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RESEARCH ARTICLE

ARSENIC CONTAMINATION OF GROUNDWATER AND HUMAN BLOOD IN VAISHALI DISTRICT OF BIHAR, INDIA: HEALTH HAZARDS.

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Abstract

Groundwater arsenic contamination has affected millions of people in the Middle-Gangetic Plain in India. In Bihar (India), 18 districts have been reported to be affected with groundwater arsenic poisoning in which majority of the effected population belongs to rural areas. In the present study, assessment of arsenic contamination in the groundwater of hand tube wells and human blood samples of village's subjects of Vaishali district of Bihar, India was undertaken. Four villages Tehrasiya, Chaunkia, Gopalpur and Kalyanpur village of two blocks Raghopur and Bidupur were the study sites. Maximum observed value of groundwater arsenic contamination was reported to be 1352µg/L from Tehrasiya village of Raghopur block. Arsenic contamination in human blood samples of the subject was found to be 368µg/L from the same household of the Tehrasiya Village of Raghopur Block. Prevalence of groundwater arsenic contamination and blood arsenic contamination was more than 50% in the overall studied population of the four villages. As a result of the arsenic poisoning villagers exhibited typical symptoms of arsenicosis in the subjects of all age groups. Present study, thus concludes that severity of groundwater arsenic contamination has led to serious health hazards to the rural population of Vaishali district of Bihar, India.

Introduction:-

Groundwater, which is used for drinking or domestic purposes, must be free from contamination; but because of industrialization, urbanization and various other sources, it is being contaminated. Heavy metals as chemical pollutants in the groundwater cause severe toxicity, carcinogenicity, and severe health-related diseases in the population (Park 2001; Antman 2001). Arsenic (As) contamination in groundwater is a major public health concern in different parts of the world for the last few decades. Arsenic has been identified in 105 countries in the world with an estimate of the exposed population of more than 200 million worldwide at concentration greater than the World Health Organization (WHO) guideline value of arsenic of 10µg/L (WHO 2011; Murcott, 2012; Naujokas et al. 2013) and it is likely that many other areas with elevated arsenic in groundwater will be found in the future.

Arsenic is abundant in the crust of the earth especially in soil, minerals, surface, and groundwater (Navin et al. 2013). The conditions under which arsenic can be released to the groundwater may expose the Indo-Gangetic plains

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to particular risks. The fluvial sediments from the Himalayas, which are composed of clay sand and silt, have been identified as the source of arsenic in the aquifers of the Indo-Gangetic plains (McArthur et al. 2004). The arsenic is released from the sediments into the groundwater through a microbiologically mediated reductive dissolution process (McArthur et al. 2001; Akai et al. 2004; Charlet and Polya 2006). In this process there is a high rate vertical percolation of surface water which takes place through the arsenic rich sediments. It is facilitated by the presence of rich organic matter ultimately influencing the solubility and mobility of arsenic in the groundwater (Islam et al. 2004; Rowland et al. 2006). Arsenic in the groundwater exists primarily as oxy anions representing two oxidation states: arsenite (As III) and arsenate (As V) (Azcue et al. 1994). Both exist within the pH range of 6–9 and it is well-established fact that arsenite (As III) is more toxic than arsenate (As V) (Kumar et al. 2015).

In Asian countries, the population inhabiting the Ganga-Meghna-Brahmaputra (GMB) plains of India and Bangladesh, are the worst arsenic affected regions in the world. In GMB-plain alone, currently more than 100 million people are at the risk from groundwater arsenic contamination above 10µg/L (Chakraborti et al. 2013). The Gangetic plain constitutes of states Uttarakhand, Uttar Pradesh, Bihar and West Bengal in India. The entire Gangetic plain of India-the upper Ganga plain, the middle Ganga plain and the lower Ganga plain are the regions with very high population density. The land here is highly fertile; hence agriculture is the main occupation and source of income of the rural population. Groundwater is the primary source of drinking, cooking, agriculture and other household purposes. In India, the most severe arsenic contamination has been first reported from the lower Ganga plains of West Bengal with correlation to groundwater arsenic poisoning (Garaiet al.1984). Arsenic contamination in the middle Ganga plains of Bihar was first reported in 2002 in Ojha Patti village, Shahpur block of Bhojpur district (Chakraborti et al. 2003). Several articles have already been published on the various aspects of groundwater arsenic contamination in the Bihar state, India including the extent and magnitude of contamination, human health effects from arsenic toxicity (Ghosh et al. 2009; Singh 2011; Singh and Ghosh 2011, 2012; Nath et al. 2013; Singh et al.2014; Singh 2015; Singh and Vedwan 2015; Kumar et al. 2015; Abhinav et al. 2016; Kumar et al. 2016; Chakraborti et al. 2016). These publications suggest that out of 38 districts of Bihar, 18 are affected from groundwater arsenic poisoning. Majority of the affected population belong to rural areas and are economically very poor. Due to unavailability of alternate source of potable groundwater and lack of knowledge, population of these areas are still drinking arsenic contaminated groundwater and are not aware of this fact and its consequences.

