भारत सरकार

GOVERNMENT OF INDIA

जलशक्तिमंत्रालय

MINISTRY OF JAL SHAKTI

जल संसाधन, नदी विकासऔर गंगा संरक्षणविभाग

DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION

केंद्रीय भूजल बोर्ड

CENTRAL GROUND WATER BOARD

URANIUM OCCURRENCE IN SHALLOW AQUIFER IN INDIA

CHQ, FARIDABAD

JUNE 2020

G C Pati
Chairman

भारत सरकार
केन्द्रीय भूमि जल बोर्ड
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग

Government of India
Central Ground Water Board
Ministry of Jal Shakti
Department of Water Resources,
River Development and Ganga Rejuvenation

FOREWORD

Water has a profound influence on human health and quality of the water supplied have significant impact on the health of individuals as well as the whole community. Safe water is a major concern with reference to public health and the well-being of the society. In CGWB, investigations are being carried out regularly for deciphering physico-chemical parameters of ground water. Uranium is one of the natural radionuclide which is sometimes found in ground water in minute quantity. Water with Uranium concentration above the maximum acceptable limit (WHO limit) of 30 µg/L, is not safe for drinking purposes. On continuous intake, it can cause damage to internal organs and can cause leukemia, stomach and urinary tract cancer as well as kidney toxicity. In the year 2019-20 CGW has made an attempt for the analysis of Uranium in shallow ground water in India based on samples collected from approximately 15000 Hydrograph Network Stations. The present report, "Uranium Contamination in Shallow Ground Water in India", summarizes the various aspects of Uranium contamination in Ground Water, and its impact on the natural environment. The State wise maps demarcating the locations of ground water with high Uranium content is the highlight of the report. Utmost caution needs to be exercised in these areas for using ground water for drinking purposes.

The efforts made by Dr. S K Srivastava and the team, who have put their best to bring out the report is highly appreciable. I am confident that the report would serve as an excellent source material for all the stakeholders in ground water including planners, researchers and even end users.

G. C. Pati
Chairman

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Central Ground Water Board

PREFACE

In recent years, the increasing threat to groundwater quality due to human activities has become a matter of great concern. A majority of groundwater quality problems are caused by contamination and by over-exploitation, or by combination of both. In many areas groundwater is the only source of drinking water, thus a large population is exposed to risk of consuming contaminated water.

Uranium in drinking water raises concerns not because of radioactivity but mainly because of its chemical toxicity. The main source of the uranium contamination is natural or geogenic. Several earlier studies have linked uranium in drinking water to kidney diseases. The World Health Organization has set a provisional safety standard of 30 micrograms of uranium per litre.

In the year 2019-20 CGWB has attempted first time for the analysis of Uranium in shallow Ground Water in India based on samples collected from approximately 15000 Hydrograph Network Stations of CGWB. Present report is compilation of the data and summarizes the various aspects of Uranium contamination in Ground Water in India along with few remediation techniques.

The sincere efforts made by Dr. S K Srivastava and his team of chemists of CGWB to bring out the report is highly appreciable. I am confident that the report would serve as a baseline material for all the stakeholders in ground water including planners, researchers and even end users.

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URANIUM OCCURENCE IN SHALLOW AQUIFER IN INDIA

EXECUTIVE SUMMARY

1. Uranium is a naturally occurring radioactive metal that occurs in low concentrations in nature. It is present in certain types of soils and rocks, especially granites. Studies have revealed that Uranium in drinking water causes Nephritis (kidney damage). This is caused by the chemical effect of uranium, rather than a radiological, even though uranium is radioactive in nature.
2. Central Ground Water Board has taken pro-active steps for monitoring of uranium contamination in shallow ground water located all across the country during 2019-20. A total of 14377 groundwater samples were collected from shallow wells water sources across the country which are being monitored by CGWB regularly.
3. Uranium concentrations in shallow ground water in India, shows a wide range from 0.0 to 2876 µg/L, indicating that uranium concentrations in groundwater greatly vary by several orders of magnitude. The Bureau of Indian Standards (BIS) has not mentioned any standard for Uranium in drinking water, the WHO have set drinking water standards for uranium in drinking water as 30 µg/L.
4. The most affected states in terms of percentage of wells found to have uranium concentration more than 30 µg/L (ppb) prescribed by World Health Organisation (WHO), are Punjab (where 24.2% wells have been observed to have Uranium concentration more than the limit of 30 ppb prescribed by WHO), Haryana (19.6 % wells are > 30 ppb), Telangana (10.1 % wells are > 30 ppb), Delhi (11.7% wells are > 30 ppb), Rajasthan (7.2 % wells are > 30 ppb), Andhra Pradesh (4.9 % wells are > 30 ppb) and Uttar Pradesh (4.4% wells are > 30 ppb). Apart from above states, other states also have been found to have Uranium concentration above the threshold level of 30 µg/L in some localised pockets, such as Karnataka(1.9%), Madhya Pradesh (1.3%), Tamilnadu (1.6%), Jharkhand(1.5 %), Chhattisgarh (1.3%), Gujrat (0.9%), Himachal Pradesh (0.8%), Maharashtra (0.3%), Odisha (0.4%), West Bengal (0.1%), and Bihar(1.7%).
5. Atomic Energy Regulatory Board (AERB) has set a radiologically based limit for uranium as 60 µg/L (ppb) of water (radiological) in drinking water. Based on that the most affected states are Punjab (where 6.0% wells > 60 ppb), Haryana (4.4 %), Telangana (2.6 %), Delhi (5.0 %), Rajasthan (1.2 %), Andhra Pradesh (2.0 %), Chhattisgarh (1.1%), Tamilnadu (0.9%), Karnataka(0.7%), Madhya Pradesh (0.6%), and Uttar Pradesh (0.4%) and Jharkhand(0.25%).
6. It has been found that **151** districts in **18** States are partly affected by high (>30ppb) concentration of Uranium in ground water.
7. For water contaminated by uranium, coagulation, precipitation, evaporation, extraction, and membrane separation or Reverse osmosis technologies are used to eliminate most Uranium from the water.

URANIUM OCCURENCE IN SHALLOW AQUIFER IN INDIA

1.0 INTRODUCTION

India is the world's largest user of groundwater. More than 60 per cent of irrigated agriculture and 85 per cent of drinking water depend on the ground water resource. Recently, groundwater monitoring has shown elevated levels of uranium in several community water systems and in private wells. Uranium is a naturally occurring radioactive metal that occurs in low concentrations in nature. It is present in certain types of soils and rocks, especially granites. Most ingested uranium is due to food intake with lesser amounts accumulated from water or from the air. Uranium mostly is rapidly eliminated from the body, however a small amount is absorbed and carried through the blood stream. Studies show that elevated levels of uranium in drinking water can affect the kidneys. Bathing and showering with water that contains uranium is not considered a health concern. In general, most drinking water sources have radioactive contaminants at levels that are low enough to be considered a public health. However, elevated levels of Uranium in drinking water have been reported in many parts of the world including India. U.S. EPA and the WHO have set drinking water standards for Uranium in drinking water at 30 μg/L. Atomic Energy Regulatory Board, India has prescribed the maximum limit of U in drinking water at 60 μg/L (ppb) Bureau of Indian Standards does not specify a norm for uranium level. The occurrence and distribution of uranium in groundwater, is very poorly understood and warrants investigations in detail. Reports of widespread uranium contamination in groundwater across India demand an urgent response. In view of the above, Central Ground Water Board has taken pro-active steps for monitoring of uranium contamination in shallow ground water through a network of 14377 observation wells (as on 31.03.2019) located all across the country.

2.0 HYDROGEOLOGY

Behaviour of ground water in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydro-chemical conditions. Broadly two groups of rock formations have been identified, depending on characteristically different hydraulics of ground water viz. Porous Formations and Fissured Formations.

Porous formations

Porous formations have been further subdivided into Unconsolidated and Semi – consolidated formations. The areas covered by alluvial sediments of river basins, coastal and deltaic tracts constitute the unconsolidated formations. These are by far the most significant ground water reservoirs for large scale and extensive development. The hydrogeological environment and ground water regime in the Indo-Ganga-Brahmaputra basin indicate the existence of potential aquifers having enormous fresh ground water resources.

The semi-consolidated formations occur mostly in narrow valleys or structurally faulted basins. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents are the most extensive productive aquifers. Under favourable situations, these formations give rise to free flowing wells. In select tracts of northeastern India, these water-bearing formations are quite productive. The Upper Gondwanas, which are generally arenaceous, constitute prolific aquifers.

Fissured Formations

The Fissured or consolidated formations occupy almost two-thirds of the country. Consolidated formations other than vesicular volcanic rocks have negligible primary porosity. From the hydrogeological point of view, fissured rocks are broadly classified into four types viz. Igneous and metamorphic rocks excluding volcanic and carbonate rocks, volcanic rocks, consolidated sedimentary rocks excluding carbonate rocks and Carbonate rocks.

i) Igneous and metamorphic rocks excluding volcanic and carbonate rocks:-The most common rock types are granites, gneisses, charnockites, khondalites, quartzites, schists and associated phyllites, slates, etc. These rocks possess negligible primary porosity but attain porosity and permeability due to fracturing and weathering, which facilitates the yield from their rocks.

ii) Volcanic rocks:-The predominant types of the volcanic rocks are the basaltic lava flows of Deccan Plateau. Water bearing properties of different flow units control ground water occurrence and movement in Deccan Traps. The Deccan Traps have usually poor to moderate permeabilities depending on the presence of primary and secondary pore spaces including vescicles/fractures.

iii) Consolidated sedimentary rocks excluding carbonate rocks:-Consolidated sedimentary rocks occur in Cuddapahs, Vindhyans and their equivalents. These formations consist of conglomerates, sandstones, shales, slates and quartzites. The presence of bedding planes, joints, contact zones and fractures controls the ground water occurrence, movement and yield potential of aquifers.

iv) Carbonate rocks :- Limestones in the Cuddapah, Vindhyan and Bijawar groups of rocks dominates the carbonate rocks other than the marbles and dolomites. In carbonate rocks, the circulation of water creates solution cavities thereby increasing the permeability of the aquifers. Solution activity leads to widely contrasting permeability within short distances in such rocks.

3.0 SOURCES OF URANIUM IN GROUND WATER

Uranium is found in very small amounts in nature in the form of minerals. Rocks, soil, surface and underground water, air, and plants and animals all contain varying amounts of uranium. Natural uranium is a mixture of three isotopes of uranium, as 234U, 235U, and 238U. They are different radioactive materials with different radioactive properties. But all three isotopes behave the same chemically, so any combination of the three would have the same chemical effect on a person's health. Uranium occurs naturally in the +2, +3, +4, +5 and +6 valence states, but it is most commonly found in the

hexavalent form. In nature, hexavalent uranium is commonly associated with oxygen as the uranyl ion, UO_2^{2+}. In concentrations below 10^{-6}M, $UO_2(OH)^+$ is the dominant species, while above this concentration polymeric forms occur. Carbonate and mixed hydroxo carbonate complexes are formed in geological environment as CO_2 in air or closed ground water plays a significant role in their formation. Dissolved uranium can also form stable complexes with naturally occurring inorganic and organic ligands such as phosphate complexes. Uranium is a primordial and heaviest naturally occurring radioactive element that occurs in dispersed state in the earth's crust with an average concentration of 2–4 mg kg-1. It is commonly present in lignite, monazite and phosphate rocks (typically in the order of 0.005 to 0.02%). In groundwater, Uranium is present as a result of leaching from natural deposits, release from mill tailings, emission from the nuclear industry, contribution from fly ash and phosphate fertilizer application. Naturally occurring uranium is associated with granitic and metasedimentary rocks, as well as younger sedimentary deposits. Naturally occurring uranium in groundwater is a result of the dissolution of uranium bearing minerals that have been in contact with groundwater for long periods of time. Elevated concentrations of natural uranium in well water are more likely to be found in drilled wells that obtain their water from the cracks and fractures of bedrock, rather than dug wells or surface water supplies. Uranium can also be found in the environment as a result of human activities such as mill tailings, emissions from the nuclear industry, and the combustion of coal and other fuels. Naturally occurring uranium has very low levels of radioactivity. The chemical properties of uranium in drinking water are of greater health concern than its radioactivity. The factors for Uranium concentration in ground water can be summarized as follows-

- Many of aquifers are composed of clay, silt and gravel carried down from Himalayan weathering by streams or uranium-rich granitic rocks. When over-pumping of these aquifers' groundwater occurs and their water levels decline, it induces oxidation conditions that, in turn, enhance uranium enrichment in the shallow groundwater that remains.
- While the primary source of uranium is geogenic (naturally occurring), anthropogenic (human caused) factors such as groundwater table decline and nitrate pollution may further enhance uranium mobilisation. Using geochemical and uranium isotope data, it suggests factors that may drive high uranium concentrations in groundwater, including uranium content in aquifer rocks, oxidation state, and groundwater chemistry that promotes the formation of soluble uranyl carbonate complexes.
- These factors include the amount of uranium contained in an aquifer's rocks; water-rock interactions that cause the uranium to be extracted from those rocks; oxidation conditions that enhance the extracted uranium's solubility in water; and the interaction of the extracted uranium with other chemicals in the groundwater, such as bicarbonate, which can further enhance its solubility.
- Human activities, especially the over-exploitation of groundwater for agricultural irrigation, may contribute to the problem,
- Uranium is more soluble in oxidizing, alkaline, and carbonate-rich water than under acidic, reducing conditions.

4.0 HEALTH EFFECTS

Exposure to uranium in the natural environment occurs most commonly via oral exposures. Uranium enters the body by eating contaminated food or drinking water that contains uranium.

Dermal exposures occur through skin contact with uranium powders or metals. Usually only those working with products or processes using uranium would be exposed in this way. Another possible route of exposure is from retained depleted uranium metal fragments (shrapnel) that embed in soft tissue. These fragments oxidize in situ and provide a source of ongoing systemic absorption.

Inhalation of uranium powder can also occur and is the primary exposure route for workers. As discussed later in this section, inhalation may be an important route of exposure for individuals in "at risk" communities.

Ingestion is the most common pathway of exposure to naturally occurring uranium for the general public. Exposures can occur through

• ingesting food or drinking water containing naturally occurring uranium and/or
• ingesting food or drinking water contaminated through uranium mining or waste activities.

Water containing low amounts of uranium is usually safe to drink. Because of its nature, uranium is not likely to accumulate in groundwater, in fish or vegetables, uranium that is absorbed and enter in human body is eliminated quickly through urine and faeces. Uranium concentrations are often higher in phosphate-rich soil, but, concentrations often do not exceed normal ranges for uncontaminated soil. Plants absorb uranium through their roots and store it there. Root vegetables such as radishes may contain higher than usual concentrations of uranium as a result.

Most ingested uranium is eliminated from the body. However, a small amount is absorbed and carried through the bloodstream to the various organs. Studies show that elevated levels of uranium from any source, including drinking water, can increase a person's risk of kidney damage. Preliminary studies on the health effects of drinking uranium-tainted water among animals and humans have revealed that it causes Nephritis (kidney damage). The kidney is the most sensitive organ for damage by uranium. Notably, this is said to be caused by the chemical effect of uranium, rather than a radiological, even though uranium is radioactive. Uranium can decay into other radioactive substances, such as radium, which can cause cancer with extensive exposures over a long enough period of time. Nonetheless, we need more comprehensive systematic studies to establish the chronic health effects of uranium exposure.

5.0 SAMPLING AND ANALYTICAL METHODS

A total of 14377 groundwater samples were collected from groundwater monitoring stations (GWMS). GWMS set-up is a system of spatially distributed observation points including dug well, hand pumps, tube wells and piezometers of various depths at which periodic monitoring of ground water and regime behaviour recording of

water levels and temperature and collection of ground water samples for water (chemical) quality analysis are done.

For uranium analyses, samples were collected from these ground water observation wells in 100ml HDPE Bottles and were acidified to pH 2 with 1:1 HNO3 (Ultra trace elemental Grade / Suprapure) after filtering using a 0.45 µm membrane. Samples are filtered prior to acidification to prevent the leeching of material from any undissolved particulates. Trace metal samples are acidified to prevent precipitation out of solution and adsorption onto container walls. Some samples need to be diluted prior to analysis, either because of matrix problems or to get the instrument response within the linear dynamic range. These samples were analyzed for uranium and other trace metal concentrations using inductively coupled plasma mass spectrometry (ICP-MS, DRC-II quadrupole) in Regional Chemical Laboratories of CGWB at Lucknow and Chandigarh. Quality assurance is an important part of laboratory work. Instruments has been calibrated before every use, and periodic check standards run to insure that everything is in working order.

