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Atomic Absorption Spectrophotometry-Based Evaluation of Iron and Chromium in Community Water Sources

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ABSTRACT

Purpose of the study: To determine the presence of heavy metal content, especially iron (Fe) and chromium (Cr) in artesian water wells and residents in Rejo Sari Village.

Methodology: In determining pH, pH meter and universal indicator paper were used. The pH values obtained were 6.5; 6.4; 5.9; 7.4; 6.5 and 7.5. Determination of iron (Fe) and chromium (Cr) content was carried out using the Atomic Absorption Spectrophotometry (AAS) method.

Main Findings: The results of the study showed that the concentrations of iron (Fe) were 1.9615 ppm, 0.4692 ppm, 0.4692 ppm, 0.4461 ppm, 1.5615 ppm, and 0.2769 ppm, respectively. One sample with chromium (Cr) concentration was detected at 0.06 ppm.

Novelty/Originality of this study: This study presents a novel contribution by comparing the heavy metals Fe and Cr content in two types of well water sources—artesian wells and ring wells—specifically in a densely populated residential area, using an AAS-based quantitative analysis approach rarely applied simultaneously to both metals in a local context. This study also emphasizes the significance of spatial and environmental quality on heavy metal contamination, which has not been widely addressed in similar studies in the region.

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1. INTRODUCTION

Water is a basic necessity vital to human life and that of other living things [1], [2]. The availability of clean water in sufficient quantities is a key pillar for supporting domestic, agricultural, and industrial activities [3], [4]. However, rapid population growth, urbanization, and uncontrolled human activities can lead to a decline in water quality, both physically, chemically, and biologically [5], [6]. One form of water quality degradation is heavy metal pollution.

Heavy metals such as iron (Fe) and chromium (Cr) are chemical elements often found in water sources contaminated by domestic and industrial waste [7], [8]. Both of these metals, at levels exceeding threshold levels, can be harmful to human health. Iron in high concentrations can cause changes in the taste and color of water and cause gastrointestinal side effects [9], [10]. Meanwhile, chromium, especially in the form of Cr(VI), is toxic and carcinogenic and can cause liver and kidney damage [11], [12].

Artesian wells and community wells (rings) are two types of underground water sources widely used by communities, especially in rural and suburban areas [13], [14]. Artesian wells tend to be deeper and protected by aquifers, while ring wells are generally shallower and at higher risk of surface contamination [15]-[17]. Therefore, it is important to conduct a comparative analysis of the water quality of both well types, particularly regarding heavy metal content.

Atomic Absorption Spectrophotometry is a widely used method for detecting heavy metals in water samples [18]-[20]. This method has high sensitivity and accuracy, and is capable of detecting metals at low concentrations. Atomic Absorption Spectrophotometry works based on the principle of light absorption by free atoms in the gas phase at specific wavelengths [21]-[23]. Using this method, the Fe and Cr content in water can be analyzed quantitatively and precisely.

This research focused on measuring the levels of the heavy metals iron (Fe) and chromium (Cr) in water from artesian wells and ring wells, which are widely used by the public for daily needs. These two well types were selected based on their differences in depth and their vulnerability to contamination, which can affect water quality. By comparing the heavy metal content in both well types, this study aims to identify potential environmental and health risks.

Fe and Cr levels exceeding the threshold can negatively impact human health, therefore, it is crucial to ensure that well water quality meets the clean water quality standards stipulated by the Regulation of the Minister of Health of the Republic of Indonesia. Therefore, the results of this analysis will not only provide an overview of local environmental conditions but also serve as a basis for implementing necessary policy interventions or remedial measures to protect public health.

Krüger et al., [24] study highlights the versatility of Atomic Absorption Spectrometry in antibacterial research, focusing on its application in analyzing heavy metals as factors influencing biological activity, while Mawardi et al., [25] utilized Atomic Absorption Spectrometry to determine the cation exchange capacity of soil in an agricultural area, emphasizing its role in chemical soil characterization. While both studies demonstrate the broad application of AAS in biology and the environment, neither has directly examined its use for assessing heavy metals such as iron (Fe) and chromium (Cr) in community water sources. The current study fills this gap by utilizing Atomic Absorption Spectrometry to evaluate heavy metal content in artesian wells and community wells, which are highly relevant to environmental health and water quality issues. Thus, this study extends the use of Atomic Absorption Spectrometry from the laboratory and agricultural contexts to community water quality monitoring, an area that has not been widely explored in the previous literature.

