DOI: https://doi.org/10.20372/star.v10i1.02
ISSN: 2226-7522 (Print) and 2305-3372 (Online)
Science, Technology and Arts Research Journal
Sci. Technol. Arts Res. J., Jan.-March 2021, 10(1), 16-26
Journal Homepage: https://journals.wgu.edu.et

Original Research

Assessment of Quality Drinking Water in Gimbi Town, West Wollega

Leta Shifera

Department of Chemistry, Wollega University, Ethiopia, P.O. Box.395 Nekemte, Ethiopia

Abstract

The purpose of this study was to collect data on the water quality in several locations around Gimbi town by analyzing samples of drinking water. Twenty by three times sixty, or composite drinking water samples, were gathered from five different locations throughout town. An AAS and UV-Vis spectrophotometer were used to examine the following parameters: temperature, conductivity, totals dissolved solids (TDS), pH, and five heavy metals: Cr (VI), Cu (II), Cd (II), Pb (II), Zn (II), and phenol in the sample. Within the permitted limits established by the World Health Organization, all samples contain lead (II), cadmium (II), chromium (VI), copper (II), zinc (II), and phenol. The range of metal ion concentrations and phenolic levels in the samples that were tested includes lead (II) (0.34 µg – 0.78 µg), chromium (VI) (0.3 µg – 0.52 µg), cadmium (II) (0.3 µg – 0.62 µg), copper (II) (0.32 µg – 0.97 µg), zinc (II) (0.31 µg – 0.92 µg), and phenol (0.3 µg – 0.99 µg).

Article Information

Article History:
Received: 08-01-2021
Revised: 27-02-2021
Accepted: 28-03-2021

Keywords:
Heavy metal ions, Phenol, Analysis, Atomic Absorption Spectrometry, UV-Visible Spectrophotometry

*Corresponding Author:
Leta Shiferaw
E-mail:
shiferal@gmail.com

INTRODUCTION

Animals and humans alike are in grave danger from the harmful effects of environmental pollution, which is a worldwide epidemic. Some of the most significant causes of environmental degradation include the expansion of contemporary technology and the quick pace of industrialization. Pollutants in the environment can spread through various pathways. 1. Living things are greatly affected by environmental pollution. Because heavy metals bioaccumulate in foods, they pose a serious threat to human and environmental health. Lakes, rivers, oceans, and even underground water sources can be contaminated, a phenomenon known as water pollution. Direct or indirect discharge of contaminants, such as heavy metals, into water bodies is what causes water contamination. The human body is known to be affected by polluting metals such as lead, cadmium, copper, chromium, and zinc (Soylak, 2017, Hassan, Mustafa, 2019). Water quality is negatively impacted by heavy metals, which in turn impacts both humans and other living things. At greater amounts, even the necessary metals become poisonous. The presence of water is crucial for all forms of life on our planet. It is typically polluted with solid waste, chemical industry effluents, and dissolved gasses, despite the fact that it is colorless, tasteless, and odorless in its most pure state as a result of human and animal activity. It has been noted that groundwater has been significantly contaminated during the last many decades as a result of increased human activity. Because it affects people's well-being directly, water quality is an important issue for humanity. Both surface and groundwater quality are affected by human activities, which include the disposal of garbage and polluted runoff from surfaces. Garbage disposal and land use are two typical factors that impact groundwater quality. The garbage might be scattered throughout the ground or piled high in piles. Disposal of waste materials on land surfaces is the main source of water contamination. Agricultural output has dropped, water-related illnesses have increased, and biodiversity has declined as a result of high pollution levels in rivers and groundwater. How much contamination various water sources experience determines the prevalence of gastrointestinal infections in different regions. A variety of pollutants can degrade drinking water, including surface water, groundwater, and raw water in general. Heavy metal-polluted water is an issue in industrialized regions. But nowadays people think of roads, dumpsite regions, and cars as places where heavy metals can be found. Their production, use, and discharge into the environment expose them to threats that can harm humans, other creatures, and the environment, despite their importance to mankind. It is believed that several heavy metals utilized by humans continue to have harmful impacts on human health.