Table 1: State wise Distribution of Ground Water Monitoring Stations

Sr. No.	State	No. of monitoring stations (as on 31.03.2019)
States		
1	Andhra Pradesh	772
2	Arunachal Pradesh	21
3	Assam	233
4	Bihar	643
5	Chhattisgarh	489
6	Delhi	99
7	Goa	102
8	Gujarat	810
9	Haryana	529
10	Himachal Pradesh	112
11	Jammu & Kashmir	256
12	Jharkhand	407
13	Karnataka	1438
14	Kerala	364
15	Madhya Pradesh	1137
16	Maharashtra	1515
17	Manipur	0
18	Meghalaya	39
19	Nagaland	0
20	Orissa	1659
21	Punjab	351
22	Rajasthan	613
23	Tamil Nadu	457
24	Telangana	360
25	Tripura	40

Sr. No.	State	No. of monitoring stations (as on 31.03.2019)
26	Uttar Pradesh	892
27	Uttarakhand	207
28	West Bengal	666
Union Territories		
1	Andaman & Nicobar	120
2	Chandigarh	18
3	Dadra & Nagar Haveli	12
4	Daman & Diu	10
5	Pondicherry	6
	Total	14377

6.0 URANIUM CONCENTRATION AND SPATIAL DISTRIBUTION

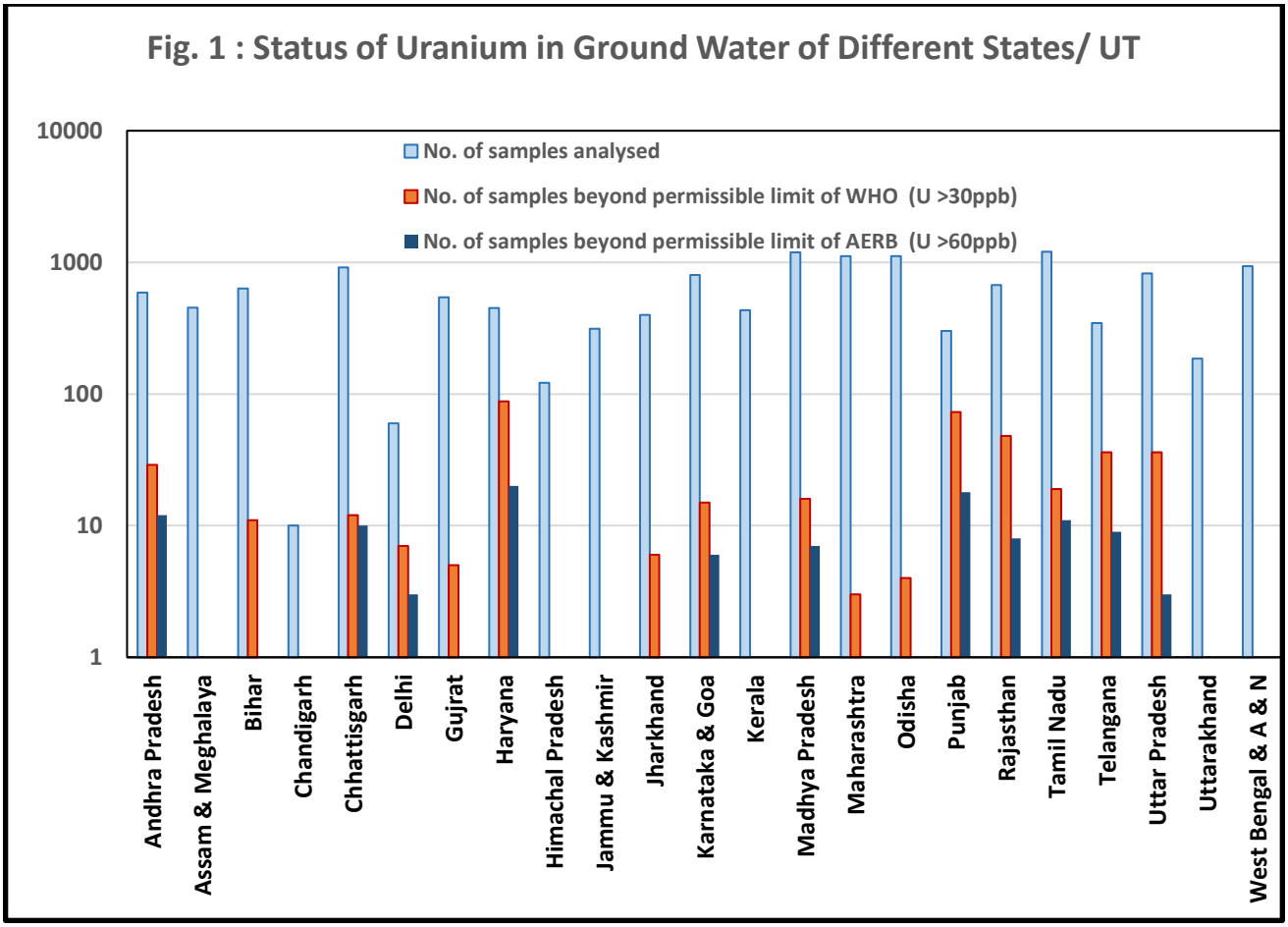
State wise distribution of samples beyond permissible limits are summarized in tables **2** and Figures 1 & 2 in their respective State descriptions. Uranium concentrations in shallow ground water in India, shows a wide range from 0.0 to 2876 µg/L, indicating that uranium concentrations in groundwater greatly vary by several orders of magnitude. The Bureau of Indian Standards (BIS) has not mentioned any standard for Uranium in drinking water, the WHO have set drinking water standards for uranium in drinking water as 30 µg/L. A hydro-chemical evaluation reveals the following-

The most affected states in terms of percentage of wells found to have uranium concentration more than 30 µg/L (ppb) prescribed by World Health Organisation (WHO), are Punjab (where 24.2% wells have been observed to have Uranium concentration more than the limit of 30 ppb prescribed by WHO), Haryana (19.6 % wells are > 30 ppb), Telangana (10.1 % wells are > 30 ppb), Delhi (11.7% wells are > 30 ppb), Rajasthan (7.2 % wells are > 30 ppb), Andhra Pradesh (4.9 % wells are > 30 ppb) and Uttar Pradesh (4.4% wells are > 30 ppb). Apart from above states, other states also have been found to have Uranium concentration above the threshold level of 30 µg/L in some localised pockets, such as Karnataka(1.9%), Madhya Pradesh (1.3%), Tamilnadu (1.6%), Jharkhand(1.5 %), Chhattisgarh (1.3%), Gujrat (0.9%), Himachal Pradesh (0.8%), Maharashtra (0.3%), Odisha (0.4%), West Bengal (0.1%), and Bihar(1.7%).

Atomic Energy Regulatory Board (AERB) has set a radiologically based limit for uranium as 60 µg/L (ppb) of water (radiological) in drinking water. Based on that the most affected states are Punjab (where 6.0% wells > 60 ppb), Haryana (4.4 %), Telangana (2.6 %), Delhi (5.0 %), Rajasthan (1.2 %), Andhra Pradesh (2.0 %), Chhattisgarh (1.1%), Tamilnadu (0.9%), Karnataka (0.7%), Madhya Pradesh (0.6%), Uttar Pradesh (0.4%) and Jharkhand (0.25%).

Table 2: The details of partly affected districts in various states

State	No. of samples analysed	No. of samples beyond permissible limit of WHO (U >30ppb)	No. of samples beyond permissible limit of AERB (U >60ppb)	Maximum value of Uranium observed (in ppb)
Andhra Pradesh	588	29	12	2876
Assam & Meghalaya	454	0	0	10.7
Bihar	634	11	0	57.0
Chandigarh	10	0	0	15.6
Chhattisgarh	917	12	10	138.2
Delhi	60	7	3	89.4
Gujrat	543	5	0	56.7
Haryana	450	88	20	131.4
Himachal Pradesh	122	1	0	70.7
Jammu & Kashmir	314	0	0	23.7
Jharkhand	399	6	1	69.9
Karnataka & Goa	804	15	6	201.1
Kerala	434	0	0	1.45
Madhya Pradesh	1191	16	7	233.9
Maharashtra	1115	3	0	48.0
Odisha	1114	4	0	59.0
Punjab	302	73	18	156.5
Rajasthan	671	48	8	181.0
Tamil Nadu	1208	19	11	302.0
Telangana	345	35	9	158.0
Uttar Pradesh	826	36	3	189.0
Uttarakhand	186	0	0	24.2
West Bengal & A & N	935	1	0	34.3



The details of partly affected districts in various states are given in Table 3. It has been found that **151** districts in **18** States are partly affected by high (>30ppb) concentration of Uranium in ground water. Figure shows the distributions of a wide range of uranium concentrations in groundwater, indicating that most samples have very low uranium concentrations. State wise discussions are as follows-

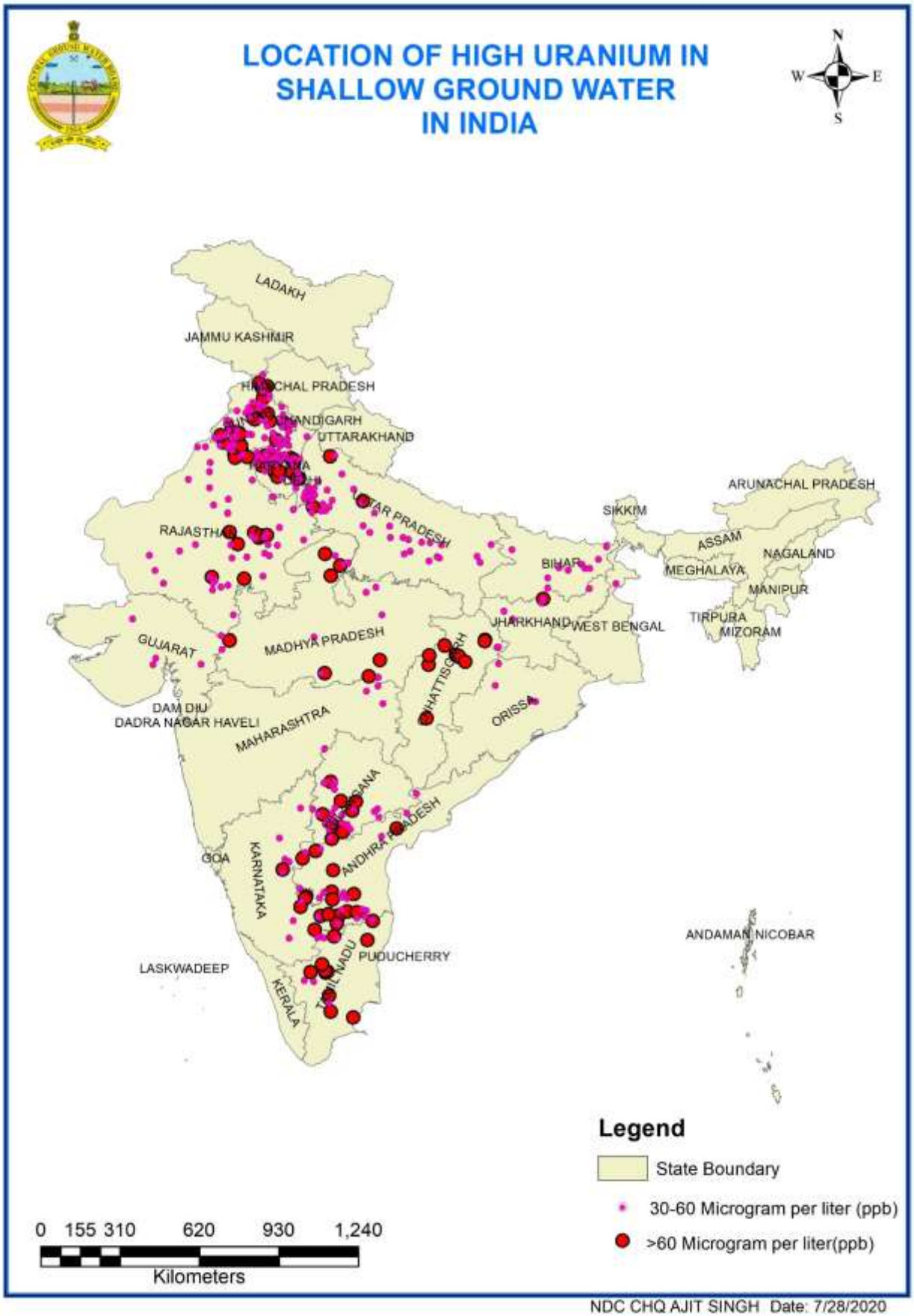

LOCATION OF HIGH URANIUM IN SHALLOW GROUND WATER IN INDIA
N
W
E
S
LADAKH
JAMMU KASHMIR
HIMACHAL PRADESH
CHANDIGARH
UTTARAKHAND
UTTAR PRADESH
RAJASTHAN
BIHAR
SIKKIM
ARUNACHAL PRADESH
ASSAM
NAGALAND
MEGHALAYA
MANIPUR
TIRPURA
MIZORAM
JHARKHAND
WEST BENGAL
GUJARAT
MADHYA PRADESH
CHHATTISGARH
ORISSA
DAM DIU
DADRA NAGAR HAVELI
MAHARASHTRA
GOA
KARNATAKA
ANDHRA PRADESH
TELANGANA
ANDAMAN NICOBAR
LASKWADEEP
PUDUCHERRY
TAMILNADU
KERALA
Legend
State Boundary
30-60 Microgram per liter (ppb)
>60 Microgram per liter(ppb)
0 155 310 620 930 1,240
Kilometers
NDC CHQ AJIT SINGH Date: 7/28/2020

Figure-2

Table 3: The details of districts partly affected with high Uranium in various states

Sl No	State	Districts Partly affected with Uranium> 30ppb
1	**Andhra Pradesh**	Ananthapur, Chittoor, Guntur, Kadapa, East Godavari, Krishna, Kurnool, Prakasam
2	**Bihar**	Saran, Bhabhua, Khagaria, Madhepura, Nawada, Sheikhpura, Purnea, Kisanganj, Begusarai
3	**Chhattisgarh**	Bilaspur, Jashpur, Kanker, Korba
4	**Delhi**	North West District, South West District, West District, North District
5	**Gujrat**	Dohad, Ahmedabad, Vadodara, Patan
6	**Haryana**	Ambala, Bhiwani, Faridabad, Fatehabad, Gurugram, Hissar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendergarh, Palwal, Panipat, Rohtak , Sirsa, Sonipat, Yamuna Nagar
7	**Himachal Pradesh**	Mandi
8	**Jharkhand**	Godda, Koderma, Latehar, Palamau
9	**Karnataka**	Bangalore Rural, Bangalore Urban, Bellary, Gulbarga, Kolar, Mandya, Raichur, Tumkur
10	**Madhya Pradesh**	Balaghat, Betul, Chhatarpur, Datia, Gwalior, Jhabua, Panna, Raisen, Seor Shivpuri
11	**Maharashtra**	Bhandara, Gondia, Nagpur
12	**Odisha**	Angul, Dhenkanal, Sundargarh, Sambalpur
13	**Punjab**	Bathinda, Moga, Faridkot, Fatehgarh Sahib, Fazilka, Ferozepur, Hoshiarpur, Jalandhar, Kapurthala, Ropar, Ludhiana, Muktsar, Pathankot, Patiala, Sangrur, SAS Nagar
14	**Rajasthan**	Ajmer, Alwar, Banswara, Barmer, Bhilwara, Bikaner, Bundi, Chittaugarh, Churu, Dausa, Ganganagar, Jaipur, Jelore, Jodhpur, Karauli, Nagaur, Pratapgarh, Rajsamand, Sawai Madhopur, Tonk, Udaipur
15	**Tamil Nadu**	Dindigul, Erode, Krishnagiri, Madurai, Mamakkal, Ramnathapuram, Salem, Thiruvannamalai, Tirupur, Tiruvallur
16	**Telangana**	Adilabad, Hyderabad, Mahabubnagar, Medak, Nalgonda, RangaReddy
17	**Uttar Pradesh**	Aligarh, Azamgarh, Bijnaur, Badaun, Bulandshaher, Deoria, Farrikhabad, Fatehpur, G.B.Nagar, Ghaziabad, Ghazipur, Hardoi, Hathras, J P Nagar, Kanpur Nagar, Mainpuri, Mathura, Pratapgarh, Raebarelli, Sultanpur, Unnao.
18	**West Bengal**	Malda

STATE WISE DISCRIPTION

6.1 Andhra Pradesh

A total of 588 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of Andhra Pradesh.

In 29 samples out of total 588 samples analysed that is in 4.9%, Uranium concentrations have been found to be more than 30ppb (permissible limit for drinking water prescribed by WHO). Uranium more than 60 ppb (permissible limits as per Atomic Energy Regulatory Board (DAE)) has been detected in 12 samples in Andhra Pradesh. The highest values obtained is 2876 ppb at Damalcheruvu in Chittoor District in Andhra Pradesh (**Table 4 & Figure 3)**. The following reasons may attribute for high concentration of Uranium in Ground water. The Districts which are partly affected by high Uranium in ground water are - Ananthapur, Chittoor, Guntur, Kadapa, East Godavari, Krishna, Kurnool, Prakasam districts.

