Indian Journal of Advances in Chemical Science

Article

Determination of the Concentrations of Heavy Metals in Drinking Water by Atomic Absorption Spectrophotometer of Chhindwara District (M.P.) India

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ABSTRACT

This research work is oriented about drinking water quality and concentration of heavy metals such as Co, Ni, Fe, Mn, Cu, Zn, Cr, Cd, Pb, and As, in the drinking water of Chhindwara District of Madhya Pradesh. This study has been conducted to identify the quality of drinking water, in various Tehsil (Block) falling under the Chhindwara region. Drinking water quality depends on its physicochemical and biological parameters. In this research work, a water sample was collected from all blocks of the Chhindwara district. It analyzed the concentration of all heavy metals, such as Co, Ni, Fe, Mn, Cu, Zn, Cr, Cd, Pb, and As, with the help of an atomic absorption spectrophotometer. In this work, approximately all Physicochemical parameters, such as Temperature, Potential pH, Turbidity, Total hardness, Alkalinity, Total Dissolved Solid, Chemical Oxygen Demand, Biochemical Oxygen Demand, and Dissolved Oxygen are measured by the various test methods of the different places samples, using standard procedures and the results are compared with other national and international acceptable level.

Key words: Atomic absorption spectrophotometer, Bureau of Indian Standards, Drinking water quality, Heavy metals, Physicochemical parameters, World Health Organization.

1. INTRODUCTION

Clean and pure drinking water is a need for human health. Pure water is a necessary birthright for humans, such as clean air. There is 3% fresh water on earth and only a small part of this freshwater is 0.01%, which we have [1]. The remaining two-thirds of fresh water available for human use is locked in ice caps and glaciers. Groundwater is an important source of drinking water all over the Earth. Contaminated drinking water is a significant threat to human health [2]. An estimated 80% of the water in the world is contaminated. Diseases are caused by consuming poor quality/unclean water [3]. Water contains some elements, but when polluted, it may become a source of undesirable substances, dangerous to human health, and cause diseases such as various cancers, adverse reproductive outcomes, cardiovascular disease, tooth decay, and neurological. Infants and young populations are more vulnerable to the toxic effects of heavy metals because fetuses, infants, and young children have rapidly developing body systems more sensitive [4]. Childhood exposure to some metals can result in learning difficulties, memory impairment, damage to the nervous system, and behavioral problems such as aggressiveness and hyperactivity [5]. Therefore, there is a need to assess the quality of ground and surface water sources continuously. These assessments are carried out by using a spectrophotometer technique known as atomic absorption spectrophotometer (AAS). The determination of the suitability of groundwater for specific uses, such as irrigation, public water supply, industrial applications, and power generation, is highly dependent on groundwater [6]. Increasing urbanization and industrialization are to be blamed for the rising levels of trace metals, especially heavy metals, in our waterways. Many hazardous chemical elements if released into the environment tend to accumulate in the sediments of soil and water bodies. Therefore, to reduce the accumulations of heavy metals monitoring and assessment of the heavy metal concentration has become a very critical area of study in recent years [8].

Therefore, the study aimed to evaluate the level of accumulation of some heavy metals such as Co, Ni, Fe, Mn, Cu, Zn, Cr, Cd, Pb, and As in drinking water in Chhindwara district using AAS.

1.1. Description of the Sample Area

This research work included 13 Tehsil (*Chhindwara, Parasia, Junnardev, Amarwada, Chourai, Sousar, Pandhurna, Bichhua, Mohkhed, Tamia, Umreth, Chand and Harrai*) falling under Chhindwara region. Chhindwara district is located in the Central part of India and it is situated at the southern border of Madhya Pradesh, Narsinghpur and Hoshangabad districts are situated in the north, Betul in the West, Seoni in the east, and Maharashtra State in the south. The present work aims to find the quality of drinking water in the Chhindwara district.