Provision of potable drinking water on a sustainable basis is a basic necessity, particularly in the rural India. Therefore, present study was undertaken in four villages under two blocks of Vaishali district in the middle Ganga plain of North-Bihar, India to know the prevalence of arsenic concentration in groundwater as well in the biological samples. The present study on groundwater arsenic toxicity in correlation with human biological samples is first ever study ever carried out in this area.

Materials and Methods:-

Ethical Approval: This study has been approved by Institutional Ethics Committee, Mahavir Cancer Institute and Research Centre, Patna, Bihar-India, as the work was on human subjects. Consents were taken from all the subjects and their young children for medical evaluation and photography before taking their biological samples. The survey and the sampling work were carried out in the months from January to May 2015.

Location: The study was conducted in Vaishali district in the North-Bihar, India, **(Fig.1).**Vaishali district covers an area of 2016 km^2 and consist of 16 blocks and 1531 villages inhabited by a total population of around 3.5 million (Census of India 2011). The study area included four villages from two blocks, Raghopur block (Diara Island) and Bidupur block of Vaishali district. This study was confined within the 10 kms from the north river bank of the Ganga. The Tehrasiya village (25º38.452'N, 085º13.203'E) and the Chaunkiya village (25º39.016'N, 085º13.700'E) comes under Raghopur block while, the Gopalpur village (25º37.124'N, 085º21.030'E) and the Kalyanpur village(25º41.005'N, 085º022.713'E) comes under Bidupur block.

Arsenic analysis and survey:-

Collection of samples: For this study, 48 groundwater (12 groundwater samples from each villages) and 48 human blood samples (12 blood samples from each villages of the same households marked for their groundwater arsenic analysis) were collected from all four villages of Vaishali district**.** Groundwater extracted by the hand tube-well (HTWs) is the primary source of drinking water in the study area. For the collection of groundwater samples, 250 ml polypropylene bottles were utilized and were cleaned and pre-treated with hydrochloric acid. Altogether, 48 groundwater samples were randomly collected in duplicates from HTWs of the households situated at every 50 meter of distance in the villages. Each hand tube-well was flushed for 10 minutes prior to collection of the water samples to remove the stagnant water and to get the actual representative groundwater samples followed by Nickson's protocol (Nickson et al. 2007) . For determining the exact location of the HTWs, hand held Global Positioning System (GPS) receivers (Garmin etrex10, USA) with an accuracy of ≈10 m was utilized. Depth of the hand tube wells were also recorded (Depth information was obtained from tube-well owners) for the correlation of arsenic concentration in groundwater with the depth of HTWs. For a total 48 human blood samples (2 ml from each subject) were collected in a vacutainer and the blood samples were kept in refrigerator at 2–4ºC adhering to standard procedures, followed by UNICEF (UNICEF 2008). After the collection, groundwater samples were on spot analysed by Merckquant Arsenic Field Test Kit (Merck, Germany) to know the trace of arsenic in the groundwater samples. Quantification of total arsenic present in groundwater as well as in human blood samples, the samples were analysed as per the NIOSH protocol (NIOSH 1994) through Graphite Furnace Atomic Absorption Spectrophotometer (Pinnacle 900T, Perkin Elmer, Singapore) technique with minimum arsenic detection limit of 0.001µg/L at Mahavir Cancer Institute and Research Centre, Patna, Bihar-India.

Health assessment: The suspected people of the four villages included in this study were exclusively interrogated and examined for arsenic related diseases and other health consequences to know their present health status. For this a questionnaire method was prepared, utilized and health related data were extensively collected (Singh et al. 2014).