Granites particularly Younger granitic intrusive are the source rocks for high concentration of Uranium in Chittoor, Anantapur, Kadapa and Kurnool districts in Andhra Pradesh. High solubility of Uranium observed from calcium rich associated minerals of host rocks and host rocks with lineaments and subsequent leaching into ground water.

Table 4: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl. No.	District	Mandal	Location	Uranium Concentration >30 ppb
1	Ananthapur	ROLLA	RollaAqII-PZ	35.95
2	Ananthapur	AMARAPURAM	Palasamudram	39.79
3	Ananthapur	KUNDURPI	Kundurpi-DW14	41.22
4	Ananthapur	PUTTAPARTI	Kambalaparthi-DW14	46.83
5	Ananthapur	KADIRI	Alampur	**111.58**
6	Ananthapur	MADAKASIRA	A Roppam-Pz	**170.48**
7	Ananthapur	TANAKAL	Tanakallu-PZ	**236.77**
8	Ananthapur	MADAKASIRA	Madakasira1	**318.84**
9	Chittoor	SRIRANGARAJUPURAM	Pillarakuppam	31.79
10	Chittoor	KAMMAPALLI	BalezapalliDW15	36.16
11	Chittoor	PUTHALAPATTU	Kanipakam-DW14	37.48
12	Chittoor	MADANAPALLE	Basani Khonda-DW14	45.39
13	Chittoor	CHANDRAGIRI	Mungilipattu	57.74
14	Chittoor	RAMASAMUDRAM	Ramasamudram-DW15	**217.59**
15	Chittoor	NIMMANAPALLE	Chintaparti-1	**594.59**
16	Chittoor	PAKALA	Damalcheruvu	**2875.97**
17	E.Godavari	CHINTUR	Sanjeeva Reddy Palem	37.44

18	Guntur	TADIKONDA	Tadikonda-Dw	**64.51**
19	Kadapa	GALIVEEDU	Bodireddygaripally-Pz	30.46
20	Kadapa	CHINNAMANDYAM	Chinnamandyam	42.30
21	Kadapa	GALIVEEDU	Galiveedu-alt	52.59
22	Kadapa	VEERABALLE	Sanipai	**99.91**
23	Kadapa	MYLAVARAM	DhodiumPZ	**211.56**
24	Krishna	VISSANNAPETA	Vissannapet New	50.57
25	Kurnool	KODUMUR	Kodumuru 2013DW	30.42
26	Kurnool	ADONI	Naganathanahalli	38.46
27	Kurnool	DEVANAKONDA	Karivemula	**78.07**
28	Kurnool	ADONI	Gulyam-DW13	**125.00**
29	Prakasam	SANTAMAGULURU	Santamaguluru	33.45

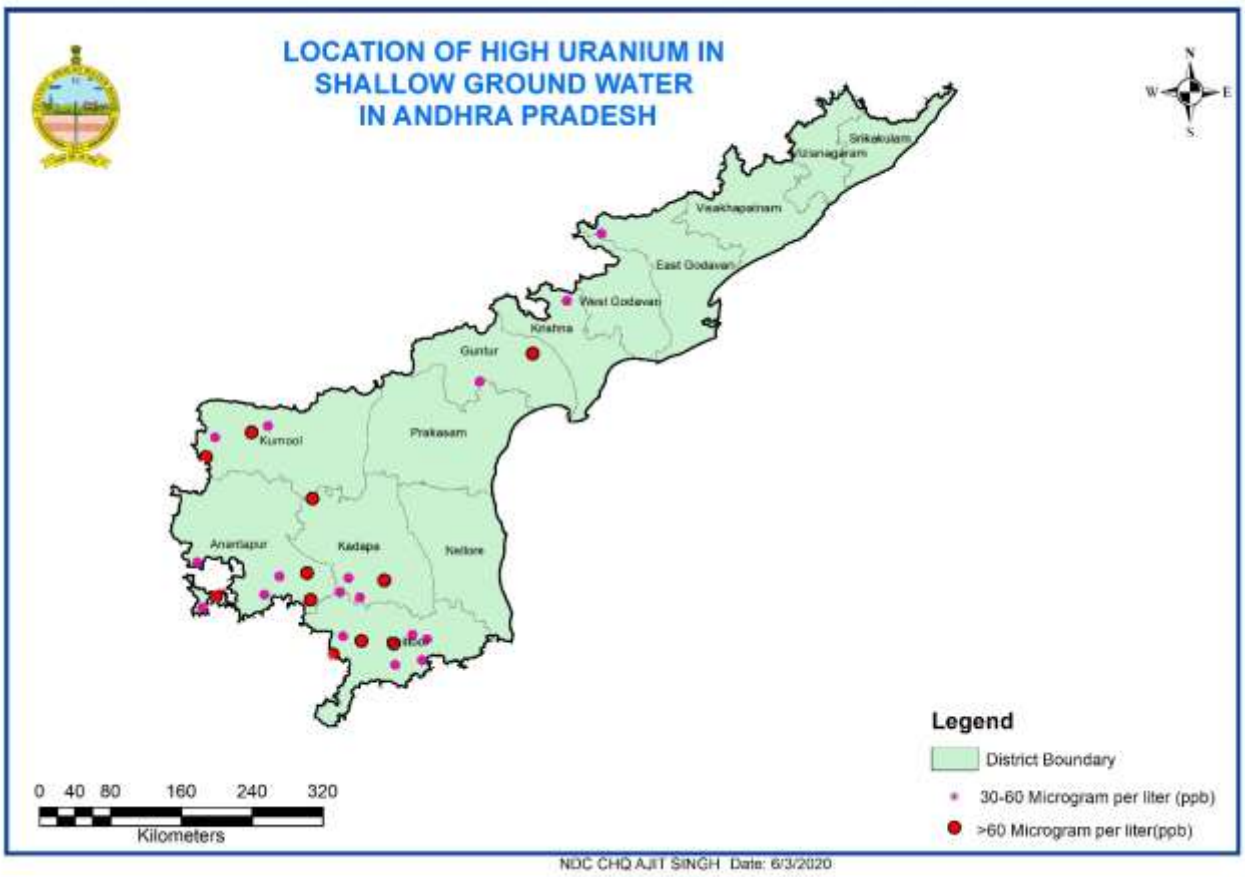


Figure-3

6.2 Assam & Meghalaya

A total of 454 ground water samples were collected during Post-Monsoon season (Nov-2019) from NHNS Stations falling in different hydro geological settings of the State.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells**.** Uranium was found to be in the range of nd to 10.66 ppb.

6.3 Bihar

A total of 634 ground water samples were collected during Post-Monsoon season (Nov-2019) from NHNS Stations falling in different hydro geological settings of the State.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except eleven samples (**Table 5 & Figure 4).** Uranium was found to be in the range of nd to 57 ppb. The Districts which are partly affected by high Uranium in ground water are - Saran, Bhabhua, Khagaria, Madhepura, Nawada, Sheikhpura, Purnea, Kisanganj, Begusarai.

Table 5: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

S.N.	District	Block	Location	U(ppb)
1	Saran	Barharia	Tarwara	34
2	Bhabhua	Nuwan	Nuwan	32
3	Khagaria	Khagaria	Durgapur	31
4	Madhepura	Chausa	Abhaiyatola	33
5	Madhepura	Bihariganj	Udakishanganj	31
6	Nawada	Kauakol	Rupau	40
7	Sheikhpura	Berbigha	Koeribigha	31
8	Purnea	Kasba	Kasba	32
9	Purnea	Rupauli	Tikapatti	31
10	Kishanganj	Bahadurganj	Bahadurganj B	57
11	Begusarai	Bakhri	Manjaul	32

Figure-4

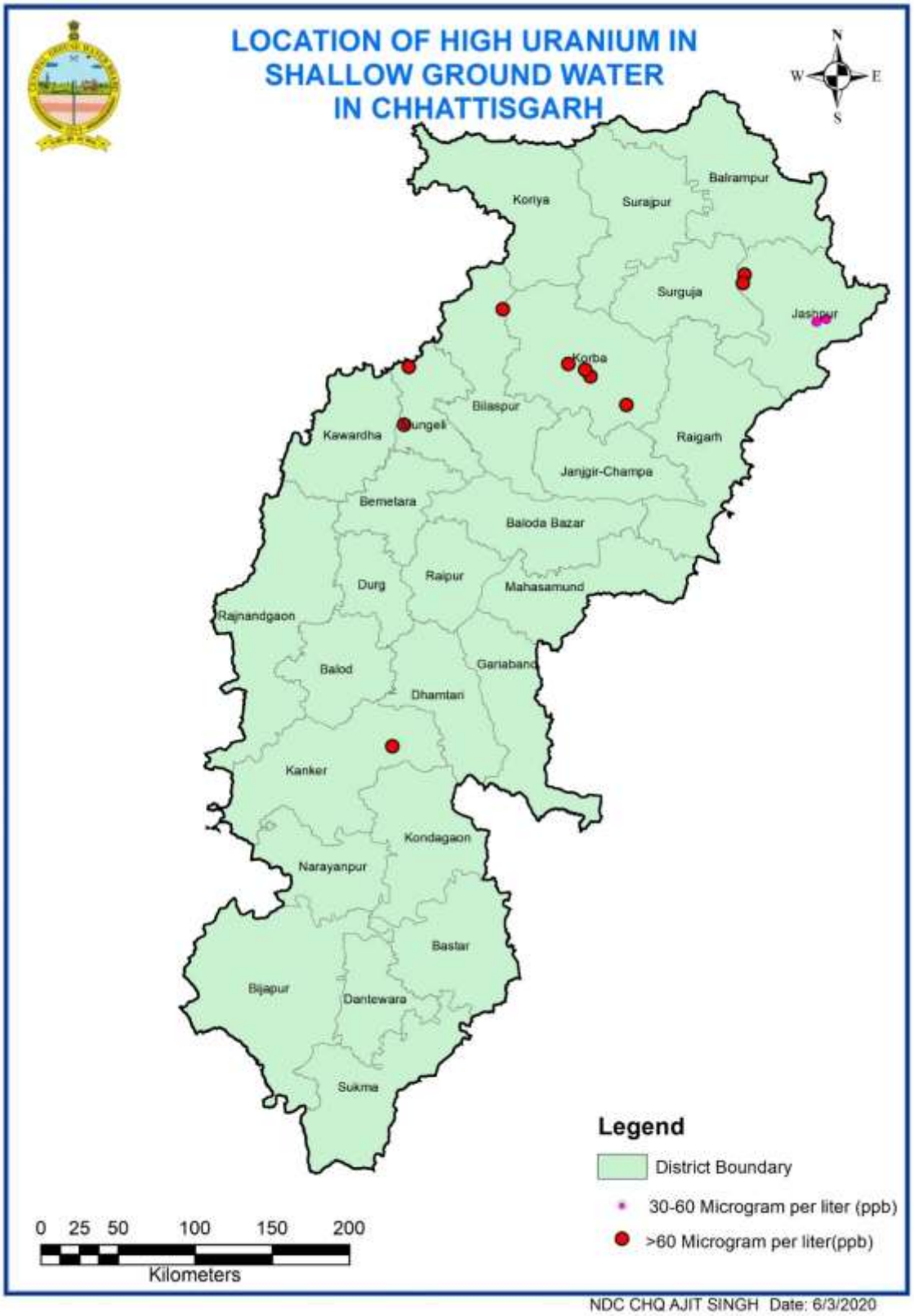
6.4 Chattisgarh

A total of 917 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except twelve samples (**Table 6 & Figure 5).** Uranium was found to be in the range of nd to 138.2 ppb. The Districts which are partly affected by high Uranium in ground water are - Bilaspur, Jashpur, Kanker, Korba.

Table 6: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl No	District	Block	Location	Uranium ppb
1	Bilaspur	Takhatpur	Jaroundha	94.5
2	Bilaspur	Pendra	Adbhar	98.6
3	Bilaspur	Pendra Road	DamDam	104.0
4	Jashpur	Kunkuri	Kandora	40.0
5	Jashpur	Kunkuri	Raikera(Kunkuri)	41.4
6	Jashpur	Bagicha	Durgapara	136.7
7	Jashpur	Bagicha	Maini	138.2
8	Kanker	Kanker	Kanker	125.0
9	Korba	Katghora	Gopalpur	112.3
10	Korba	Katghora	Katghora	112.7
11	Korba	Katghora	Chhuri	115.6
12	Korba	Kartala	Nonbirra-4	124.2


LOCATION OF HIGH URANIUM IN SHALLOW GROUND WATER IN CHHATTISGARH
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Koriya
Surajpur
Surguja
Jashpur
Korba
Bilaspur
Kawardha
Mungeli
Raigarh
Janjgir-Champa
Bemetara
Baloda Bazar
Durg
Raipur
Mahasamund
Rajnandgaon
Balod
Gariaband
Dhamtari
Kanker
Kondagaon
Narayanpur
Bastar
Bijapur
Dantewara
Sukma
Legend
District Boundary
30-60 Microgram per liter (ppb)
>60 Microgram per liter(ppb)
0 25 50 100 150 200
Kilometers
NDC CHQ AJIT SINGH Date: 6/3/2020

Figure-5

6.5 Delhi

A total number of 60 water samples from NHS Groundwater monitoring wells in 2019 were collected for Uranium analysis after 1:1Ultrapure Nitric acid treatment.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except in seven samples**.** Uranium was found to be in the range of nd to 89.4 ppb (**Table 7 & Figure 6)**. The Districts which are partly affected by high Uranium in ground water are - North West District, South West District, West District, North District.

Table 7: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl No	District	Location	Uranium in ppb
1	North West District	Kanjhawala Pz	31.3
2	North West District	Auchandi Pz	44.3
3	North West District	Rai Khera DW	60.4
4	North West District	Nizampur EW	89.4
5	South West District	Ojwah Pz	31.7
6	West District	Peeragarhi DW	40.4
7	West District	Tikri Kalan	64.1

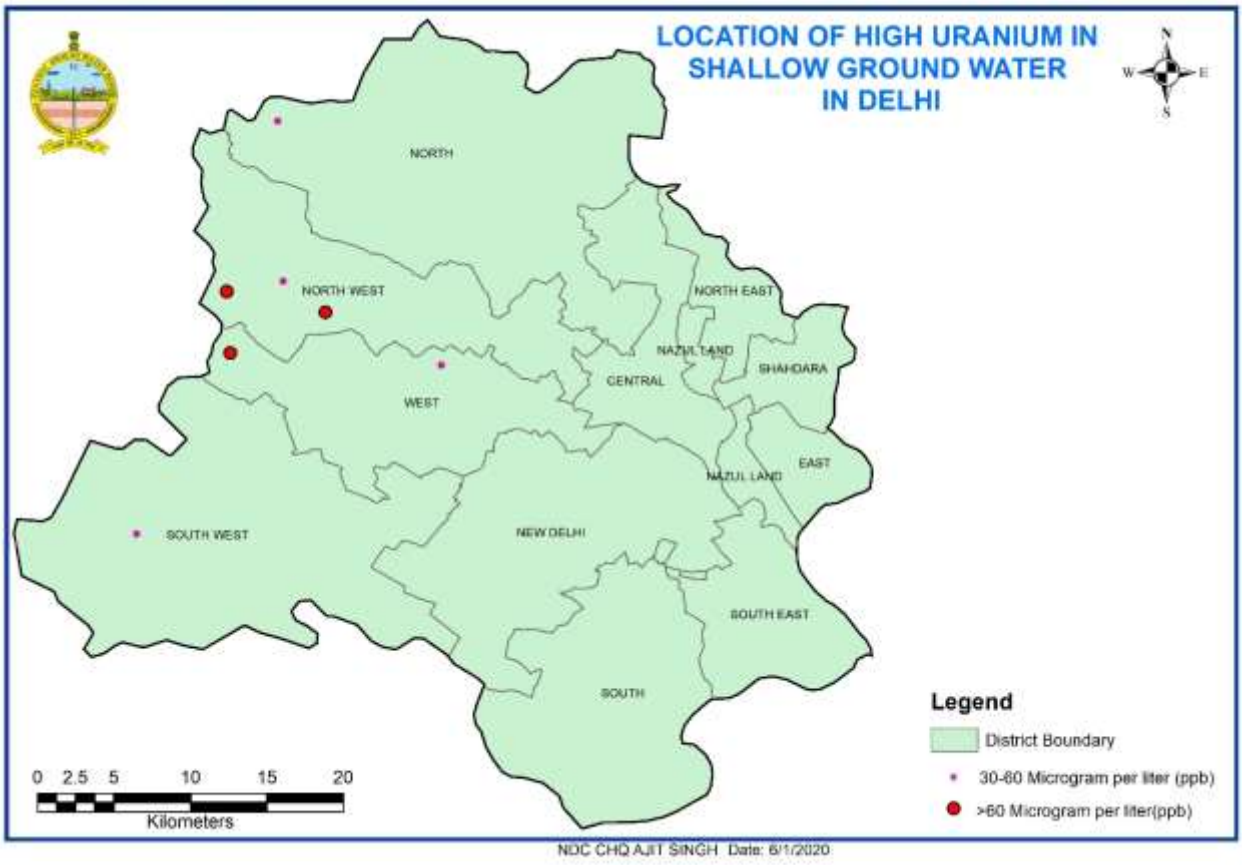


Figure-6

6.6 Gujrat and Daman & Diu

A total number of 543 water samples from NHS Groundwater monitoring wells in 2019 were collected for Uranium analysis after 1:1Ultrapure Nitric acid treatment.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except five samples (**Table 8).** Uranium was found to be in the range of nd to 56.73ppb (**Table 8 & Figure 7)**. The Districts which are partly affected by high Uranium in ground water are - Dohad, Ahmedabad, Vadodara, Patan.

