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Original Research Article

Use of atomic absorption spectroscopy in determining minerals in water

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ABSTRACT

Background: As climate change, industrial activities and urbanization alter water sources, ongoing mineral analysis becomes vital for sustainable water management and regulatory compliance. This study was done to apply the technique of atomic absorption spectroscopy in determining mineral content in water from different sources. It emphasized how natural and anthropogenic factors influence water quality, impacting both ecosystem and human safety.
Methods: The study was done to measure mineral content of water from different sources with the help of flame atomic absorption spectroscopy (AAS). We took water samples from urban tap- water, local well-water and a spring-water. With the help of AAS calcium, magnesium, iron, sodium, potassium and zinc levels were measures in water samples. In order to verify the reliability of the method, the reference sample was determined. The accuracy of the calibration curve was evaluated by an independent calibration verification.
Results: Magnesium and calcium were found predominantly in spring water, while zinc and iron were absent, which suggested that mineral profile of natural groundwater is influenced by geological and environmental conditions specific to location. The presence of zinc and iron in tap and well water is attributed to the plumbing materials or environmental factors influencing water supplies.
Conclusions: Understanding mineral dynamics in water helps to protect public health and preserve environmental integrity in a rapidly changing world. This work shows that AAS technique is highly sensitive, specific and affordable method for detecting trace and toxic elements, which implements AAS as indispensable tool in modern laboratories and research centres.

Keywords: Atomic absorption spectrometer, Water quality, Water analysis, Water mineral monitoring, Water safety

INTRODUCTION

Atomic absorption spectroscopy (AAS) is method of quantitative determination of chemical elements present in a sample by measuring absorption of radiation of fixed wavelength corresponding to the given element. AAS was developed in 1953 by Alan Walsh and became commercially used analytical technique since 1960s.[1] AAS remains popular analytical technique, as it delivers accurate results. It is based on the principle that atoms can absorb light at a specific, unique wavelength. When this specific wavelength of light is provided, the light energy is absorbed by the atom. Electrons in the atom move from the ground state to an excited state. The amount of light absorbed is measured and the concentration of the element in the sample can be calculated.[2] There are a variety of types of AAS like flame atomic absorption spectroscopy (FAAS), graphite furnace atomic absorption spectroscopy (GF-AAS) also known as electro thermal AAS, mercury hydride system atomic absorption spectroscopy (MHS-AAS), which carry out qualitative and quantitative analysis.[3] Flame atomic absorption spectroscopy (FAAS) is ideally suited to labs in which a small number of elements are routinely measured. It has many benefits over the other techniques due to its low-cost affordability, simplicity of operation, single element analysis over a wide range of concentrations with high sensitivity in detecting concentrations as low as parts per million (ppm).[4] This makes flame atomic absorption a very useful technique for most laboratories that have a particular need for a low-cost technique for the analysis of multiple elements in the samples. There are some limitations of flame AAS, like it consumes more time, as same sample is measured multiple times once for each element.[5] AAS is used in different fields of medicine, like monitoring trace elements such as iron, zinc, copper, lead in biological fluids like blood and serum, detecting toxic heavy metals like mercury and cadmium in biological specimens, assessing nutritional status by analyzing mineral levels in tissues, monitoring metal containing drugs like lithium or platinum-based medicines like cisplatin to ensure their therapeutic efficacy and avoid toxicity.[6] Residential water quality is a matter of importance to both residents and water providers.[7] Recent environmental shifts alter natural water cycles and introduce new pollutants, impacting mineral concentrations in water. Determining mineral content in water is vital as a public health issue to ensure water safety, prevent mineral deficiencies such as hypocalcemia and toxicities like lead poisoning, also for appropriate choice of water treatment and sustainable water resource management.

The purpose of this study was to measure mineral content in water from different sources with the help of flame atomic absorption spectroscopy.

