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Research Note

# Arsenic and physico-chemical calamity in the ground water samples of Ballia district , Uttar Pradesh, India

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The level of arsenic contamination in ground water quality in and around Ballia district was elucidated. The study revealed that most of the locations, the concentration of arsenic ranged from 0.01 to 0.05 mg/L (avg 0.03 ± 0.01 mg/L); which is higher than the permissible limit 0.01 mg/L. The physico-chemical parameters were recorded such as hardness 180 to 220 mg/L (avg 199.10 ± 12.62 mg/L), alkalinity 84 to 112 mg/L (avg 96.40 ± 7.88 mg/L), TDS 225 to 605 mg/L (avg 295.85 ± 87.55 mg/L), conductivity 340 to 916 µs/cm (avg 447.90 ± 132.47 µs/cm), chloride 12.12 to 36.36 mg/L (avg 18.38 ± 7.03 mg/L), pH 7.40 to 7.80 (avg 7.51 ± 0.10), phosphate 0.05 to 0.44 mg/L (avg 0.16 ± 0.10 mg/L), sulphate 3.20 to 12 mg/L (avg 5.86 ± 2.22 mg/L), salinity 0.20 to 1.10 ppt (avg 0.27 ± 0.20 ppt), nitrate 3.06 to 7.64 mg/L (avg 5.11 ± 1.34 mg/L) and fluoride 0.21 to 1.19 mg/L (avg 0.61 ± 0.24 mg/L). The *Escherichia coli* and *coliform* MPN number also found in the within the limit (<3/100 mL) except at Chandpur (23/100 mL), Hanumangunj (9.1/100 mL), Bansdih (3.6/100 mL) and Tika Dewari (460/100 mL).
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## INTRODUCTION

Ballia district is deceit in eastern part of the Uttar Pradesh (longitude 84°11'08.99"E, latitude 25°49'40.25"N). It has total area 2981 km$^2$ and as per 2011 census having population 27,61,620. Ballia district is bordered by the Ghaghara in north, ChotiSaraju and Ganga River in south. There are a chain of lakes and ponds such as Surha Tal, Reoti Tal Mundvi Shah among Maniyar, Sikandarpur Tal, Bansdeeh, etc. According to Imran et al. [1] groundwater; tube well and artificial canal are the main source of irrigation and agriculture water resources in Ballia district.

In groundwater, arsenic combines with oxygen to form inorganic pentavalent arsenate, As(V) and trivalent arsenite, As(III) depending on pH and other conditions. Arsenite is more stable than arsenate due to its electronic configuration and more toxic because it binds to single with higher affinity to vicinal sulfhydryl groups that reacts with a variety of proteins and inhibits their activity. Arsenic is a carcinogen and its consumption can negatively affect the gastrointestinal tract, cardio-vascular and central nervous systems. Certain severe diseases are faced by humans due to consumption of arsenic contaminated water include liver, lungs, skin, kidney and cardiovascular diseases, etc. In Asia, recent years in many countries where skin lesions caused by arsenic in drinking water, have been extensively reported. These countries are: India, Nepal, Pakistan, Myanmar, Taiwan, Viet Nam, Laos, part of China, including Inner Mongolia, Thailand, Cambodia and Bangladesh [2, 3]. Arsenic is mobilized from the soil to the water by complex geochemical mechanisms [4]. Therefore, arsenic contamination of drinking water has to be taken as worldwide environmental issue that requires serious attention. To overcome these impacts on human health, guidelines of World Health Organization (WHO) [5] and US Environmental Protection Agency (USEPA) have been reduced from 50 to 10 ppb as drinking water quality standard.