Table 8: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

S .No.	District	Taluka	Name of village	Uranium(ppb)
1	Dohad	Garbada	Garbara	42.5
2	Ahmedabad	Barvala	Barvala	56.7
3	Ahmedabad	Dhandhuka	Tagadi	31.9
4	Vadodara	Sankheda	Bodeli	35.5
5	Patan	Santalpur	Piprala	56.7

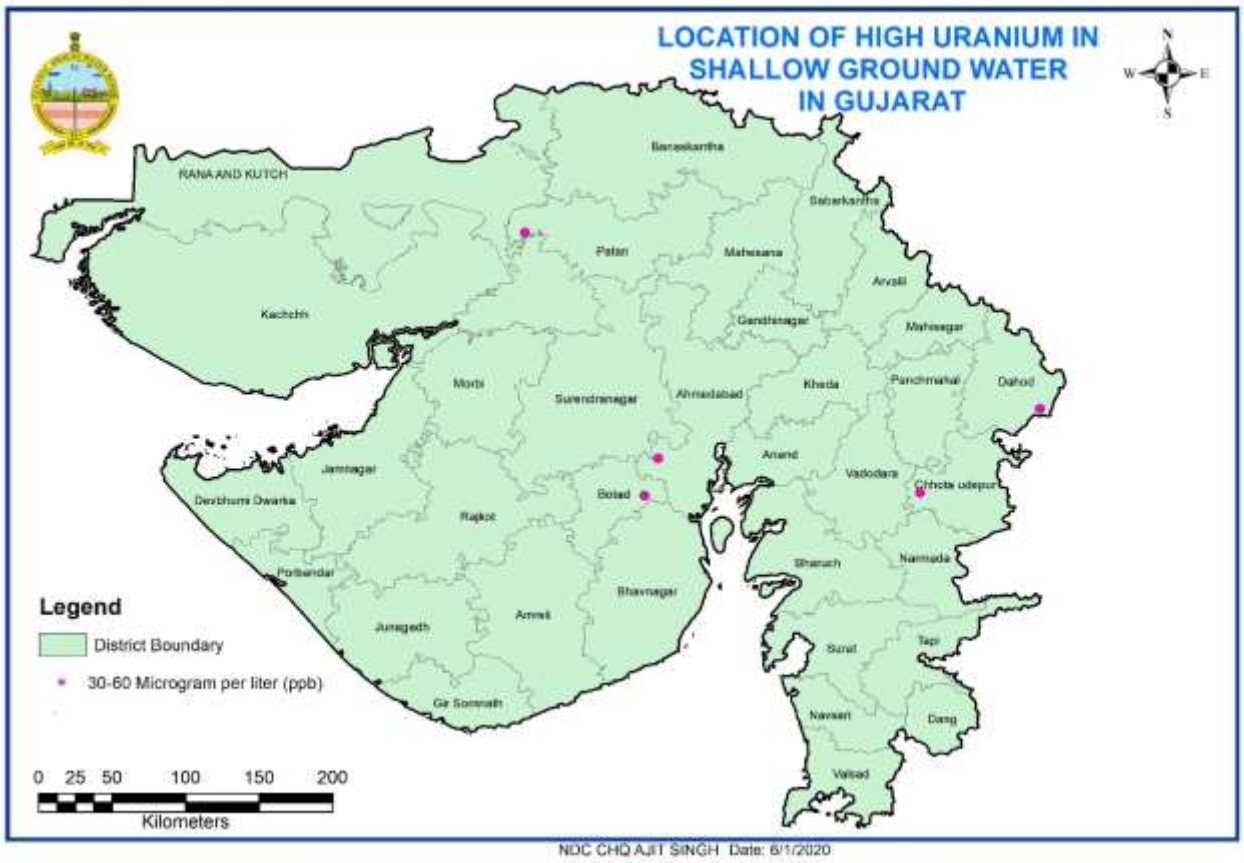


Figure-7

6.7 Haryana & Chandigarh

A total number of 451 water samples from NHS Groundwater monitoring wells in 2019 were collected for Uranium analysis after 1:1Ultrapure Nitric acid treatment.

In 88 samples out of total 451 samples analysed that is in 19.5%, Uranium concentrations have been found to be more than 30ppb (permissible limit for drinking water prescribed by WHO). Uranium more than 60 ppb (permissible limits as per Atomic Energy Regulatory Board (DAE)) has been detected in 20 samples in Haryana. The highest values obtained is 131.4 ppb at Sohu in Hissar District. In Chandigarh all samples have been found to be within the permissible limit. The Districts which are partly affected by high Uranium in ground water are - Ambala, Bhiwani, Faridabad, Fatehabad, Gurugram, Hissar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendergarh, Palwal, Panipat, Rohtak , Sirsa, Sonipat, Yamuna Nagar(**Table 9 & Figure 8)**.

Table 9: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl N	District	Block	Location	U > 30ppb	Sl No	District	Block	Location	U > 30ppb
1	Ambala	Ambala I	Jandheri	32.7	45	Karnal	Assandh	Gangateri	37.9
2	Bhiwani	Bh. Khera	Dhanana	**62.7**	46	Karnal	Assandh	Mound	40.8
3	Bhiwani	Bhiwani	Badala	**78.1**	47	Kurukshetra	Pehowa	Bodhni	33.5
4	Faridabad	Faridabad	Ballabhgarh	37.7	48	Kurukshetra	Pehowa	Thana	33.6
5	Fatehabad	Bhuna	Khajuri Jatti	40.8	49	Mahendergarh	Narnaul	Narnaul	56.1
6	Fatehabad	Fatehabad	Badopal	36.1	50	Palwal	Hathin	Kot	30.8
7	Fatehabad	Ratia	Aharwan	37.2	51	Palwal	Hathin	Lakhnaka	32.4
8	Fatehabad	Tohana	Nangla	45.9	52	Palwal	Hodal	Hassanpur	30.5
9	Gurugram	Gurugram	Kasan	45.9	53	Palwal	Hodal	Bamnikhera	48.1
10	Hissar	Adampur	Basra	37.2	54	Palwal	Palwal	Jawan	31.3
11	Hissar	Agroha	kanoh	33.3	55	Palwal	Palwal	Jaindapur	45.2
12	Hissar	Barwala	Banbhauri	32.6	56	Palwal	Palwal	Rasulpur	58.7
13	Hissar	Barwala	Barwala	40.9	57	Panipat	Bapoli	Nimbri	44.5
14	Hissar	Barwala	Gianpura	54.1	58	Panipat	Gannaur	pugthala	47.4
15	Hissar	Hansi	Khanda Kheri	55.2	59	Panipat	Israna	Khalila Manjran	35.2
16	Hissar	Hissar - I	Balawas	31.2	60	Panipat	Israna	Israna	**67.6**
17	Hissar	Hissar - I	Hissar	**71.9**	61	Panipat	Madlauda	Urlana Kalan	32.1
18	Hissar	Hissar I	Kharar	45.8	62	Panipat	Madlauda	Etola	53.8
19	Hissar	Narnaud	Kherijalab	32.4	63	Panipat	Madlauda	Lohari	**82.6**
20	Hissar	Narnaud	Moth Majra	42.7	64	Panipat	Madlauda	Untala	32.9
21	Hissar	Narnaud	Rajthal	56.8	65	Rohtak	Maham	Maham	**72.4**
22	Hissar	Uklana	Uklana Mandi	47.4	66	Rohtak	Rohtak	Kansla	**60.7**

23	Hissar	Uklana	Sohu	**131.4**	**67**	Sirsa	Baragudha	Shergarh	35.5
24	Jhajjar	Bahadurgarh	Gabhana	44.3	**68**	Sirsa	Baragudha	Phaggu	63.4
25	Jhajjar	Beri	Bagoa	44.5	**69**	Sirsa	Dabwali	Goriwala	36.4
26	Jind	Alewa	Alewa	33.9	**70**	Sirsa	Dabwali	Chotala	48.8
27	Jind	Alewa	Dorana	34.2	**71**	Sirsa	Dabwali	Khuiyan Malkana	48.8
28	Jind	Julana	Rojhala	34.7	**72**	Sirsa	Dabwali	Masitan	56.7
29	Jind	Julana	Julana	37.5	**73**	Sirsa	Dabwali	Tejakhera	57.6
30	Jind	Narwana	Korar	32.2	**74**	Sirsa	Dabwali	Rasalia Khera	**67.9**
31	Jind	Safidon	Lochap	39.5	**75**	Sirsa	Ellenabad	Sri Jiwan Naga	**75.4**
32	Jind	Safidon	Bhuslana	63.3	**76**	Sirsa	Ellenabad	Bhuratwala	**94.2**
33	Jind	Uchana	khatkaran	40.2	**77**	Sirsa	Nathusari Chopta	Sherpura	**90.7**
34	Jind	Uchana	Baroda	43	**78**	Sirsa	Odhan	Nuhian Wali	**83.7**
35	Jind	Uchana	Uchana	**136.7**	**79**	Sirsa	Odhan	Mithri	**103.5**
36	Kaithal	Gulha	Padla	36.4	**80**	Sirsa	Odhan	Odhan	**145.1**
37	Kaithal	Gulha	Khanpur	37.1	**81**	Sirsa	Odhan	Chormar	**154.2**
38	Kaithal	Gulha	Rasulpur Ghamri	37.9	**82**	Sirsa	Odhan	Kalanwali Mandi	**300.8**
39	Kaithal	Gulha	Balhera	50.9	**83**	Sirsa	Rania	Mammer Khera	44
40	Kaithal	Gulha	Titiana	54.4	**84**	Sirsa	Sirsa	Mangala	32.2
41	Kaithal	Kaithal	Siwan	31.6	**85**	Sirsa	Sirsa	Sirsa	42.1
42	Kaithal	Kaithal	Manaspatti	38.5	**86**	Sonipat	Gohana	Khanpur kalan	34.2
43	Kaithal	Kalayat	Mataur	56.9	**87**	Sonipat	Kharkhoda	Rohat	32.4
44	Kaithal	Pundri	Jajanpur	31.2	**88**	Yamuna Nagar	Jagadhri	Umari	39.7

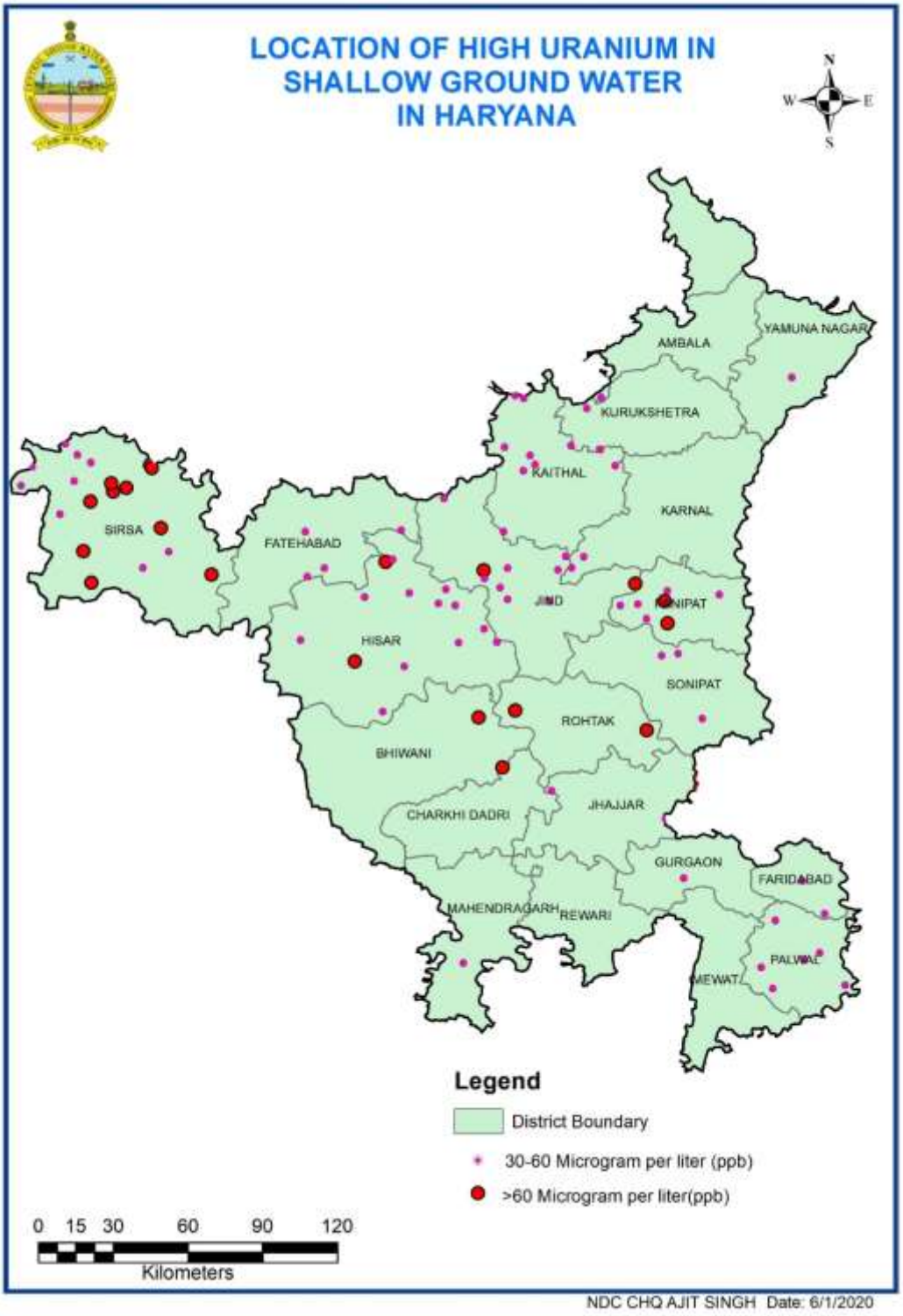


Figure-8

6.8 Himanchal Pradesh

A total of 122 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except in one sample at Lohara (70.7 ppb) in Mandi District**.**

6.9 Jammu & Kashmir

A total of 314 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells. The highest value has been obtained in sample at Arnia-II (23.7 ppb) in Ramgarh block of Jammu District**.**

6.10 Jharkhand

A total of 399 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except six samples (1.5%). Uranium more than 60 ppb (permissible limits as per Atomic Energy Regulatory Board (DAE)) has been detected in one sample in Jharkhand. The highest values obtained is 69.9 ppb at Koderma in Koderma District. (**Table 10 & Figure 9).** Uranium was found to be in the range of nd to 69.9 ppb. The Districts which are partly affected by high Uranium in ground water are - Godda, Koderma, Latehar, Palamau.

