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Assessment of drinking water quality in mining affected Hospet and Sandur Talukas of Ballari district

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Abstract
An assessment of water quality, heavy metals and coliform content in drinking water samples from mining and non-mining areas of Hospet and Sandur talukas of Ballari district was carried out. The physico-chemical variables such as pH (7.2), total dissolved solids (179mg/l), total hardness (61 mg/l), calcium (19.5 mg/l), magnesium (5.1mg/l), sulphate (19mg/l) and nitrate (0.2mg/l) contents in mining area were slightly higher compared to water samples of non-mining area, but both were in the acceptable level of Bureau of Indian standards (BIS) and Indian Council of Medical Research (ICMR).The chloride and fluoride contents were present in both water samples of mining and non-mining areas did not differ (24mg/l and 0.2mg/l) and were within the desirable limits of Bureau of Indian standards (BIS) and Indian Council of Medical Research (ICMR) (30mg/l and 1.0 mg/l respectively).The heavy metals such as cadmium, arsenic, lead, mercury, zinc and copper were not detected in both the water samples. Though the traces of iron was detected in water samples of mining area (0.16 mg/l) but were within in the desirable limits. Total coliforms content of water from mining and non-mining area were within the desirable limits of BIS and ICMR (1MPN/100ml).

Keywords: Water quality, physico chemical variables, heavy metals, total coliform content

Introduction
Mining process has adverse impact on surrounding environment. It can result in unnaturally high concentration of chemicals such as arsenic, sulfuric acid and mercury over a significant area of surface or groundwater (Anon. 2012) [1]. There is potential for massive contamination of the area surrounding mines due to the various chemicals used in the mining process as well as the potentially damaging compound and the metal removed from the ore. Large amount of water produced from mine drainage, mine cooling, aqueous extraction and other mining processes increases the potential for these chemicals to contaminate ground and surface water (Hudson, 2012) [3].

Water pollution in mining areas can occur in two basic ways-physically and chemically. Physical impact mainly results from silting in the surface water bodies. Deterioration in drinking water quality is a serious human health issue. Mining activities are known to release both major and trace elements into the environment. Trace elements which are mainly the heavy metals are classified among the most dangerous groups of pollutants due to their toxicity and persistence in the environment. Metals in the contaminated soils and water may reach human body through agricultural products. Leaching of heavy metals from the mine spoils is possible during the rainy season thereby contaminates the groundwater (Singh *et al*., 2012) [7].

The quality and quantity of groundwater may get affected through various factors like surface hydrology, soil texture and terrestrial vegetation. Though the quantity of water may be intercepted and pumped out or lost by evaporation thereby lowering the water table (Hudson, 2012) [3]. Ground water quality is affected when waste water infiltrate through surface water into groundwater and hydraulic connection between groundwater and surface water also contaminating the groundwater.

A research done by National Environment Engineering Research Institute in 2002 revealed that during monsoon period in the Ballari Hospet region, the fine material from dump site get carried away along the hill slopes through surface run-off and enters in to the nearby water bodies which leads to poor water quality due to presence of iron and manganese in groundwater resources around mining areas. Considering all these environmental impacts, a study was planned with the objective to assess the drinking water quality of the mining affected talukas (Sandur and Hospet) of Ballari district (Kottureshwara *et al.* 2009) [10].

Material and Methods

Collection of water

Water samples were collected both from mining and non-mining sites of Sandur and Hospet talukas for analysis of water quality. The sampling sites were selected randomly by considering the population. Polythene bottles of three liters capacity with stopper were used for collection of samples. After collection of water, bottles were closed with stopper and carried to the laboratory with cold chain transport.

Parameters of drinking water quality

i) pH

The pH of water samples was determined using potentiometric method as described by Tandon (2017) [11].

ii) Total dissolved solids

Total dissolved solids were determined by the residue left after evaporation of the filtered samples (Sparks, 1973).

iii) Total hardness as $CaCO_3$

Temporary hardness is due to the presence of bicarbonate of Ca^{2+} and Mg^{2+}, while permanent hardness is due to sulphates, chlorides of Mg^{+2} and Ca^{2+}. Besides these, Sr^{2+}, Fe^{2+} Mn^{2+}, HCO_3^- SO_4, Cl^- and SiO_3 are also responsible for the hardness of water. Carbonates and bicarbonate ions in the extract were determined by titrating it against standard sulphuric acid (H_2SO_4) using phenolphthalein and methyl orange as indicators respectively (Tandon, 2017) [11]. Addition of phenolphthalein gives pink colour in presence of carbonates and titration with sulphuric acid convert these CO_3^{2-} into HCO_3^- and decolorizes the red colour.