Statistical analysis:-

All the data were analysed with statistical software (Graphad Prism 5.0) and values were expressed as mean ± SEM. Differences between the group were analysed by one way analysis of variance (ANOVA) using the Dunnet's test while scattered graphs were plotted through another statistical software SPSS-16.0 using linear regression analysis methods (Kumar et al. 2015)**.**

Results:-

Groundwater arsenic assessment:-

Result of groundwater analysis of all the 48 samples revealed high prevalence of total arsenic contamination. The highest arsenic concentration recorded in the groundwater sample was 1352µg/L from Tehrasiya village of Raghopur block. Overall maximum arsenic concentration recorded in the groundwater samples of all the four villages were 1352µg/L in Tehrasiya, 190µg/L in Chaukiya, 83µg/L in Gopalpur and 211µg/L in Kalyanpur village respectively (**Fig 2).**

Blood arsenic assessment:-

Altogether, 48 blood samples were analysed for total arsenic concentration. The highest arsenic concentration in the blood sample of the subject was 368µg/L of Tehrasiya village. Overall maximum arsenic concentration recorded in the blood samples of the subjects of all the four villages were 368µg/L in Tehrasiya, 139µg/L in Chaukiya, 11µg/L in Gopalpur and 9.5µg/L in Kalyanpur village respectively (**Fig 3**).

Health assessment:-

Altogether 500 subjects (125 subjects from each village) were interviewed during health assessment. Subject age interviewed in this study was between 05 to 70 years old. Many villagers exhibited typical symptoms of arsenicosis like hyperkeratosis in sole and palm. Few of the subjects exhibited hyper-pigmentation (spotted pigmentation) on their whole body **(Fig 4)**. Blackening of skin, nodular-keratosis of skull, typical arsenicosis symptoms on palm and sole and hyperkeratosis of skin were also observed in children's at the age of 05 to 15 year old **(Fig 5)**. Apart from typical symptoms of arsenicosis, other health related problems like gastrointestinal, liver, neurological disorder and hormonal imbalance were frequently observed.

Correlation coefficient study:-

Correlation coefficient between groundwater arsenic concentration and depth of HTWs: Depth of the 48 HTWs of all the four villages included in this study ranged from 10-50 metres. The average depth of the HTWs was found to be 25 metres. Elevated level of arsenic concentration was frequently observed in the groundwater collected from shallow HTWs in comparison to deep HTWs. A positive correlation was found between groundwater arsenic concentration and the depth of HTWs **(Fig 6 A)**.

Correlation coefficient between blood arsenic concentration and groundwater arsenic concentration*:* The results showed significant increase in blood arsenic levels with increased groundwater arsenic levels. Although, few blood samples did not correlate with elevated groundwater arsenic concentration **(Fig 6 B)**.