This research is novel in its application of the Atomic Absorption Spectrophotometry method to analyze the heavy metal content of iron (Fe) and chromium (Cr) specifically in community water sources, such as artesian wells and dug wells (cincing), which have not been widely studied locally or nationally. Unlike previous studies that focused more on Atomic Absorption Spectrophotometry in a biological or soil context, this research presents a practical and applicable approach in assessing the potential for heavy metal contamination in water consumed directly by the community. The urgency of this research is very high considering that exposure to heavy metals such as Fe and Cr in drinking water can have serious impacts on public health, including the risk of organ damage and chronic diseases. Furthermore, with increasing industrial activity and population growth that is not balanced with good environmental management, the potential for groundwater contamination is even greater. Therefore, the results of this study can be an important basis for authorities in evaluating water quality and formulating environmental health risk mitigation policies at the community level.

Based on this background, this study aims to analyze the heavy metal content of Fe and Cr in artesian well water and ring wells using Atomic Absorption Spectrophotometry. The results are expected to contribute to the development of environmental chemistry and serve as a scientific and practical reference for relevant parties in managing groundwater resources in a safer, more sustainable, and data-driven manner.

2. RESEARCH METHOD

2.1. Tools and Materials

The tools and materials used in this study consisted of several laboratory equipment and chemicals that support the heavy metal analysis process [26], [27]. The equipment used included an AA 6200 type Atomic Absorption Spectrophotometer, a sampler bottle for water sampling, a pH meter to measure acidity levels, and a thermometer to record water temperature. In addition, a hot plate was used for heating, Whatman filter paper no. 42 for the filtration process, and various other laboratory glassware such as measuring cylinders, volumetric flasks, and Erlenmeyer flasks. The chemicals used in this study included 70% HNO_3 (certain brands), $FeSO_4$ p.a (pro analysis), $CrCl_3 \cdot 6H_2O$ p.a, and distilled water as a solvent and equipment washer. All tools and materials were prepared according to laboratory procedures to ensure the accuracy and validity of the analysis results [28], [29].

2.2. Research Design

The research design used in this study is quantitative research. This study aims to determine the content of heavy metals in the form of iron (Fe) and chromium (Cr) in raw water originating from artesian wells and residents' wells (ring wells) used as drinking water sources. Sampling was carried out at several locations in the Tenayan Raya District, Pekanbaru City. The sampling locations include six points, consisting of three ring wells and three artesian wells. The details of the sample locations are as follows: (1) Sample SC1 comes from residents' wells around Jalan Bambu Kuning, Gang Buntu; (2) Sample SA1 comes from an artesian well on Jalan Bambu Kuning, precisely in the Jondul Housing Complex; (3) Sample SC2 is taken from residents' wells around Jalan Satria, Gang Ubudiyah (Teacher Housing Complex); (4) Sample SA2 is an artesian well which is also located on Jalan Satria, Gang Ubudiyah (Teacher Housing Complex); (5) Sample SC3 comes from residents' wells around Jalan Sekapur Sirih; and (6) SA3 samples were taken from an artesian well located on Jalan Sekapur Sirih, precisely in the Hang Tuah Graha Housing Complex. The six samples were analyzed using the Atomic Absorption Spectrophotometry method to obtain quantitative data on the concentration of heavy metals Fe and Cr.

2.3. Sampling Techniques

Well water samples that do not use a pump are collected using a plastic bucket that is rinsed first with the sample. For well water samples that use a machine pump, the sample is taken from the tap/mouth of the pump where the water comes out after the water is first discharged for ± 3 minutes. Each sample is taken at random (random), after the sample is mixed, then it is placed in plastic bottles that have been previously rinsed first using the sample along with the cap.