The public health effects of environmental pollution have garnered more and more attention during the last several decades. Many cities, particularly in developing nations, suffer from environmental contamination and degradation due to poor solid waste management. Subterranean storage tanks, urban storm water runoff, mine drainage, salt, salinity, seawater intrusion, lateral migration, vertical seepage, urban runoff, wells, and oil-field brines are some of the most common sources of heavy metal pollution in groundwater. It is impossible to overstate the significance of groundwater to human civilization. It is crucial to be aware of the water's physico-chemical properties, including its pH, conductivity, temperature, and total dissolved solids, while AAS and UV-vis spectrophotometers ascertain the content of heavy metals. There has been an evaluation of surface water, groundwater, and potable water quality in relation to the World Health Organization's (WHO) standard desirable limit.

While there are sufficient surface and groundwater sources for drinking water in Gimbi, these are in short supply. The city's water supplies, both in terms of quantity and quality, have been under tremendous strain due to rapid population expansion and urbanisation. Clean surface and groundwater is essential for human, agricultural, fishery, and industrial health. The most common types of contaminants that might end up in water include inorganic and organic substances, sediments, radioactive elements, heavy metals, and others. Industrialization, urbanization, agricultural practices, and other environmental and global changes are the primary causes of water contamination. As a result of heavy metal pollution and human activities, surface and groundwater resources are among the most critical environmental concerns

(Ballinger, 2018). The use of commercial agrochemicals in farming, manufacturing, and mining, as well as incorrect waste disposal practices, has led to heavy metal contamination of natural water sources, which has become an important issue in numerous towns and farming regions (Corporation, 2020). The long-term dispersion and accumulation of heavy metals in soil, surface water, and groundwater poses a threat to human and animal health. Erosion mixes heavy metals with naturally occurring water, which can happen as a result of discharges from mining, agrochemicals, textiles, tanneries, and garbage disposal sites in garages. According to Vennilamani, Pattabhi, Kadirvelu, Karthika, and Radhika (2017), improper domestic waste management pollutes natural water sources.

As a result of modernity, ill-planning, fast population increase, and industrialization, vast quantities of chemicals are utilized. This has the potential to cause the entry of pollutants into bodies of water. Water contamination from toxic heavy metals is a problem that ecosystems around the world are trying to solve. Heavy metals are mostly found in the following elements: chromium, zinc, copper, lead, and cadmium. Even at low concentrations, heavy metals are harmful to aquatic plants, animals, and humans (Geneva, 2019). Any organic chemical whose concentration in drinking water is higher than the legal limit is termed a water contaminant. Pesticides, hydrocarbons, phenol and its derivatives, oils, greases, medicines, proteins, carbs, and detergents are common organic contaminants. Phenol and its derivatives are crucial ingredients in numerous resins used in industrial and automotive applications, such as phenolic resins, epoxy resins, polyamide, and many more. There are benefits to using phenol, but there are also drawbacks owing to its toxicity. Aside from its unpleasant smell and taste, phenol-containing water can induce nausea, vomiting, anorexia, an elevated respiratory rate, damage to the liver and kidneys, and a headache. It is crucial for public health research to analyze natural water for physical and chemical qualities, including the levels of trace elements.

The study examined the quality of drinking water, groundwater, and surface water as well as the types of water and the sources of contaminants. For environmental and human health safety evaluations, it is crucial to study economically viable and socially acceptable ways of removing the pollution. Chemical precipitation, ion exchange, sludge separation, reverse osmosis, membrane separation, electrochemical treatment, evaporation, and chemical oxidation or reduction were some of the standard and innovative ways developed by researchers to lessen the impact of these harmful substances. Problems with these approaches include inefficiency in removal, sludge generation, and cost incompatibility. When it comes to water treatment, adsorption is the way to go because it's inexpensive, easy to use, readily available, effective, and doesn't react negatively to harmful compounds.

