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Research Paper

A Review of Arsenic Contamination in Groundwater in Gangetic Plain as well as in Plateau Area of the Jharkhand State of India

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ABSTRACT

Across the globe, there are 107 countries and in India, 20 states and 4 Union territories have reported arsenic-contaminated drinking water. Jharkhand is one of the Indian states in which nine districts (approximately 37% districts), out of 24 districts have reported arsenic-contaminated drinking water as reviewed in the different research papers. Almost, all 6 districts of the Santhal Paragana division of Jharkhand viz. Sahibganj, Pakur, Godda, Dumka, Deoghar and Jamtara have reported arsenic contamination in their drinking water and few districts of Chhotanagpur Plateau viz Giridih, Ranchi and Hazaribagh have also reported the arsenic contamination in their drinking water. One affected district (11% approximately) out of 9 districts in Jharkhand is in the Gangetic plain while 8 affected districts (88% approximately) are plateau regions. The maximum concentration of arsenic is reported at 1.5, 0.2 and 1.2 mg/l in Sahebganj, Ranchi and Deoghar districts respectively which is more than the permissible limit of World Health Organization(WHO) Standards (0.01mg/l) and the Bureau of Indian Standards (0.01mg/l). The review study reveals that the arsenic contamination in Jharkhand is not only limited to the Gangetic plain but also to the plateau region.

Keywords: Arsenic Contamination; Groundwater; Gangetic Plain; Plateau area; Santhal Paragana

INTRODUCTION

The term "Arsenic" is derived from the Greek word "arsenikos" which means "male" or "virile", further, this is taken in Latin as "arsenicum" and in French as "arsenic". It has also an origin in Arabic word as "al Zarnik" which means "yellow or gold coloured" which is similar to colour of arsenic ores, Orpiment or realgar (Douglas, 2010).The use of arsenic is known from ancient times as either medicine or chemical pigments or as poison to murder the emperor, so it is also called the "king of poison or poison king" (Vahidnia et al., 2010). It is found in the earth's crust at 1.5 ppm and 53rd most abundant element out of the total 80 elements in the earth's crust (Emsley, 1998). It is found in the form of the compound of iron, Sulphur and other metals such as copper and different forms of arsenic ores contain sulphur such as Orpiment (As_2S_3), Realgar (As_4S_4) and Arsenolite (As_2O_3) and others.

The discovery of the arsenic element lies in the work of the Alchemist during the middle ages of the world. Around 300 BC, Theophrastus, Aristotle's pupil, recognized the two forms of what he called Arsenic, but these were not the pure elemental form of Arsenic. These were the arsenic sulfides minerals, Orpiment, As2

S3 and Realgar, As4 S4 (Emsley, 1998*)*. The toxicity and its use as pesticides in the Rice fields are also mentioned in the Chinese encyclopedia of Pen Ts'aoKan-Mu. The making of Gold from arsenic was also written by the Roman writer, Pliny and he wrote that King Caligula (12-41 AD) had financed one project to make gold from arsenic but the amount of gold was so little that the project was abandoned (Emsley, 1998). Although the arsenic compounds were mined by the Chinese, Greek and Egyptian civilizations but the credit for the discovery of the elemental arsenic goes to a German scientist, Albertus Magnus in 1250 AD. He obtained the elemental arsenic (As) as a sublimate product by heating the arsenic trioxide (White Arsenic, dangerous arsenic) with vegetable oil (Emsley, 1998).

Study area

The selected study area for review of the arsenic contamination in groundwater is Jharkhand which is a newly formed state from Bihar on 15th Nov 2000. It lies at latitude $21^0 55' 00"$ N to $25^0 15'00"$ N and Longitude $83^0 15'00"$ E to $87^0 55'00"$ E. It has 24 districts, 62 Blocks and 32620 Villages and a 79714 km^2 area (Kumari and Pathak, 2014).The state of Jharkhand is mainly known as the "land of forest and Tribal" because a major portion of the state is covered by forest as well as Tribal, which is further, divided into the five zones for administrative and political purposes viz SanthalPargana, North Chhotanagpur, South Chhotanagpur, Kolhan and Palamu. The districts Sahibgnaj, Godda, Pakur, Dumka, Deoghar and Jamtara are lies under SanthalPragana and the districts East Singhbhum, WestSinghbhum, Saraikela are under Kolhan and Garhwa, Palamu (Daltanganj), Latehar are under Palamu division and rest all districts are under the Chhotnagpur. So, the major portions of the state lie on the Chhotnagpur Plateau which is made up of Gneisses and Granites lithological. The study area's administrative and natural drainage is shown in Fig. 1.

