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ORIGINAL ARTICLE

Recent Trends of Arsenic Contamination in Groundwater of Ballia District, Uttar Pradesh, India

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ABSTRACT:
Arsenic in the ground water is a worldwide problem as about 150 million people are at risk and more than 70 countries are suffering from this havoc. Arsenic is a carcinogen and responsible of various types of cancers. India is also having this problem in some parts including Ballia District, UP. The overall objective of this study to study the mitigation of arsenic by using chemical data and GIS application. 100 samples were collected from deep, medium and shallow aquifer twice in pre-monsoon (April, 2010) and post-monsoon seasons (December, 2010). The samples were analyzed by atomic absorption spectrometer and correlated with geological features. The correlation between arsenic contamination with geological features and seasonal variation were analyzed by GIS. The Arsenic concentrations in shallow, medium and deep aquifers were 14-820, 30-450 and 6-300 ppb in pre-monsoon. But in post-monsoon these values were 13-950, 10-600 and 2-500 ppb, respectively. The seasonal variations were analyzed indicating high arsenic concentrations in post-monsoon season. These results indicated that arsenic mitigation is from shallow to medium and deep aquifers. The concentration of arsenic is found in all blocks of the study area. There was evidence of seasonal variation in concentrations of arsenic between pre and post-monsoon seasons. The concentrations of arsenic were higher in post-monsoon than pre-monsoon due to insufficient rainfall during study year.

***Keywords*:** GIS, Arsenic contamination, Aquifer, Seasonal variations, Water pollution; Ground water, Health effects.

1. INTRODUCTION

Arsenic contamination in the groundwater is a worldwide problem [1-3]. The ground waters of nearly 70 countries are being contaminated by arsenic. About 150 million people are at risk due to drinking of arsenic polluted water [4]. The presence of arsenic in the ground water has been reported from many parts of the world with Bangladesh as the most affected nation [5-6]. Besides, the ground waters of Bengal delta of India, China [7], Vietnam [8] (UNESCAP-UNICEF-WHO 2001) and Nepal have also been contaminating by this deadly metalloid [9]. Arsenic contamination in India is well documented [10-14]. In India, first arsenic contamination was reported in West Bengal in 1983 [13]. Later on, it was reported in the

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ground water of some parts of Bihar. Recently, Ballia (Uttar Pradesh) has been reported to have arsenic contamination in the ground water [15]. This trend indicates the mitigation of arsenic from east to west in Indian continent.

It is well known that consumption of arsenic contaminated ground water leads to chronic health effects. The early symptoms of arsenic drinking water include the presence of arsenic in nail, hair, urine and skin. The serious issues concerning arsenic epidemics are keratosis, anemia, skin pigmentation, pulmonary and neurological problems [16]. Moreover, serious concerns are the occurrence of lung, skin and prostate cancers [17]. These clinical symptoms, especially dermal lesions (the most commonly observed symptom) occur after some years of consumption of arsenic contaminated drinking water. GIS is becoming a valuable scientific tool since its inception in 1960s. It is designed for storing, querying, analyzing as well as for displaying data and/or information with spatial characteristics. Its application spans is to cover a wide range from simple inventory and management to sophisticated analysis and modeling of spatial data. It is also widely used in the environmental sciences. The application of GIS on arsenic problems has been of more concerns. In Bangladesh, GIS was used in groundwater arsenic mitigation program. It tackled many aspects of arsenic problems, including analysis of present groundwater conditions, assessment of exposure and potential health subsequences, planning and implementation of emergency and long term sanitation [18]. Therefore, it is very important to study the mitigation of arsenic in the ground water. The ground water of Ballia District was selected as a model for studying the mitigation of arsenic. The present paper describes the behavior of arsenic movement in the ground water by using chemical analytical values of arsenic in pre- and post monsoon seasons. Besides, GIS and Remote sensing approaches were also used to study the arsenic mitigations in the ground water of Ballia District.