MATERIALS AND METHODS

Chemicals

Analytical-reagent-grade chemicals were used. Lead Nitrate (Pb $(NO_3)_2$), Potassium dichromate (K2Cr2O7), Nitric acid (HNO_3), Sodium hydroxide (NaOH), Sulphuric acid (H_2SO_4), Sodium carbonate (NaCO3), Biphenyl carbazide and cadmium nitrate ($Cd(NO_3)_2$), Zinc Sulphate ($ZnSO_4$), Copper Sulphate ($CuSO_4$), Phenol (C_6H_5OH), 4-aminoantipyrine (C11H13N3O), Ferric Cyanide ($[Fe(CN)_6]^{3-}$), chloroform ($CHCl_3$), and sodium sulphate ($NaSO_4$), distilled water

APPARATUS

Plastic bottles, amber bottles, thermometer, volumetric flask, measuring cylinder, thermostatic water bath, simple distillation apparatus

Instruments

Atomic Absorption Spectroscopy (AAS) (Model Analytic Jena Nov AA 300, Germany), pH metre (HANNA instruments, pH 211), conductometrey, electronic balance (Model AFP-110L, ADAM, China), thermostatic water bath (Model Grant GLS 400, England), and UV-ViS Spectro photometry (Model DR 5000, Hach USA).

MATTERIALS AND METHODS

Collection of water Sample

The study was conducted at the Wollega University Chemistry Laboratory, East Wollega.