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Human being is critically affected by direct contact to arsenic through drinking water [6]. The presence of arsenic in groundwater has been reported from many parts of the world, particularly in the Bengal delta of India and Bangladesh (BGS/DPHE) [7], China [4], Vietnam and Nepal [8]. Arsenic contamination in India is well documented especially in Ganga-Meghana-Brahmaputra plain [9]; firstly arsenic contamination was reported in west Bengal in 1983 [10]. Arsenic has been growing rapidly during the last few years as major pollutants of drinking water in several districts of West Bengal and many other states of India [11]. Recently, Ballia district has been reported to have arsenic contamination in the ground water [12]. Evidence suggests the presence of arsenic in groundwater in India and Bangladesh throughout the region defined as the Indo-Gangetic Plain [13]. Quaternary aquifers are important sources of groundwater resources and are also important links between terrestrial and marine biogeochemical cycles in coastal zones [14-16]. Arsenic mobilization processes can vary with geochemical conditions [17-20]. Most previous studies have focused on the geochemical conditions of arsenic in aquifers [21-25]. Arsenic-rich iron oxy-hydroxides undergo microbially mediated reductive dissolution; arsenic is mobilized, along with soluble iron and bicarbonate [20, 26, 27]. The objective of present study is to determine and establish a database of ground water quality along with severity of arsenic in and around of Ballia district, Uttar Pradesh.

## MATERIALS AND METHODS

Twenty numbers of ground water samples were collected from India Mark-II and shallow hand pumps. The locations of sampling points are shown in Fig. 1. Prior to sampling, the hand pumps flushed with 30 to 40 L of water. The samples were collected in plastic sterilized bottles for analysis. Before filling the samples, bottles were rinsed for three times with water. For the analysis of metals, 1.0 mL of nitric acid is added in each bottle; then, water was filled to the brim of the bottle without any air bubble and air exposure. For the bacteriological study, samples were collected in the sterilized barrow mouthed glass bottles of 150 mL capacity and preserve all the samples in dry ice. Sites were identified by recording the co-ordinates using the Global Positioning System (GPS) (Table 1). The samples were collected during January 2013 to December 2013 in Ballia. The complete process of methods for examination of water and waste water [28]. sample preparation and analysis of physico-chemical and metals were conducted according to standard

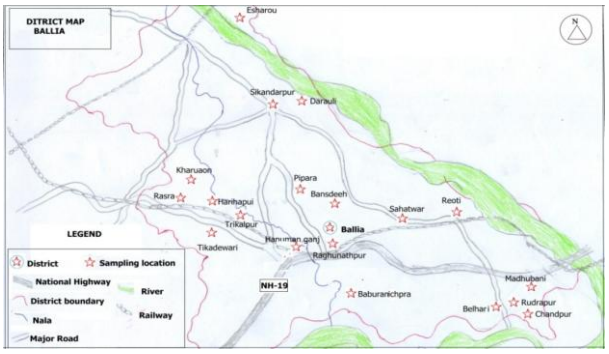


**Figure 1**. Sampling locations of Ballia district

**TABLE 1.** GPS sampling locations of Ballia district

| S. No. | Location name | Longitude | Latitude |
|---|---|---|---|
| 1 | Belhari | 84°20’28.32”E | 25°46’08.93”N |
| 2 | Baburanichpra | 84°11’25.58”E | 25°44’56.86”N |
| 3 | Hariharpur | 83°58’42.42”E | 25°50’07.89”N |
| 4 | Rudrapur | 84°23’18.14”E | 25°46’57.06”N |
| 5 | Chandpur | 84°27’26.36”E | 25°45’02.25”N |
| 6 | Hanuman gunj | 84°08’15.28”E | 25°48’05.50”N |
| 7 | Reoti | 84°22’42.45”E | 25°50’47.10”N |
| 8 | Bansdih | 84°13’04.71”E | 25°52’56.32”N |
| 9 | Trikalpur | 84°02’37.83”E | 25°49’37.92”N |
| 10 | Raghunathpur | 84°10’41.25”E | 25°46’46.14”N |
| 11 | Sikandarpur | 84°03’00.15”E | 25°01’59.70”N |
| 12 | Darauli | 84°06’54.34”E | 26°03’26.08”N |
| 13 | Esharou | 83°52’47.17”E | 26°11’17.62”N |
| 14 | Kharuaon | 83°50’28.77”E | 25°55’45.38”N |
| 15 | Ballia | 84°11’08.99”E | 25°49’40.25”N |
| 16 | Pipra | 84°04’39.10”E | 25°54’42.65”N |
| 17 | Sahatwar | 84°17’05.58”E | 25°49’59.06”N |
| 18 | Madhubani | 84°28’41.82”E | 25°48’15.96”N |
| 19 | Rasra | 84°51’19.70”E | 25°51’32.96”N |
| 20 | TikaDewari | 83°53’38.53”E | 25°47’06.11”N |