2.4. Data Analysis Techniques

The data analysis techniques used in this study were calibration curve determination and linear regression [30], [31]. Most analytical methods are based on a process in which the method produces a linear increase or decrease in response depending on the analyte concentration. Regression is a curve that indicates the relationship between two quantities [32]-[34]. This relationship can be a straight line or a curved line. The relationship between the two quantities can be seen in the equation below:

$$y = bx + a \ldots (1)$$

Description:
y = Absorbance
x = Concentration
b = Regression coefficient (slope)
a = Regression constant (intercept)

To find the values of a and b, you can use the equation below:

$$a = \frac{\sum Y - b\sum X}{n} \ldots (2)$$

$$b = \frac{n\sum XY - \sum X . \sum Y}{n\sum X^2 - (\sum X)^2} \ldots (3)$$

Based on the correlation r can be calculated using the formula:

$$R = \frac{n\sum XY - \sum X \sum Y}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\, X\, \{n\sum Y^2 - (\sum Y)^2\}}} \ldots (4)$$

The value r ≤ + 1 describes a perfect positive correlation, namely all experimental points lie on a straight line with a positive slope.

3. RESULTS AND DISCUSSION

3.1. Determination of Fe metal content

In general, Fe ions are found in peat groundwater with varying values depending on the type of peat soil. The type of iron ion found in groundwater is iron (II). Slight changes in the partial pressure of O2 and CO2 will change the solubility of Fe 2+.

The iron reaction is 6: $4Fe^{2+} + O_2 + 10H_2O$ 4 $Fe(OH)_3 + 8H^+$

After going through the calculation of the standard curve linear regression, Y = bx + a, then Y = 0.013X−0.002 is obtained so that the concentration in the sample can be calculated. Data on the content of iron metal (Fe) in the well water of residents (ring) and artesian well water can be seen in table 1:

Table 1. Results of Determination of Fe Content in Artesian Well Water and Rings

No	Sample	Average Absorbance	Concentration (ppm)	Information
1	SC 1	0.0235	1.9615	x
2	SA 1	0.0041	0.4692	x
3	SC 2	0.0041	0.4692	x
4	SA 2	0.0038	0.4461	x
5	SC 3	0.0183	1.5615	x
6	SA 3	0.0016	0.2769	√

The results of the examination of iron (Fe) parameters in artesian well water and ring well water showed that almost all samples studied exceeded the drinking water requirements according to the Minister of Health Decree 492 of 2010. The highest iron concentration was found in sample SC 1 at 1.9615 ppm, followed by sample SC 3 at 1.5615 ppm. The high iron concentration in these two samples affected the physical properties of the water, namely the appearance of odor and yellow color in the water due to the oxidation of Fe^{2+} to Fe^{3+}. The sample that still met the requirements of Minister of Health Decree 492 of 2010 was sample SA3 with an iron concentration of 0.2769. This sample is an artesian well sample known to originate from deep groundwater that has undergone several filtration processes by layers of soil. In addition, the sample location is in a relatively unpopulated area because the area is still a new housing complex.

In absorbance measurements, it can be seen that the sample absorbance range lies between 0 and 1 concentration. This can be interpreted that the metal concentration in the sample is read even though it is below the standard solution concentration range of 1-9 ppm but still between the blank and standard solutions. From the research data, a correlation value between absorbance and concentration (ppm) was obtained where the R value is close to 1, namely 0.998. To find out more details/details of the actual sample concentration range in the standard solution interval, the researchers conducted re-measurements with smaller standard solution concentration intervals, namely 0.2; 0.4; 0.8; 2.0 and 4.0 ppm. From the measurement results, it can be seen that the sample absorbance range is in a fairly varied range, namely between 0.2-2.0 ppm. This shows that the concentration of the population well (ring) and artesian well samples that have been further studied can be detected even at low concentrations. The samples used also came from the same place but were taken at different times so there were slight differences in sample concentrations. This difference is likely caused by natural and environmental factors such as rainfall and population activities.