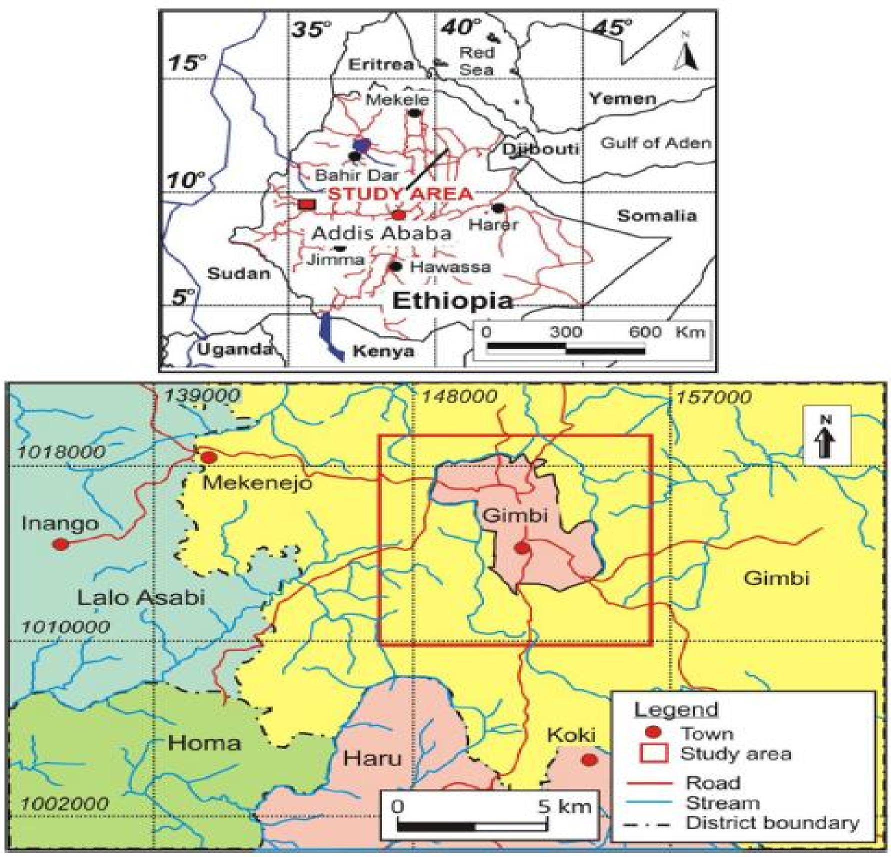

Figure1. *Map of Country; Ethiopia, Gimbi Town location*

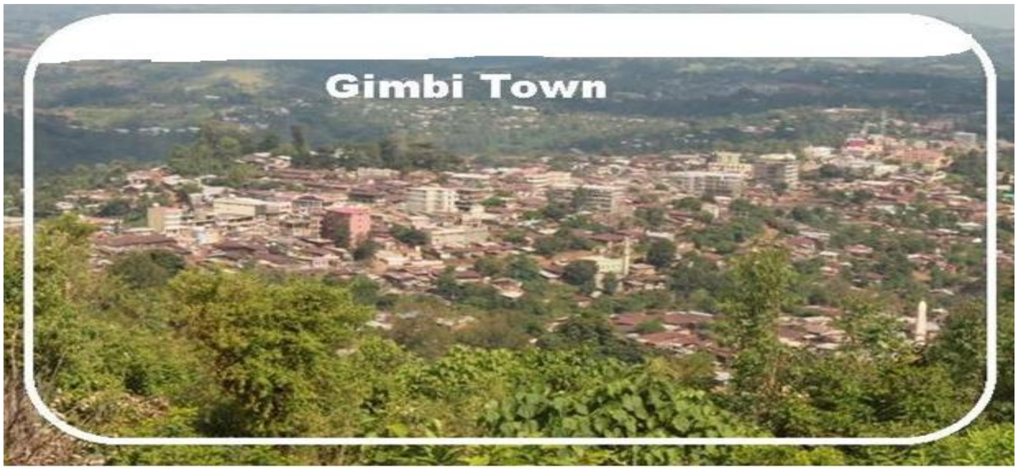

Figure 2 *Overall view of Gimbi town*

Sample sites: Sarxe, Medini, Malifu, bus station, Isaksi (Colli).

Each sample container was thoroughly rinsed. The plastic bottle containers were washed using a combination of detergent and tap water. Next, distilled water and a 1:1 solution of HNO3 were added. In the months of June and July of 2011 E.C., twenty composite water samples were collected from five different spots across town. Sixty samples were collected in all (20x 3= 60). In order to keep the water samples stable for examination, 2 drops of pure HNO3 were added to each one before freezing them. In preparation for phenol analysis, the amber bottles were washed with a soap-and-water mixture, rinsed with distilled water, and allowed to air dry. The water samples were preserved with 1 cc of 10% NaOH before sampling, and then placed in amber bottles.

Analysis of Pb (II), Zn (II), Cd (II), Cu (II), and Cr (VI)

To break down the samples, hydrogen peroxide was employed. A beaker containing 100 mL of sample and 5 mL of concentrated nitric acid was heated on a hot plate. By progressively adding additional acid, a transparent, pale-colored solution was produced. The water samples were subjected to AAS analysis upon their cooling. Standard solutions and blanks were used in the analysis to ensure accuracy. The water contained trace levels of lead (II), zinc (II), cadmium (II), copper (II), and chromium (VI).

Analysis of Chromium (VI)

A 100 ml reagent bottle was filled with 50 ml of a thoroughly mixed solution. To it, 5 mL of a mixture of 2% NaOH and 3% Na2CO3 was added, and the mixture was heated on a hotplate at 95 oC for 45 minutes. A 25 mL volumetric flask was used to transfer the cooled and filtered solution. The solution in the volumetric flask was supplemented with 2.0 mL of sulfuric acid (6 N) and thoroughly stirred. To the mixture, we added half a milliliter of biphenyl carbazide solution and then diluted it with distilled water until it reached the desired consistency. We used a spectrophotometer set at 540 nm to examine a small sample of the flask's solution that had been transferred to a cuvette. Calibration curves and analytical precision were ensured by using stock solution (standard solution) and blanks.

Analysis of Phenol

Simple distillation was used to extract the distillate from water samples. To get an orange-colored distillate, the liquid was measured out and transported to a different funnel, where it was extracted with isobutyl acetate. To determine the extract's absorbance, a UV-visible spectrophotometer was used at a wavelength of 510 nm. For calibration and accuracy, the stock solution (standard) and blank were analyzed using the exact same process.

RESULTS AND DISCUSSION

Pb (II), Zn (II), Cu (II), Cd (II), Cr (VI),) and phenol contents in water

A study has been conducted, and the concentration levels of Pb (II), Zn (II), Cu (II), Cd (II), Cr (VI), and total phenol were determined.

Calibration and quality control

From a 100 g/l stock solution of K2Cr207, standard solutions with concentrations ranging from {0.000390625 - 0.00625 g/l} were made and tested with blanks. By graphing the absorbance against the concentration of the standard solution, the outcome is demonstrated.

