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Analysis the Amounts of Heavy Metals and Trace Elements in Water of Different Sources of Ranchi city by using ICP-OES Technique

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Abstract – *The study was aimed to analyze the concentration of metals including heavy metals and trace elements in the water of four different small water bodies or sources including two pond, one lake and one river around the Ranchi city. The metals or trace elements such as Ag, Al, B, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn were analyzed by using Inductively Coupled Plasma- Optical Emission Spectroscopy technique. The results indicated that the concentration of approximately all the metals, heavy metals and trace elements in these waterbodies were found within the maximum permissible limit set by IS:2296, EPA and WHO for surface water quality standard. Higher concentrations of Al in Lake of Chamber, Bi and Mn in Jumar river than other sites, were reported.*

Key Words: **Heavy Metal Analysis, Trace Elements, ICP-OES Technique, Water Analysis, Emission Spectroscopy, Ranchi City.**

1. INTRODUCTION

India is a country with a diverse landscape and rivers. There are 14 major rivers and other freshwater bodies, both large and small. Water, the universal solvent, has the property of dissolving most compounds due to its high dielectric constant, but an excess of these chemicals causes water pollution, including heavy metal and trace element contamination. The discharge of effluents from industries, home activities, and soil contamination from adjacent dumping sites and agricultural drainage, damage the water bodies based on water quality prospective[1].

Jharkhand, one of the states in eastern part of India, is known to have minerals rich state globally. Jharkhand is a wonderful land with enormous potential and a plethora of other natural resources. The state covers a geographical area of 79,714 km^2, has 29.61 percent forest land, and holds roughly 40% of India's total mineral resources, as per data provided by Department of Mines and Geology, Government of Jharkhand [2].

Due to being one of the minerals rich State of Indian Republic, there are various metals including heavy metal and trace element contaminations in water including ground and surface water, soil and air as well. The presence of these types of heavy and trace metals/elements in water bodies causes serious impact on human health as they enter in human body directly through drinking or indirectly through the consumption of aquatic products (viz. fishes, etc.) obtained from these water bodies and agricultural products, irrigated with water from these sources. As per explained by [3] (G. S. David and I. A. Isangedighi, 2019), heavy metals transferred into the marine environment may be absorbed into the marine food chain and eventually reach human consumers via aquatic transport, causing a number of major health risks.

Heavy metals are described as "any metallic element with a relatively high density (mass/volume) that is poisonous even at extremely low concentrations; or a class of metals and metalloids having an atomic density greater than 4g/cm^3 or 5 times that of water"[4]. The body cannot detoxify certain metals because they are stable. In the acidic medium of the stomach, these metals are turned to their stable oxidation states such as Cd^{2+}, Mg^{2+} Zn^{2+}, Pb^{2+}, Ni^{2+}, Cr^{3+}, Cr^{6+}, etc and unite with the sulfhydryl groups of biomolecule of human body such as proteins, lipids, DNA and enzymes to establish strong and stable chemical bonds[5]. Protein denaturation (Hg, Pb and Cd), Inhibition of cell division (Hg, Pb, Cd and Ni), Cell membrane disruption (Hg, Pb, Zn, Ni, Cu and Cd), Inhibition of enzyme activity (Hg, Pb, Zn, Ni, Cu and Cd) and transcription inhibition, are the main toxicity mechanism affecting the microorganisms. Heavy metals enter the environment through both natural and human-caused sources. Earth's crust natural weathering, sewage effluents, soil erosion, urban runoff, industrial discharge, pest or disease control agents applied to plants, and air pollution fallout are examples of such sources. Heavy metal contamination of the aquatic environment has become a global issue in recent years, owing to their indestructibility and the fact that most of them have hazardous effects on species[6].

As per being one of the main objectives of this instrumental analysis, there are some heavy metals and trace elements whose concentration in water bodies, were analyzed by using Inductively Coupled Plasma- Optical Emission Spectrometry (ICP-OES) technique. These metal and elements are- Silver (Ag), Aluminum (Al), Boron (B), Chromium (Cr), Copper (Cu), Iron (Fe), Potassium(K), Magnesium (Mg), Manganese (Mn), Calcium (Ca), Cadmium

(Cd), Cobalt (Co), Sodium (Na), Nickel (Ni), Lead (Pb), Bismuth (Bi) and Zinc (Zn).