iv) Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

Versenate method was used for determining calcium. A known volume of water was taken and titrated with standard 0.01N EDTA solution at pH 12 by using 4N NaOH. Ammonium purpurate was used an indicator. At the end point of reaction, colour changes from orange red to purple as outlined by Tandon (2017) [11].

v) Chloride (Cl^-)

Mohr's titration method is most commonly used for chloride estimation (Tandon, 2017) [11]. It depends upon the formation of a sparingly-soluble brick-red silver chromate ($AgCrO_4$) precipitate at the end point when the sample is titrated against standard silver nitrate ($AgNO_3$) solution in presence of potassium chromate (K_2CrO_4) as indicator.

vi) Sulphate (SO_4^{2-})

Sulphates were determined colorimetrically by measuring the turbidity produced by barium chloride ($BaCl_2$). The turbidity created by precipitation as barium sulphate suspension was measured at 490 nm wavelength on spectrophotometer as outlined by Tandon (2017) [11].

vii) Nitrate nitrogen (NO_3-N)

Nitrate nitrogen was determined by taking a known volume of water sample and treating with NaOH along with Devarda's alloy and mixtures distilled. Ammonia is quantitatively expelled and absorbed in excess standard boric acid which was titrated directly with standard 0.01 H_2SO_4 as outlined by Tandon (2017) [11].

viii) Fluoride

Fluoride was determined as fluoride ions in water based on titration with aluminium chloride solution to a fixed potential (Tandon, 2017) [11].

ix) Heavy metals (Cadmium, Iron, Arsenic, Lead, Copper and Zinc)

Determination of heavy metal concentration was done with Inductively Coupled Plasma Mass Spectrometer based on ionization of analytes in a sample, separation and detection of the ions for determination of metal concentration (Northington, 1987) [5]. The technique involved two steps. In the first, the spectrometer was calibrated by introducing in the inductively coupled plasma mass spectrometer and the mass analyzer a multi-element standard solution to obtain a spectrum used for generating a calibration curve. In the second, water sample stored in centrifuge vial was diluted by adding 5 ml of deionized water to 5 ml of sample and the solution was acidified with 1% w/v nitric acid to bring more concentrated analytes into the specified range. To improve the accuracy and sensitivity of the ICP-MS data, Rh, Re and Ge as internal standards were added to the sample solution before it was introduced in the ICP-MS and the nature and concentrations of elements were then determined according to standard procedures described by Skoog *et al.* (2007) [9]. According to this procedure, the spectrum generated and displayed on a Multi-Channel Analyser (MCA) is compared to the calibration curve to identify the elements and determine their concentrations after using the internal standards for quality control. The concentration values for the quantified elements in water taken from the study area were expressed in μg/l.

x) Total coliforms

The coliform group includes all the aerobic and facultative anaerobic gram negative, non-spore forming rod shaped bacteria which ferment lactose with gas formation within 48 hr at 37 °C. Water samples were tested for the presence of coliforms. The three principle tests *viz.*, presumptive, confirmed and completed tests were conducted.

i) Presumptive coliform test

Multiple tube fermentation method: It is called as presumptive coliform count-multiple tube test. An estimate of the number of coliform organisms is usually made by adding varying quantities of water (0.1-50 ml) to double strength MacConkey's broth and single strength MacConkey's broth containing bromocresol blue sterilized in bottle or tubes containing Durham's tube (for indication of gas production).

ii) Confirmed test

This was done by transferring a loopful of culture from a positive tube from the presumptive test into a tube of brilliant green lactose bile broth (oxoid) with Durham tubes. The tubes were incubated at 37 ˚C for 24-48 hr for total coliforms and 44.5 °C for 24-48 hr for fecal coliform and observed for gas production.

iii) Completed test

Completed test was carried out in accordance with (Anon. 2009) by streaking a loopful of broth from a positive tube into eosin methylene blue (EMB) agar plate for pure colonies. The plates were incubated at 37 °C for 24-48 h. Colonies developed on EMB agar or MacConkey's agar was further identified as coliforms and fecal coliforms (*E. coli)* using culture characteristic, morphology and biochemical test. For fecal coliforms, colonies with green metallic sheen were Gram-stained and the IMVIC test was carried out to identify the colony as *E. coli*. The most probable number (MPN) per 100 ml water was determined using the completed test.

iv) Determination of coliform count

Number of positive test tubes with acid (yellow coloration) and gas production were matched with the McCrady's Statistical table and MPN of coliform present in 100 ml of sample was calculated.