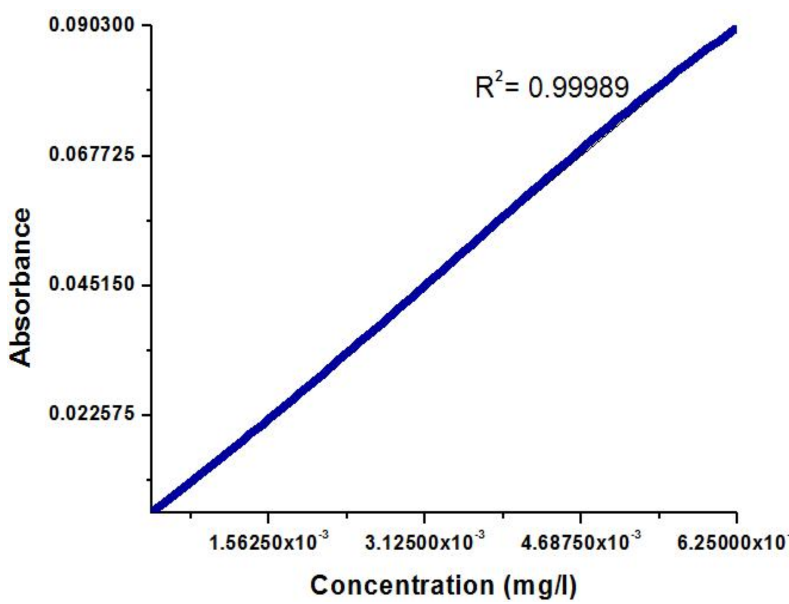

Figure 3. *A calibration graph of $K_2Cr_2O_7$ solution*

For this research, researchers in Gimbi town gathered water samples from five separate locations. Ground and surface water, as well as treated water (both before and after distribution to households), were among the sample types categorized. We calculated the analyses as the mean ± SD of three separate runs.

Table 1

Heavy metal and phenol concentrations in surface, treated, and ground water

S.No	Sample site	Heavy metals						EC(µS / cm)	pH	TO	TDS (g/L)
		Pb (II)	Zn(II)	Cd(II)	Cu(II)	Cr(VI)	Total Phenol				
1	SW	0.35± 0.1	0.38±0.2	0.42±0.1	0.32±0.18	0.35±0.3	0.39±0.1	89	6.7	27.5°C	0.038
2	DSTW	0.34±0.19	0.34±0.2	0.41±0.2	0.54±0.3	0.37±0.25	0.3±0.23	84	7.0	25°C	0.00710
3	STW	0.49±0.19	0.35±0.3	0.31±0.1	0.64±0.4	0.35±0.25	0.62±0.13	83	7.1	25°C	0.00734
4	SSTWS1	0.51±0.19	0.33±0.31	0.421±0.1	0.35±0.4	0.39±0.27	0.31±0.24	83.15	7.3	25°C	0.00725
5	SSTWS2	0.41±0.18	0.31±0.1	0.31±0.1	0.55±0.3	0.36±0.25	0.39± 0.15	88.25	7.3	25°C	0.0232
6	SSTWS3	0.59±0.18	0.34±0.1	0.31±0.1	0.63±0.3	0.31±0.25	0.63±0.3	103.6	7.1	25°C	0.00497
7	RW	0.788±0.238	0.42±0.2	0.32±0.1	0.72±0.21	0.3±0.23	0.4±0.2	89.8	6.9	25°C	0.0776
8	RW+Al	0.68±0.20	0.36±0.16	0.41±0.1	0.84±0.11	0.3±0.2	0.31±0.23	94.4	6.8	25°C	0.00610
9	RW+Cl	0.47±0.11	0.37±0.3	0.41±0.1	0.97±0.11	0.34±0.13	0.41±0.25	96.3	6.8	25°C	0.00506
10	DWIS1	0.49±0.18	0.45±0.1	0.3±0.1	0.83±0.18	0.32±0.29	0.87±0.1	91	6.5	25°C	0.0537
11	DWIS2	0.56±0.23	0.55±0.2	0.42±0.32	0.5±0.13	0.315±0.7	0.42±0.13	95.9	6.7	25°C	0.0254
12	DWABST	0.51±0.1	0.92±0.40	0.52±0.1	0.38±0.27	0.48±0.4	0.74±0.3	96	6.4	25°C	0.0238
13	DWMA1	0.53±0.1	0.41±0.2	0.53±0.1	0.90±0.18	0.5±0.27	0.85±0.3	93	6.46	24°C	0.04453
14	DWMA2	0.42±0.7	0.38±0.1	0.42±0.1	0.60±0.5	0.40±0.1	0.94±0.4	93.5	6.26	23.5°C	0.03347
15	DWM1	0.44 ±0.18	0.45±0.1	0.41±0.3	0.48±0.18	0.52±0.28	0.93±0.5	91	6.5	24°C	0.0102
16	DWM2	0.45±0.32	0.44±0.29	0.52±0.1	0.53±0.16	0.34±0.1	0.99±0.1	92	6.5	24°C	0.0640
17	DWME1	0.42 ±0.36	0.77±0.36	0.62±0.3	0.52±0.19	0.32±0.12	0.87±0.4	88	6.6	23.5°C	0.0489
18	DWME2	0.45±0.32	0.76±0.19	0.42±0.2	0.41±0.21	0.35±0.20	0.92±0.2	86	6.3	24°C	0.00645
19	DWS1	0.71±0.18	0.54±0.6	0.41±0.2	0.72±0.18	0.36±0.23	0.94±0.6	91	6.3	25°C	0.00382
20	DWS2	0.59±0.15	0.31±0.13	0.65±0.3	0.65±0.1	0.32±0.2	0.93±0.3	93	6.7	25°C	0.00381
MPL (µg/l)		10	50	3	2000	50	200				