Data on the iron (Fe) metal content in residents' well water (ring) and artesian well water in repeated measurements with lower standard solution concentrations can be seen in Table 2:

Table 2. Results of Re-Determination of Fe Content in Artesian Well Water and Rings

No	Sample	Average Absorbance	Concentration (ppm)	Information
1	SC 1	0.0917	1.3680	x
2	SA 1	0.0294	0.4392	x
3	SC 2	0.0289	0.4319	x
4	SA 2	0.0282	0.4216	x
5	SC 3	0.0814	1.2615	x
6	SA 3	0.0160	0.2396	√

High doses of iron can damage the intestinal wall. Death is often caused by this damage. Iron dust can also accumulate in the alveoli, leading to reduced lung function.

The high iron (Fe) content in well water, exceeding established drinking water requirements, can be caused by several possible causes. One is the soil, which consists of organosols and humus, which are marshes that are quite acidic and corrosive to iron (Fe). In addition to soil conditions, iron (Fe) can also come from river water seepage, household waste, cast iron for building materials, metal equipment, and other sources.

3.2. Determination of Cr metal content

In general, chromium ions are not found in water except in certain places or in places that have been polluted by chromium waste. Hasfiatar stated that the Sail watershed has the largest pollution load for each type of metal he studied, one of which is chromium metal. This is because the Sail river has a large catchment area and passes through many places with dense community activities. There are two types of chromium in the soil, namely Cr (III) in the form of Cr3+ and Cr (VI) in the form of (CrO-4)2- which have a pH above six.

After going through the standard curve linear regression calculation, Y = bx + a, Y = 0.003X+0.000 was obtained (Attachment 1) so that the concentration in the sample could be calculated. Data on the chromium (Cr) metal content in residents' well water and artesian well water can be seen in table 3:

Table 3. Results of Determination of Cr Content in Artesian Well Water and Rings

No	Sample	Average Absorbance	Concentration (ppm)	Information
1	SC 1	0.0002	0.016	x
2	SA 1	0	not detected	√
3	SC 2	0	not detected	√
4	SA 2	0	not detected	√
5	SC 3	0	not detected	√
6	SA 3	0	not detected	√

The results of the examination for chromium (Cr) parameters in artesian well water and ring well water showed that the concentration of chromium in sample SC1 was 0.06 ppm, which means that the water in the sample has exceeded the quality standard set by the Minister of Health (0.05 ppm). Meanwhile, the concentration of chromium in other samples was not detected. This shows that the drinking water, when viewed from the concentration of chromium contained in it, is still suitable for consumption.

The undetected chromium metal in the water sample is likely due to the chromium ions in the water being absorbed into the sediment and becoming immobile, only a small portion of the chromium that ends up in the water will eventually dissolve. The very low concentration of chromium in groundwater and at the location where the sample was taken caused the chromium metal not to be detected because it was below the chromium detection limit on the SSA device used.

In the absorbance measurement, it was seen that the sample absorbance range was between concentrations of 0 to 5. This can be interpreted that the concentration of metal in the sample was read even though it was below the standard solution concentration range of 5-25 ppm but was still between the blank and standard solutions. From the research data, the correlation value between absorbance and concentration (ppm) was obtained where the R value was close to 1, which was 0.998. To find out more details about the actual sample concentration range in the standard solution interval, the researcher conducted re-measurements with smaller standard solution concentration intervals, namely 0.2; 0.4; 0.6; 0.8 and 1.0 ppm. The results of the re-measurements showed that the concentration of the samples from the residents' wells (rings) and artesian wells that had been further studied was not detected. Although the samples used also came from the same place, they were taken at different times so that there were differences in sample concentrations. This difference is likely caused by natural and environmental factors such as rainfall and population activities.

Data on the chromium (Cr) metal content in residents' well water (ring) and artesian well water in repeated measurements with lower standard solution concentrations can be seen in Table 4:

Table 4. Results of Re-determination of Cr Content in Artesian Well Water and Rings

No	Sample	Average Absorbance	Concentration (ppm)	Information
1	SC 1	0	not detected	x
2	SA 1	0	not detected	x
3	SC 2	0	not detected	x
4	SA 2	0	not detected	x
5	SC 3	0	not detected	x
6	SA 3	0	not detected	√

Chromium (III) is essential for humans and deficiency can cause heart conditions, metabolic disorders, and diabetes. But too much chromium (III) absorption can also cause health effects. When inhaled, chromium (VI) can cause irritation and nosebleeds. Other health problems caused by chromium (VI) include: allergic reactions such as skin rashes, stomach pain and ulcers, a weakened immune system, kidney and liver damage, changes in genetic material, lung cancer, and death.