Study Area

Ballia district lies in eastern part of the Uttar Pradesh (25°23" and 26°11" North latitude and 83°38" and 84°39" East longitudes). It has total area of 2981 sq. km. District headquarter is Ballia with six Tehsils viz. Rasra, Belthra, Ballia (Sadar), Bairia, Bansdih and Sikanderpur. It has seventeen blocks viz.. Nagra, Rasra, Chilkahar, Pandah, Navanagr, Siar, Maniyar, Veruarwari, Revati, Bansdih, Garwar, Sohaon, Belhari, Dubhad, Bairiya, Murlichapra and Hanumanganj. It has 2761620 population as per 2001 census; with 1413774 males and 1347846 females, respectively. Urban and rural and population is 269944 and 2491676, respectively. The density of population is 926 person/sq.km [19].

Ballia is surrounded by Ghaghara River in North and Chhoti Saraju and Ganga Rivers in south (Fig.1). The district is drained by the Ghaghara, Chhoti Saraju and Ganga rivers. There are a series of lakes and ponds such as Surha Tal, Mundvi Shah among Maniyar, Bansdeeh, Sikandarpur Tal, Reoti Tal etc.

Ground water, tube well and artificial canal are the main sources of irrigation in the district. Total length of canal is 419 km by which 29829 hectare area is irrigated. The irrigation in Ballia takes place by Dharighat Lift Irrigation canal and tube wells. About 27.39% land is irrigated by surface water and remaining 72.61% is irrigated by ground water [19].

The major source of income of the district is agriculture. Major food and commercial crops are wheat, lentil, maize, paddy, sugarcane etc. Major horticulture crops are potato, tomato mango, guava, banana etc. Predominant economic activities of district are agriculture, dairy and handicrafts. The industrial sector of Ballia is dominated by agro processing. The main agro processing activities are being followed in the district are Rice mills (328 units), Oil expeller (172 units), Flour mills (4 in no.), Bakery units (22), Potato based industries, Dairy industries, Spice making industries.

The mean maximum monthly temperature (42.1 °C) has been recorded during May and minimum (22.9 °C) in January. In summers, the temperature, sometimes, reaches up to 46 °C while in peak winter it falls up to 4 °C. The study area falls under sub humid climate with grassland vegetation. The maximum humidity is reported in August (82.5%) followed by September (80%) [19].