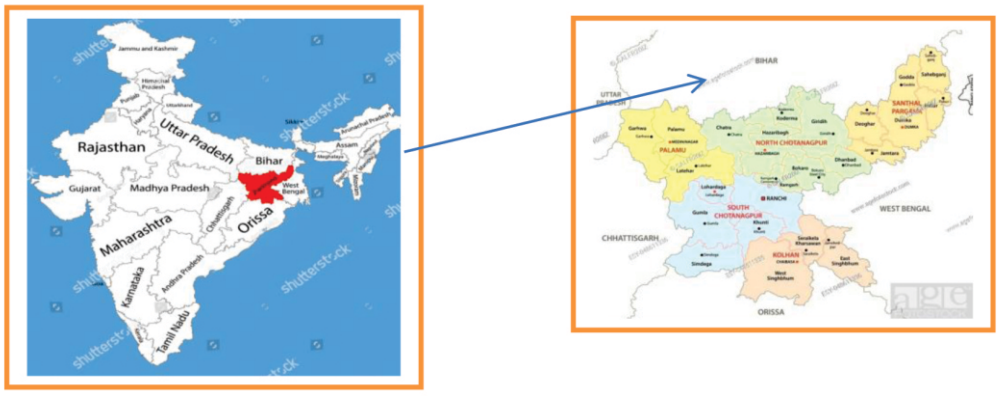


Fig.1 Location map of the study area

DISCUSSION

Sources of Arsenic

There are mainly two sources of arsenic in the environment which contaminate drinking water. These two sources are natural and anthropogenic. Arsenic is found in the earth's crust and is a constituent of 245 minerals species approximately. It is found in the form of alloys (4 minerals), arsenide (27 Minerals), sulfides

(13 minerals), and Sulfosalt which is the sulfides of arsenic with metals such as lead, copper, silver and thallium (65 minerals) and oxidation products (2 Oxides, 11 Arsenities,116 Arsenates and 7 Silicates) (National Academy of Science. Washington DC 1997). Out of these minerals, the most important are pyrites which contain approximately 5% arsenic content and sulfides and sulfosalts are oxidized readily under surface conditions. In the USA, some experts and scientists have analyzed Igneous and sedimentary rock to find out the arsenic concentration which is shown in Fig. 2 and Fig. 3. The graph is showing the maximum arsenic concentration in ultrabasic and cilicic volcanic in the igneous rock (3.00ppm) and iron-containing sedimentary ores (400ppm) in the sedimentary rock respectively (National Academy of Science, 1997).