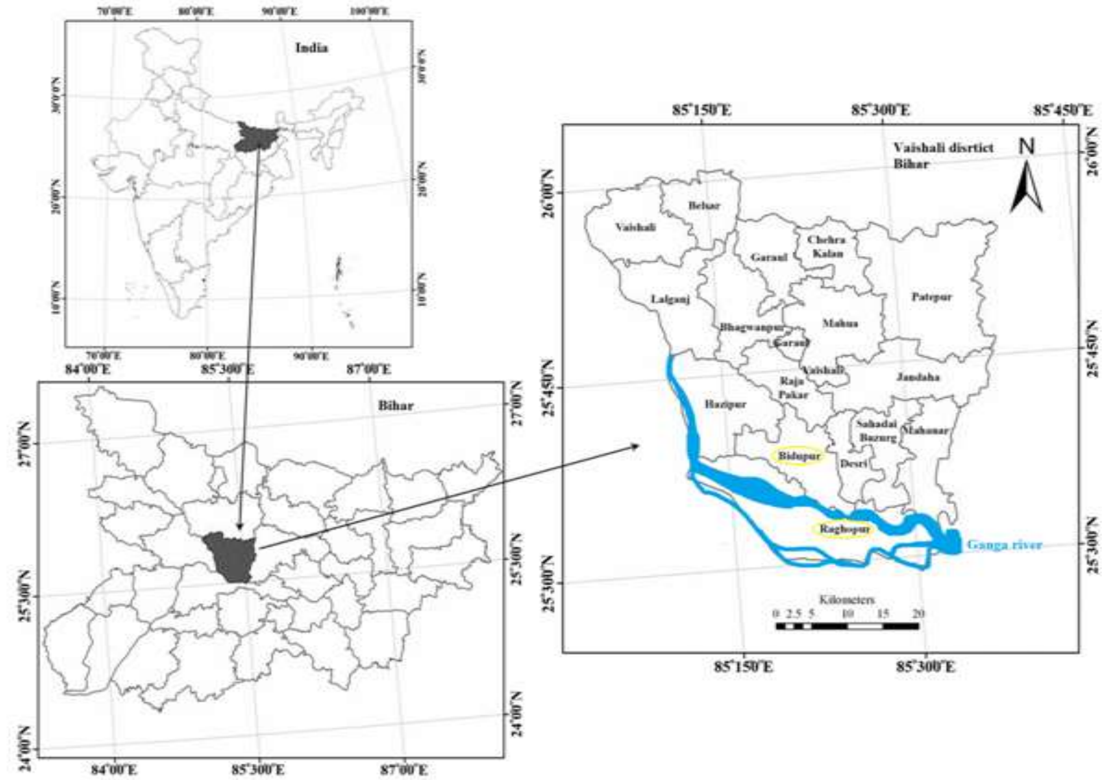

Figure 1 Study area: Two blocks Raghopur and Bidupur of Vaishali district, Bihar, India

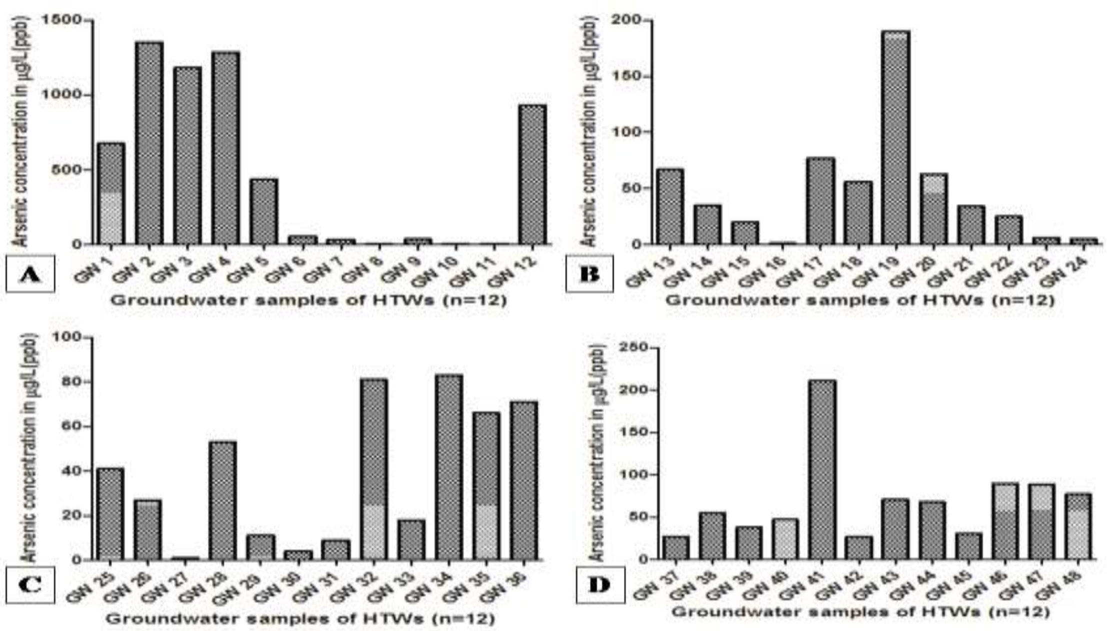

Figure 2. Arsenic level in the Groundwater of all the four villages (A) Tehrasiya (B) Chaunkiya (C) Gopalpur and (D) Kalyanpur