The analysis of preserved water samples for given parameters are studied in laboratories. Ion-selective electrode used for pH, salinity and conductivity, Argentometric titration method for the chloride, sulphuricacid titration method for total alkalinity, EDTA titration method for total hardness, UV spectro-photometric screening method for nitrate, turbidity metric method for sulfate, Ion-selective electrode (Orion) for fluoride, gravimetric method for TDS and UV spectro-photometric stannous chloride method for phosphate analysis. For the heavy metal (Cd, Fe, Mn, Cr, Pb, Ni, Zn and Cu) estimation acid digestion as per method IS 3111 ($HNO_3$: $HClO_4$, 4:1 v/v) were used. For estimation of total arsenic, 2 mL of HCl was added in

equal volume of water sample. Thereafter 1 mL of ascorbic acid and 1 mL of potassium iodide was added and kept for 45 min at room temperature (27°C) for incubation. Finally volume was makeup 20 mL with distilled water and readout at AAS/ICP method.

For bacteriologicalstudy, multiple tube fermentation method was used (described in APHA [28]). Total 15 tubes are taken in which 5 tubes having double strength culture broths and other 10 tubes are single strength culture broths. The double strength culture broth having volume 10 mL with inverted vials (Durham's tubes) are prepared and other 10 tubes in 2 series with single strength culture broth having volume 5 mL with inverted vials respectively and autoclaved the fermented tubes. The samples were inoculated with $1/10^{th}$ decreasing volumes and incubated usually at 37°C (44°C to fecal coliform) and readout after 24-48 h [28]. For statistical analysis Origin 9.1 version was used in present study.

## RESULT AND DISCUSSION

Physical properties of ground water samples of different sites in Ballia district are shown in Fig. 2. Hardness is the sum of polyvalent metallic ions in water which varied from 180 to 220 mg/L (avg 199.10 ± 12.62 mg/L). The classification of ground water samples could be grouped into 3 classes soft waters with 60 mg/L; moderately hard waters with 61 to 120 mg/L and hard waters with 121 to 180 mg/L. All samples with more than 180 mg/L indicating very hard water.

Salinity varied from 0.20 to 1.10 ppt (avg 0.27 ± 0.20 ppt). Nitrate were found between 3.06 to 7.64 mg/L (avg 5.11 ± 1.34 mg/L) and fluoride content varied from 0.21 to 1.19 mg/L (avg 0.61 ± 0.24 mg/L). Ternary plot showed that the impact of hardness concentration on ground water quality was more, in compare to TDS and alkalinity (Fig. 2). Alkalinity were found between 84 to 112 mg/L (avg 96.40 ± 7.88 mg/L) and TDS ranged from 225 to 605 mg/L (avg 295.85 ± 87.55 mg/L). The pH ranges were 7.40 to 7.80 (avg 7.51 ± 0.10). Phosphate varied from 0.05 to 0.44 mg/L (avg 0.16 ± 0.10 mg/L). Sulphate varied from 3.20 to 12 mg/L (avg 5.86 ± 2.22 mg/L). The sulphate concentration > 250 mg/L causes gastrointestinal irritation particularly when $Mg^{2+}$ and Na+ are also present in ground water.

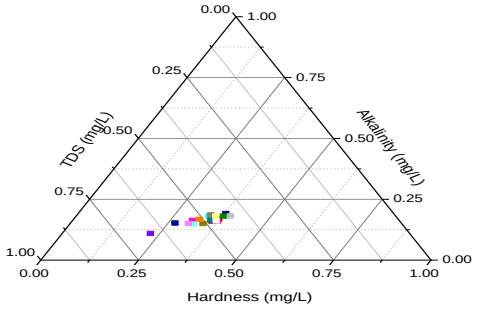


**Figure 2.** Ternary plot of hardness, alkalinity and TDS of ground water samples

The water containing sulphate ions beyond 1000 mg/L have purgative effects 9 [28]. The Conductivity was found between 340 to 916 µs/cm (avg 447.90 ± 132.47 µs/cm), Chloride varied from 12.12 to 36.36 mg/L (avg 18.38 ± 7.03 mg/L); the higher chloride ions concentration >250 mg/L may develop salty taste and the excessive chloride ions imparts bitter taste to portable water. The greater concentration of $Cl^-$ in ground water could be associated with chloride rich minerals [29].