Where MPL (µg/l) represents Maximum permissible limit in drinking water SW: Surface water DW: Drinking water STW: Stream water

According to the World Health Organization's guidelines, all of the water samples taken from Gimbi town—surface, raw, processed, and stream—contained heavy metal and phenol concentrations that were considered acceptable. The tested samples showed concentrations of heavy metal ions and phenol ranging from 0.34 g/l to 0.78 g/l for lead (II), 0.3 g/l to 0.62 g/l for cadmium (II), 0.3 g/l to 0.52 g/l for chromium (VI), 0.32 g/l to 0.97 g/l for copper (II), 0.31 g/l to 0.92 g/l for zinc (II), and 0.3 g/l to 0.99 g/l for phenol. The water sample's content of Cr (VI), C (g/l), was determined using a standard calibration curve. Table 1 shows that the concentrations of heavy metals and phenols in surface, treated, and groundwater are below acceptable levels. Possible causes include seasonal reductions in agricultural runoff, street runoff in cities, runoff from building sites and residential lawns, and the buildup of contaminants that can be washed into water sources through erosion. Findings demonstrated variations in heavy metal and phenol concentrations across several town geographic locations, according to this study's determinations. The area's water distribution pipe lines, as well as nearby vehicles, garages, and gasoline, are likely to blame for the fluctuating quantities of heavy metals and phenols. Lead stands out among heavy metals due to its toxicity, prevalence, and potential harm at concentrations beyond the permissible range (Tuthill, 2021). There are numerous routes of lead exposure to humans. Lead is a carcinogen that can be ingested through lead paint dust or lead fuel exhaust. Industrial pollution is a major problem, and it is present in trace amounts in many foods, especially fish. Lead pipes, which are present in some houses, pose a threat to the safety of drinking water. According to Acharya, Hathi, Patel, and Parmar (2008), lead can harm the kidneys, central nervous system, and brain at high enough concentrations. The lead concentration in the drinking water samples examined in this investigation fell within the permissible range of lead (II) (0.34 g/l-0.78 g/l), as shown in Table 1.