METHODS

AAS is based on the measuring of absorption of radiation of fixed wavelength corresponding to the given element.[8] Resonant radiation from a hollow cathode lamp passes through a flame, where the solution of the sample being analyzed is placed. The radiation falls into the entrance slit of a monochromator, which is positioned so that only the resonance line of the element being determined is separated from the spectrum, the intensity of which is measured photoelectrically.[9] The decrease in the intensity of the resonance line, due to its absorption by atoms of the given element, is measured, and the intensity of the attenuated line is taken as 100%.[10] The amount of absorption of resonant radiation is proportional to the number of atoms present in the absorbing layer. The number of excited atoms increases with increasing temperature, which in turn depends mainly on the heat capacity of the gas producing the flame.[11]

The study was performed at the PharmaTech CJSC pharmaceutical manufacturing plant using an atomic absorption spectrometer "The Agilent 55 AA". It is a dual-beam battery with LCD display and a reliable hardware with an integrated software interface for quick and easy operation (Table 1).

Table 1: Agilent 55 AA atomic spectroscopy conditions for each element.

Element	Wave-length (nm)	Slit width (nm)	Lamp current (A)	Burner angle
Calcium	422.67	0.7	30	30°
Magnesium	285.21	0.7	30	30°
Iron	258.33	0.2	30	0°
Sodium	589.00	0.2	10	30°
Potassium	766.49	0.7	30	30°
Zinc	213.86	0.7	10	0°

A standard flame atomic absorption spectrometer contains the following parts – a sample introduction system, the burner (flame) and its associated gas supplies: air-acetylene either nitrous oxide-acetylene, a light source, which is the hollow cathode lamp (HCL), a monochromator (the optical components inside the box in the diagram), an optical detector (photomultiplier tube or PMT) and computerized instrument control, data collection, and analysis (Figures 1 and 2).[6,12]

The atomic absorption spectrometer is brought into operation according to the manufacturer's instructions and the required wavelength is set.[13] Water samples were taken from urban tap- water, local well-water and as a spring-water mineral bottled water was purchased from local grocery store.

Due to the high content of some minerals in water samples, the combustion head was rotated 30° to suppress the signal intensity, so as to meet the needs of mineral analysis.[14]

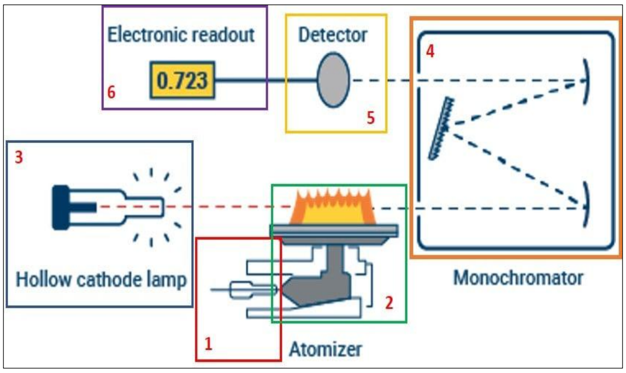

Figure 1: Components of atomic absorption spectrometer.

The correlation coefficient of all calibration curves was 0.999. The accuracy of the calibration curve was evaluated by an independent calibration verification (ICV) solution diluted 100 times to fall within the calibration curve (Table 2).

Table 2: ICV test results.

Element	Concentration (mg/l)	Reference value (mg/l)	% Recovery rate
Calcium	5.00	4.96	99
Magnesium	5.00	4.81	96
Iron	1.00	1.00	100
Sodium	5.00	5.21	104
Potassium	5.00	4.86	97
Zinc	0.20	0.23	115

Table 3: Reference sample test result (mg/dl).

Element	Concentration (mg/l)	Reference value (mg/l)	% Recovery rate
Calcium	33.6	35.0	96
Magnesium	8.73	9.0	97
Iron	0.09	0.1	90
Sodium	5.82	6.0	97
Potassium	2.31	2.5	92
Zinc	0.07	0.07	100

Figure 2: Steps of atomic absorption spectrometry.

In order to verify the reliability of the method, the reference sample was determined at first, and the determination results are shown in Table 3. The recovery rate fluctuates within 10% of the standard value, which fully demonstrates the accuracy of the method.