1.1 Study Area

The present research work involves the assessment of the concentrations of heavy metals and trace elements in the water of four different water resources of Ranchi city (The capital city of Jharkhand, India). There are total 17 metals including heavy metals and trace elements as well, which were analyzed by using Inductively Coupled Plasma- Optical Emission Spectrometry (ICP-OES) technique. These four water bodies/sources are - i) Lake of Chamber HEC Ranchi, ii) RMCH Pond, iii) Jumar River and iv) Karamtoli Pond (Summarized in table- 1). Geographically, Ranchi is situated on the southern end of the Chhota Nagpur Plateau, which comprises the easternmost section of the Deccan plateau system. The 'City of Water Falls' refers to the area surrounding Ranchi city that has been donated with natural attractions. The average elevation at the Ranchi city is 645 m above Mean Sea Level (MSL). Ranchi lies at 23°22'N and 85°20'E near to the Tropic of Cancer[7].

1.2 Monitoring Sites

The contaminations of heavy metals and trace elements in (surface) water of four different small waterbodies (2 ponds, 1 lake and 1 river) around Ranchi city, were analyzed. These sampling sites and their coordinate values with clickable hyperlink, are summarized in Table- 1 given below.

Table- 1: Sampling Sites, Sites' Code and their Coordinate values

Site Code	Sampling location	Coordinate Values
I	Lake of Chamber, HEC Ranchi	23°18'04.4"N 85°15'59.9"E
II	RMCH Pond, RIMS Ranchi	23°23'17.1"N 85°20'54.4"E
III	Jumar River, Ranchi	23°24'25.4"N 85°24'36.7"E
IV	Karamtoli Pond, Ranchi	23°23'14.5"N 85°19'48.2"E

2. METHODOLOGY: MATERIALS AND METHODS

2.1 Sampling Procedures

The purpose of sampling procedures was to collect a small amount of material (water) that could be easily transported to the analytical research laboratory while still representing the sample being handled. In clean plastic bottles, an equal amount of water samples was collected. The bottles were cleaned, rinsed with tap water then with distilled water before the samples were being collected. The samples were collected by keeping in mind the standard sample collection protocol, procedure and guidelines given in Indian Standard methods IS: 3025 (Part- I) and American Public Health Association (APHA) 22nd edition. Special precautions were taken at the time of collection of samples[6]. The samples were collected in plastic bottles, from four different small waterbodies (ponds) located around Ranchi city (as summarized in Table- 1) and each sample bottles were clearly marked with water proof black ink and other relevant details were recorded. This sampling procedures were carried out during the end of the monsoon in Jharkhand (viz. after Mid of September 2021). The collected water samples were filtered, by using a vacuum type filtration apparatus as soon as they arrived at the laboratory. The water samples were filtered using a 0.45 µm membrane filter[8].

2.2 Elemental Analysis by ICP-OES

A variety of inorganic instrumental techniques such as atomic absorption spectroscopy (AAS), inductively couled plasma- optical emission spectroscopy (ICP-OES) and ICP mass spectrometry (ICP-MS), can be used measure and analyze the contaminations of metals, heavy metals and trace elements in water either it is drinking water, surface water or waste water. Based on the number of metallic or non- metallic elements that need to be analyzed or determined and the number of material samples that need to be run, the most suitable and preferable technique for business requirements can be chosen. ICP-OES is a good match with the productivity requirements of many laboratories and requires only a moderate investment[9]. The ICP-OES technique was used to analyze the concentrations of metals, heavy metals and trace elements in these (Table -1) water bodies/sources during the course of this study.

2.2.1 Inductively Coupled Plasma- Optical Emission Spectrometry (ICP-OES)

ICP-OES is an analytical instrumental technique that is used for determination of heavy and trace metals. This is a multi-element instrumental technique which uses a plasma source to excite the atoms in samples. These excited atoms from ground states to excited states, emit light of a characteristic wavelength, and a detector measures the intensity of the emitted light on returning back to the ground state, which is

then related with the concentrations of the analyte. Samples are heated through 10000 K to atomize effectively which is an important advantage for ICP technique. Another advantage is multi-elemental analysis. With ICP technique, approximately 60 metallic or non-metallic elements can be analyzed in single sample run within a minute simultaneously, or in a few minutes sequentially. High operating temperature lowers the interferences.[10].