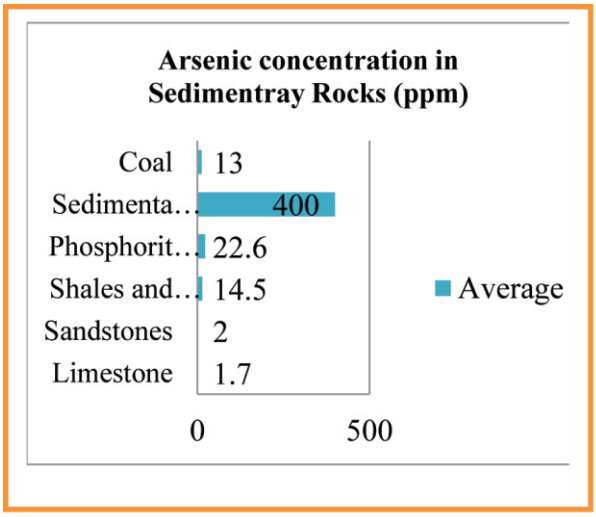


Fig. 2 Arsenic concentration in Igneous Rock

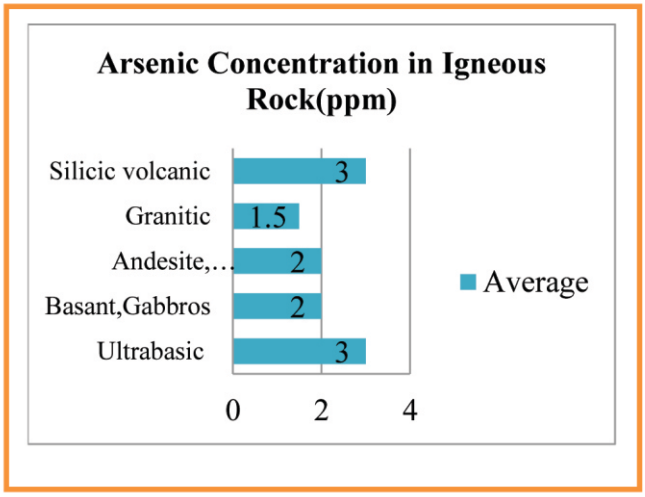


Fig. 3 Arsenic concentration in sedimentary rock

Although, a detailed study of the arsenic concentration in the igneous rock of Jharkhand was not done. The maximum part of the Jharkhand is situated on the plateau of Chhotanagpur which is made up of Igneous Rock, So, the concentration of arsenic shown in graph-1 & 2, may be the strong relation of arsenic contamination in the plateau area rather than the Gangetic plain area. So, the natural causes of arsenic contamination in the drinking water in Jharkhand are geogenic in the Chhotangapur plateau and arsenic-containing alluvial soil in the Gangetic plain or its near about area in Santhal Pragana division of the Jharkhand.

The sources of arsenic which are generated through human activities are called anthropogenic sources. It is account for 8200 Metric tons per year worldwide (Bhattacharya et al., 2002). The anthropogenic sources of arsenic are mining, and smelting where it is found with other metals such as copper, gold, iron etc. Few anthropogenic industrial processes directly release arsenic into the environment such as wood preservatives (Chromated copper Arsenate-CCA), mining of arsenopyrite, electrical waste (semiconductors), insecticides, pesticides, weed controller, disposal of industrial and sewage materials and paint products (Webb, 1963; Bhattacharya et al., 2007). Approximately, 55% of affected countries have natural sources of arsenic contamination and 27 % of countries have anthropogenic sources of contamination and only 18% of countries have both sources of arsenic contamination which are shown in Fig. 4.

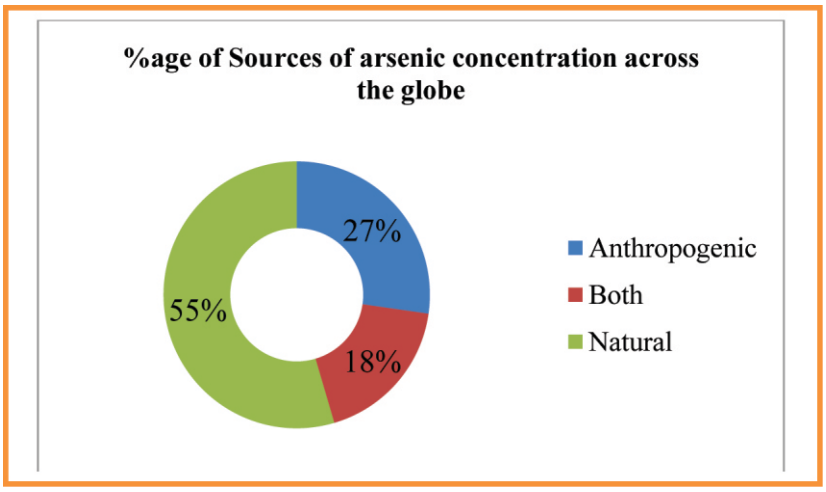


Fig. 4 Sources of arsenic concentration across the globe

Standards for Arsenic in Drinking water

The history of international standards for Arsenic in drinking water goes back to 1958 when World Health Organization (WHO) published the first version of "International Standards for Drinking Water" in which it was kept at 0.2mg/l (WHO, 1958). On the second time, it was reduced to 0.05mg/l by WHO in 1963 without any proper justification (WHO, 1963). In 1971 and 1984, the value of standards was kept the same at 0.05mg/l (WHO, 1971, 1984) and in 1993; it was reduced to 0.01mg/l (WHO, 1993).Several countries have adopted the WHOs recommendation of the 1993 version i.e. 0.01mg/l but few countries have delayed and few are still following the previous version of WHOs recommendation i.e.0.05mg/l as shown in Fig. 5. Numbers of countries following different permissible limits are given in Fig. 6.