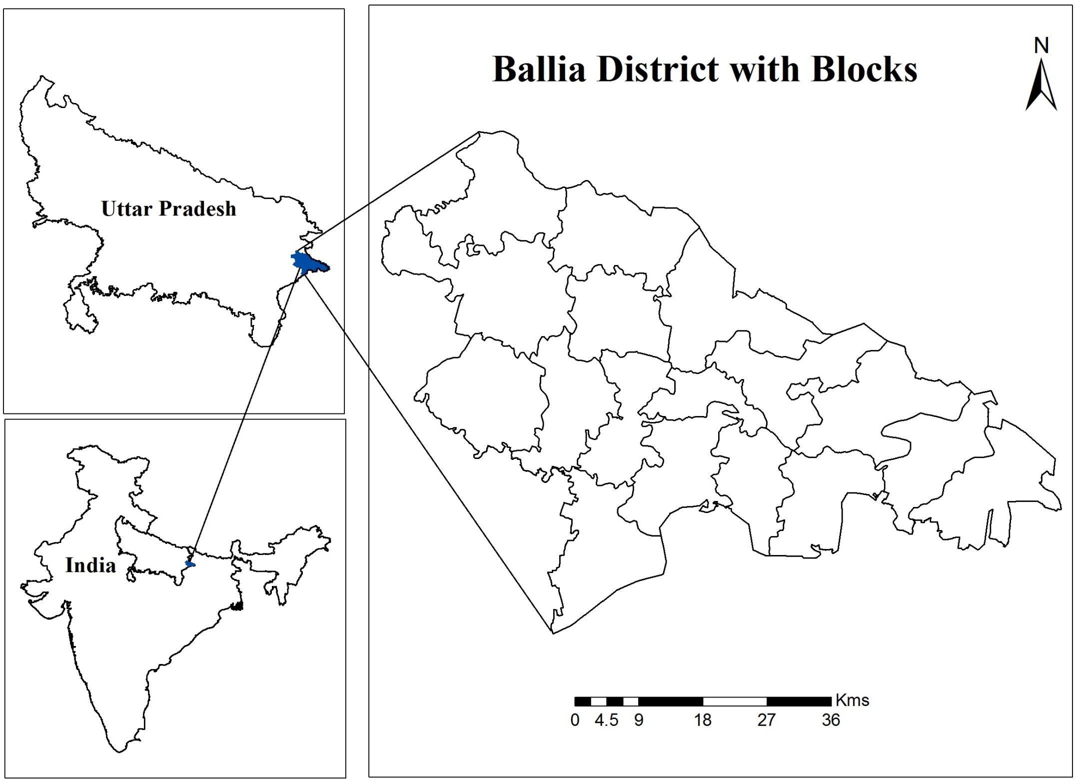

Fig. 1. Locational Aspect of the Study Area of Ballia district (25°23" and 26°11" North latitude and 83°38" and 84°39" East longitudes).

2. EXPERIMENTAL

2.1. Chemical, Reagents and Apparatus

Sodium arsenate ($Na_2HAsO_4.7H_2O$) was purchased from Merck, Germany. Hydrochloric acid and nitric acid were supplied by Qualigens, New Delhi India. The deionized water was prepared by Millipore purification system. Analyses of arsenic were carried by atomic absorption spectrometer (AA-6300 Shimadzu).

2.2. Sampling

Site locations were determined by A portable Garmin E-trex GPS (12-channel Garmin 12, UTM system), which is accurate to around 15 m. It was used for GIS mapping and for assisting in relocating the tube wells. The latitude and longitude were recorded in decimal degrees, and the waypoints were stored in the device until transferred to the computer with G7ToWin software. Data were saved as CSV (comma separated value) files that automatically convert to spread-sheets and were saved as data base IV to be used by the Arc GIS software. The sampling of ground water of Ballia District Uttar Pradesh was carried out during pre-monsoon April, 2010-11 and post-monsoon December, 2010-11. 100 Water samples were collected from 34 points sources (Fig. 2). The samples were grouped into three categories (1) Shallow (0-80 feet), (2) Medium (81-120 feet), and (3) Deep aquifer (above 120 feet). Ground water samples were collected in a 500 mL of Polyethylene bottles for Arsenic analysis. Before sampling, the hand pumps were flushed with 35-45 L of water and then 1.0 mL of conc. HNO_3 was added to 500 mL sample bottles to preserve arsenic and stored in refrigerator. The analyses were carried out within 15 days of sample collection. Total water samples were filtered through 0.45 µm and stored at 4◦C in polyethylene bottles until the analyses.