All physico-chemical parameters were evaluated based on standard methods [28]. It is depicted that all the parameter was within the permissible limit except TDS. The heavy metals and arsenic present in the collected ground water samples were also determined and summarized in Table 3. The metal concentrations in ground water samples are illustrated in Fig. 3. However most of the samples Cd, Ni and Cu were below detection limit. While other heavy metal such as Fe level were found between 0.07 to 2.51 mg/L (avg 0.83 ± 0.74 mg/L); Mn varied from 0.01 to 0.55 mg/L (avg 0.13 ± 0.14 mg/L); Cr level were found between 0.01to 0.03 mg/L (avg 0.01 ± 0.01 mg/L); Pb level were found between 0.01 to 0.05 mg/ L (avg 0.02 ± 0.01 mg/L); Zn level were found between 0.13to 2.27 mg/L (avg 0.85 ± 0.59 mg/L).

**TABLE 2.** Physico-chemical characteristics of groundwater sample of Ballia District

| Parameters | pH | Hardness (mg/L) | Alkalinity (mg/L) | Conductivity (µs/cm) | TDS (mg/L) | $PO4^{3-}$ (mg/L) | $SO4^{2-}$ (mg/L) | Salinity (ppt) | $Cl^-$ (mg/L) | $NO^{3-}$ mg/L | $F^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | 7.40 | 180.00 | 84.00 | 340.00 | 225.00 | 0.05 | 3.20 | 0.20 | 12.12 | 3.06 | 0.21 |
| Max | 7.80 | 220.00 | 112.00 | 916.00 | 605.00 | 0.44 | 12.00 | 1.10 | 36.36 | 7.64 | 1.19 |
| Avg | 7.51 | 199.10 | 96.40 | 447.90 | 295.85 | 0.16 | 5.86 | 0.27 | 18.38 | 5.11 | 0.61 |
| SD | 0.10 | 12.62 | 7.88 | 132.47 | 87.55 | 0.10 | 2.22 | 0.20 | 7.03 | 1.34 | 0.24 |
| CV | 1.33 | 6.34 | 8.18 | 29.58 | 29.59 | 64.26 | 37.79 | 75.14 | 38.22 | 26.18 | 39.54 |
| GM | 7.50 | 198.72 | 96.09 | 434.19 | 286.78 | 0.13 | 5.56 | 0.24 | 17.40 | 4.95 | 0.56 |
| Median | 7.50 | 196.00 | 98.00 | 404.00 | 267.00 | 0.15 | 5.10 | 0.20 | 16.16 | 4.90 | 0.56 |
| Kurtosis | 3.51 | -1.24 | -0.55 | 8.09 | 8.06 | 1.81 | 2.88 | 16.73 | 2.00 | -0.80 | 0.22 |
| Skewness | 1.65 | 0.23 | 0.17 | 2.59 | 2.59 | 1.33 | 1.75 | 3.98 | 1.69 | 0.35 | 0.35 |

**TABLE 3**. Heavy metals and arsenic concentration (mg/L) in ground water sample of Ballia District

| Parameters | Cd | Fe | Mn | Cr | Pb | Ni | Zn | Cu | As |
|---|---|---|---|---|---|---|---|---|---|
| Min | BDL | 0.07 | 0.01 | 0.01 | 0.01 | BDL | 0.13 | BDL | 0.01 |
| Max | BDL | 2.51 | 0.55 | 0.03 | 0.05 | BDL | 2.27 | BDL | 0.05 |
| Avg | BDL | 0.83 | 0.13 | 0.01 | 0.02 | BDL | 0.85 | BDL | 0.03 |
| SD | BDL | 0.74 | 0.14 | 0.01 | 0.01 | BDL | 0.59 | BDL | 0.01 |
| CV | BDL | 89.39 | 101.24 | 40.66 | 46.09 | BDL | 69.84 | BDL | 45.67 |
| GM | BDL | 0.54 | 0.07 | 0.01 | 0.02 | BDL | 0.66 | BDL | 0.02 |
| Median | BDL | 0.46 | 0.11 | 0.01 | 0.02 | BDL | 0.63 | BDL | 0.02 |
| Ku+rtosis | BDL | -0.45 | 3.40 | 20.00 | 3.89 | BDL | -0.01 | BDL | -1.25 |
| Skewness | BDL | 0.92 | 1.62 | 4.47 | 1.72 | BDL | 0.90 | BDL | 0.52 |

BDL: below detection limit.