Results and Discussion

The physico chemical constituents in the water samples of mining and non-mining areas of Ballari district are presented in the Tale.1. The pH of water samples of mining area was 7.3 (7.2-7.4) and non-mining area 7.2 (7.10-7.3) and both were in desirable limits of 8.5 prescribed by Bureau of Indian standards (BIS) and Indian Council of Medical Research (ICMR). The total dissolved solids (TDS) signifies the level of inorganic pollutants and small amounts of organic matter. The TDS of water samples of mining area was slightly higher (179 mg/l) compare to water samples of non-mining area (144 mg/l). But both were within the desirable limits set by the BIS and ICMR (500 mg/l). The hardness of water is attributed to the presence of carbonate, bicarbonate, sulphates, chlorides of calcium and magnesium. Total hardness as $CaCo_3$ (61 mg/l), calcium (19.5 mg/l) magnesium (5.1mg/l), sulphate (19mg/l) and nitrate (0.11mg/l) of water samples of mining area were slightly higher compared to water samples of non-mining areas. But all were not exceeding the acceptable limits given by the BIS and ICMR. The chloride and fluoride contents present in both water samples of mining and non-mining areas were almost similar level (24mg/l and 0.2mg/l) and were within the desirable limits of BIS and ICMR (30mg/l and 1.0 mg/l respectively). Similar result mentioned in studies Ekwule *et al*. (2019) [2] where water quality test of water samples of coal mining in Odagbo, Ankpa L.G.A., Kogi State, Nigeria in dry and wet seasons revealed that the values of EC, TDS, chloride and sulphate for the three water sources (pond, borehole and river) were within World Health Organization (WHO) and standard organization of Nigeria (SON) safe limits for both the dry and wet seasons. Patil (2018) [6] also revealed that water analysis of among three different places near the Tunga-Bhadra dam. (Station-1-Tungabhadra River Back water-up stream, Near Tollagate, Hospet, Station-2-Tungabhadra River Back water-downstream, primary water canal, Near Bridge, Station-3-Tungabhadra River Back water near Gunda Forest, Hospet) Station-1 physico chemical characteristics of water was within the limits as specified by World Health Organization.

During mining process erosion of waste material, toxic chemicals and contaminated waste water generated are leached out in to the surface and ground water sources thus altering the chemical properties of water which further leads to decrease in the quality and make unfit for drinking. Apart from this, heavy metals and intake of toxic chemical from the water leads to various chronic diseases such as cancer in the surrounding communities. Heavy metal content in the water samples of mining and non-mining areas of Ballari district are shown in Table. 2. The heavy metals such as cadmium, arsenic, lead, mercury, zinc and copper were not detected in water samples of both mining and non-mining areas. But traces of iron was detected in the water samples of mining area (0.16mg/l) which was within the desirable level of Bureau of Indian standards and Indian Council of Medical Research (0.3 to 1.0 mg/l). However, long term usage of these water may cause health problems such as skin diseases and cancer to people residing in these areas. Similar results also noted in the studies of Ekwule *et al*. (2019) [2] where water quality test of water samples of coal mining in Odagbo, Ankpa L.G.A., Kogi State, Nigeria in dry and revealed that the levels of the heavy metals were relatively low in all the water samples during the dry season with copper, chromium, manganese, cobalt, iron, lead and nickel not being detected. Simillarly in the studies of Patil (2018) [6] revealed that heavy metal analysis in water samples of among three different places near the Tunga-Bhadra dam. (Station-1-Tungabhadra River Back water-up stream, Near Tollagate, Hospet, Station-2-Tungabhadra River Back water-downstream, primary water canal, Near Bridge, Station-3-Tungabhadra River Back water near Gunda Forest, Hospet) iron concentration at station-2 was found to be well within the limits as specified by World Health Organization.