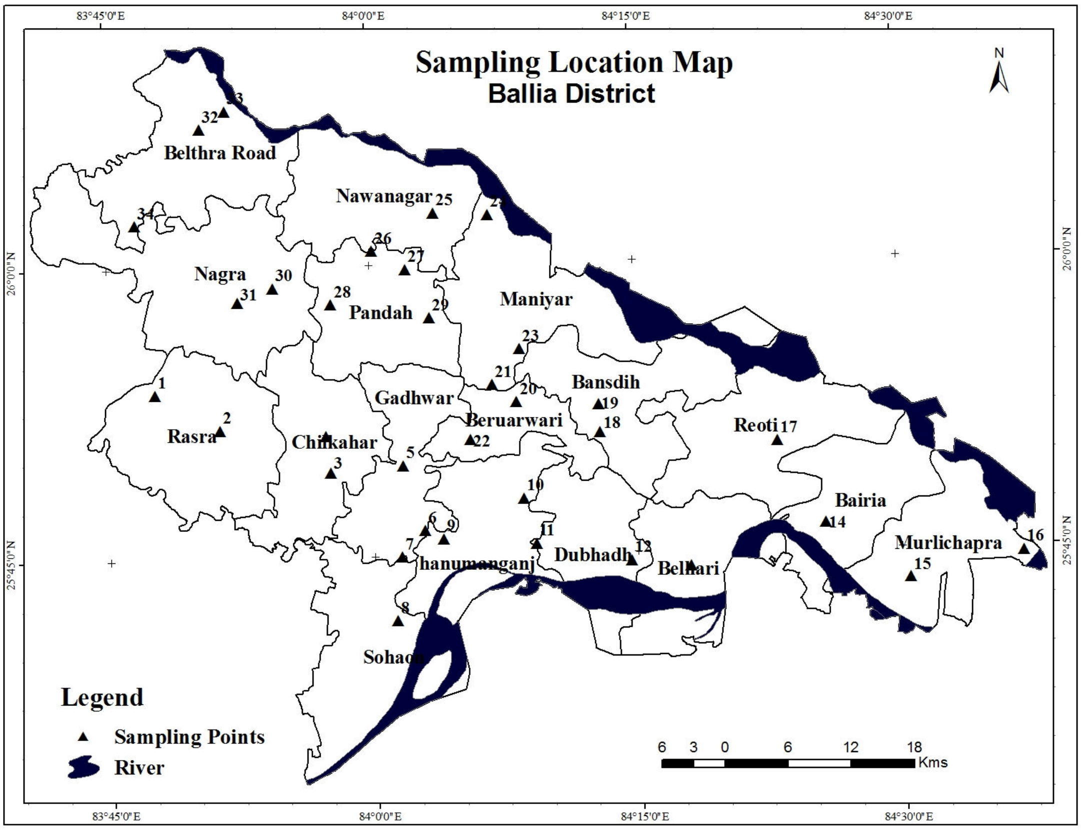

Fig. 2. Sampling location map, Ballia District

S.No.	Sampling Points	Latitude/Longitude	S.No.	Sampling Points	Latitude/Longitude
1	Pakwainaar	25°53'35"/83°47'41"	18	Rajpur	25°51'15"/84°12'58"
2	Rasra	25°51'42"/83°51'20"	19	Bansdih	25°52'41"/84°12'55"
3	Chilkahar	25°49'27"/83°57'34"	20	Bruwarwari	25°52'53"/84°8'16"
4	Hajauli	25°51'18"/83°57'22"	21	Karmar	25°53'48"/84°6'53"
5	Gharwar	25°49'43"/84°1'44"	22	Shukhpura	25°54'11"/84°4'41"
6	Feffna	25°46'22"/84°2'52"	23	Bara gawon	25°58'41"/84°5'54"
7	Chitbaragaon	25°45'3"/84°1'33"	24	Kharid	25°58'22"/84°9'45"
8	Beria	25°41'46"/84°1'14"	25	Sikadrpur outer	26°3'17"/84°4'59"
9	Kapoori	25°45'54"/84°3'55"	26	Dadar	26°0'56"/83°59'38"
10	Hanumanganj	25°47'55"/84°8'33"	27	Barachapra	26°0'48"/84°0'11"
11	Ballia	25°45'35"/84°9'13"	28	Shankarpur	26°0'25"/84°3'13"
12	Dubhar	25°44'38"/84°14'37"	29	Gauria	25°57'42"/84°4'6"
13	Haldi	25°44'17"/84°17'59"	30	Narhi	25°59'6"/83°55'24"
14	Taya-chhapra	25°46'21"/84°25'42"	31	Nagra	25°57'32"/83°49'42"
15	Murlichapra	25°43'26"/84°30'27"	32	Belthra road	26°7'8"/83°52'13"
16	Jaiprakashnagar	25°44'41"/84°36'55"	33	Ubhawon	26°7'13"/83°50'31"
17	Revati	25°50'36"/84°23'4"	34	Barewa	26°4'13"/83°55'18"