Chromium is a biologically and environmentally important element that is vital for plant and animal life. With the exception of areas with significant chromium deposits, the naturally occurring concentration of chromium in potable water is often quite low. Hexavalent chromium in particular can be harmful at high concentrations (Farag, & Eweida, (2020)). Published in 2018 by Stuewer, Broekaert, Barnowski, and Jakubowski Chromic acid can induce skin ulcers and dermatitis with both short-term and long-term exposure. Chronic exposure can harm the nervous system, kidneys, liver, and blood vessels (Hills, & Johansen, 2017). Fish that may have been exposed to high levels of chromium can be harmful to consume (Shubhashish, Pandey, & Pandey, 2018). Chromium accumulates in aquatic life. A trace amount of chromium (VI) was found in this investigation. Nickel (II) (0.3 g/l-0.52 g/l) Many different things might contribute to Cr (VI) in the water that consumers drink. Cr (VI) levels in source waters may be high due to natural causes or human interference. Cast iron, cement, and stainless steel are common materials used in water plants and distribution system infrastructure; however, these materials can release chromium into water through corrosion or leaching (Toomuluri, Eckert & Guo, 2018).

Many species rely on zinc, a trace element, for crucial physiological and metabolic functions. Unfortunately, the organism can become poisonous when exposed to larger amounts of zinc (Acharya, Hathi, Patel, & Parmar, 2008). Delidou, Gregoriadou, Dermosonoglou, Tsoumparis, Edipidi, & Katsougiannopoulos (2020) found that this metal, which is essential for protein synthesis, is present in surface water at relatively low amounts because of its limited mobility from rock weathering sites or other natural sources. All of the water samples taken for this investigation had at least a minimal concentration of zinc. Between 0.31 to 0.92 g/l of zinc (II).

Toskovic et al. (2021) found that zinc-coated ("galvanised") pipes and fittings corrode and release cadmium into the water supply. It is known to be hazardous at greater quantities. Industrial processes account for the majority of cadmium's emissions; the metal finds extensive application in many different products, including batteries, pigments, plastics, and electroplating (Nassef, Hannigan, EL Sayed, & Tahawy, 2020). Many incidents of food poisoning have been linked to cadmium, a highly hazardous metal. Even trace amounts of cadmium can alter the structure of the human kidney's arteries in an unhealthy way. It biochemically substitutes zinc and leads to hypertension, renal impairment, and other health problems (Rajappa, Manjappa, & Puttaiah, 2021). The present analysis found that all of the samples tested had cadmium (II) concentrations that were below permissible limits. Range: 0.3–0.62 g/l of cadmium (II)

According to Acharya, Hathi, Patel, & Parmar (2008), chronic anemia can be caused by consuming water that is contaminated with a high quantity of copper. The study found that the concentration level of copper is low (Table 1), which is below permissible limits in all sampling areas. This is likely because there aren't many copper-related industrial and mining activities in these areas. Copper (II), ranging from 0.32 g/l to 0.97 g/l.

By exceeding the permissible threshold in drinking water, organic substances might be regarded as water contaminants. There are benefits to using phenol, but there are also drawbacks owing to its toxicity. When phenol concentrations in water surpass safe limits, it can be said that the water is polluted. Water with phenol in it has a terrible flavor and smell and makes you sick to your stomach, makes your breathing faster, makes you lose weight, damages your liver and kidneys, and gives you migraines. Based on the results of this investigation, the phenol concentration is safe. Range: 0.3–0.99 g/l of phenol

CONCLUSIONS

A database detailing the water quality at several locations in Gimbi town was created through the examination of a drinking water sample. Phosphorus, lead (II), cadmium (II), copper (II), zinc (II), and total dissolved solids (TDS) were among the parameters examined.

The amounts of lead (II), cadmium (II), chromium (IV), copper (II), zinc (II), and phenol in all of the samples are within the allowable ranges suggested by the World Health Organization (2008). The following elements are found in moderate concentrations in the water: lead (II), cadmium (II), chromium (VI), copper (II), zinc (II), phenol (0.3 µg/l - 0.99 µg/l), and zinc (II) (0.32 µg/l - 0.97 µg/l).

Consequences of drinking polluted water over an extended period of time become obvious when heavy metal concentrations exceed the permissible range. Therefore, to avoid an overabundance of these heavy metals in the human food chain, it is recommended that heavy metals in drinking water and food items be monitored regularly. In addition, the study stresses the need of environmental quality in the larger community.

ACKNOWLEDGEMENT

I acknowledge Wollega University, Ethiopia, College of Natural Science, Department of Chemistry, for providing the necessary facilities for conducting this research.

DECLARATION

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

Data sets generated during the current study are available from the corresponding author on reasonable request.