The ranges of arsenic level were found between 0.01 to 0.05 mg/L (avg 0.03 ± 0.01 mg/L) in all the ground water sample of Ballia. It was depicted that all the parameter was within the permissible limit except TDS. The depiction of heavy metal and arsenic were compared according to standard method. As, Fe, Mn, and Pb were represented little high in collected water samples. Ballia district 30-40% net cultivated land in under irrigation and more than 60% of this irrigation is net from potable water. The A to T are the 20 sampling locations of ground water in Ballia district, respectively (see Table 1).

Coliform MPN (most probable number) were found within the limit (<3/100 mL) in all locations except Chandpur (23/100 mL), Hanuman gunj (9.1/100 mL), Bansdih (3.6/100 mL) and Tika Dewari (460/100 mL).The higher MPN numbers created problems in digestive system and other body organs whereas *E. coli* was found 9.1/ 100 mL and 3.6/ 100 mL in Chandpur and Bansdih, respectively (Table 4).

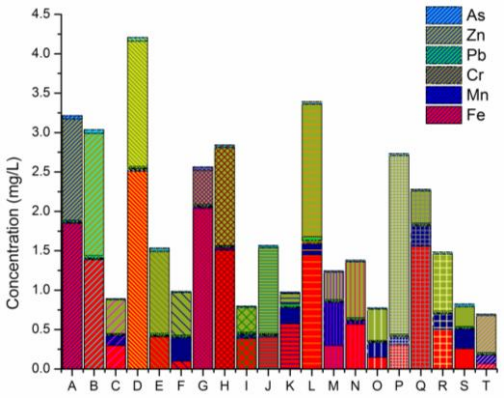


**Figure 3.** Metal concentrations in ground water samples of Ballia district

**TABLE 4**. Bacteriological Quality of ground water samples of Ballia district

| S. No. | Location name | | |
|---|---|---|---|
| 1 | Belhari | <3 | <3 |
| 2 | Baburanichpra | <3 | <3 |
| 3 | Hariharpur | <3 | <3 |
| 4 | Rudrapur | <3 | <3 |
| 5 | Chandpur | 23 | 9.1 |
| 6 | Hanuman gunj | 9.1 | <3 |
| 7 | Reoti | <3 | <3 |
| 8 | Bansdih | 3.6 | 3.6 |
| 9 | Trikalpur | <3 | <3 |
| 10 | Raghunathpur | <3 | <3 |
| 11 | Sikandarpur | <3 | <3 |
| 12 | Darauli | <3 | <3 |
| 13 | Esharou | <3 | <3 |
| 14 | Kharuaon | <3 | <3 |
| 15 | Ballia | <3 | <3 |
| 16 | Pipra | <3 | <3 |
| 17 | Sahatwar | <3 | <3 |
| 18 | Madhubani | <3 | <3 |
| 19 | Rasra | <3 | <3 |
| 20 | TikaDewari | 460 | <3 |

## CONCLUSION

The present study concluded that mostly groundwater quality parameters that's creates a terrified problems in human and animals life on the behalf of arsenic contamination. *E. coli* and coliform MPN number also found in the within limit (<3/100 mL) except Chandpur (23/100 mL), Hanuman gunj (9.1/100 mL), Bansdih (3.6/100 mL) and Tika Dewari (460/100 mL). High MPN numbers have created problems in digestive system and other body organs. It is concluded that some parameters have not obeyed the WHO and IS 10500 standards such as Arsenic, TDS, Fe and hardness in some sampling locations. This parameter exceeds the acceptable limits. So the government of India and other NGO has taken actionable responsibility to provide the uncontaminated groundwater for drinking purposes in Ballia population such as Aquagard facility, water treatment plants, chemical and survey of contaminated area.

Table 5 summarized the quality of drinking water based on Indian Standard, IS 10500 and WHO guidelines.