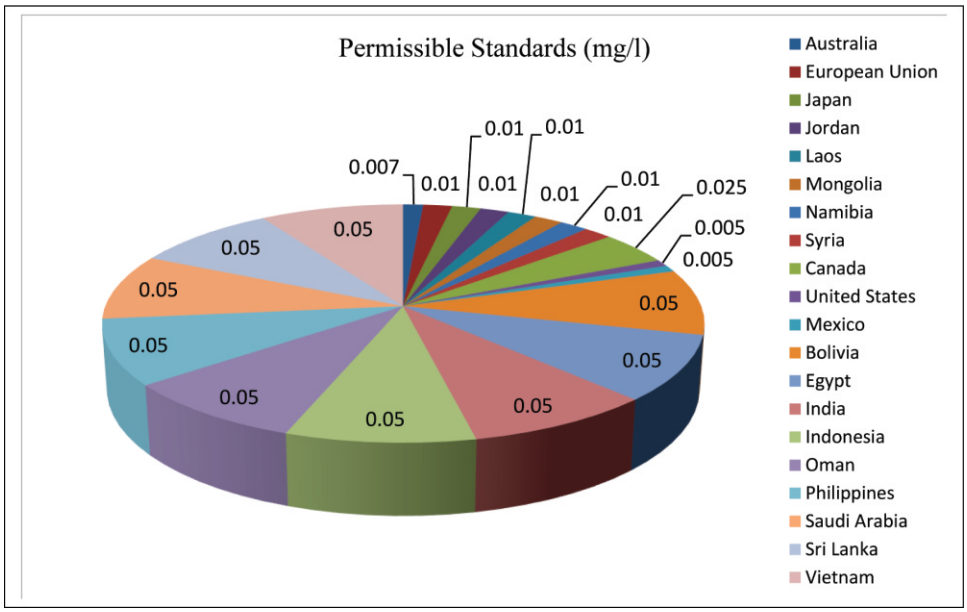


Fig. 5 Different permissible standards of Arsenic for drinking water across the globe

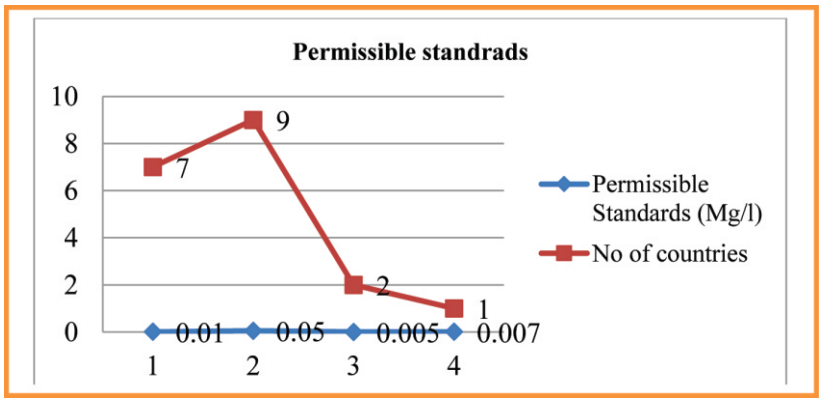
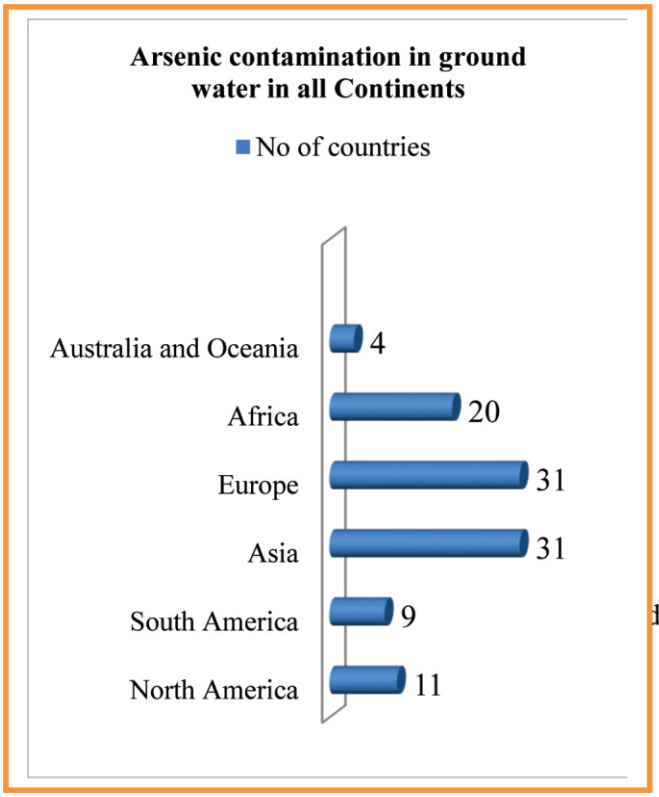