1.2. Sample Collection

13 samples were collected from all the blocks in the summer season in May 2024. These samples were taken from places where more people use water for drinking. The various parameters have been tested, such as Temperature, Potential Hydrogenii (pH), turbidity, Total

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ISSN NO: 2320-0898 (p); 2320-0928 (e)
DOI: 10.22607/IJACS.2025.1303008

Received: 15th January, 2025;
Revised: 06th August, 2025;
Accepted: 10th August, 2025

hardness, Alkalinity, Total Dissolve Solid (TDS), Heavy Metals (Co, Ni, Fe, Mn, Cu, Zn, Cr, Cd, Pb, and As) chemical oxygen demand (COD), biochemical oxygen demand (BOD), and dissolved oxygen (DO). Various parameters were tested with the help of our laboratory Madhya Pradesh Council of Science and Technology Bhopal, Maulana Azad National Institute of Technology Bhopal, and Public Health Engineering Department Chhindwara (Tables 1-3).

2. MATERIALS AND METHODS

The method of measuring physicochemical parameters is as follows:

2.1. Method to Measure Turbidity

Drinking water turbidity is used to test, water quality. However, other factors, including microbiological contamination and organic matter also affect the turbidity level of water leaving a treatment plant [7].

Switch on the instrument and allow warming up for 15 min. Measure the standard on the turbidity meter covering the range of interest. Calibrate the instrument using (Turbidity-free Distilled Water) followed by 1.0 NTU standard./10 NTU standard or 100 NTU standard. In case of low Turbidity is observed, calibrate the instrument 1 NTU standard or 100 NTU Standard.

1. Turbidity <40 units- Shake the sample to disperse the solids. Wait until air bubbles disappear. Pour the sample into the turbidity meter tube and read turbidity directly from the instrument scale or the calibration curve.
2. If the turbidity values are >40 units, diluted sample with Turbidity free water to bring the values within the range. Take the reading of the diluted sample. Compute the Turbidity of the original sample from the Turbidity of the diluted sample and the dilution factor [50].

2.2. Method to Measure pH

pH (Potential Hydrogenii) measures the concentration of acidity or alkalinity in water [12]. If the free H^+ ions are more than the OH ions, the water will be acidic, if the free OH ions are more than the H^+ ions, the water will be alkaline. pH is usually expressed as the negative logarithm, and is represented as,

$$pH = -\log [H^+].$$

pH scale is ranging from 0 to 14 and pH = 7 at 25°C represents to neutral. pH value is measured electronically on a direct reading pH meter using glass and calomel combined electrode. Standardize the pH meter with a new buffer solution of pH = 4, 7 and 9 and wash the electrode. Take a 100 mL water sample in a clean beaker and dip the electrode in it and record the pH value of the water sample (E.9) [11].

2.3. Method to Measure Odour

Odour is attributed to the presence of some volatile substances in water and is released as a vapor from the sample. It is also produced by organic and some inorganic compounds. A 100 mL sample of water was taken in a 1 L bottle. The stopper was then put in and shaken vigorously for 3 s. The odor was immediately observed at room temperature (E.5) [11].

2.4. Method to Measure Temperature

The temperature of dug-well water changes concerning depth, season, and environment, which in turn influence some parameters, such as free COD, DO, and BOD. The water temperature depends on the season. Normally, the temperature may be made good mercury thermometer and should have a scale marked for 0.1°C thermometer calibrated using the standard thermometer periodically.

2.5. Method to Measure Alkalinity

Water is alkaline due to the presence of strong bases and salts of weak acids. The alkalinity in water is caused due to presence of Carbonates (CO_3), Bicarbonates (HCO_3), and Hydroxides (OH) [13].

Now take 20 mL of sample, add 2–3 drops of phenolphthalein indicator solution and 2–3 drops of methyl orange indicator then titrate with standard sulfuric acid till a pale pink color appears, note the amount of acid used [48].