**TABLE 5**. Indian Standard, IS 10500 and WHO guidelines for drinking water quality

| S. No. | Parameter | Indian Standard 10500 (2012) | | WHO (2004) | |
|---|---|---|---|---|---|
| | | Required | Permissible | Required | Permissible |
| 1 | pH | 6.5-8.5 | NR | 6.5-8.5 | - |
| 2 | EC | NG | - | 400 | 1000 |
| 3 | TDS | 500 | 2000 | 500 | - |
| 4 | TH | 200 | 600 | 100 | - |
| 5 | TA | 200 | 600 | 200 | - |
| 6 | $Cl^-$ | 250 | 1000 | 250 | - |
| 7 | $SO_4^{2-}$ | 200 | 400 | 250 | - |
| 8 | $NO_3^-$ | 45 | NR | 50 | - |
| 9 | $F^-$ | 1.0 | 1.5 | 1.0 | - |
| 10 | Cr | 0.05 | NR | - | - |
| 11 | Mn | 0.1 | 0.3 | 0.1-0.5 | - |
| 12 | Fe | 0.3 | NR | 0.3 | - |
| 13 | Ni | 0.02 | NR | 0.07 | - |
| 14 | Cu | 0.05 | 1.5 | 2 | - |
| 15 | Zn | 5.0 | 15 | 0.01 | - |
| 16 | Cd | 0.003 | NR | 0.003 | - |
| 17 | Pb | 0.01 | NR | 0.01 | - |
| 18 | $PO_4^{3-}$ | - | - | - | - |
| 19 | As | 0.01 | 0.05 | 0.01 | 0.05 |

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**Persian Abstract**

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**چکیده**

سطح آلودگی ارسنیک در کیفیت آب زمینی در داخل و خارج منطقه‌ی Balia مشخص شد، این مطالعه نشان می‌دهد که غلظت آرسنیک در بیشتر مناطق در محدوده‌ی ۰/۰۱ تا ۰/۰۵ میلی گرم بر لیتر(متوسط ۰/۰۱± ۰/۰۳) است که این مقدار بیشتر از حد مجاز ۰/۰۱ میلی گرم بر لیتر می باشد. پارامترهای فیزیکی-شیمیایی مانند سختی از ۱۸۰ تا ۲۲۰ میلی گرم (متوسط ۱۲/۲۶±۱۰/ ۱۹۹میلی گرم بر لیتر)، قلیایی بودن ۸۴ تا ۱۱۲میلی گرم بر لیتر(متوسط ۷/۸۸±۹۶/۴۰میلی گرم بر لیتر)، کل مواد جامد محلول از ۲۲۵ تا ۶۰۵ میلی گرم بر لیتر(متوسط ۸۷/۵۵±۸۵/ ۲۹۵ میلی گرم برلیتر)، قابلیت رسانایی از ۳۴۰ تا ۹۱۶ میکرو ثانیه بر سانتی متر (متوسط۱۳۲/۴۷±۴۴۷/۹۰ میکرو ثانیه بر سانتی متر)، میزان کلراید ۱۲/۱۲ تا ۳۶/۳۶ میلی گرم بر لیتر(۰/۱±۰/۱۶ میلی گرم بر لیتر)، میزان سولفات از ۳/۲ تا ۱۲ میلی گرم بر لیتر(متوسط ۲/۲۲±۵/۸۶ میلی گرم بر لیتر)،میزان شوری از PPT۰/۲ تا ۱/۱ میلی گرم بر لیتر (متوسط ۰/۲±۰/۲۷ میلی گرم بر لیتر)، میزان نیترات از ۳/۰۶ تا ۷/۶۴ میلی گرم بر لیتر(متوسط ۱/۳۴±۵/۱۱ میلی گرم بر لیتر ) و فلوراید از ۰/۲۱ تا ۱/۱۹ میلی گرم بر لیتر (متوسط ۰/۲۴±۰/۶۱ میلی گرم بر لیتر). *Escherichi coli و تعداد کولیفرم* MPN نیز در محدوده ی کمتر از ۳ در ۱۰۰ میلی لیتر بوده است به جز چاندپور با ۲۳ در ۱۰۰ میلی لیتر، هانومنگوج با ۹/۱ در ۱۰۰ میلی لیتر، بانسدیح با ۳/٦ در ۱۰۰ میلی لیتر و تیکا دواری با ٤٦۰ در ۱۰۰ میلی لیتر.