Table 10: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl. no	District	Block	Location	Uranium (ppb)
1	Godda	Godda	Godda	36.3
2	Koderma	Tilaya	Buchitanr	51.8
3	Koderma	Kodarma	Kanobigha	59.6
4	Koderma	Kodarma	Koderma	**69.9**
5	Latehar	Baresad (Lalmatia)	Garu	42.6
6	Palamu	Lesliganj	Lesliganj	34.5

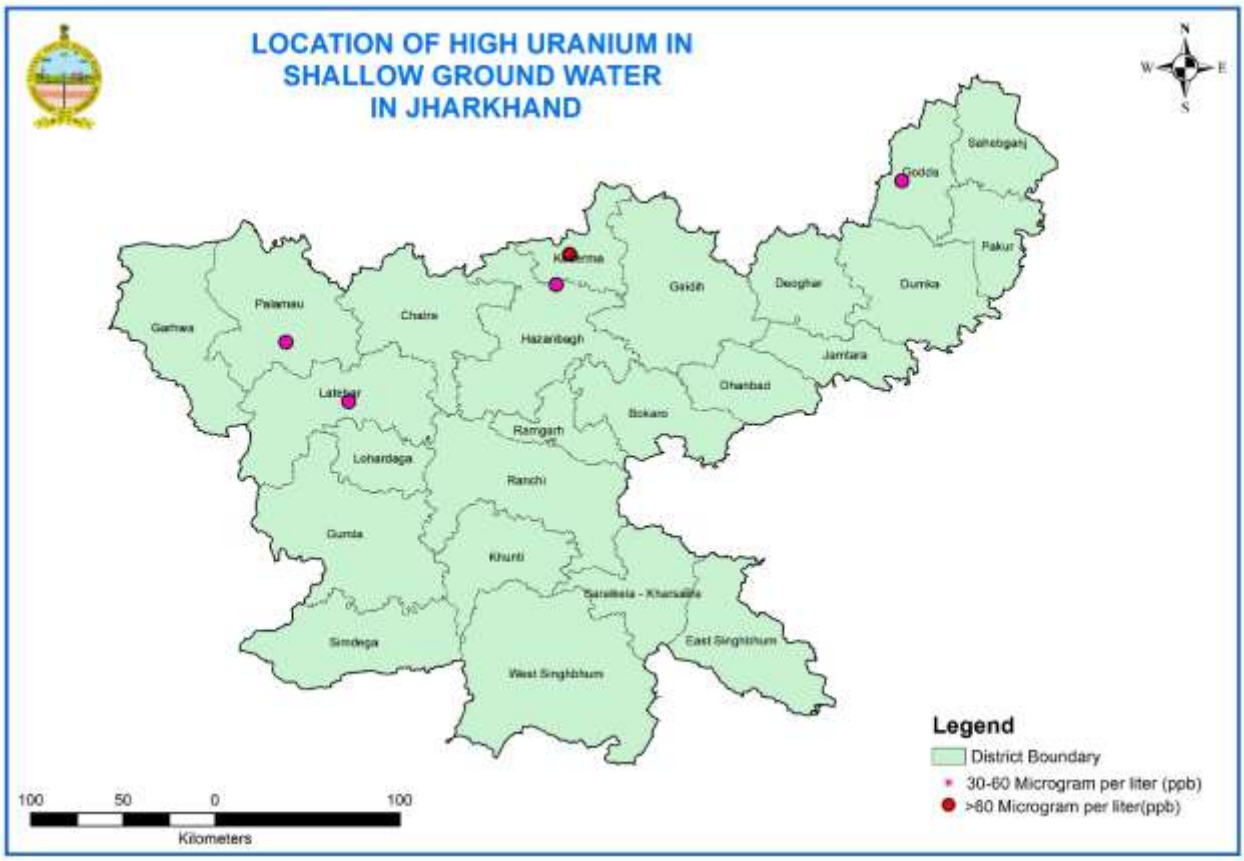


Figure-9

6.11 Karnataka & Goa

A total number of 737 water samples from NHS Groundwater monitoring wells were collected. The concentration of uranium ranges from 0.0 to 201.01µg/L with an average of 4.22µg/L. Out of 737 wells, 14 wells (2%) exceed the WHO permissible limit of 30 µg/L, which are from the districts of Gulburga, Mandya, Raichur, Bangalore Urban, Bangalore Rural, Tumkur, Bellary and Kolar. The details of locations which exceed the permissible limit of 30 µg/L is given in **Table 12 & Figure 10.** The highest value of 201.01 µg/Lwas recorded at location Chintamani, Chintamani Tehsil of Kolar district.

Uranium concentration in the shallow ground water of the state varies primarily due to recharge and discharge, which would have dissolved or leached the uranium from the weathered soil to groundwater zone. High uranium concentrations observed in shallow ground water may be due to local geology, anthropogenic activities, urbanization and use of phosphate fertilizers in huge quantity for agriculture purpose. The total uranium resources in phosphate rocks is estimated at 9 X 10^6metric tons of uranium. Studies have shown that phosphate fertilizer possess uranium concentration ranging from 1 mg/kg to 68.5mg/kg. Hence, the phosphate fertilizers manufactured from phosphate rocks may also contribute uranium to ground water in agriculture region. It is also observed that most of

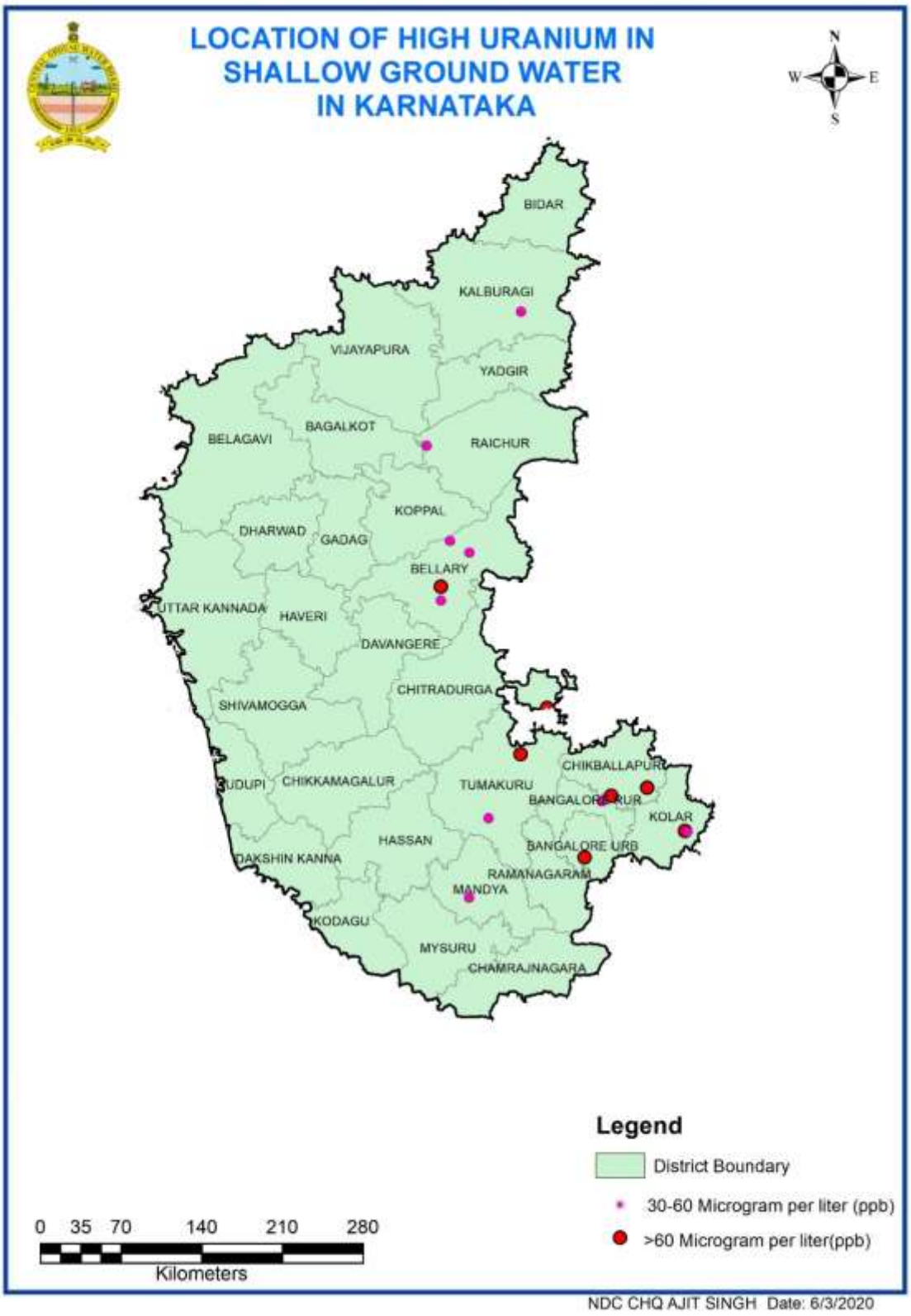
the higher concentrations of uranium were found in the samples collected from intensive agriculture region. To study the impact of mineralization, it is also important to monitor the groundwater quality in deeper aquifer in the area where the higher values of uranium were noticed from shallow aquifer.

Table 11: Statistical summary of Uranium (µg/L) district wise

S. No	District	Min	Max	Average	Std Dev
1	Bagalkot	0.08	14.85	3.84	5.26
2	Bangalore Rural	0.16	111.85	29.75	39.03
3	Bangalore Urban	1.39	104.03	24.04	31.63
4	Belgaum	0.00	2.24	0.67	0.57
5	Bellary	1.19	150.64	20.89	35.68
6	Bidar	0.00	1.79	0.61	0.47
7	Bijapur	0.11	5.62	1.74	1.60
8	Chanrajnagar	0.01	3.33	1.30	1.37
9	Chikballapur	0.46	17.82	6.76	8.28
10	Chikkamagalur	0.00	17.82	1.83	4.17
11	Chitradurga	0.62	23.65	5.74	7.20
12	Dakshin Kannada	0.00	0.66	0.03	0.11
13	Dharwad	0.82	5.85	3.28	1.82
14	Davanagere	0.85	17.32	6.07	5.32
15	Gadag	1.16	24.65	8.91	9.82
16	Gulburga	0.01	34.21	2.79	6.35
17	Hassan	0.00	23.04	1.96	4.52
18	Haveri	0.10	13.00	5.56	5.38
19	Kodagu	0.00	1.08	0.07	0.21
20	Kolar	0.29	201.01	23.85	48.99
21	Koppal	0.26	11.06	6.37	3.24
22	Mandya	0.00	40.39	4.94	9.51
23	Mysore	0.05	11.71	2.34	3.35
24	Raichur	0.38	54.63	9.35	12.45
25	Ramanagara	0.22	24.13	4.38	7.59
26	Shimoga	0.01	3.25	0.38	0.67
27	Tumkur	0.35	145.78	12.64	34.78
28	Uttara kannada	0.00	1.62	0.16	0.30
29	Udupi	0.0	2.2	0.1	0.4
30	Yadgir	0.33	19.43	5.27	6.32

Table 12: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

SL No	District	Tahsil	Site	Uranium(µg/L)
1	Bangalore Rural	Devanhalli	Kodagurki A	39.47
2	Bangalore Rural	Devanhalli	Avathi	111.84
3	Bangalore Urban	Bangalore north	Gollahalli	104.02
4	Bellary	Kudligi	Kakkuppi	42.13
5	Bellary	Hospet	Venkatapura	54.73
6	Bellary	Kudligi	Jogikallu	150.64
7	Gulbarga	Chitapur	Chitapur A	34.21
8	Kolar	Mulbagal	Kurudmale	30.80
9	Kolar	Mulbagal	Angondanahalli	73.57
10	Kolar	Chintamani	Chintamani A	201.01
11	Mandya	Nagamangala	Tirumala SagaraChatra	40.38
12	Raichur	Sindhnur	Hanchihal	35.66
13	Raichur	Lingsugur	Bomanhal	54.63
14	Tumkur	Madhugiri	Badavanahalli(A)	145.77


LOCATION OF HIGH URANIUM IN SHALLOW GROUND WATER IN KARNATAKA
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YADGIR
BAGALKOT
BELAGAVI
RAICHUR
KOPPAL
DHARWAD
GADAG
BELLARY
UTTAR KANNADA
HAVERI
DAVANGERE
CHITRADURGA
SHIVAMOGGA
CHIKBALLAPUR
UDUPI
CHIKKAMAGALUR
TUMAKURU
BANGALORE RUR
KOLAR
HASSAN
BANGALORE URB
DAKSHIN KANNA
RAMANAGARAM
MANDYA
KODAGU
MYSURU
CHAMRAJNAGARA
Legend
District Boundary
30-60 Microgram per liter (ppb)
>60 Microgram per liter(ppb)
0 35 70 140 210 280
Kilometers
NDC CHQ AJIT SINGH Date: 6/3/2020

Figure-10

6.12 Kerala

A total of 423 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells**.** Uranium was found to be in the range of nd to 1.45 ppb.

6.13 Madhya Pradesh

A total of 1191 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State. The Ground Water samples are analyzed in ICP-MS.

The concentration of uranium ranges from 0.0 to 233.91 µg/L(**Table 13 & Figure 11)**. Out of 1191 wells, 16 wells (1.3%) exceed the WHO permissible limit of 30 µg/L and in 7 wells it has been found to be more than 60 ppb. The details of locations which exceed the permissible limit of 30 µg/L is given in Table. The highest value of 233.9 µg/Lwas recorded at location Ghantigaon, Ghantigaon Tehsil of Gwalior district. The Districts which are partly affected by high Uranium in ground water are - Balaghat, Betul, Chhatarpur, Datia, Gwalior, Jhabua, Panna, Raisen, Seoni, Shivpuri.

Table 13: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

S. No.	District	Block	Location	Uranium >30 ppb
1	Balaghat	Katangi	Katedhara	30.7
2	Betul	Betul	Betul1	**108.1**
3	Betul	Betul	Khedi	39.4
4	Chhatarpur	Bijawar	Gulganj	47.5
5	Chhatarpur	Chhatarpur	Kurri	39.2
6	Datia	Datia	Datia	**96.7**
7	Datia	Datia	Imaliya	51.9
8	Datia	Bhander	Bhander	32.9
9	Gwalior	Ghatigaon	Ghantigaon	**233.9**
10	Gwalior	Dabra	Tekanpur	58.5
11	Jhabua	Thandla	Thandla1	**75.0**
12	Panna	Shahnagar	Kuankheda	37.1
13	Raisen	Obaidullaganj	Maindwa	51.3
14	Seoni	Keolari	Dhangada	**203.3**
15	Seoni	Kurai	Khawasa	**61.4**
16	Shivpuri	Pichhore	Dhola	**79.1**

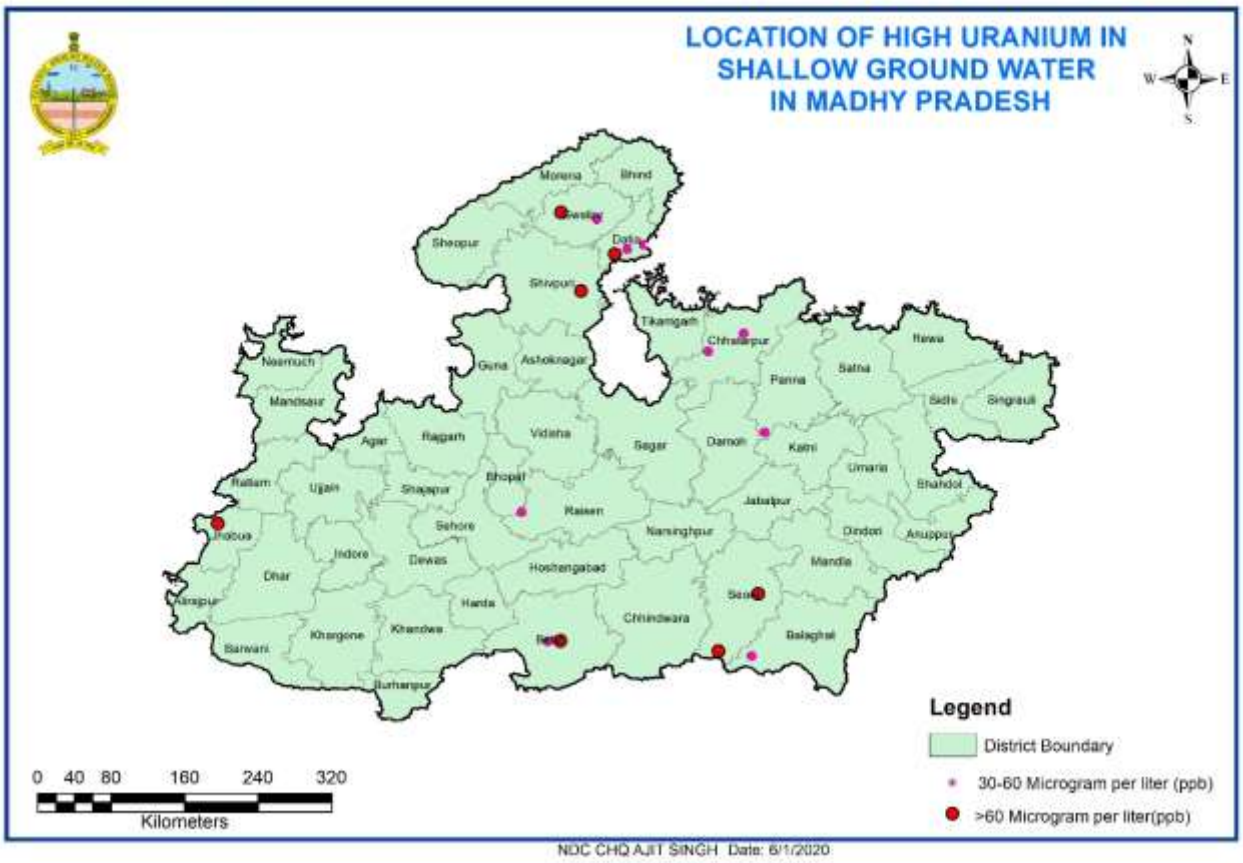


Figure-11

6.14 Maharashtra

A total of 1085 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State. The Ground Water samples are analyzed in ICP-MS.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except three samples (Table 14 & Figure 12). Uranium was found to be in the range of nd to 47.98 ppb. The Districts which are partly affected by high Uranium in ground water are - Bhandara, Gondia and Nagpur.