2.6. Method to Measure Total Dissolved Solid

The solids which are dissolved form go into the solution even after filtration [11], these types of solids can be identified by using a glass fiber filter through which the water sample passes [15]. If the filtered portion of the water sample is placed in a small vessel and then evaporated, the residue is the solids left behind. This quantity is usually called the total dissolved solids [14].

Total solid = Total dissolved solids + Total suspended solid [11].

2.7. Method to Measure Total Hardness

In groundwater, hardness is mainly contributed by bicarbonates, carbonates, sulfates, and chlorides of calcium and magnesium [16,17]. Now take 20 mL of sample, add 2 mL of buffer solution, add 1–2 drops of Erio-chrome black T indicator, and titrate with standard ethylenediaminetetraacetic acid solution while stirring slowly up to disappear of red and purple color and formation of sky blue color, which are final reading [18].

2.8. Method to Measure Dissolved Oxygen

Concentrations of dissolved oxygen in drinking water provide better water quality. DO is determined by titration using the modified Winkler's method as given by [19]. This procedure needs special BOD bottles that seal the inside environment from atmospheric oxygen [20].

Take a 300 mL water sample in a BOD bottle, to which 2 mL of $MnSO_4$ and 2 mL of alkaline iodide azide solution are added immediately after the sample is collected. The tip of the pipette should be below the liquid level while adding the reagent, close the bottle with a stopper, and shake well. When the sample contains dissolved oxygen, the brown precipitate is formed and in the absence of dissolved oxygen white precipitate is formed, wait to settle down the precipitate leaving the clear supernatant. Then brown precipitate is dissolved by adding 2 mL of concentrated H_2SO_4 and the same solution taken 200 mL (clear solution) in a conical flask and is titrated against 0.025 N Na_2S_2O3 using starch as an indicator till the end point is reached from the initial dark blue color to colorless (E. 35) [11].

2.9. Method to Measure Biochemical Oxygen Demand

This is the time required for the tests; nevertheless, these methods are based on the same bacterial population (high variability) and the same required analysis duration as the reference method [21]. Typically the test for BOD is conducted over a 5-day, period, and determined by standard method [22].

2.9.1. Preparation of dilution water

Distilled water is prepared by aerating until it becomes saturated with oxygen. The desired volume of distilled water is placed in a suitable bottle, and 1ml each of phosphate buffer solution, $MgSO_4$ solution, $CaCl_2$ solution, and $FeCl_3$ solution is added per liter of water.

Figure 1: Location of the Study Areas in Chhindwara District.

2.9.2. Dilution of sample

Acidic water samples or alkaline are neutralized to pH 7.0 with 1N NaOH/H_2SO_4.

Make the different dilutions in duplicate and fill with dilution water in a D.O. bottle. Care must be taken that there is no air bubble in the bottle. Determine the initial immediately for one set of samples. The other set is incubated for 5 days at 20°C, after incubation determine the final DO (E 37) [11].

2.10. Method to Measure Heavy Metals

Certain heavy metals are essential as micronutrients their presence in concentrations exceeding minimum requirements can induce toxicity [25]. Due to the bioaccumulation, biomagnifications, and toxicity of heavy metals in the food chain, heavy metal contamination causes serious problems [26]. Heavy metals represent the predominant environmental contaminants and their occurrence in water signifies the existence of natural or anthropogenic origins [27].

The samples are acidified to 1% with nitric acid and stored in 500 mL double-capped polyethylene bottles [28]. Samples in duplicate were used for analysis using AAS. Analysis of heavy metals, such as Co, Ni, Fe, Mn, Cu, Zn, Cr, Cd, Pb, and As can be done to avoid errors; a blank solution (triple distilled water) is run before and after each sample is put into flame. A separate lamp is used for determining each element as given in Table 1. Preparation of a standard solution for each

Table 1: Instrument setting.