2.3. Water Analysis

The analyses of water samples were carried out through atomic absorption spectrophotometer model number (AA-6300 Shimadzu). The standards of arsenic of 1.0, 2.0 and 5.0 ppm were prepared to calibrate atomic absorption spectrometers. The linearity curve was plotted and the limit of detection was determined.

2.4. GIS

All the 34 coordinates of sample locations imported in Arc GIS 9.3 software and non spatial data has been added with spatial data using shape files in Arc GIS software. On the basis of 34 arsenic values in all 17 blocks, arsenic concentrations were measured in all over the district using Inverse Distance Weighted (IDW) interpolation technique. Geological map was digitized from Geological Survey of India map and was composed using GIS software.

3. RESULTS and DISCUSSION

3.1. Geomorphology

Ballia District is the part of Central Ganga plain. The topography is flat to gentle undulation covered with two types of Alluvium plain (Fig.3). One is older alluvial of Pleistocene (2.588 million to 12 million years before from present) and second one younger alluvial of Holocene (11700 years to present). The depth of sediment is 1-2 km. Alluvial tract of Ballia district is underlain by sands of various grades, gravels, silt and clay with have extension. The coarse, medium and fine sand are good water bearing formations. Main geomorphic units have been demarcated in the district which are given below [19].

(1) Flood Plain: It is restricted all along the river channels, which is comprised of coarse to fine sand, silt, clay and gravel [19].

(2) Newer Alluvial Plain: It denotes to old flood plain cycle of deposition which mostly consists of unconsolidated coarse to fine sand, silt and clay of varying amounts. There are fluvial landforms, such as paleo-channels meander scar, back swamps etc. [19].

(3) Older Alluvial Plain: It forms the central part of the Ganga-Ghaghra interfluves where surface water divide passes through the area. It consists coarse to fine sand, silt and clay. There are some landforms found such as Palaeo-channels, meander, lakes, marshy swampy lands etc. [19]