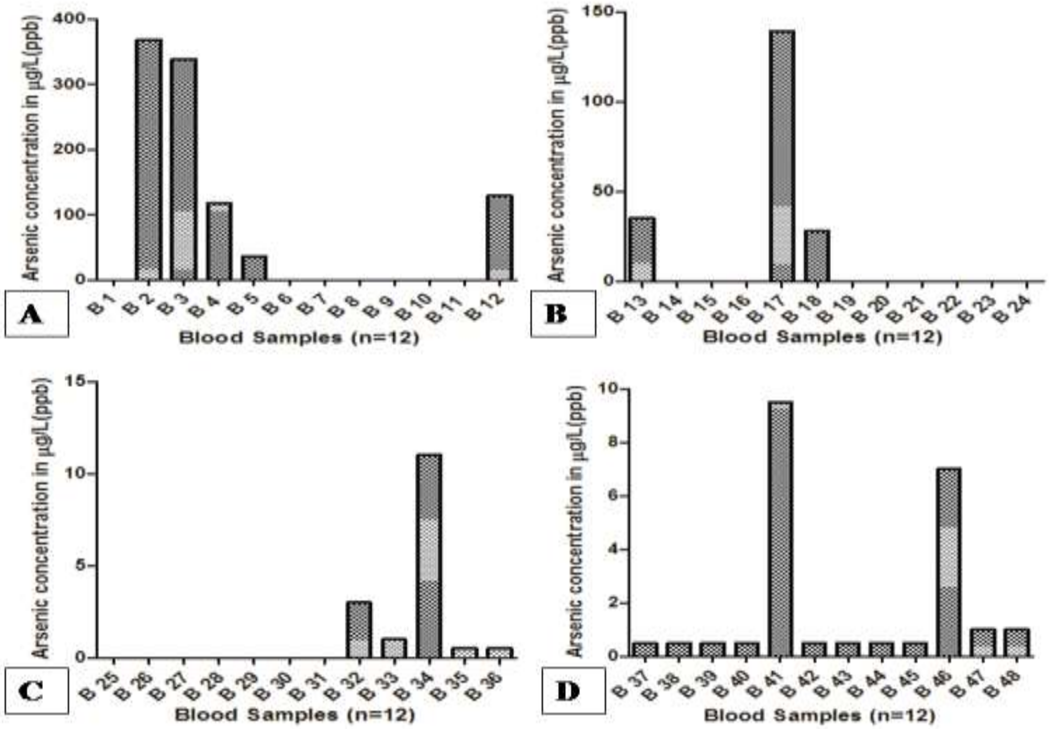

Figure 3: Arsenic level in the Blood samples of all the four villages (A) Tehrasiya (B) Chaunkiya (C) Gopalpur and (D) Kalyanpur

Arsenicosis of palm in 55 year old female

Spotted pigmentation in 30 year old female

Whole body pigmentation in 60 year old male

Hyperkeratosis of leg in 45 year old female

Figure 4. Typical arsenicosis symptoms in the subjects above the age of 18 of the four villages .

Figure 5 Typical arsenicosis symptoms in the subjects below the age of 18 of the four villages of Viashali district, Bihar, India

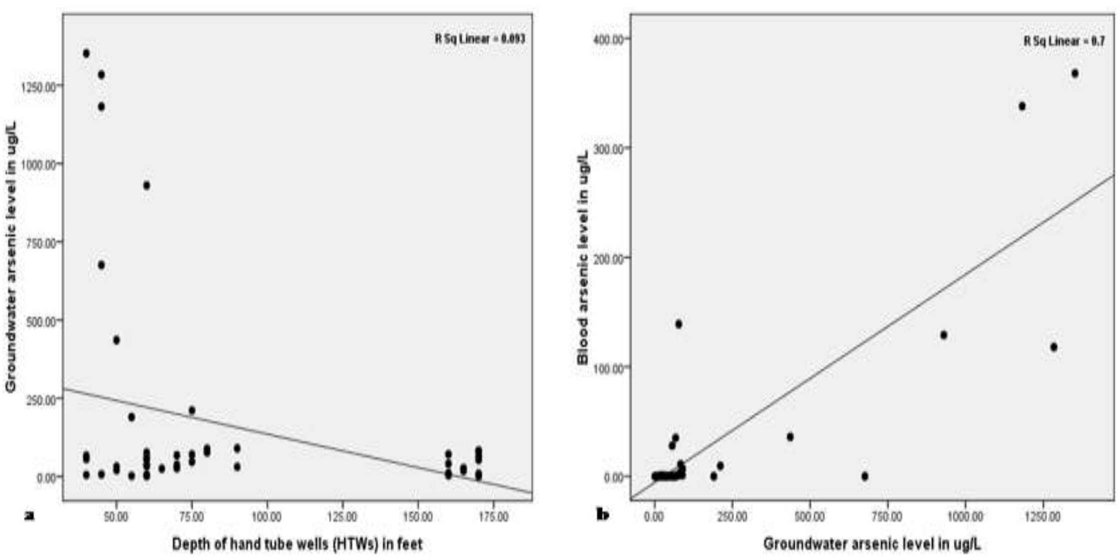

Figure 6 a&b Correlation coefficient between groundwater arsenic level and depth of HTWs and Correlation coefficient between blood arsenic level and groundwater arsenic level

Discussion:-

Severity of arsenic contaminated groundwater and its adverse effect on public health in the lower Gangetic plains of West Bengal, India, was first identified in July 1983 (Ghosh et al. 2009 and Singh et al. 2011). After two decades of this incidence first foot print of groundwater arsenic poisoning in the middle Gangetic plains of Bihar, India, was identified in July 2002, in the Bhojpur district of Bihar (Akai *et al.* 2004 and Singh *et al.* 2011). Incidence of groundwater arsenic contamination and its health hazards in the rural population of state of Bihar has increased at a higher rate in past twenty years (Charlet and Polya 2006; Singh and Ghosh 2012). Presently, Bihar is the second highest arsenic contaminated state followed by West Bengal in India.