S. No.	Element	Hollow Cathode lamp	Slit	Wavelength	Fuel	Oxidant	Type of flame
1	Cu	Cu	4	324.7	Acetylene	Air	Oxidizing
2	Pb	Pb	4	283.3	Acetylene	Air	Oxidizing
3	Cd	Cd	4	228.8	Acetylene	Air	Oxidizing
4	Fe	Fe	3	248.3	Acetylene	Air	Oxidizing
5	Zn	Zn	4	670.8	Acetylene	Air	Oxidizing
6	Cr	Cr	3	358.0	Acetylene	Air	Reducing
7	Mn	Mn	4	279.8	Acetylene	Air	Oxidizing
8	Ni	Ni	3	232.0	Acetylene	Air	Oxidizing
9	Co	Co	3	240.7	Acetylene	Air	Oxidizing
10	As	As	4	193.7	Acetylene	Air	Oxidizing

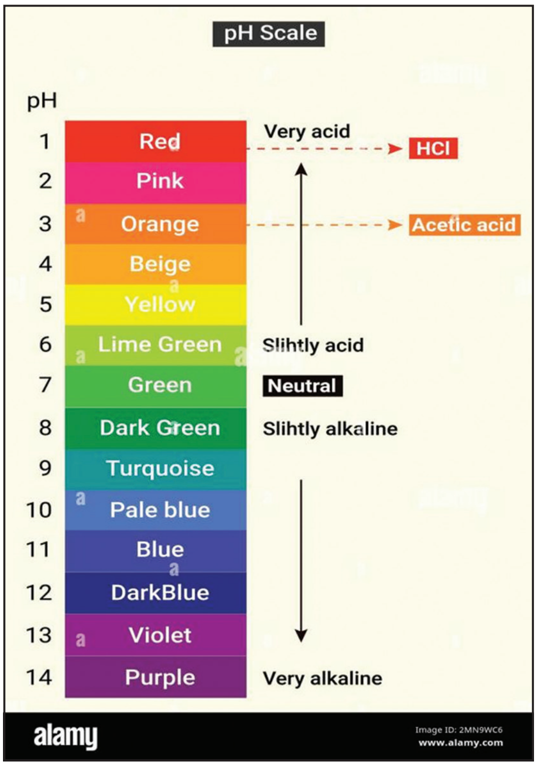

Figure 2: pH Ranges from 0 to 14.

element is required according to the manual [11]. Determinations of the concentration of metal in the sample by comparing it with the calibration curve.

2.11. Method to Measure Chemical Oxygen Demand

Water pollution is a problem that affects by population [23]. The amount of oxygen required to oxidize organic and inorganic substances present in water COD value in water is determined by COD testing and COD determines water quality [24].

Take a 20 mL water sample in 250 mL of COD reflux flat bottom flask to which add 10 mL of 0.25 N $K_2Cr_2O_7$ solutions along with a pinch of Ag_2SO_4 and $HgSO_4$. To it add very slowly and carefully 30 mL concentrated H_2SO_4 and mix the content thoroughly. Connect the flask to the condenser, reflux for 2 h, and then cool to room temperature. The volume is made to 150 mL titration using 2–3 drops of ferroin as an indicator. The solution is titrated against 0.1 N $Fe(NH_4)_2(SO_4)6H_2O$ till the color changes from green to red. Note the endpoint. Perform the same procedure for blank [11].

3. RESULTS AND DISCUSSION

The above studies show after testing the physicochemical parameters including pH, turbidity, total hardness, alkalinity, DO, COD, BOD, TDS, and heavy metals (Co, Ni, Fe, Mn, Cu, Zn, Cr, Cd, Pb, and As) of the drinking water samples are given in Table 2.