The samples were diluted 10 times and prepared by adding 1% nitric acid and 0.1% lanthanum chloride as releasing agent for the determination of calcium and magnesium, and as ionization inhibitor for the determination of sodium and potassium.

RESULTS

Flame atomic absorption spectroscopy enabled qualitative and quantitative assessment of mineral content in the different water samples. Zinc and iron were detected in the urban tap water and local well water but were not detected in the spring water.

Magnesium and calcium were predominant in the spring water compared with the tap and well water samples. Sodium and potassium were present in all three water sources, with noticeable variation in their levels among the samples (Table 4).

Table 4: Sample test result (mg/l).

Element	Urban water	Well Water-1	Well water-2	Spring water
Calcium	16.4	37.1	31.6	18.1
Magnesium	6.61	4.83	5.12	5.86
Iron	<DL	0.023	<DL	<DL
Sodium	31.3	18.42	27.41	6.74
Potassium	<DL	4.91	4.13	0.71
Zinc	0.009	0.02	0.016	<DL

<DL: below detectable limit.

DISCUSSION

The presence of zinc and iron in tap and well water in the present study may be attributed to corrosion of plumbing materials and leaching from distribution systems, as reported for galvanized steel and iron-based pipes that release zinc and iron into drinking water under corrosive conditions. Similar observations of elevated trace metals, including iron and zinc, in distributed and groundwater sources have been documented in previous assessments of drinking water quality, where infrastructure materials and environmental inputs were identified as major contributors. The absence of detectable zinc and iron in the spring water in this study suggests minimal contribution from plumbing-related contamination and supports the view that, in relatively undisturbed settings, trace metal levels can remain low when anthropogenic inputs are limited.

The finding that magnesium and calcium were predominant in the spring water is consistent with earlier groundwater studies showing that these ions are commonly derived from dissolution of limestone, dolomite, and other rock formations along the flow path, forming a characteristic hard-water profile. Previous work on groundwater chemistry has similarly linked calcium and magnesium concentrations and Mg/Ca ratios to the influence of specific rock types and aquifer geology, reinforcing the interpretation that the spring water in this study reflects natural geochemical processes rather than contamination.[15] From a public health perspective, trace metals such as zinc and iron act as essential micronutrients at low concentrations but may pose health concerns when present at elevated levels, whereas calcium and magnesium contribute beneficially to hardness within recommended limits, underscoring the value of regular monitoring to ensure concentrations remain within guideline values. These findings align with earlier reports that emphasize both the nutritional and toxicological dimensions of trace metals and hardness-forming minerals in drinking water and highlight the importance of routine surveillance of multiple parameters rather than single-metal assessment.[16]

Overall, the present results support previous literature indicating that mineral composition of water sources reflects a combination of natural geologic controls and anthropogenic influences, particularly corrosion and infrastructure-related inputs, and they reinforce the need for ongoing assessment of both macro- and trace-element profiles for protection of public health.

Limitations

The present study has several limitations. First, the number of sampling sites and samples per source was limited, which restricts the ability to generalize the findings to broader regional water supplies. Second, only a single analytical technique (AAS) and a limited set of elements were investigated, so other relevant contaminants, e.g. additional trace metals or organic pollutants, were not characterized. Third, sampling was conducted over a limited time frame without seasonal replication, which may overlook temporal variability in mineral and metal concentrations.

Future studies with larger sample sizes, expanded analytical panels, and multi-season sampling would provide a more comprehensive understanding of mineral dynamics and contaminant risks in different water sources.

CONCLUSION

This work shows that AAS can successfully determine minerals composition in drinking water samples, including urban tap water, well water and spring water. Trace elements and mineral elements can be determined by rotating the combustion head and adopting the emission mode of the instrument. AAS technique has been proved to be a highly sensitive analytical technique to detect and quantify trace and toxic elements in various samples by detecting the absorption of specific wavelengths of light by free atoms in the gaseous state. Its precision, specificity, and relatively simple implementation make AAS an indispensable tool in modern medicine, laboratories and research centres.

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