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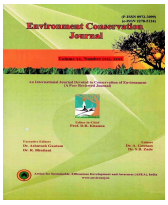

Evaluation of the toxicological effects of uranium on human health in Chandrapur, Maharashtra, with reference to the water quality index

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ABSTRACT

Groundwater is an important resource and approximate 80% of the world's population depends solely on it to satisfy their needs. In the present investigation groundwater quality was assessed using WQI. For the same parameters viz, temperature, pH, conductivity, DO, alkalinity, TDS, sulphate, fluoride, bicarbonate, chloride, uranium, total hardness, calcium and magnesium hardness were assessed during post monsoon period in November 2021 in the Chandrapur region. For conducting this research total 116 groundwater samples were collected from different hydrological stations for the assessment of WQI. WQI is an important tool to assess quality of water for drinking and is classified as excellent to unsafe, i.e., 0-100 score. In this investigation WQI was found to be in the range between 27.63-674.56 exceeding both minimum and maximum score. The results of the present investigation showed that only 5.17% of water is safe for drinking,18% of water indicated poor water quality, 15% of water has very poor water quality and 77% of water is unsuitable for drinking purpose and proper treatment is required before use. During this investigation uranium in groundwater was also assessed considering its chemotoxical and radiological effects on human health. The chemotoxical and radiological effects were analyzed adopting standard equations given by USEPA. The radiological risk of mortality and morbidity was found to be 1.37E-05-1.47E-05, respectively. Thus, presence of uranium was noted and radiological risk was found to be below the permissible limit of AERB standard. The chemical toxicity of average value of Lifetime Average Daily Dose (LADD) and Hazard Quotient (HQ) was observed 0.315 and 0.00571, respectively and chemical toxicity of LADD was found to be in 8.62% sample population and above the permissible limits which can affect human health and can have kidney toxicity, bone and lung toxicity.

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Introduction

Groundwater can be found practically anywhere beneath the Earth's surface. The earth's surface is not uniformly distributed. However, there are many localized aquifer sources and segments with similar personalities (Vasanthavigar *et al*., 2010; Ahamad *et al.,* 2022). The quality of groundwater changes with the level of water, seasonal fluctuations, dissolved ions and subterranean surroundings (Gebrehiwot *et al*., 2011; Ruhela *et al.,* 2022a; Ahamad *et al.,* 2023). According to the World Health Organization (WHO), in 2017, more than 80% of all human infections were waterborne. Because groundwater is polluted, ensuring its safety is challenging (Ram *et al*., 2021; Bhutiani *et al*., 2021). An appropriate analysis of the features of groundwater reservoirs is necessary to establish a sustainable exploitation of groundwater resources for further growth and requirements because there are many elements that might affect groundwater quality (Carrera-Hernandez and Gaskin, 2006; Chenini and Ben, 2010). To help with enhancing groundwater management techniques (protection and

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sustainability from degradation), hydrogeochemical information must be gathered for the area (Vasanthavigar M., *et al*., 2010; Ruhela *et al.,* 2022b). An extensive hydrological study based on policy deployments is required in each area where drinking water will be extracted. In these cases, water quality assessment indices (WQIs) are commonly used as collection and management technologies for monitoring water quality. In general, indices were created to summarize water quality data in a conveniently expressed and unstainable format. By definition, indices contain less data than the raw data that they summarize. As a result, indices are typically useful for illustrative purposes and common questions. Depending on the available data, various approaches to developing an index of water quality are possible (Saeedi *et al*., 2010; Bhutiani *et al*., 2018). The quality of recharged water, atmospheric rainfall, coastal surface water and lithospheric geochemical processes all influence groundwater quality. Periodic changes in groundwater quality can be caused by changes in the origin and composition of recharged water as well as hydrologic and human factors (Vasanthavigar M., *et al*., 2010). In the present study, the water quality index was assessed in combination with uranium in groundwater considering its chemical and radiological risk. The presence of groundwater uranium is affected by a variety of factors, including geomorphological, lithological and other geological conditions. The uranium concentration in groundwater is affected by natural and anthropogenic activities (Duggal *et al*., 2017; Kumar *et al*., 2016). Despite the fact that uranium is naturally present in the environment, has no known positive metabolic activities and is considered a nonessential constituent, when uranium is acquired in humans, it can cause radioactive and chemical effects in the form of numerous different health hazards (Duggal *et al*., 2020; Sharma *et al*., 2016; Bojago *et al*., 2023).