3.1. Iron

The shortage of iron causes a disease called "anemia" and prolonged consumption of drinking water with high concentrations of iron may lead to a liver disease called hemosiderosis [41,42]. The lowest iron value among the samples analyzed was 0.693 mg/L from Amarwada blocks. The highest iron value of 3.018 mg/L was recorded in the drinking water sample from the Tamia block and the rest of the block has a value of zero However, according to the Bureau of Indian Standards (BIS), the minimum value of iron in drinking water should be between 0.3 mg/L maximum value of iron should be 1 mg/L.

3.2. Copper

Copper generates oxygen radicals through a Fenton-type reaction [43], and many investigators have hypothesized that excess copper might cause cellular injury through an oxidative pathway, giving rise to enhanced lipid peroxidation, thiol oxidation, and ultimately DNA damage [44-46]. The highest copper value of 0.254 mg/L was recorded in the drinking water sample from the Umreth block. The lowest copper value among the samples analyzed was 0 mg/L from all blocks. However, according to the BIS, the minimum value of copper in drinking water should be between 0.05 mg/L maximum value of copper of should be 1.5 mg/L.

3.3. Cadmium

In humans, Cd exposure can result in a variety of adverse effects, such as renal and hepatic dysfunction, pulmonary edema, and testicular damage [47]. The lowest cadmium value among the samples analyzed was 0 mg/L from all blocks. The highest value of cadmium 0.005 mg/L was recorded in the drinking water sample from the Tamia block. However, according to the World Health Organization (WHO), the minimum value of copper in drinking water should be 0.01 mg/L. Heavy metal ions can cause serious health problems such as liver and kidney damage, skin disorders, cognitive impairment, and even cancer. To prevent the harmful effects of these toxic metals, it is important to find an eco-friendly and cost-effective method to remove heavy metal ions contamination from wastewater [49]. Testing of drinking water

Table 2: Drinking water quality analysis of various blocks of Chhindwara district.

S. No.	Physicochemical parameter	Chhindwara	Mohkhed	Bichhua	Chourai	Parasia	Junnardeo	Amarwada	Harrai	Sousar	Pandhurna	Tamia	Umreth	Chand
1.	Turbidity (NTU)	7	1	1	8	1	5	1	3	7	9	0	1	2
2.	Potential hydrogenii	7.98	7.95	7.65	8.19	7.79	8.10	8.08	8.20	7.71	8.30	7.57	7.71	7.72
3.	Total dissolve solid (mg/L)	185	180	304	238	765	174	184	207	510	253	19.3	448	500
4.	Alkalinity (mg/L)	120	105	275	200	265	115	195	215	200	195	30	260	230
5.	Total Hardness (mg/L)	65	70	85	85	220	85	70	75	140	40	5	110	95
6.	Chemical oxygen demand (mg/L)	0	0	0	0	0	0	0	0	0	0	0	0	0
7.	Dissolve oxygen (mg/L)	12.2	18	17.4	18	12.4	14.6	14.2	21.2	16.9	13.1	18.2	7.5	15
8.	Biochemical oxygen demand (mg/L)	3.8	1.7	3.8	1.8	2.4	4.1	0.5	2.7	1.1	2.8	0.5	2.1	5.7
9.	Iron (mg/L)	0	0	0	0	0	0	0.639	0	0	0	3.018	0	0
10.	Copper (mg/L)	0	0	0	0	0	0	0	0	0	0	0	0.254	0
11.	Cadmium (mg/L)	0	0	0	0	0	0	0	0	0	0	0.005	0	0
12.	Lead (mg/L)	0	0	0	0	0	0	0	0	0	0	0	0	0
13.	Chromium (mg/L)	0	0	0	0	0	0	0	0	0	0	0	0	0
14.	Zink (mg/L)	0	0	0	0	0	0	0	0	0	0	0	0	0

through AAS in all the blocks revealed that the value of heavy metals, such as lead, chromium, zinc, manganese, nickel, cobalt, and arsenic was 0 mg/L.