Table 14: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl No	District	Block	Location	U (ppb)
1	Bhandara	Tumsar	Khair Langi	47.98
2	Gondia	Arjuni Morgaon	Dhabetekdi	31.95
3	Nagpur	Mauda	Tarsha	33.44

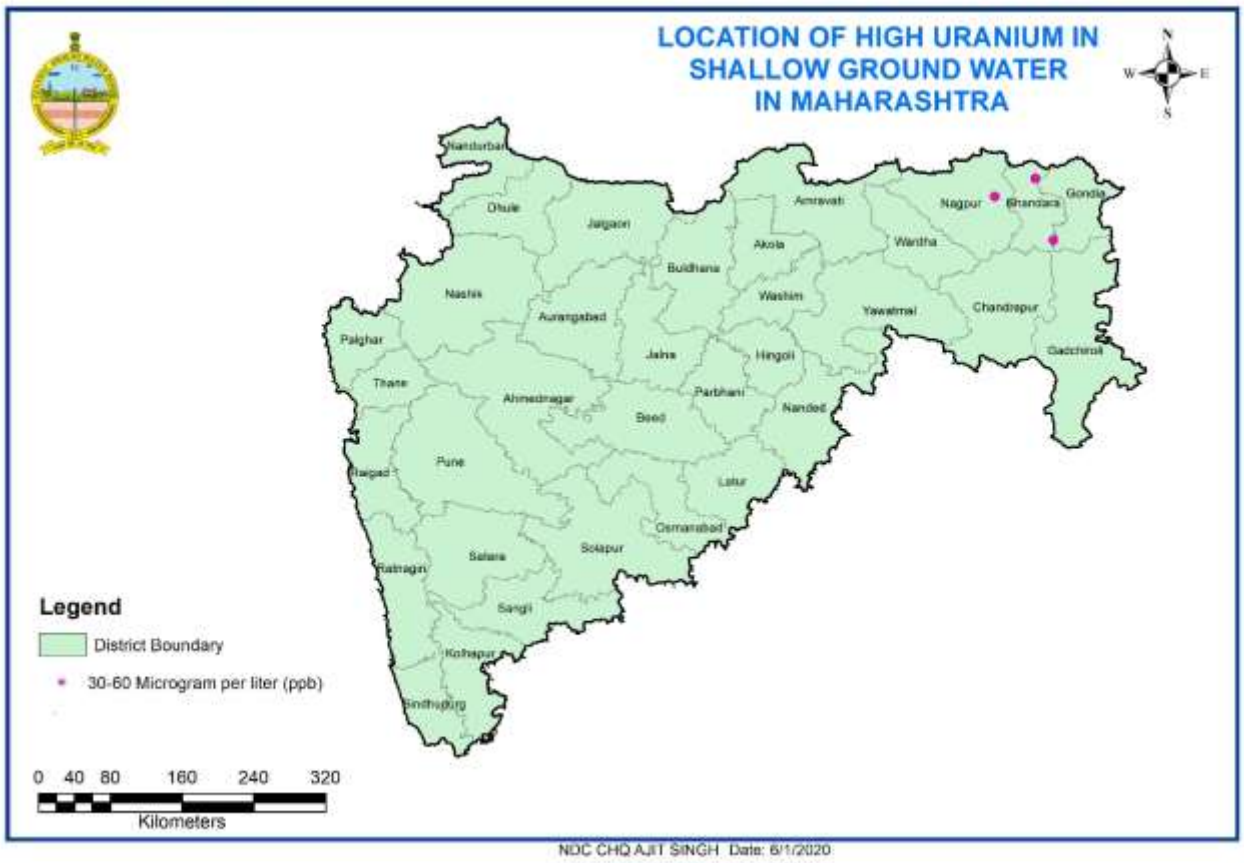


Figure-12

6.15 Odisha

A total of 1114 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State. The Ground Water samples are analyzed in ICP-MS.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except four samples (Table 15 & Figure 13). Uranium was found to be in the range of nd to 59 ppb. The Districts which are partly affected by high Uranium in ground water are - Angul, Dhenkanal, Sundargarh and Sambalpur.

Table 15: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl No	District	BLOCK	SITE	U_ppb
1	Angul	BANARPAL	Kukurang	36
2	Dhenkanal	PARAJANG	Kandarsingha	38
3	Sundargarh	SUBDEGA	Alikera	38
4	Sambalpur	MANESWAR	Gosala	59

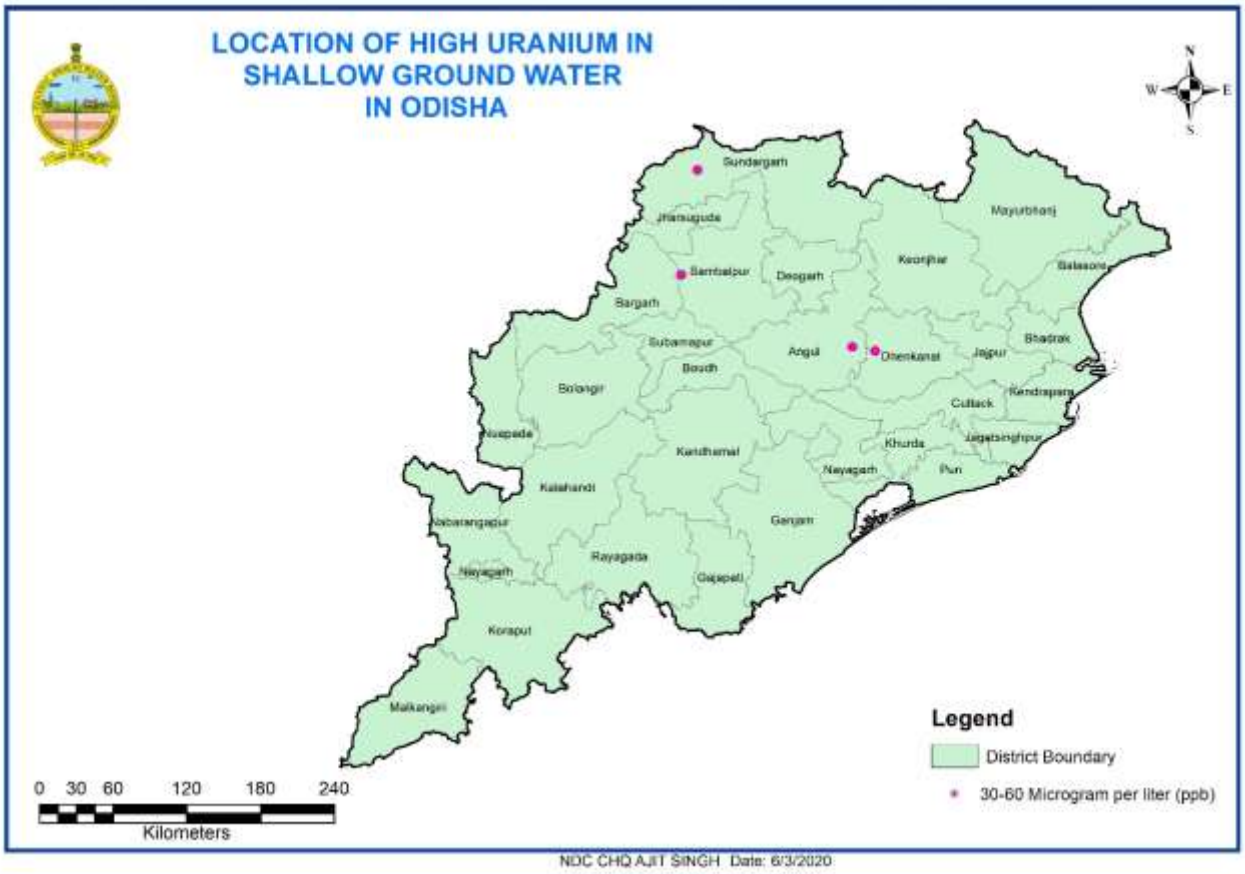


Figure-13

6.16 Punjab

The total 302 ground water samples collected during monitoring of nationational hydrograph network station established by CGWB .all the samples collected in 100ml HDPE Bottles and all samples filtered with special filter and also acidified the sample with 0.50ml suprapure nitric acid (67%). The analysis of Uranium has been carried out by Inductive cupple plasma techniques with ICP-MS.

The varied hydrogeological conditions in the alluvium of Punjab are also reflected in the type and nature of the Heavy Metals present in ground water of the State. On the basis of present studies the concentration of uranium more than 30ppb and 60ppb respectively describe in the Table 16 & Figure 14 given below. The Districts which are partly affected by high Uranium in ground water are - Bathinda, Moga, Faridkot, Fatehgarh Sahib, Fazilka, Ferozepur, Hoshiarpur, Jalandhar, Kapurthala, Ropar, Ludhiana, Muktsar, Pathankot, Patiala, Sangrur and SAS Nagar.

Table 16: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl. No	District	Block	Location	Uranium > 30 ppb	Sl. No.	District	Block	Location	Uranium > 30 ppb
1	Bathinda	Bathinda	Baluanga	44.5	38	Hoshiarpur	Talwara	Talwara	84.0
2	Bathinda	Bathinda	Ablu	68.0	39	Jalandhar	Jalandhar city	Jalandhar	52.8
3	Bathinda	Bathinda	Nahian wala	71.0	40	Jalandhar	Nakodar	Nakodar	140.4
4	Bathinda	Bathinda	Dera tappa	82.5	41	Jalandhar	Nur mahal	Sarih	49.9
5	Bathinda	Rampur phul	Rampur phul	42.9	42	Jalandhar	Shahkot	Shahkot	39.5
6	Bathinda	Rampura	Badiala	41.5	43	Kapurthala	Kapurthala	Kapurthala	35.4
7	Bathinda	Sangat	Raike kalan	31.4	44	Kapurthala	Phagwara	Phagwara	33.3
8	Bathinda	Sangat	Ghudda	33.1	45	Kapurthala	Sultanpur lodhi	Dalla	36.1
9	Faridkot	Faridkot	Jand sahib	31.2	46	Ludhiana	Dehlon	Gopalpura	42.0
10	Faridkot	Faridkot	Sher singh wala	37.1	47	Ludhiana	Jagraon	Jagraon	150.4
11	Faridkot	Faridkot	Deep singh wala	38.2	48	Ludhiana	Khanna	Maksudra	79.7
12	Faridkot	Faridkot	Sadiq	39.0	49	Ludhiana	Ludhiana i	Chatar singh park	64.5
13	Faridkot	Kotkapura	Matta	33.0	50	Ludhiana	Ludhiana i	Pau ludhiana	76.1
14	Faridkot	Kotkapura	Karirwali	36.1	51	Ludhiana	Ludhiana ii	Mangat	92.4
15	Fatehgarh sahib	Bassi pathana	Fatehgarh sahib	41.0	52	Ludhiana	Sudhar	Halwara	34.8
16	Fatehgarh sahib	Bassi pathana	Bassi pathana	51.8	53	Moga	Kote ishe khan	Bajeke	31.1
17	Fatehgarh sahib	Khera	Bhagrana	36.2	54	Moga	Moga-i	Chogawan	39.9
18	Fatehgarh sahib	Khera	Chunni kalan	42.6	55	Muktsar	Malout	Kaburwala	30.5
19	Fatehgarh sahib	Khera	Badli ala singh	72.0	56	Muktsar	Muktsar	Lubnaian wali	31.5
20	Fatehgarh sahib	Sarhind	Innayatpur	46.0	57	Muktsar	Muktsar	Balochkhera,	41.5
21	Fatehgarh sahib	Sirhind	Nalini	33.2	58	Pathankot	Dhar kalan	Parmota	44.3
22	Fazilka	Abohar	Abohar	33.6	59	Patiala	Ghanaur	Kami kalan	44.2
23	Fazilka	Abohar	Bazidpur bhoma	69.5	60	Patiala	Ghanaur	Lacharu kalan	51.1
24	Fazilka	Abohar	Khundal	156.5	61	Patiala	Nabha	Majhi	52.7
25	Fazilka	Khuiyan serovar	Khllian serovar	36.6	62	Patiala	Samana	Behmana	31.3
26	Ferozepur	Makhu	Lauke kalan	30.5	63	Patiala	Sanour	Mardan heri	66.9
27	Hoshiarpur	Bhunga	Garhdiwala	50.3	64	Ropar	Nurpur bedi	Dumewal	44.1
28	Hoshiarpur	Dasuya	Haler rampur	64.6	65	Ropar	Rup nagar	Bara chauta	42.9

29	Hoshiarpur	Dasuya	Dulmiwal	135.2	66	Sangrur	Amargarh	Maler kotla	44.3
30	Hoshiarpur	Hajipur	Nangal bhiala	35.0	67	Sangrur	Andana	Bhulan	31.2
31	Hoshiarpur	Hajipur	Dagan	49.8	68	Sangrur	Sunam	Sunam	37.1
32	Hoshiarpur	Hoshiarpur i	Sham chaurassi	71.9	69	Sas nagar	Dera bassi	Chhat	39.6
33	Hoshiarpur	Hoshiarpur ii	Chohal	31.1	70	Sas nagar	Dera bassi	Issapur	54.0
34	Hoshiarpur	Hoshiarpur ii	Rampur camp colony	59.0	71	Sas nagar	Kharar	Landran	51.9
35	Hoshiarpur	Mukerian	Bhangala	37.3	72	Sas nagar	Kharar	Dheri	55.1
36	Hoshiarpur	Mukerian	Pankhuh	40.0	73	Sas nagar	Kharar	Goga	56.6
37	Hoshiarpur	Mukerian	Chak sheru	97.1					

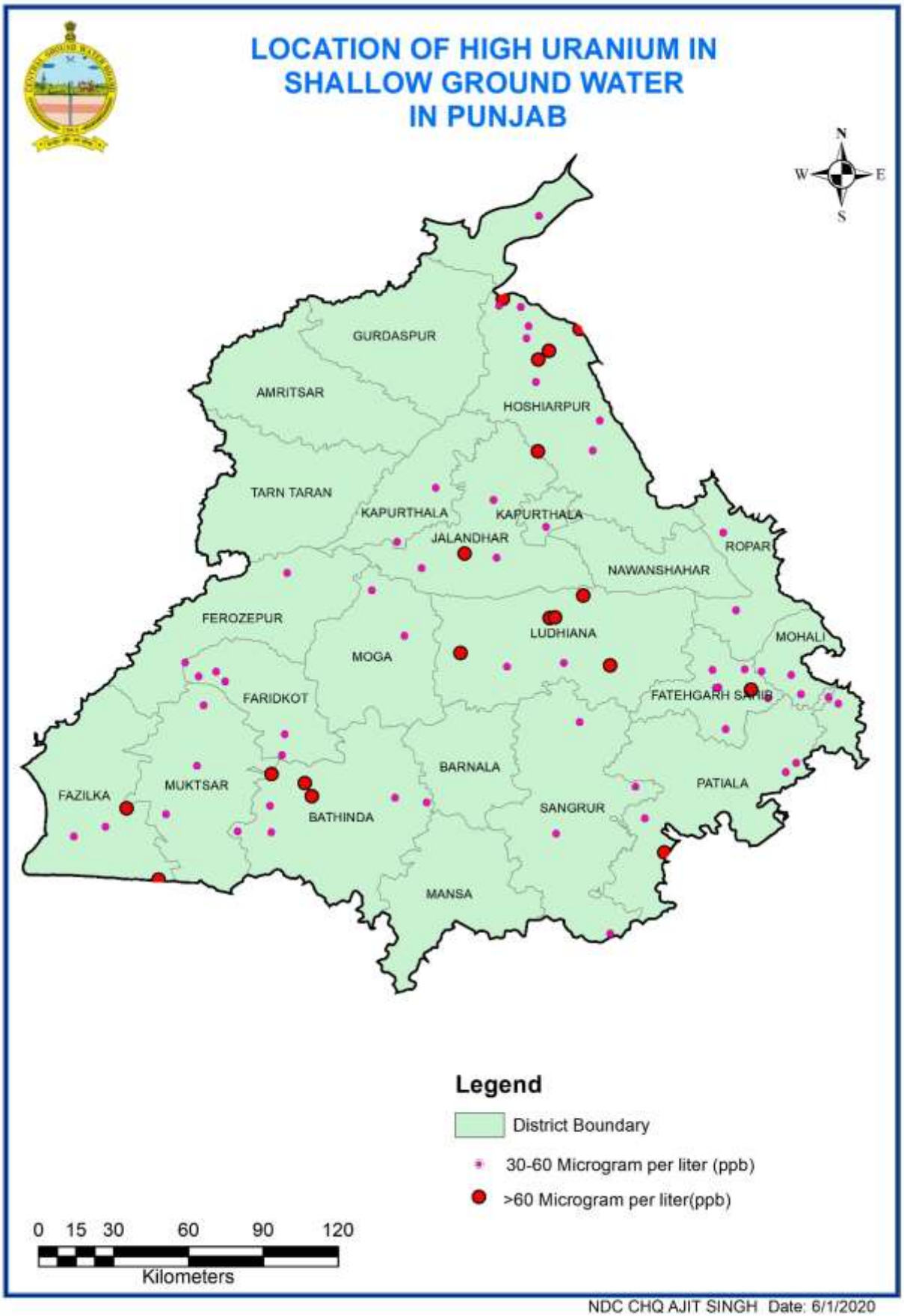

LOCATION OF HIGH URANIUM IN SHALLOW GROUND WATER IN PUNJAB
N
W
E
S
GURDASPUR
AMRITSAR
HOSHIARPUR
TARN TARAN
KAPURTHALA
KAPURTHALA
JALANDHAR
ROPAR
NAWANSHAHAR
FEROZEPUR
LUDHIANA
MOHALI
MOGA
FARIDKOT
FATEHGARH SAHIB
BARNALA
PATIALA
MUKTSAR
FAZILKA
BATHINDA
SANGRUR
MANSA
Legend
District Boundary
30-60 Microgram per liter (ppb)
>60 Microgram per liter(ppb)
0 15 30 60 90 120
Kilometers
NDC CHQ AJIT SINGH Date: 6/1/2020

Figure-14

6.17 Rajasthan

A total of 671 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State.