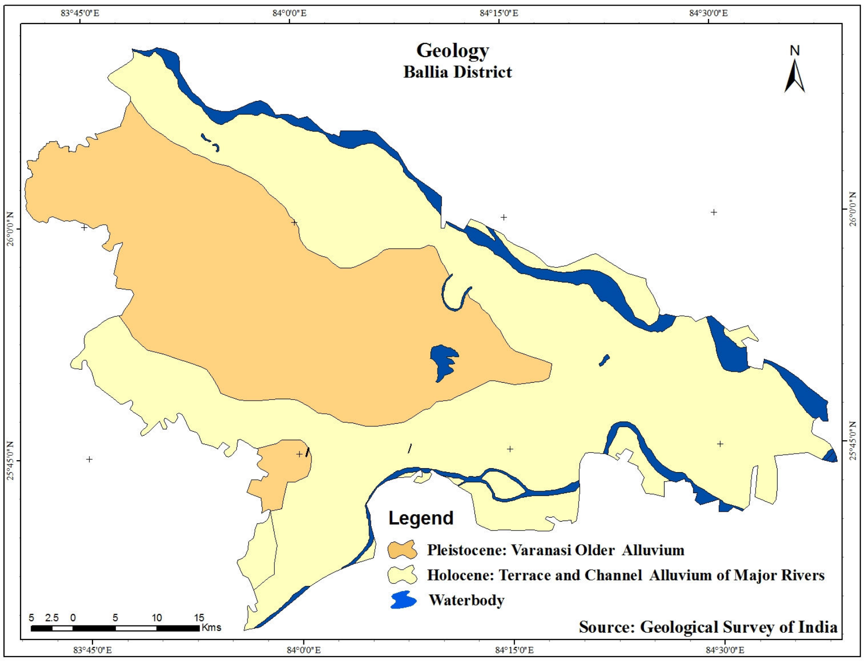

Fig. 3. Geology of the Balia District

3.2. Rainfall

The average rainfall of the Ballia district is 983 mm with 864.8 mm as monsoon rain fall. The maximum humidity is recorded in August (82.5%) and September (80%) respectively. On the basis of Varansi data, annual PET of Ballia district is 1608.9 mm. Normally, the annual rainfall is recorded 983 mm while monsoon rainfall is 864.8 mm. In the years 2006, 2007, 2008, 2009 and 2010 the rainfall were 605.3, 777, 1210.4, 281.2 and 511.5 mm, respectively, that is below normal annual rainfall accept; rainfall for the year of 2008 [19].

3.3 Chemical Analysis

The chemical analyses indicated arsenic concentrations in shallow, medium and deep aquifers as 14-820, 30-450 and 6-300 ppb in pre-monsoon. But in post-monsoon these values were 13-950, 10-600 and 2-500 ppb, respectively (Fig.4-5). These results indicated that arsenic mitigation is from shallow to medium followed by deep aquifers. In shallow aquifer, the map indicated arsenic values varied from 14 to 820 ppb in pre-monsoon 2010 (Fig. 4). Arsenic concentrations have been found 14 to 180 ppb in Belthara Road, Nagra, Rasra, Chilkahar, and Pandah, 181 to 360 ppb in Navanagar, Beruarwari, Gharwar, and Hanumanganj, 361 to 540 ppb in Maniyar and Sohaon, 541 to 720 ppb in Dubhad, Bansdeeh and Revati, 721 to 820 ppb in Beriya, Belhari and Murlichapra blocks. But in post-monsoon these values were 23 to 950 (Fig. 5) i.e. 23-180, 181-360, 361-540, 541-720 and 720-950 ppb, in above cited area, respectively.