Fig. 6 Different permissible standards vs. countries

Arsenic contamination across the globe

The first time, arsenic contamination over the globe came to light in Germany in 1885. In the 20th century, nearly five countries viz India, Bangladesh, China, Taiwan and Thailand reported arsenic contamination in groundwater across the world (Chakraborti et al., 2019). But now, arsenic contamination in the drinking water has been reported in more than 100 countries on all five continents of the world. The worst affected continents are Asia, Europe and Africa (Shaji et al., 2021) as reflected in Fig. 7 and 8.



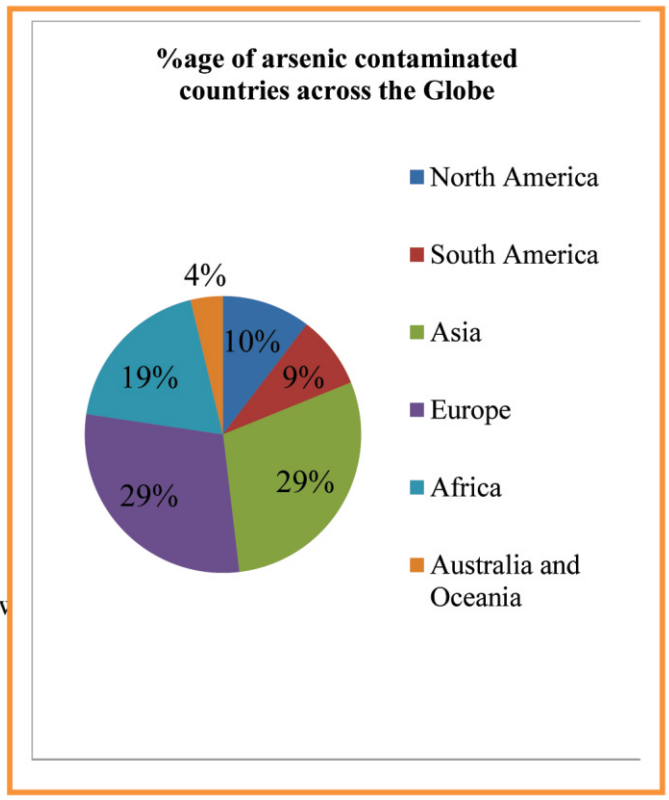


Fig. 7 No of the countries affected across the globe

Fig. 8 Percentage of countries affected across the globe

Arsenic Contamination in India

In India, first time, it was reported in groundwater in Chandigarh and north Punjab in 1976 (Biswajit et al., 2008) and later in four districts of West Bengal in 1983 (Singh et al., 2003) and its impact on human beings was reported with maximum concentration 3.0 mg/l. Nowadays, it is reported that 20 states and 4 union territories are affected by arsenic contamination in groundwater (Shaji et al., 2021) such as Bihar, Assam, Uttar Pradesh, Punjab, Haryana, Karnataka and Jharkhand, which is shown in Fig. 9.

Arsenic Contamination in Jharkhand

In Jharkhand, arsenic contamination in groundwater has been reported first time in three blocks (Udhwa, Rajmahal and Sahibganj) of the Sahibganj district which is situated on the bank of river Ganga Plain in 2003-2004. The Maximum concentration of arsenic in groundwater in these blocks of the Sahibganj district has been reported up to 0.09 mg/l (Biswajit et al., 2008). In 2014, the Godda district (Dubey et al., 2014)of Jharkhand under tribal dominated Santhal Pragana region also reported arsenic contamination in both surface and groundwater samples in a few villages of Barijor block and its concentration was above (0.053 mg/l) the permissible limit of BIS standards (0.010mg/l).