In 48 (7.15%) samples Uranium concentrations have been found to be more than the permissible limit for drinking water prescribed by WHO. Uranium more than 60 ppb (permissible limits as per Atomic Energy Regulatory Board (DAE)) has been detected in 8 (1.19%) samples in the States. The highest values obtained is 181 ppb at Bagot in Nagaur District in Rajasthan (Table 17 & Figure 15). Uranium concentration above 30 µg/l is observed in 21 districts out of 33 districts of Rajasthan state (7.15%). The Districts which are partly affected by high Uranium in ground water are - Ajmer, Alwar, Banswara, Barmer, Bhilwara, Bikaner, Bundi, Chittaugarh, Churu, Dausa, Ganganagar, Jaipur, Jelore, Jodhpur, Karauli, Nagaur, Pratapgarh, Rajsamand, Sawai Madhopur, Tonk and Udaipur.

Table 17: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

S. No.	District	Block	Village	U (> 30ppb)	S. No.	District	Block	Village	U (> 30ppb)
1	Ajmer	Peesangan	Tabiji	33.1	25	Jaipur	Chaksu	Tootoli	43.1
2	Ajmer	Kekri	Nai Khera	33.5	26	Jaipur	Dudu	Mozmabad	50.9
3	Ajmer	Srinagar	Kanpura1	63.4	27	Jaipur	Sanganer	Goner	52.2
4	Alwar	Ramgarh	Ramgarh1	34.9	28	Jaipur	Phagi	Bhojpura	66.6
5	Banswara	Sajjangarh	Chota Dungra	34.1	29	Jaipur	Dudu	Nasnota	80.0
6	Barmer	Baetu	Panavada	33.5	30	Jaipur	Phagi	Majhi Renwal	95.5
7	Barmer	Sindhari	Arniyali	34.5	31	Jaipur	Chaksu	Shivdaspura	138.4
8	Bhilwara	Hurda	Gulabpura	47.0	32	Jalore	Bhinmal	Bhinmal1	35.9
9	Bhilwara	Mandalgarh	Mandalgarh1	64.9	33	Jodhpur	Luni	Khudala	40.3
10	Bikaner	Khajuwala	Chhatargarh	34.4	34	Jodhpur	Pipar City	Ramrawas	43.2
11	Bikaner	Lunkaransar	Kaloo	35.9	35	Karauli	Karauli	Bhauapura	56.3
12	Bikaner	Lunkaransar	Arjansar	41.9	36	Nagaur	Didwana	Singhana1	44.2
13	Bundi	Talera	Ballop	57.5	37	Nagaur	Didwana	Singhana1	53.0
14	Chittaurgarh	Kapasan	Mungana	30.4	38	Nagaur	Parbatsar	Bagot	181.1

15	Chittaurgarh	Chittaurgarh	Purohitokasavat	46.6	39	Pratapgarh	Pratapgarh	Suhagpura	45.6
16	Churu	Bidasar	Soniasar	32.4	40	Rajsamand	Railmagra	Khandel 1	33.1
17	Churu	Ratangarh	Bhojasar	33.3	41	Rajsamand	Amet	Gugli	37.4
18	Churu	Rajgarh	Rajgarh1	45.4	42	Rajsamand	Railmagra	Oda 1	56.0
19	Dausa	Dausa	Jasuta	36.1	43	Rajsamand	Amet	Chattarpur	108.7
20	Ganganagar	Ganganagar	Tatarsar	30.1	44	Sawai Madhopur	Bonli	Bonali	33.2
21	Ganganagar	Karanpur	Rupanagar	33.5	45	Tonk	Newai	Niwai1	37.1
22	Ganganagar	Sangariya	Kheruwala	42.1	46	Tonk	Uniara	Dikoliya	38.1
23	Ganganagar	Suratgarh	Piperan	45.8	47	Tonk	Tonk	Arniyalmal	59.5
24	Jaipur	Phagi	Choru	31.2	48	Udaipur	Mavli	Mavli1	38.7

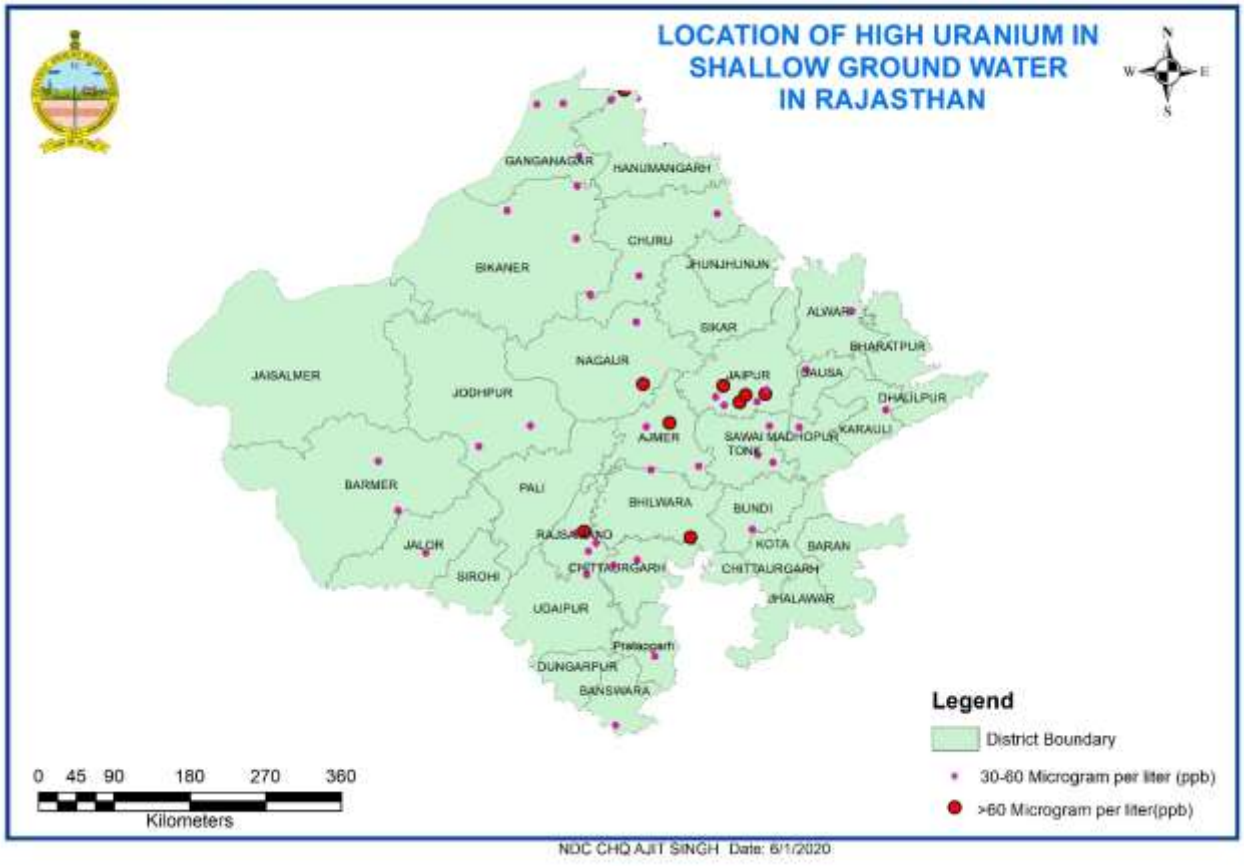


Figure-15

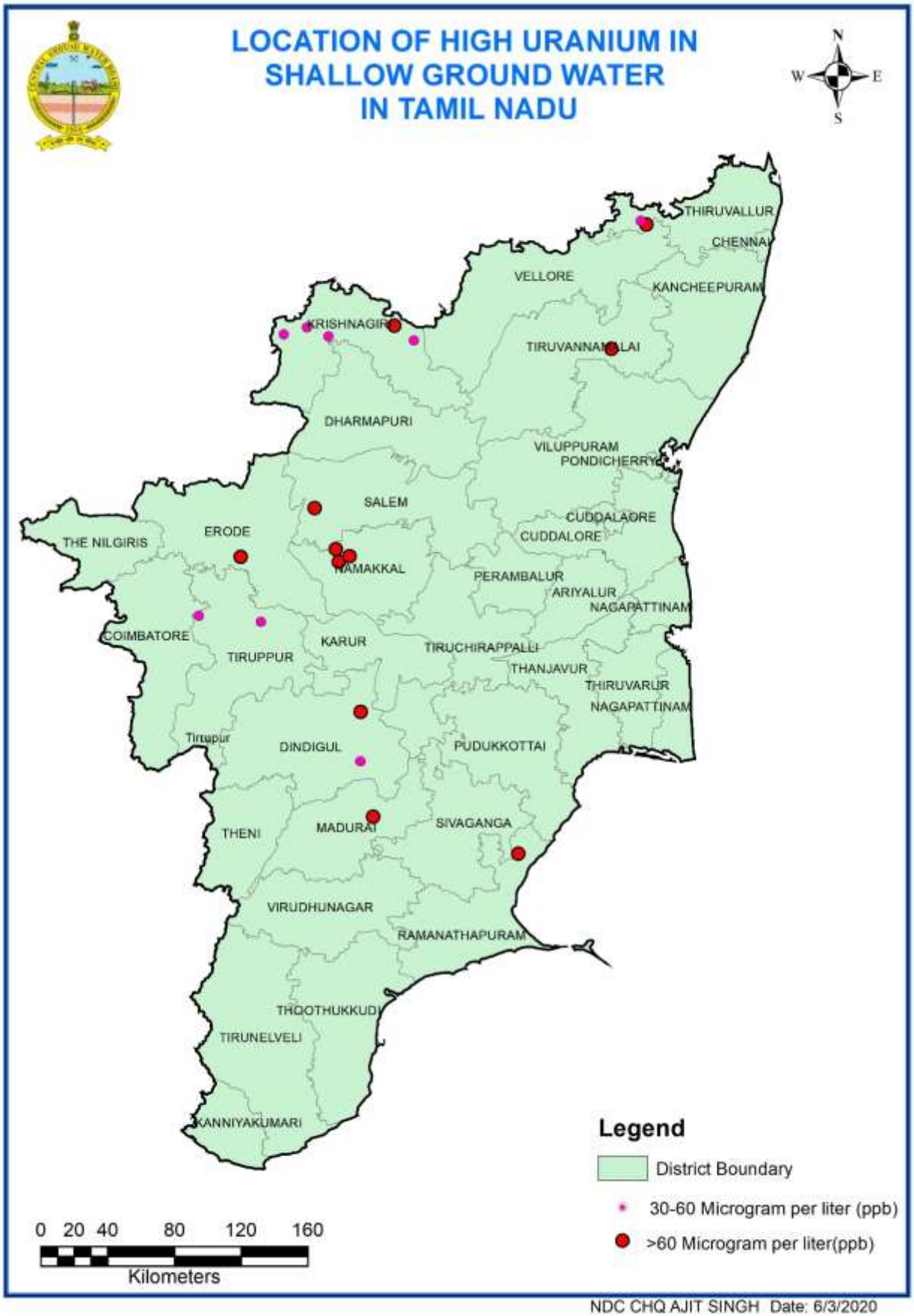
6.18 Tamil Nadu & Pondicherry

A total of 1208 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State.

In 19 samples Uranium concentrations have been found to be more than the permissible limit for drinking water prescribed by WHO. Uranium more than 60 ppb (permissible limits as per Atomic Energy Regulatory Board (DAE)) has been detected in 11 samples in the States. The highest values obtained is 302 ppb at Megalachinnapalli pz in Krishnagiri District in Tamil Nadu (**Table 18 & Figure 16)**. The Districts which are partly affected by high Uranium in ground water are - Dindigul, Erode, Krishnagiri, Madurai, Mamakkal, Ramnathapuram, Salem, Thiruvannamalai, Tirupur and Tiruvallur.

Table 18: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl No	District	Block	Village Name	U in ppb
1	Dindigul	VEDASANDUR	Vaivespuram	**113.4**
2	Dindigul	SANARPATTI	Senarpatti	53.9
3	Erode	GOPICHETTIPALAIYAM	Kolappalur	**88.9**
4	Erode	GOPICHETTIPALAIYAM	Erakalpudur (Sivanmalai)	49.7
5	Krishnagiri	KRISHNAGIRI	Megalachinnapalli pz	**302.3**
6	Krishnagiri	HOSUR	Machinayampalli	58.0
7	Krishnagiri	THALLY	Thally	39.5
8	Krishnagiri	KELAMANGALAM	Anusonai	32.6
9	Krishnagiri	BARGUR	Bargur	45.0
10	Madurai	TIRUPARANKUNRAM	Thirupallai	**104.0**
11	Namakkal	ELACHIPALAYAM	Unjanai	**174.8**
12	Namakkal	ELACHIPALAYAM	Elachipalayam	**61.8**
13	Namakkal	ELACHIPALAYAM	Uthandipalayam	**134.9**
14	Ramanathapuram	TIRUVADANAI	Tiruvadanai1	**70.2**
15	Salem	EDAPADI	Chittoor pz	**67.7**
16	THIRUVANNAMALAI	KANCHEEPURAM	Kancheepuram	**61.3**
17	TIRUPUR	TIRUPUR	Uthukadu	42.1
18	Tiruvallur	TIRUTTANI	Madam(S)	**160.1**
19	Tiruvallur	TIRUTTANI	Agoor(S)	47.1


LOCATION OF HIGH URANIUM IN SHALLOW GROUND WATER IN TAMIL NADU
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THIRUVALLUR
CHENNAI
VELLORE
KANCHEEPURAM
KRISHNAGIRI
TIRUVANNAMALAI
DHARMAPURI
VILUPPURAM
PONDICHERRY
SALEM
CUDDALORE
CUDDALORE
ERODE
THE NILGIRIS
NAMAKKAL
PERAMBALUR
ARIYALUR
NAGAPATTINAM
COIMBATORE
KARUR
TIRUCHIRAPPALLI
TIRUPPUR
THANJAVUR
THIRUVARUR
NAGAPATTINAM
Tirupur
DINDIGUL
PUDUKKOTTAI
THENI
MADURAI
SIVAGANGA
VIRUDHUNAGAR
RAMANATHAPURAM
THOOTHUKKUDI
TIRUNELVELI
KANNIYAKUMARI
Legend
District Boundary
30-60 Microgram per liter (ppb)
>60 Microgram per liter(ppb)
0 20 40 80 120 160
Kilometers
NDC CHQ AJIT SINGH Date: 6/3/2020

Figure-16

6.19 Telangana

A total of 345 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of Telangana State.

Out of 345 samples analysed, in 36 samples (10.4%)Uranium concentrations have been found to be more than 30ppb, the permissible limit for drinking water prescribed by WHO. Uranium more than 60 ppb (permissible limits as per Atomic Energy Regulatory Board (DAE)) has been detected in 10 samples in Telangana States. The highest values obtained is 158 ppb at Koti in Hyderabad district of Telangana. The following reasons may attribute for high concentration of Uranium in Ground water (**Table 19 & Figure 17)**.