Materials and Methods

Study Area

Chandrapur is part of the Vidarbha region of Maharashtra and covers an area of 11,364 km^2. It is also called the black gold city due to the dominance of coal mines around the city (Environmental Status Report, 2007). The latitude and longitude of the district are 19.30'N to 20.45'N and 78.46'E, respectively. The district is located within the Wainganga and Wardha Basins and flows through the boundaries of the Eastern and Western regions of the district (CGWB,2011). The sources of water-bearing formations in this district are Deccan Trap Bsalt, Vindhya Limestone, Alluvium, Lower Gondwana sandstone and Archean metamorphic rocks (CGWB, 2009; Satapathy *et al*., 2009).

Sample collection and preservation

In the present study, sample collection and preservation were performed according to standard methods given in APHA and AWWA (2017). With the help of the grid map, 116 groundwater samples were collected from 15 different locations in the district during the postmonsoon season. The sampling bottles were soaked in 10% HNO3 overnight and were washed before sample collection. The clean bottles were used for the collections, and water samples were collected without aeration. The samples were sealed tightly with the help of cello tape and labeled after collection. In situ parameters such as temperature, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), pH, oxidation–reduction potential (ORP), salinity, etc., were measured with the help of a Bluetooth multiparameter portable kit, and off-situ chemical parameters such as alkalinity (titration), total hardness (EDTA titration method), chloride, bicarbonate, fluoride, sulphate, and uranium were analyzed with the help of standard methods prescribed by the APHA and AWWA and NEERI in the laboratory; in particular, uranium was analyzed at the KITS College, Ramtek, by using an LED fluorimeter.

Water quality index

The water quality index is a mathematical tool for calculating a single value that represents water quality based on multiple water quality metrics. The WQI is used to measure water quality parameters because it allows the creation of a numerical expression that can be used to characterize water quality.

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The water quality index categorizes the water quality data into a single value using a methodological approach or model. The WQI calculations consider all water quality criteria and are based on the suitability of both surface water and groundwater for their desired use (Ghoderao, *et al.,* 2022).

$$Qi = \frac{(Vobserved - Videal)}{(Vstandaed - Videal)} \times 100 \quad \text{---------- 1}$$

where
Qi = Quality rating of the i^{th} parameter for a total of n^{th} water quality parameters.
$V_{observed}$ = Actual value of the water quality parameter obtained from laboratory analysis
V_{ideal} = the ideal value of that quality parameter can be obtained from the standard tables.
V_{ideal} for pH = 7 and for other parameters is equal to zero and DO
V_{ideal}= 14.6 mg/L
$V_{standard}$ = Recommended

WHO standard of the water quality parameter.

Calculation of Unit weight (Wi):
The unit weight was calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression:

$$Wi = \frac{K}{Si} \quad \text{---------- 2}$$

where
Wi = Unit weight for the nth parameter,
Si = Standard permissible value for the nth parameter
K = proportionality constant. For the sake of simplicity, K is assumed to be 1,

The overall WQI was calculated by aggregating the quality rating with unit weight linearly using the following equation:

$$WQI = \frac{\sum WiQi}{\sum Wi} \quad \text{---------- 3}$$

where Qi = quality rating,
WI = Unit weight

Radiological risk assessment
The radiological risk is nothing but the excess cancer risk (ECR) (Patra, *et al*., 2013). The excess cancer risk was determined with the following formula provided by the United States Environmental Protection Agency (USEPA):

$$ECR = U \times Risk\ factor \quad \text{---------- 4}$$

where the uranium concentration (µg/L) is converted into Bq/L.
The conversion factor is 0.025 Bq/L.