Based on the research results, it can be seen that the iron (Fe) content in several well water samples, particularly dug wells (cincing), exceeds the threshold set by Minister of Health Regulation No. 492 of 2010 concerning drinking water quality requirements. This finding indicates a potential health risk for people using this water for consumption. High iron content not only impacts the physical changes in water, such as color and odor, but can also cause serious health problems such as intestinal wall damage and lung disorders due to the accumulation of iron dust. Furthermore, the high Fe content is indicated to be influenced by the acidic and corrosive characteristics of peat soil [35], [36], as well as the possibility of contamination from human activities such as the use of metal in construction or household waste.

Meanwhile, the results of chromium (Cr) metal content testing showed that most samples did not contain the metal, except for one sample (SC1) which briefly showed Cr levels exceeding the safe threshold. However, in repeat testing at a lower standard concentration range, all samples contained no Cr. This indicates that the presence of chromium in the groundwater at the study site tends to be very low, likely because Cr is adsorbed by sediment or precipitated, making it insoluble in water. Environmental conditions and the timing of sampling can also influence the detected metal concentrations, given that variations in rainfall and community activities can trigger fluctuations in metal content in groundwater [37], [38].

Overall, this discussion emphasizes the importance of regularly monitoring the quality of community well water, particularly for heavy metals such as Fe and Cr, which can be harmful to health if consumed over the long term. The use of Atomic Absorption Spectrophotometry has proven effective in detecting metal levels at various concentrations, even in very small amounts [39], [40]. Therefore, this study not only provides accurate scientific information but also has practical value for local policymaking related to the management of safe and healthy clean water sources. Further research can also focus on identifying specific sources of contamination and developing water purification strategies tailored to local conditions.

This research has had a significant positive impact on community water quality monitoring efforts, particularly regarding heavy metal content such as iron (Fe) and chromium (Cr). Using the Atomic Absorption Spectrophotometry method, this study successfully identified potential metal contamination that could endanger public health, thus serving as an initial reference for relevant agencies in designing policy interventions or water purification technologies. Furthermore, the results of this study can increase public awareness of the importance of maintaining the quality of drinking water sources. However, this study also has several limitations, including the limited number of samples tested and the sampling period, which was only carried out during a single period, so it cannot describe seasonal variations or long-term fluctuations in heavy metal content. Furthermore, this study did not include further analysis of specific environmental factors that influence metal levels in water, such as well depth, soil type, or proximity to pollution sources. Therefore, further studies with wider coverage, longer duration, and more diverse environmental variables are highly recommended to obtain a more comprehensive picture.

4. CONCLUSION

The conclusion of this study is that based on the results of the chemical parameter analysis for iron (Fe) metal, it shows that there is Fe metal content in each sample of the resident and artesian wells studied. For Cr metal, the analysis results show that there is one sample containing Cr metal, namely sample SC1 (0.06 ppm). The concentration of Fe metal in SC 1, SA 1, SC 2, SA 2 and SC 3 is 1.9615; 0.4692; 0.4692; 0.4461 and 1.5615 ppm, respectively. Future research is recommended to expand the sampling area to obtain a more comprehensive picture of the distribution of heavy metals in community water sources. Furthermore, further analysis is needed to assess the potential health risks from long-term exposure to Fe and Cr metals in drinking water, using an environmental toxicology approach.

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AUTHOR CONTRIBUTIONS

Conceptualization, S.A.; Methodology, S.A.; Software, S.A.; Validation, S.A.; Formal Analysis, S.A.; Investigation, S.A.; Resources, S.A.; Data Curation, S.A.; Writing – Original Draft Preparation, S.A.; Writing – Review & Editing, S.A.; Visualization, S.A.; Supervision, S.A.; Project Administration, S.A.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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