Fig. 9 Arsenic affected states and union territories in India

Tirky et al. (2016) conducted the assessment of heavy metals in groundwater in Tunkitola near Kokar industrial peri-urban area of Ranchi, Jharkhand and reported that 15.91% of samples in monsoon season had concentrations more than BIS permissible limit (0.010 mg/l) and maximum concentration was up to 0.2mg/l. In the pre-monsoon season, it was found that only 3.13% sample had concentrations beyond the BIS and up to 0.015mg/l maximum, whereas in the post-monsoon season, it was found below the detection limit (0.002mg/l). Later, in 2018, it was also reported in Ranchi urban area, Pathalkudwa of Ranchi districts (Bhengra et al., 2018, Tirky et al., 2018). In 2017-2018, arsenic contamination was also reported in the municipal area of the Pakur districts (Dumraj et al., 2018) in the Jharkhand but the level of concentration was just equivalent (0.010 -0.012 mg/l) to the permissible limit of the BIS standards. In December 2019, arsenic contamination in groundwater has reported in the Urban area of Deoghar district (Kumar, 2019) of Jharkhand and the maximum concentration was up to 1.2 mg/l (Table 1). Few districts such as Dumka, Jamtara of SanthalPragana Division and Gridih, Hazaribagh district of Chhotangapur Plateau have also reported arsenic contamination in their groundwater (Fig. 10). Maximum concentration of Arsenic in groundwater of Jharkhand is shown in Fig. 11.

Table 1 Arsenic contamination in groundwater in Jharkhand

S. No	Districts	Rural/ Urban	Year of Detection	Maximum Concentration(mg/l)	References
1	Sahibganj	Rural	2003	1.5	Nayak et al. (2007)
2	Ranchi	Periurban/ urban	2014	0.2	Tirky et a l.(2016, 2018); Bhengra et al. (2018)
3	Deoghar	Urban	2019	1.2	Kumar (2019)
4	Godda	Rural	2014	0.053	Dubey et al. (2014)
5	Pakur	Urban	2017	0.012	Saha et al. (2019)

