit	**AAS (Pb) Test Result**	Provisions		Description
				Minister of Health Regulation 2010	**SNI 2015**	
O1	Ozone	mg/L	<0,001	<0,01	<0,005	C
O2	Ozone	mg/L	<0,001	<0,01	<0,005	C
O3	Ozone	mg/L	<0,001	<0,01	<0,005	C
RO3	RO	mg/L	<0,001	<0,01	<0,005	C
RO1	RO	mg/L	<0,001	<0,01	<0,005	C
RO2	RO	mg/L	<0,001	<0,01	<0,005	C
UV3	UV	mg/L	<0,001	<0,01	<0,005	C
UV2	UV	mg/L	<0,001	<0,01	<0,005	C
UV1	UV	mg/L	<0,001	<0,01	<0,005	C

(Source: Personal Data, 2025)

Description:

C = Compliant

According to the Minister of Health Regulation No. 492 of 2010, the maximum permissible limit of Plumbum (Pb) in drinking water was <0.01 mg/L, whereas SNI 3553:2015 set the limit of <0.005 mg/L. The results of this study showed that all refilled drinking water samples had very low or undetectable Pb concentrations (<0.001 mg/L), indicating the absence of significant lead contamination and showing that the raw water sources were safe (Artati, 2018). Plumbum is recognized as a toxic heavy metal that could leach into water from distribution pipes due to corrosion processes influenced by environmental conditions, pipe material and age, and water pressure (Artati, 2018). Long-term exposure to Pb was reported to be neurotoxic and was associated with anemia, abdominal pain, nervous system damage, decreased cognitive function in children, and, at high concentrations, an increased risk of kidney failure (Ismayanti *et al*., 2019). Therefore, although the measured Pb levels were within the established standards, routine monitoring remains necessary to ensure consistent water quality.

a. Cadmium

Cadmium (Cd) is a toxic heavy metal that can contaminate groundwater and surface waters. The presence of Cd in aquatic environments is generally associated with human activities. Cadmium can enter drinking water through the infiltration of industrial waste containing Cd into water distribution systems, as well as through the use of polyethylene-based pipes and containers (Pulungan & Wahyuni, 2021). The results of the atomic absorption spectrophotometry (AAS) analysis of Cd are presented in Table 9.

Table 9 Atomic Absorption Spectrophotometry (Cd) Test Result

Sample	Method	Unit	AAS (Cd) Test result	Provisions		Desription
				Minister of Health Regulation 2010	SNI 2015	
O1	Ozone	mg/L	<0,001	<0,003	<0,003	C
O2	Ozone	mg/L	<0,001	<0,003	<0,003	C
O3	Ozone	mg/L	<0,001	<0,003	<0,003	C
RO3	RO	mg/L	<0,001	<0,003	<0,003	C
RO1	RO	mg/L	<0,001	<0,003	<0,003	C
RO2	RO	mg/L	<0,001	<0,003	<0,003	C
UV3	UV	mg/L	<0,001	<0,003	<0,003	C
UV2	UV	mg/L	<0,001	<0,003	<0,003	C
UV1	UV	mg/L	<0,001	<0,003	<0,003	C

(Source: Personal Data, 2025)

Description:

C = Compliant

The analysis results showed that cadmium (Cd) concentrations in all refilled drinking water samples were below the instrument detection limit (<0.001 mg/L), far below the maximum allowable limit of 0.003 mg/L established by the Regulation of the Minister of Health of the Republic of Indonesia No. 492 of 2010 and SNI 3553:2015. Therefore, no significant Cd contamination was detected in the samples. Cadmium is recognized as one of the most toxic heavy metals after mercury and could contaminate water through sediments or industrial waste, particularly from mining activities (Dewa *et al*., 2015). This metal is highly toxic even at low concentrations; acute exposure to high doses caused gastrointestinal disturbances, whereas chronic exposure to low doses led to impaired kidney function (Herman, 2006). The kidneys and liver are identified as the primary organs for Cd accumulation, with a half-life of approximately 20–30 years. Cd levels ≥20 mg/g wet weight were reported to cause kidney failure and even death (Ismayanti *et al*., 2019). Long-term exposure was also

e-ISSN : 2715-9957

p-ISSN: 2354-8487

associated with liver disorders, bone damage, chronic anemia, coughing, headaches, and vomiting (Pulungan & Wahyuni, 2021).

b. Chromium

There are two forms of chromium present in soil, namely Cr(III), which exist as Cr^{3+} ions, and Cr(VI), which occur as chromate ions $(CrO_4)^{2-}$, typically found under conditions with a pH above six (Lazulva & Apriani, 2012). The results of the atomic absorption spectrophotometry (AAS) analysis of chromium (Cr) are presented in Table 1.10.

Table 10 Atomic Absorption Spectrophotometry (Cr) Test Result

Sample	Method	Unit	**AAS (Cr) Test Result**	Provisions: Minister of Health Regulation 2010	Provisions: SNI 2015	Description
O1	Ozone	mg/L	<0,001	<0,05	<0,05	C
O2	Ozone	mg/L	<0,001	<0,05	<0,05	C
O3	Ozone	mg/L	<0,001	<0,05	<0,05	C
RO3	RO	mg/L	<0,001	<0,05	<0,05	C
RO1	RO	mg/L	<0,001	<0,05	<0,05	C
RO2	RO	mg/L	<0,001	<0,05	<0,05	C
UV3	UV	mg/L	<0,001	<0,05	<0,05	C
UV2	UV	mg/L	<0,001	<0,05	<0,05	C
UV1	UV	mg/L	<0,001	<0,05	<0,05	C

(Source: Personal Data, 2025)

Description:

C = Compliant

According to the Regulation of the Minister of Health of the Republic of Indonesia No. 492 of 2010 and SNI 3553:2015, the maximum allowable concentration of chromium in drinking water was 0.05 mg/L. The analysis of nine refilled drinking water samples showed that all samples had chromium levels below the instrument detection limit (<0.001 mg/L), indicating that no significant chromium contamination was detected (Emilia, 2018). These findings indicated that the refilled drinking water in the study area was safe from chromium exposure. However, periodic monitoring remains necessary because chromium, particularly Cr(VI), is known to be toxic even at low concentrations. Chromium was reported to cause liver and kidney damage, exhibit cytotoxic effect to human cells, and have carcinogenic, teratogenic, and mutagenic effects (Emilia, 2018).

Conclusion

1. Heavy metals (Fe, Pb, Cd, and Cr) were detected in refilled drinking water in Demak Regency.

2. The Fe concentrations in the samples were as follows: O1 (0.22 mg/L), O2 (0.25 mg/L), O3 (0.12 mg/L), RO3 (0.09 mg/L), RO1 (0.06 mg/L), RO2 (0.12

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p-ISSN: 2354-8487

mg/L), UV3 (0.18 mg/L), UV2 (0.15 mg/L), and UV1 (0.31 mg/L). The concentrations of Pb, Cd, and Cr in all samples were < 0.001 mg/L.

3. The disinfection and ion purification methods applied in the refilled drinking water treatment did not significantly affect the concentrations of heavy metals in refilled drinking water in Demak Regency.
4. The concentrations of Pb, Cd, and Cr in refilled drinking water in Demak Regency complied with the permissible limits established by the Regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES/PER/IV/2010 and SNI 3553:2015. However, the Fe concentrations in samples treated using ozonation and UV methods still required monitoring, as some values exceeded the established limits.

Declaration of Competing Interest

No Conflict Interest

Reference

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