REFERENCES

Acharya, G. D., Hathi, M. V., Patel, A. D., & Parmar, K. C. (2008). Chemical properties of groundwater in bhiloda taluka region, north Gujarat, India. *Journal of Chemistry*, *5*, 792-796.

Ballinger, G. D. (2018). *Methods for chemical analysis of water and wastes*. EPA, Ohio, 78-87. Dissolved Hexavalent Chromium Determination in Drinking Water, Groundwater, and Industrial Wastewater Effluents by Ion Chromatography. Environmental Protection Agency, U.S., *Method, 218*(6), 45-54.

Corporation, D. (2020). *Determination of Cr (VI) in Water, Waste Water, and Solid Waste Extracts,* 345-349.

Delidou, K., Dermosonoglou, D., Gregoriadou, A., Tsoumparis, P., Edipidi, C., & Katsougiannopoulos, B. (2020). Heavy metals in drinking water in Thessaloniki area, Greece. *Proceedings of the 7th International Conference on Environmental Science and technology*, Aristotle University, Ermoupolis.

EL Sayed, K.A., Tahawy, M.S., Nassef, M., & Hannigan, R. (2020). Determination of some heavy metals in the environment of Sadat industrial city. *Proceeding of the 2nd Environ-mental Physics Conference* (pp. 145-152), Cairo University, Egypt.

Farag, A., & Eweida, A. (2020). Heavy metals in drinking water and their environmental impact on human health. *International Conference on Environmental Hazards Mitigation* (pp. 542-556), Cairo University, Egypt.

Guo, Q. (2017). Increases of Lead and Chromium in Drinking Water from Using Cement—Mortar-Lined Pipes: Initial Modeling and Assessment. *Journal of Hazardous Materials, 56*(1-2), 181.

Hassan, H.M., & Mustafa, H.T, (2019). *Pb and Cr concentrations in the potable water of the eastern province of Saudi Arabia:* Bull. *Environ. Contam. Toxicol. 43*,529.

Geneva, B. (2019). *Water quality—determination of cobalt, nickel, copper, zinc, cadmium and lead. International Organization for Standardization,* 8288:1986.

Hills, L.M., & Johansen, V.C. (2017). *Hexavalent Chromium in Cement Manufacturing: Literature Review.* Portland cement Association, Skokie.

Rajappa, B., Manjappa, S., & Puttaiah, E.T. (2021). Monitoring of heavy metal concentration in groundwater of Hakinaka Taluk, India. *Contemporary Engineering Sciences, 3*(4),183-190.

Shubhashish, K., Pandey, R., & Pandey, J. (2018). Heavy metal contamination of Ganga River at Varanasi in relation to atmospheric deposition. *Tropical Ecology, 51*(2), 365-373.

Soylak, M. (2017). Chemical contaminants in drinking water: Erciyes Universities, *Yayin, 104*, 94-98.

Stuewer, D., Broekaert, J. A., Barnowski, C., Jakubowski, N. (2018). Speciation of chromium by direct coupling of ion exchange chromatography with ICP-MS. *At Spectrum, 1155*(12), 1155–1161. Doi: 10.1039/a702120h

Toomuluri, P.J., Eckert, Jr., J.O. & Guo, Q. (2018). Leachability of Regulated Metals from Cement-Mortar Linings. *Journal AWWA, 90*(3), 62-73

Toskovic, D.V., Pantelic, G.K., Ristic, N.M., Jovanic, S., Rajkovic, M.B., Lacnjevac, C.M., Ralevic, N.R., & Stojanovic, M.D. (2021). Identification of metals (heavy and radioactive) in drinking water by indirect analysis method based on scale tests. *Sensors, 8,* 2188-2207.

Tuthill, A.H. (2021). Stainless-Steel Piping. *Journal AWWA, 86*(6), 67-80.

Vennilamani, S., Pattabhi, K., Kadirvelu, M.C., Karthika, M., Radhika, N. (2017). Agricultural by-product as metal adsorbent. *Environmental Technology, 21* (10), 1091-1097.

World Health Organization. (2009). *Calcium and magnesium in drinking-water: public health significance*. World Health Organization.