Fig. 10 Arsenic-affected districts in Jharkhand

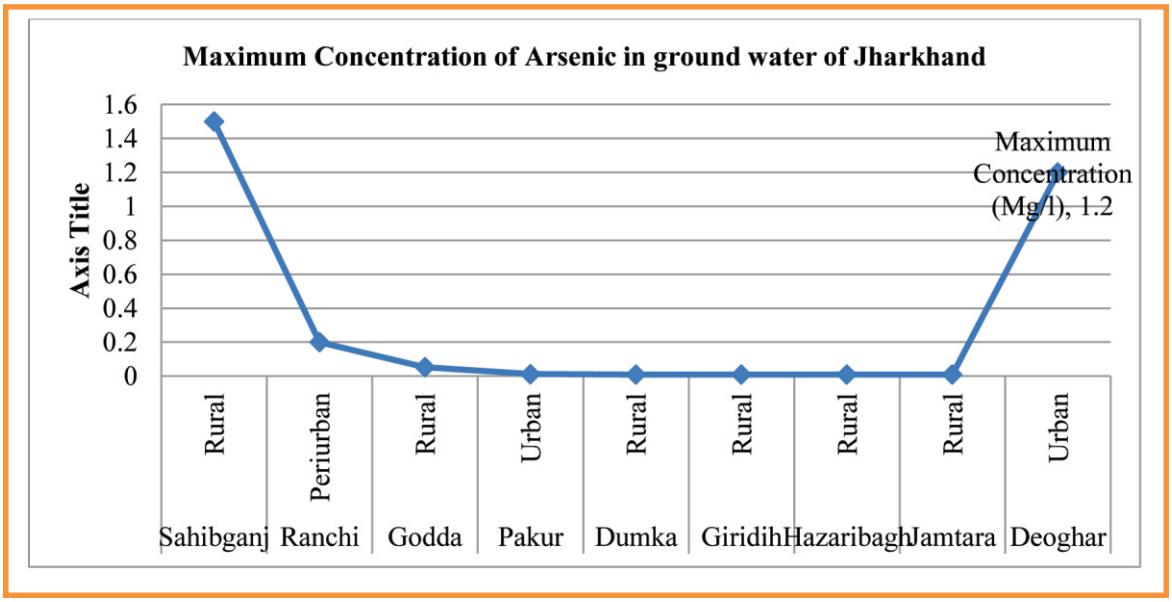


Fig. 11 Maximum concentration of Arsenic in groundwater of Jharkhand

Policy Guideline Concerned to Arsenic

Water supply is the state subject and included in the 11th schedule of the constitution. The National Rural Drinking Water Programme (NRDWP) which was under the Ministry of Jal Shakti (Previously, called The Ministry of Drinking Water and Sanitation) has certain provisions for the water quality affected area. The state can use 20% fund of NRDWP annual budget and even 67% if state has more issues regarding water quality. The water quality Monitoring & Surveillance (WQMS) programme was started in Feb 2006 under NRDWP to address the issues of water quality by the community Involvement and Panchayat Raj and then 5% fund are earmarked to states in 2011((Shrivastava, 2016)) and then National submission on water quality programe (NSWQP) specially for the arsenic, fluoride, nitrate and Iron in 2017 and in the same year the Arsenic Contamination (Prevention) Bill 2017 was brought in Lok Sabha to provide for effective regulation of the level of arsenic in ground water and identification of the risk areas of arsenic contamination, formulation of a national policy for mitigating and preventing arsenic contamination in food and drinking water in the country for the overall welfare, care and protection of the citizen. Now Jal Jeevan Mission (JJM) was started in 2019 to cover all aspects of the water supply including special plan for arsenic, fluoride, Nitrate and Iron affected area.

CONCLUSIONS

As per a detailed review of a research paper, approximately more than 100 countries across the globe have arsenic-contaminated groundwater which accounts for 29% of countries in the European and Asian continents. So Europe and Asia are worst affected by the arsenic contaminated drinking water. The natural sources of arsenic are igneous rock and sedimentary rock and the maximum concentration was found in Silicic Volcanic & Ultrabasic Igneous rock (3 mg/l) and sedimentary Iron Ores (400 mg/l). Approximately 55% of countries have

natural sources of contamination, and 27% of affected countries have anthropogenic sources of contamination and 18% of countries have both, anthropogenic & natural sources of contamination. There are 9 districts, out of 24 districts of Jharkhand, having an arsenic concentration in their drinking water. Almost, all 6 districts (out of 9 affected districts of Jharkhand) of Santhal Paragana division viz Sahibganj, Pakur, Godda, Dumka, Deoghar and Jamtara districts have reported arsenic contamination in their drinking water and a few districts of Chhotanagpur Plateau viz Giridih and Ranchi have also reported the arsenic contamination in their drinking water. The maximum concentration of arsenic is reported at 1.5 mg/l, 0.2 mg/l and 1.2 mg/l in Sahebganj, Ranchi and Deoghar districts, respectively. The different research papers also revealed that Coal mining and metal processing, smelting of copper, having arsenic-contaminated drinking water (Shaji et al., 2021) across the globe. In Jharkhand, Bokaro and Dhanbad districts are the coal mining area and East Singhbhum, and West Sighbhum districts are concerned with both coal mining and copper smelting process area, so it is a probability of arsenic contamination in these districts also but there is no detailed study has been laid out in these districts. So, our study review is going to put the finger to study the arsenic contamination in the Kolhan division (East Singhbhum, West Singhbhum and Saraikela) also. The review study also reveals that the arsenic contamination in Jharkhand is not only limited to the Gangetic plain but also the plateau region. All 9 districts except Sahibganj are in the plateau area. Only Sahibganj district is under the Gangetic plain. So Fig. 6 is clearly showing the arsenic contamination in the Gangetic plain as well as in the plateau area of Jharkhand. But the arsenic contamination in drinking water in the plateau region is more (88% districts) than in the Gangetic plain (11%) in the Jharkhand. The water quality monitoring & Surveillance programme should be very effective especially for Arsenic, Fluoride, Nitrate and Iron by involving community and apex research and Development center and University (State & Central both) with proper awareness of preventive measures and mitigations.

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