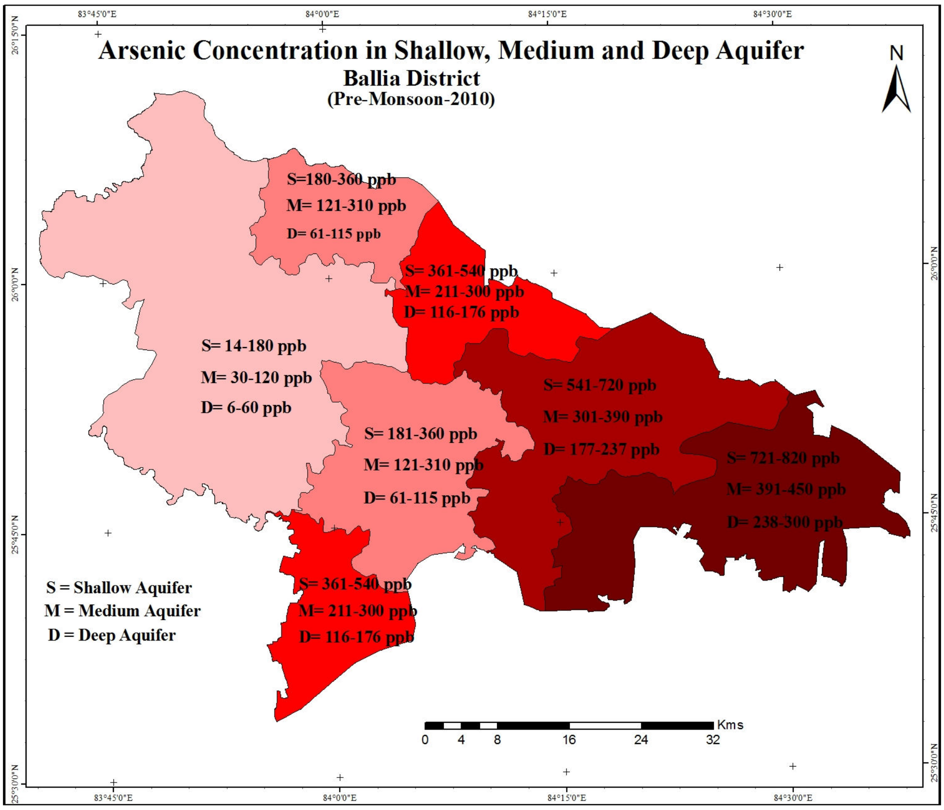

Fig. 4. Arsenic concentration in shallow, medium and deep aquiferin Ballia district, pre-monsoon-2010

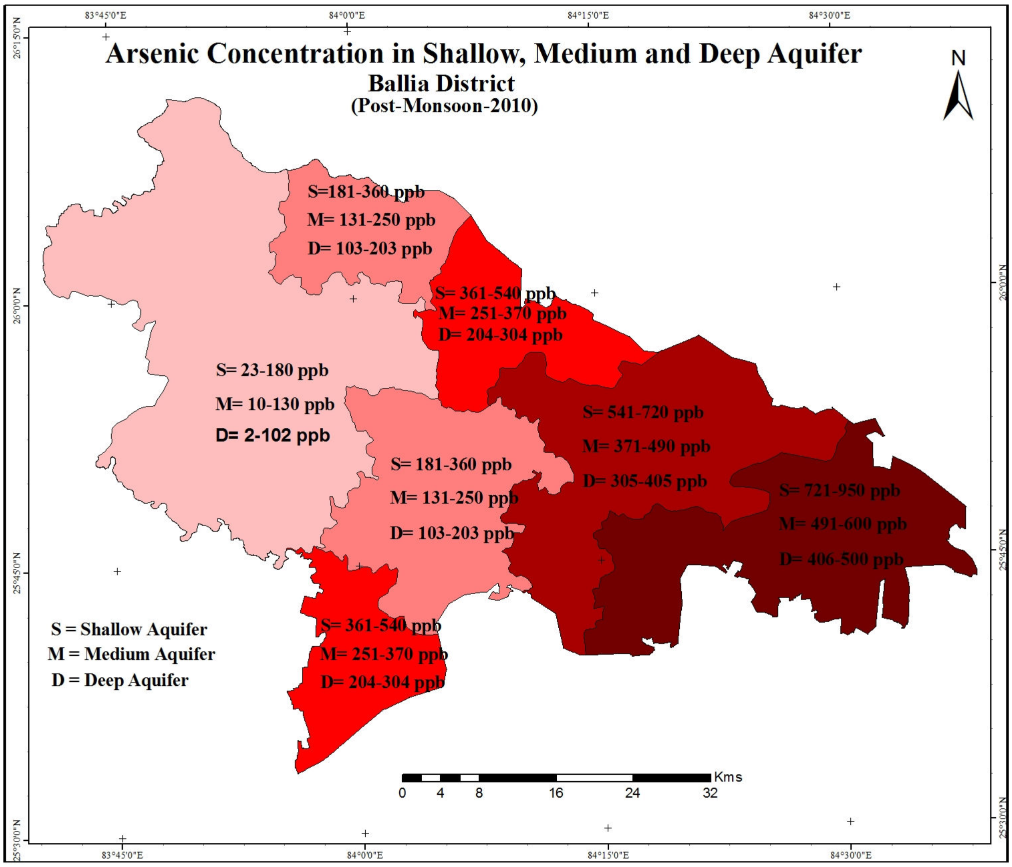

Fig. 5. Arsenic concentration in shallow, medium and deep aquiferin Ballia district, post-monsoon-2010