Microbial quality of the water is usually assessed by the presence of the coliform content. Water samples of mining area were free from coliform. Where as in water samples of non-mining area had 0.11 MPL/100ml coliform count of which was within the acceptable level of BIS (1 MPN/100ml). Though coliform content in water samples of non-mining area was within the desirable level, the local government need to take action to clean the water regularly to reduce the chances of spreading contagious diseases such as diarrhoea and cholera. Similar results were observed in the studies of Suresh and Kottureshwara. (2009) [10] where few samples were found to be highly contaminated with coliforms while most of the samples were suitable for human consumption among 43 bore wells at various locations in Sandur taluk of Ballari district in Karnataka.

Table 1: Physico chemical properties of the drinking water quality of mining and non-mining areas

Parameter	BIS (IS 10500-91)		ICMR		Mining area	Non-mining area
	Desirable Limit	Max. permissible limits in the absence of alternate source	Desirable Limit	Max. permissible limits		
PH	6.5 to8.5	No relaxation	7.0-8.5	6.5-9.2	7.3 (7.2-7.4)	7.2 (7.10-7.3)
Total dissolved solids (mg/l)	500	2000	500	1500-3000	179 (173-185)	144 (118-170)
Total hardness as CaCO3 (mg/l)	300	600	300	600	61 (52-72)	56 (50-62)
Calcium as Ca (mg/l)	75	200	75	200	19.5 (19-20)	18.6 (18-19.2)
Magnesium as Mg (mg/l)	30	100	-	50	5.1 (4.9-5.3)	5.05 (4.9-5.1)
Chloride as Cl (mg/l)	250	1000	200	1000	24 (22-26)	24 (23-25)
Sulphate as SO_4 (mg/l)	200	400	200	400	19 (18-20)	16.5 (16-17)
Nitrate as NO_3 (mg/l)	45	100	20	100	0.2 (0.11-0.3)	0.11 (0.10-0.11)
Fluoride as F (mg/l)	1.0	1.5	1.0	1.5	0.20 (0.19-0.22)	0.19 (0.19-0.20)

#Note: Figures in parentheses indicate range.
BIS: Bureau of Indian Standards.
ICMR: Indian Council of Medical Research.

Table 2: Heavy metal content of the drinking water of mining and non-mining areas

Parameter	BIS (IS 10500-91)		ICMR		Mining area	Non-mining area
	Desirable Limit	Max. permissible limits in the absence of alternate source	Desirable Limit	Max. permissible limits		
Iron as Fe (mg/l)	0.3	1.0	0.1	1.0	0.16 (0.11-0.22)	0
Cadmium as Cd (mg/l)	0.01	0.01	-	0.01	0	0
Arsenic as As (mg/l)	0.05	0.05	-	0.05	0	0
Lead as Pb (mg/l)	0.05	0.05	-	0.5	0	0
Mercury as Hg (mg/l)	0.001	0.001	-	0.001	0	0
Zinc as Zn (mg/l)	5	15	0.1	5.0	0.01 (0.010-0.012)	0
Copper as Cu (mg/l)	0.05	1.5	0.05	1.5	0	0

#Note: Figures in parentheses indicate range.
BIS: Bureau of Indian Standards.
ICMR: Indian Council of Medical Research.

Table 3: Microbial quality of the drinking water of mining and non-mining areas

Parameter	BIS (IS 10500-91)		ICMR		Mining area	Non-mining area
	Desirable Limit	Max. permissible limits in the absence of alternate source	Desirable Limit	Max. permissible limits		
Total coliforms MPN/100 ml	1	10	-	-	0	0.11 (0.1-0.19)

#Note: Figures in parentheses indicate range.
BIS: Bureau of Indian Standards.
ICMR: Indian Council of Medical Research.
MPN: Most Probable Number.

Conclusion

Mining is widely regarded as having adverse effects on environment in both magnitude and diversity. Physico-chemical investigation of the water samples in the mining and non-mining areas of Hospet and Sandur talukas of Ballari district revealed that the parameters such as pH, total solids, total hardness, calcium, magnesium, sulphate, nitrate, chloride, fluoride were in the desirable limits. Similarly, heavy metals such as cadmium, arsenic, lead, mercury, zinc and copper were in acceptable level. Though drinking water of mining area had 0.16mg/l of iron, it was within BIS prescribed level (0.3mg/l). However long-term use of this water may pose health problems for local residents.

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