Granites particularly Younger granitic intrusive are the source rocks for high concentration of Uranium in Nalgonda and Mahabubnagar districts in Telangana. High solubility of Uranium observed from calcium rich associated minerals of host rocks and host rocks with lineaments and subsequent leaching into ground water. The Districts which are partly affected by high Uranium in ground water are - Adilabad, Hyderabad, Mahabubnagar, Medak, Nalgonda and RangaReddy.

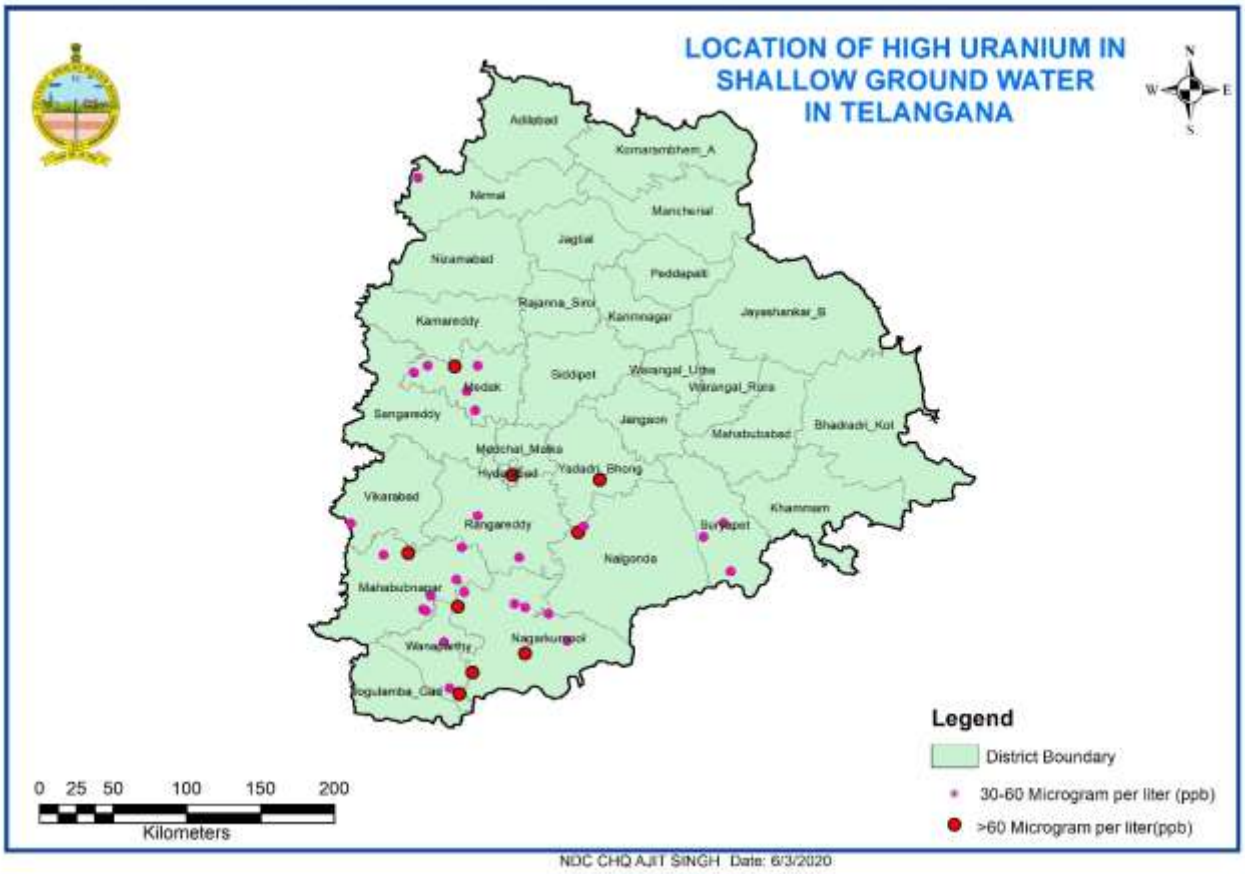

Figure-17

Table 19: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl. No.	District	Mandal	Location	U >30 ppb	Sl. No.	District	Mandal	Location	U >30 ppb
1	Adilabad	Kubeer	Sonari-Alt	58.5	19	Mahabub nagar	Bijinapalle	Manganur-PZ	**68.7**
2	Hyderaba d	Nampall y	Koti-PZ	**158.2**	20	Mahabub nagar	Lingal	Lingal-PZ	**85.7**
3	Mahabub nagar	Kothur	Kothur 2012Pz	34.3	21	Mahabub nagar	Veepangan dla	Pedda Dagada-PZ	**134.4**
4	Mahabub nagar	Kodanga l	Ravalpalle	38.1	22	Medak	Shankaram pet(r)	Bodagutta	34.5
5	Mahabub nagar	Veepang andla	Velgonda-PZ	39.5	23	Medak	Shankaram pet(r)	Nizampet	35
6	Mahabub nagar	Timmaji pet	Timmajipet 2012Pz	39.9	24	Medak	Kaudipalle	Kaudipally-PZ	37
7	Mahabub nagar	Sankala mandi	Jananpet-Pz	41.6	25	Medak	Medak	Medak IMD-Pz	37.9
8	Mahabub nagar	Jadcherla	Jadcharla 2012Pz	41.7	26	Medak	Narsapur	Reddypalli-PZ	38.5
9	Mahabub nagar	Wanapar thy	Vanaparthi-PZ	44.2	27	Medak	Papannape t	Yusuf Peta-DW13	**61.4**
10	Mahabub nagar	Amrabad	Amrabad-PZ	45.1	28	Nalgonda	Chendur	Ghattupal-pz14	30.2

11	Mahabub nagar	Balanagar	Balanagar 2012Pz	46.9	29	Nalgonda	Mungala	Madharam 2013Dw	30.4
12	Mahabub nagar	Sankala mandi	Ponnakelpz	49	30	Nalgonda	Munugode	Chikatimamidi DW13	30.6
13	Mahabub nagar	Nagarkur nool	Nagarkurnoo l-PZ	49.6	31	Nalgonda	Penpahad	Penpahad-PZ	36.7
14	Mahabub nagar	Vangoor	Vangur-PZ	51.3	32	Nalgonda	Gundlapall e	G.palli(dindi) - PZ	39.9
15	Mahabub nagar	Vangoor	Polkampalli-PZ	53.4	33	Nalgonda	Marriguda	Antampet-PZ1	**62**
16	Mahabub nagar	Kosigi	Gundimal	53.5	34	Nalgonda	Valigonda	Nagaram Aq-I	**82.2**
17	Mahabub nagar	Sankala mandi	Kandur-Pz	58.3	35	Ranga Reddy	Ganded	Nancherla 2011Pz	**65.9**
18	Mahabub nagar	Kodair	Narsaiahpall y-Pz	**61.6**					

6.20 Uttarakhand

A total number of 186 water samples from NHS Groundwater monitoring wells in 2019 were collected for Uranium analysis after 1:1Ultrapure Nitric acid treatment.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells**.** Uranium was found to be in the range of nd to 24.17 ppb.

6.21 Uttar Pradesh

A total number of 826 water samples from NHS Groundwater monitoring wells in 2019 were collected for Uranium analysis after 1:1Ultrapure Nitric acid treatment.

In 22 samples Uranium concentrations have been found to be more than the permissible limit for drinking water prescribed by WHO. Uranium more than 60 ppb (permissible limits as per Atomic Energy Regulatory Board (DAE)) has been detected in 3 samples in the States. The highest values obtained is 189 ppb at Mohammadpur in Bijnor District in Uttar Pradesh (**Table 20 & Figure 18)**. The Districts which are partly affected by high Uranium in ground water are - Aligarh, Azamgarh, Bijnaur, Badaun, Bulandshaher, Deoria, Farrikhabad, Fatehpur, G.B.Nagar, Ghaziabad, Ghazipur, Hardoi, Hathras, J P Nagar, Kanpur Nagar, Mainpuri, Mathura, Pratapgarh, Raebarelli, Sultanpur and Unnao.

Table 20: The district wise location list of uranium concentrations more than permissible limits of 30 ppb.

Sl No	District	Block	U (ppb)	Sl No	District	Block	U (ppb)
1	Aligarh	Dhanipur	41	19	Hathras	Mursan	31
2	Aligarh	Gonda	53	20	Hathras	Sasni	53
3	Azamgarh	jahanaganj	32	21	J P Nagar	Joya	59
4	Bijnor	Kiratpur	34	22	Kanpur Nagar	Chaubepur	32
5	Bijnor	Mohammadpur	**189**	23	Mainpuri	KISHNI	42
6	Budaun	WAJIRGANJ	37	24	Mathura	Goverdhan	31

7	Budaun	BISOULI	48	25	Mathura	Nandgaon	40
8	Budaun	MIAON	**62**	26	Mathura	Raya	45
9	Bulandshahar	Shikarpur	51	27	Mathura	Chhata	**71**
10	Deoria	Bhaluwani	51	28	Pratapgarh	Baba Bekhernath	32
11	Farrukhabad	RAJEPUR	34	29	Pratapgarh	Babaganj	32
12	Fatehpur	Malwan	43	30	Pratapgarh	Sangaipur	54
13	Gautam Buddha Nagar	Dankaur	35	31	Rae Bareili	Lalganj	38
14	Gautam Buddha Nagar	Jewar	39	32	Rae Bareili	Chhatoh	55
15	Ghaziabad	Dholana	42	33	Sultanpur	Jagdishpur	31
16	Ghazipur	jakhaniya	37	34	Sultanpur	P.P Kannaicha	33
17	Hardoi	Mallawan	33	35	Unnao	Nawabganj	35
18	Hathras	Hathras	30	36	Unnao	Unchahar	45

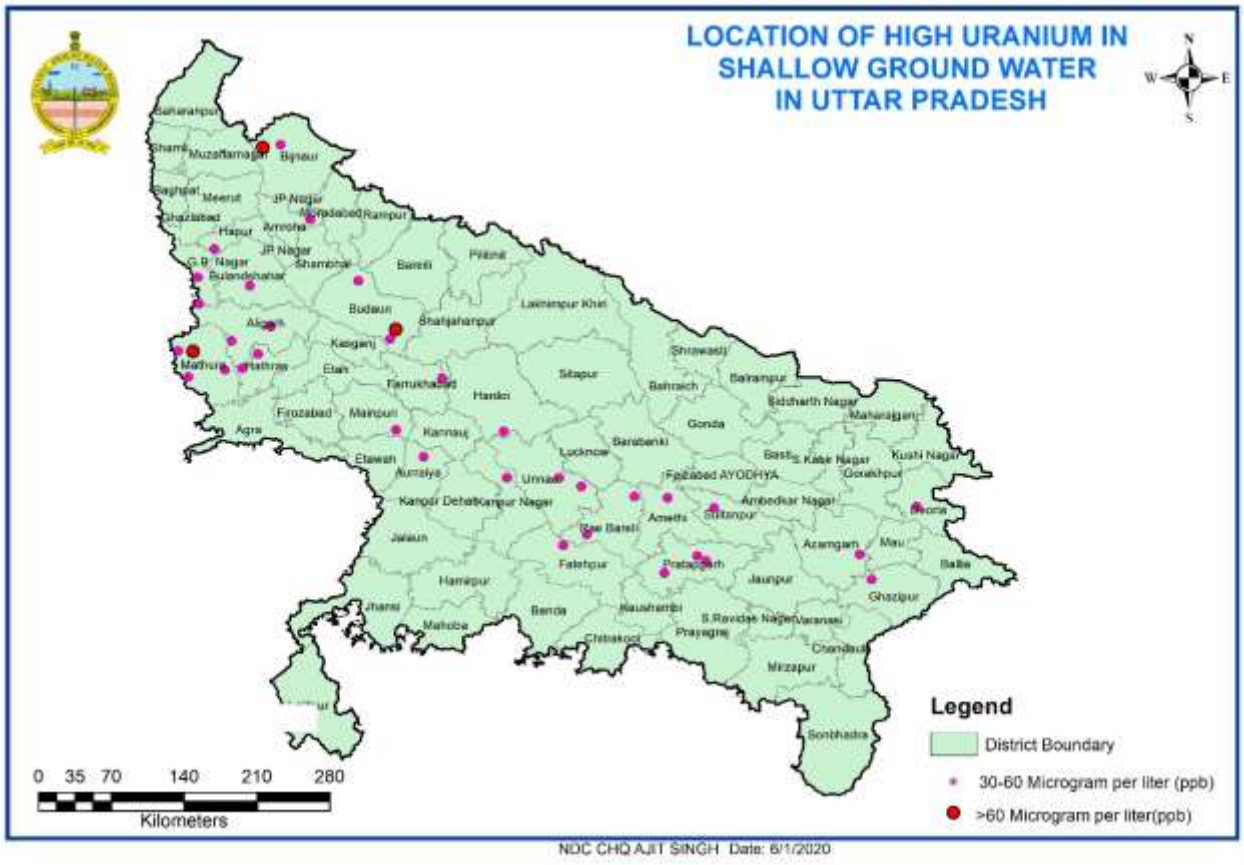

Figure-18

6.22 West Bengal & A & N

A total of 935 ground water samples were collected during Pre-Monsoon season (May-2019) from NHNS Stations falling in different hydro geological settings of the State of West Bengal and A & N.

Uranium was found to be within the permissible limit of 30 ppb in all the samples collected from NHS Groundwater monitoring wells except in one sample at Malda Town (34.26 ppb) in Malda District.

7.0 REMEDIAL MEASURES

Ex situ Treatment of radioactive contaminants in ground water fall into following categories

1. **Adsorption or ion exchange**: The water soluble contaminants are captured by sorption onto a solid support that can be natural or synthetic material.
2. **Reactive sorption:** is based on reaction of contaminant with solid substrate. It is often applied in situ as a barrier wall that the contaminant is forced through and is trapped.
3. **Precipitation:** This is mostly practiced above ground and involves addition of alkali to raise the pH & precipitate the oxide or hydroxide.
4. **Reverse osmosis**: Water is transported through a high pressure gradient through a membrane essentially non permeable to the contaminant.
5. **Stripping:** Only applicable to volatile contaminants like radon.

Remedial strategies based on in-situ chemical stabilization are as effective as the geochemistry of the site permits. Such chemical technologies may be generally grouped according to the following paradigm.

1. **Redox Technologies**: These technologies attempt to manipulate oxidation-reduction conditions of the subsurface to reduce uranium to uranous (uranium IV) forms. The techniques include in-situ redox manipulation using sodium dithionite, zero-valent iron, microbial induced reduction, and calcium polysulfide technologies. The common deficiency of technologies in this category is that the reduced environment and corresponding uranium precipitate is easily re-oxidized over time. Consequently, over time the "treated" uranium is remobilized.
2. **Co-precipitated Iron Oxy-hydroxide**: This technology affects only temporary stabilization because the reaction is reversed as the precipitate ages.
3. **Phosphate Precipitation Technologies**: These technologies apply and modify phosphate with uranyl (uranium VI) forms to remove soluble uranium and prevent further dissolution of uranium by sequestration, immobilization, or precipitation. The resulting reaction seeks to create a stable, long-lasting reaction that removes the source of ongoing uranium contamination to the groundwater. However, this group of technologies requires further development.

4. **Flushing Technologies**: This group of remediation technologies uses a variety of leaching solutions to dissolve solid-phase uranium and hydraulic extraction techniques to remove the solubilized uranium. Subsurface stratigraphic heterogeneities make comprehensive treatment difficult to attain. Hydraulic capture and capture of the mobilized uranium can be problematic.

Pilot Study Cases

1. **Bioremediation of uranium-contaminated groundwater**: Microbial reduction of soluble U(VI) to insoluble U(IV) by U(VI)-reducing capacity of the Geobacter species that are naturally present in subsurface environments can be simply and effectively stimulated with the addition of an acetate solution to the groundwater. This precipitates uranium from the groundwater preventing its further mobility and concentrations uranium dispersed in a large volume of groundwater into a discrete zone for subsequent removal.
2. **Uranium removal from groundwater by natural zeolites**: It is found that adsorption on clinoptilolite manganese oxide coated zeolite (MOCZ) may be useful for uranium removal.
3. **Permeable Reactive Barriers:** Installation of Permeable reactive barriers (PRBs) like bone char phosphate, zero valent iron or ferric iron across the flow path of the contaminant plume has consistently lowered the input U concentration in the pilot studies.
4. Ground water with higher uranium concentration can be made potable by the use of techniques such as Reverse Osmosis (RO). Based on field study carried out in Punjab, it was established that uranium content in RO treated water is below 0.1 microgram per litre.

URANIUM CONTAMINATION IN SHALLOW GROUND WATER IN INDIA

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