3.4. pH

The lowest pH value of drinking water in the study area was 7.57 and the highest pH value was 8.30. According to BIS, the pH of drinking water should be between 6.5 and 8.5 whereas the everywhere was slightly alkaline [29].

3.5. Total Dissolved Solids

The palatability of water with a TDS level of <500 mg/L is generally considered to be good. The TDS levels above 1000 mg/L, drinking water becomes largely unpalatable. TDS >1200 mg/L may be objectionable to consumers and could have impacts on those who need to limit their daily salt intake, for example, severely hypertensive, diabetic, and renal dialysis patients [30]. The lowest TDS value among the samples analyzed was 19.3 mg/L from Tamia blocks. The highest TDS value of 765 mg/L was recorded in the drinking water sample from the Parasia block. However, according to the BIS, the lowest value of TDS of drinking water should be between 200 mg/L and the highest value should be between 600 mg/L.

3.6. Turbidity

The dirt in water stimulates the growth of bacteria risks consumer health [31]. Many national organizations, such as the BIS have also set their drinking water standards [Table 3]. The lowest turbidity value among the samples analyzed was 1 NTU from the Bichhua, Mohkhed, Parasia, Amarwada, and Umreth blocks. The highest turbidity value of 9 NTU was recorded in the drinking water sample from the Pandhurna block. However, according to the WHO, the lowest value of turbidity of drinking water should be between 1 NTU and the highest value should be between 5 NTU.

3.7. Alkalinity

Alkalinity is one of the important properties of water, which is a measure of the ability of water to neutralize acids [32]. Alkalinity poses no known health risks to humans. The lowest alkalinity value among the samples analyzed was 30 mg/L from Tamia blocks. The highest alkalinity value of 275 mg/L was recorded in the drinking water sample from Bichhua block. However, according to the BIS, the lowest value of alkalinity of drinking water should be between 200mg/L and the highest value should be between 600 mg/L.

3.8. Hardness

Hard water can reduce the rate of heart disease, there are some negative effects of using hard water, these include wastage of soap, and scaling of pipes and boilers [33,34]. According to WHO maximum value of total hardness should be 500 mg/L. The lowest hardness value among the samples analyzed was 5 mg/L from Tamia blocks. The highest hardness value of 220 mg/L was recorded in the drinking water sample from the Parasia block. However, according to the BIS, the lowest value of hardness of drinking water should be between 300 mg/L and the highest value should be between 600 mg/L.

3.9. Dissolved Oxygen

Dissolved oxygen is said to free oxygen in water, which is involved in various biochemical and physiological activities [35,36]. The amount of oxygen dissolved in water is an important indicator of water quality and an important factor in water purification. The lowest DO value among the samples analyzed was 7.5 mg/L from Umreth blocks. The highest DO value of 18.2 mg/L was recorded in the drinking water

Figure 3: Water quality index district Chhindwara.

sample from the Tamia block. However, according to the BIS, the lowest value of DO in drinking water should be between 6.5 mg/L and the highest value should be between 8 mg/L.

3.10. Biochemical Oxygen Demand

BOD represents an approximate assessment of biodegradable organic matter content existing in an aquatic ecosystem [37]. The lowest BOD value among the samples analyzed was 0.5 mg/L from the Tamia and

Table 3: Maximum and minimum permissible limit of some physicochemical parameters and heavy metals in water BIS 2012[9] and WHO 2008 [10].