Inductively Coupled Plasma (ICP) is an argon gas plasma maintained by the interaction of an RF field and ionized argon gas. The plasma starts allowing complete atomization of the elements in water sample and minimizing potential chemical interferences when the temperature reached as high as 10,000 K. ICP-OES is the measurement of emission intensity on selected wavelength for individual analyte, of the light emitted by the elements in a sample introduced into an ICP source. The measured emission intensities are then compared to the intensities of standards of known concentration to obtain the elemental concentrations in the unknown sample [11] with the help of calibration curve. The light emitted from an ICP can be viewed in two ways viz, radial view which results in the higher upper linear ranges, and axial view which results continuum background from the ICP itself reduces and sample path is maximized. The detection limits obtained by axial viewing are better than those obtained by radial viewing. The block diagram for ICP-OES relevant procedure steps is depicted in Figure-2.

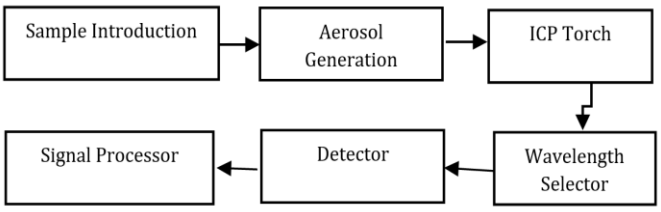

Figure- 2: Block Diagram of ICP-OES

The final concentration of contaminants in water bodies carried out by calibration curves (Intensity vs Concentration) of individual analyte separately.

2.2.2 Instrumentation

An ICP-OES instrument of Model Optima ™ 2100 DV ICP-OES (Perkin Elmer, USA) with (specifications in Table-2), was used to determine the concentrations of these heavy metals and trace elements in the water samples of corresponding water bodies (Table-1). The working mechanism diagram or instrumental set up of ICP-OES and optimum instrumental conditions are given in Figure- 3 and Table – 3 respectively.

Table- 2: Optima 2100 DV ICP- OES Instrument Specifications

Parameters	Instrument Specifications
Detectors	UV Sensitive dual backside illuminated CCD array detector
Spectral Range	160 nm – 900 nm
Spectral Resolution	0.009 nm at 200 nm
Speed	20-25 elements in less than 5 minutes

Table- 3: Optimum Instrumental Conditions

Parameters	Operating Conditions
View	Axial View
Optical System	Echelle
Power	1450 w
Plasma Gas Flow	15 L/min
Auxiliary Gas Flow	0.2 L/min
Sample Flow Rate	1.5 mL/min
Nebulizer Nebulizing Chamber	Cyclonic
Nebulizer	Concentric Glass (Meinhard) Type A
Integration Time	1.0 second

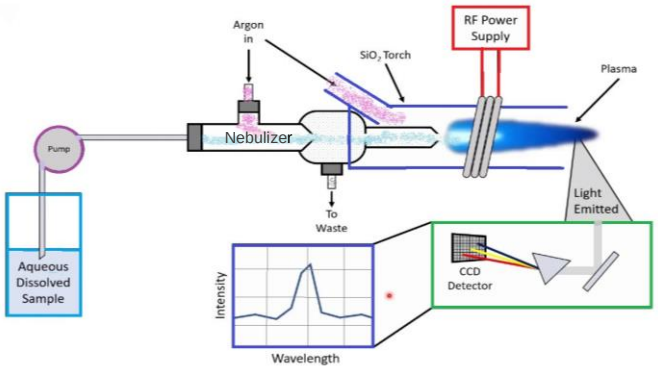

Figure- 3: ICP-OES Instrumental Mechanism Set up

2.3 Sample Analysis

Water samples were often immediately injected into plasma without any further more dilution. To keep their elemental and metallic components in solution, they were usually acidified with nitric acid (HNO_3). A concentric nebulizer and a cyclonic spray chamber are typical sample introduction systems for this kind of sample type. With regards to particles in solution, a nebulizer can typically handle particle sizes up to one third of the capillary diameter without becoming blocked[7][13]. All the water samples were analyzed for Ag, Al, B, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn, by following proper steps, procedures with various components and procedures either it was sample introduction, aerosol generation, ICP torch, wavelength selection, detection, signal processing or determination of metallic concentrations by calibration graph etc, were followed as per guidelines prescribed by [4][11][14][15][16][17] and[18].

3. RESULTS AND DISCUSSIONS

The metallic and elemental concentrations of above mentioned four water sources of Ranchi city (Table-1), were analyzed based on appropriate instrumental methods and by using required materials, as mention in previous 'Materials and Method' section. These experimental results with their selected wavelength for ICP-OES, are depicted in Table- 4.