First incidence of arsenic contaminated groundwater was jointly reported by two government agencies Central Ground Water Board, Govt. of India and Public Health and Engineering Department, Govt. of Bihar respectively in few blocks of Vaishali district of Bihar (CGWB 2007; PHED 2009). According to the report only few groundwater samples show arsenic concentration above the permissible limit of 50µg/L set by government of India (BIS 2012). In the present study, the groundwater sample test results revealed that all the four villages of the district Viashali are exposed to arsenic concentrations exceeding 50µg/L (the permissible limit of arsenic in drinking water set by the government of India; the limit for acceptable safe drinking water is 1µg/L). Maximum observed value of arsenic concentration in the groundwater samples of HTWs from all the four villages was much higher than the acceptable range recommended by World Health organisation. In the present study, the water samples analysed showed significant arsenic concentration above the permissible limit of ≤10µg/L. Previous studies also suggested that Raghopur and Bidupur were the most exposed and the same blocks where groundwater arsenic contamination has already been detected (Chakraborti etal. 2009; Singh et al. 2014). Recently, a statistical geospatial model also predicted Raghopur, Bidupur and Hajipur as unsafe arsenic aquifer blocks of Vaishali districts located in the vicinity of the river Ganga (Jangle et al. 2016). Depths of the sampled HTWs from the studied areas were also included as one of the parameter to compare the correlation with groundwater arsenic poisoning and the result revealed a positive correlation. The shallow aquifer was found to be more arsenic contaminated and deep aquifer was least or safe. This type of result was also found for the same study area in previous years (Saha et al. 2009, 2011; Saha and Shukla 2013).

Biological samples act as biomarker for arsenic exposure. Determination of arsenic in urine is generally considered as most reliable indicator of recent exposure in humans (NRC, 1999). Elevated arsenic levels in hair and nails are a good indicator of past exposure (generally 6-12 months) (NRC, 1999). Elevated arsenic level in blood act a good indicator with long-term exposure (more than one year) of arsenic. The literature suggested that blood receives inputs not only from recent exogenous exposure but also from tissue compartments may better reflect an individual’s total internal arsenic burden (Hall et al. 2006). World Health Organisation (WHO 2011) and the U.S. Environmental Protection Agency (USEPA 1999) have well recommended threshold of 1µg/L inorganic arsenic concentration in human blood. In the present study blood samples results showed significant arsenic concentrations in them. Similar work has been carried out in different regions of India including Bihar (Katiyar and Singh 2013: Abhinav et al. 2016). Frequently, observed typical symptoms of arsenicosis in the villagers revealed the magnitude of the severity of groundwater arsenic poisoning among four villages of Vaishali district. There are several factors which directly influence the prevalence of skin lesions in arsenic exposed rural population like nutritional factors and poor socio-economical status which enhance the risk of arsenicosis (Chowdhury et al. 2000; Chowdhury et al. 2001; Mitra et al. 2004. Therefore, the present study on blood arsenic levels and its correlation with groundwater arsenic contamination in the rural population of Vaishali district of Bihar has been assayed for the first time.

Conclusion:-

From the entire study, it can be concluded that the magnitude of arsenic groundwater contamination is severe in all the four villages of Vaishali district. Incidence of arsenic contamination of groundwater has increased at a higher rate in last one decade. Presence of arsenic in the blood samples of the subjects of all the age groups are very alarming. It reflects that there is no any or limited alternate safe source of drinking, cooking and irrigation water supply in these areas. The study also concludes that inhabitant population of these four villages of two blocks are not showing arsenical skin lesions, but are sub-clinically affected. Therefore, the arsenic exposed population of these villages need proper health care management. Furthermore, the future health risk can be controlled through supply of safe drinking water.

Disclosure of Interest:-

The authors declare that they have no conflict of interest concerning this article.

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