In medium aquifer, the map indicated arsenic values varied from 30 to 450 ppb in pre-monsoon 2010 (Fig. 4). Arsenic concentrations have been found 30 to 120 ppb in Belthara Road, Nagra, Rasra, Chilkahar, and Pandah, 121 to 210 ppb in Navanagar, Beruarwari, Gharwar, and Hanumanganj, 211 to 300 ppb in Maniyar and Sohaon, 301 to 390 ppb in Dubhad, Bansdeeh and Revati, 391 to 450 ppb in Beriya, Belhari and Murlichapra blocks. But in post-monsoon these values were 10 to 600 (Fig. 5) i.e. 10-130, 131-250, 251-370, 371-490 and 491-600 ppb in above cited area, respectively.

In deep aquifer, the map indicated arsenic values varied from 6 to 300 ppb in pre-monsoon 2010 (Fig. 4). Arsenic concentrations have been found 6 to 60 ppb in Belthara Road, Nagra, Rasra, Chilkahar, and Pandah, 61 to 115 ppb in Navanagar, Beruarwari, Gharwar, and Hanumanganj, 116 to 176 ppb in Maniyar and Sohaon, 177 to 237 ppb in Dubhad, Bansdeeh and Revati, 238 to 300 ppb in Beriya, Belhari and Murlichapra blocks. But in post-monsoon these values were 2 to 500 (Fig. 5) i.e. 2-102, 103-203, 204-304, 305-405 and 406-500 ppb in above cited area, respectively.

3.4. Arsenic, Geology and Meteorology of Ballia District

Basically, the study area comprises two geological features i.e. older and younger alluvium plains. Although arsenic has been reported in both older and younger alluvium plains yet the high concentrations were reported in younger alluvium plain. It may be due to the fact that the younger alluvium is un-oxidized in nature and consists of organic-rich sand silt and clay [20]. It is interesting to mention here that some authors [21-22] reported younger alluvium deposits as highly prone to arsenic contamination. The younger alluvium plains are restricted all along the river channels of the Ganga. Arsenic bearing pyrite minerals are transported with the fluvial sediments from the Himalayas along with the Ganga river. During the course of time these minerals get deposited into and younger alluvium plains. This may be the basic source of arsenic contamination into the ground water of Ballia district. Therefore, higher concentration of arsenic is present in the younger than older plains. High concentrations of arsenic in post-monsoon season are crucial issue in this study, which may be low rain fall during study period. Only 511.5 mm rainfall was observed in 2010, which was not sufficient to recharge the ground water. Besides, the excessive withdrawal of the ground water reduces the amount of the ground water in the study area, which resulted into an increase of arsenic concentration. Therefore, rainfall affected the concentration of arsenic in the groundwater, which may be called as seasonal variation in concentrations of arsenic between pre and post-monsoon seasons.

4. CONCLUSION

A systematic study was conducted in the Ballia District; UP to investigate the geochemistry of arsenic in ground water with a view to obtaining a better understanding regarding the mechanisms governing the mobilization of arsenic into the ground waters. The study involved one year collection of the ground water samples in and around Ballia district during two seasons namely, pre- and post-monsoons seasons. The samples were collected from deep, medium and shallow aquifers. Arsenic is found in all blocks of the study area. Arsenic concentrations varied from 6 to 820 ppb in pre-monsoon season while these ranged from 2 to 950 ppb in post-monsoon season. There was evidence of seasonal variation in concentrations of arsenic between pre and post-monsoon seasons. The concentrations of arsenic were higher in post-monsoon than pre-monsoon due to insufficient rainfall during study year. The results indicated that arsenic mitigation is from shallow to medium followed by deep aquifers. There is a risk that excessive ground water withdrawal from the deeper aquifers could induce their contamination by infiltration of arsenic into deeper ground water. Therefore, routine monitoring of tube wells for arsenic is necessary to ensure safe drinking water for a longer period.

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