Table-4: Instrumental Results of metal concentrations

Metals	Analyte Wavelength	Concentration Mean (mg/L)			
		Site- I	*Site- II*	*Site- III*	*Site-IV*
Ag	328.068	0.050	0.017	0.068	0.050
Al	396.153	1.224	0.113	0.541	0.308
B	249.677	0.329	0.343	0.362	0.362
Bi	223.061	0.432	0.765	1.130	0.549
Ca	422.676	23.86	61.19	57.78	49.70
Cd	228.802	0.026	0.007	0.010	0.009
Co	228.616	0.007	0.040	0.018	0.007
Cr	267.716	0.029	0.238	0.150	0.157
Cu	324.752	0.006	0.085	0.022	0.003
Fe	259.939	0.653	0.120	1.250	0.470
K	766.490	2.208	15.38	6.397	6.272
Mg	279.077	6.298	17.91	11.97	9.454
Mn	257.610	0.024	0.017	1.311	0.001
Na	589.592	2.412	48.71	24.87	22.72
Ni	231.604	0.034	0.075	0.028	0.029
Pb	220.353	0.132	0.465	0.125	0.023
Zn	213.857	0.121	0.224	0.327	0.231

(Sites' code as mentioned in table- 1)

All the metals and elements are further classified in two groups (Group- 1 and Group- 2) based on their concentration level viz, High and Low Concentration. The metals having high concentration of Group- 1, depicted in Chart- 1 and the metals/elements having low concentration of Group- 2, depicted in Chart- 2.

The concentration of group- 1 metals (Na, K, Mg and Ca) were found to be within the permissible range, as per suggested by Surface Water Quality Standard (IS; 2296)[19], Environmental Protection Agency(EPA), USA and World Health Organization (WHO) for outdoor bathing, for fish culture and wild life propagation, for irrigation, industrial cooling and controlled waste disposal except for drinking purpose (Chart- 1).

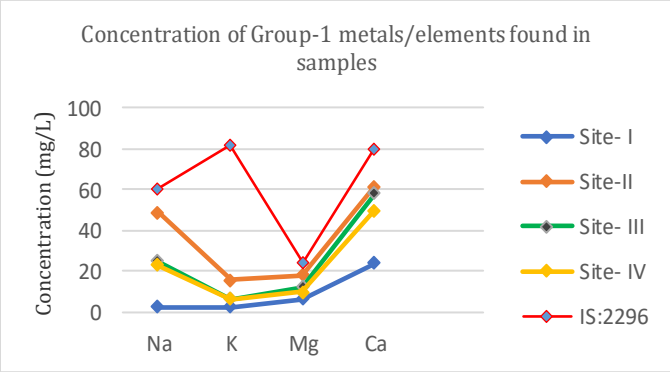

Chart- 1: Conc. of Group-1 metals

The concentrations of heavy metals and trace elements of Group- 2, such as Ag, Al, B, Bi, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn, in these four water sources were also found to be withing the permissible range, as per suggested by IS 2296, EPA, and WHO for various activities including fish culture and wildlife propagation not for drinking purpose[20][21]. The concentration of Al in Lake of Chamber, HEC Ranchi (Site- I), were found to be greater than other sites. It might be due to closeness of this lake to Heavy Engineering Corporation (HEC) Ltd, Ranchi (Chart- 2). The concentration of Bi and Mn, in the water of Jumar river (Site- III) was reported higher than other sites. At the end after analyzing the contaminations of heavy metals, trace elements in these water sources, were found to be in range of maximum permissible range of surface water quality standard.

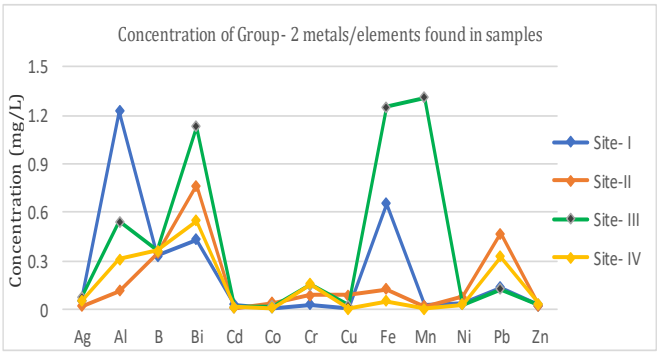

Chart-2: Conc. of group- 2 metals and elements

3. CONCLUSION

The present study based on the analysis of metals, heavy metals and trace elements in the water four different water sources (two pond, one lake and one river) located around the Ranchi city (Jharkhand), were carried out in the mid-month of September 2021. As the results, the approximately all the metals and elements were found within the range maximum permissible limit set by Indian Standard (IS: 2296), EPA and WHO for various purpose of use, except for drinking.

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