S. No.	Parameter	Unit	Minimum permissible limit	Maximum permissible limit	References
1.	Potential hydrogenii	-	6.5	8.5	[9]
2.	Electrical conductivity	$\mu S\ cm^{-1}$	200	1000	
3.	Turbidity	NTU	1	5	[10]
4.	Color	TCU	5	15	[10]
5.	Total dissolve solid	mg/L	200	600	[9]
6.	Dissolve oxygen	mg/L	3.5	5.0	[9]
7.	Hardness	mg/L	300	600	[10]
8.	Biochemical oxygen demand	mg/L	-	2	[9]
9.	Chemical oxygen demand	mg/L	-	-	[9]
10.	Chloride	mg/L	250	1000	[9]
11.	Alkalinity	mg/L	200	600	[9]
12.	Iron	mg/L	0.3	1	[9]
13.	Nickel	mg/L	0.07	No Relaxation	[10]
14.	Zink	mg/L	5	15	[9]
15.	Copper	mg/L	0.05	1.5	[9]
16.	Cadmium	mg/L	0.01	No Relaxation	[10]
17.	Lead	mg/L	0.05	No Relaxation	[9]
18.	Chromium	mg/L	0.05	No Relaxation	[9]
19.	Arsenic	mg/L	0.01	No Relaxation	[10]

WHO: World Health Organization, BIS: Bureau of Indian Standards

Amarwada blocks. The highest BOD value of 3.8 mg/L was recorded in the drinking water sample from Chhindwara and Bichhua block. However, according to the BIS, the lowest value of the BOD of drinking water should be between 1 mg/L and the highest value should be between 2 mg/L.

3.11. Chemical Oxygen Demand

The most relevant pollution effect of wastewater is organic matter. The pollution level of organic matter in water bodies is roughly estimated by analyzing the COD [38]. COD is a superior representative of organic matter than BOD because BOD does not provide any information regarding the oxidation state of an organic substance [39]. By contrast, COD can overcome the drawbacks obtained by BOD. Thus, COD is considered an important water quality parameter for representing the degrees of organic pollution [40]. The value of Chemical Oxygen Demand is zero in all blocks which is correct according to BIS and WHO.

4. CONCLUSION

The goal of this research work was to identify the quality of drinking water of all the tehsils falling under the Chhindwara region of Madhya Pradesh. The standard procedure for physicochemical parameters analyzed samples taken from all the blocks.

Now at this time, Science is able to detect contaminated and healthy water. In the study of TDS, pH, Alkalinity, Total hardness, COD, DO, and BOD it was found that the values of all blocks are inside the BIS and WHO limits. This study's water status results reflect the actual water quality status. The turbidity value of Chhindwara, Chourai, Sousar, and Pandhurna is outside according to BIS. According to BIS, the value of iron was found to be high in the samples of Tamia blocks. Furthermore, the value of cadmium is inside as per BIS in all the blocks. According to BIS, the value of copper was found to be high in the samples of the Umreth block but according to BIS, it is inside. Heavy metals, such as lead, chromium, zinc, manganese, nickel, cobalt, and arsenic have zero values in all blocks. Luckily humans can control these serious diseases by removing excess amounts of heavy metals in drinking water. Equal importance should be given to the quantity and quality of water. Awareness related to 'water conservation' and 'safe drinking water' is extremely important [50].

5. ACKNOWLEDGMENT

I am thankful to the Department of Chemistry, Government College Bichhua, Chhindwara for providing the necessary laboratory facilities. I am thankful to the Madhya Pradesh Council of Science and Technology (MPCST) Bhopal for the necessary funding for the research project. I am also thankful to the laboratory staff of MPCST and the Chemical Engineering Department, Maulana Azad National Institute of Technology (MANIT) Bhopal, for AAS analysis. Again thankful to the Public Health Engineering (PHE) Department, Chhindwara, for analysing water samples during the study.

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Bibliographical Sketch

I am thankful to the Departmentof Chemistry, Government College Bichhua, Chhindwara for providing the necessary laboratory facilities. I am thankful to the Madhya Pradesh Council of Science and Technology (MPCST) Bhopal for the necessary funding for the research project. I am also thankful to laboratory staff of MPCST and Chemical Engineering Department, Maulana Azad National Institute of Technology (MANIT) Bhopal, for AAS analysis. After that, thankful to Public Health Engineering (PHE) Department Chhindwarafor analyzing water samples during the study.