R is the risk factor and is calculated by the following equation:

$$Risk\ Factor\ (L/Bq) = Risk\ Coefficient \times IR \times TEP \quad \text{---------- 5}$$

where r is the uranium risk coefficient for mortality and mobility and was taken as 1.19×10^{-9} and 1.84×10^{-9} Bq/L, respectively (Mehra, *et al*., 2017).
The water ingestion rate (IR)= 1.38 (L/day) (Kale and Kulkarni, 2018).
The total exposure duration days (TEP) = 70 years, i.e., 25550 days for adults (Rani *et al*. 2013; WHO, 2011; Duggal and Rani, 2017)
TEP =3650 (Sharma *et al*., 2016) days for children.
This equation was used for the assessment of mortality and morbidity related to cancer risk resulting from groundwater consumption of uranium over a lifetime.

Chemical toxicity risk assessment
The consumption of uranium-contaminated groundwater can cause kidney and bone damage because of chemical toxicity (Kale, 2021). The following equation is used to assess the lifetime average daily dose (LDAA) (WHO, 2011; Bhardwaj, *et al*., 2015):

$$LADD\ (\mu g/L/Kg/Day) = \frac{U\times IR\times EF\times LE}{BW\times AT} \quad \text{----- 6}$$

where U = the uranium concentration in the water sample (µg/L)
IR (Ingestion Rate) =1.38 (L/Day)
EF (exposure frequency) = 365 (day/year) (Ali *et al*., 2019)
BW (body weight)=70 kg
AT (average time of exposure) = 25550 days for adults (Kale, *et al*., 2018).

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Hazard quotient (HQ)

The degree of effect of uranium through water ingestion is estimated such that an HQ value less than 1 (<1) indicates no adverse health issues (Bajwa, *et al*., 2015). The following formula was used to calculate HQ:

$$HQ\ (\mu g/L/Kg/Day) = \frac{LADD}{RfD} \text{ -------- 7}$$

where Rfd is the reference dose. Rfd=4.53 µg/kg/day (WHO, 2011 and Duggal, *et al*., 2016; Ganesh, *et al*., 2020)

Assessment of the annual effective dose (AED)

The calculated annual effective dose from uranium consumption from groundwater is shown in Table 2.

$$\text{AED} = \text{AC} \times \text{F} \times \text{I} \times 365 \text{---------- 8}$$

where AC (average concentration of uranium) = (Bq/L)
F (effective per unit intake) (µSv/year/Bq/L) = 4.5×10^{-8}
I (age-dependent daily water intake) (L/Day) = 503.7 L (1.38×365).

Cumulative Dose

The cumulative dose is the total dose resulting from exposure to ionizing radiation throughout a human being. The cumulative dose was calculated by using the following formula:

$$\text{Cumulative dose} = \text{DE} \times \text{lifetime} \text{ ---------- 9}$$

DE means the annual effective dose, and lifetime = 70 years (WHO, 2011; ICRP, 2012).

Results and Discussion

The following parameters were assessed for calculating the WQI

The alkaline material used in residential and industrial purposes contributed to the increasing pH. In the present study, the pH was observed to range from 4.7-8.11 during the postmonsoon season (Table 3). Yadav and Mishra (2014) observed the same minimum or maximum results for groundwater pH, which supports our investigation. The salinity risk and quality of groundwater can be determined with the help of electrical conductivity (Mahalakshmi and Rivachandrabose, 2021; Rao, *et al*., 2019). During the present study period, ECs were observed in the range of 370-5260 µS/cm (Table 3). Similar results were observed by Mahalakshmi and Rivachandra bose, 2021, Rao *et al*., 2019, supporting our results. In the present investigation, the TDS concentration was found to be in the range of 106-1981 mg/L (Table 3). The TDSs, which include organic salts such as sulfate, bicarbonate, chlorides, sodium, potassium, calcium and magnesium, as well as organic salts, are dissolved in water. Similar results were observed by Ruhela *et al*., 2017. DO determines the anaerobic and aerobic organisms involved in changes in biological processes. DO plays an important role in aerobic treatment processes for the purification of industrial and domestic wastewater. In the present study, DO concentrations ranged from 1.23-2.86 mg/L (Table 3). Similar results were observed by Bhutiani *et al*., 2018; Kumar *et al.,* 2012). The alkalinity is the qualitative analysis of water used to neutralize an acid. During the present investigation, the alkalinity of the groundwater ranged from 84-660 mg/L (Table 3). Similar findings were reported by Khanna and Bhutiani (2011) and Ruhela *et al.* (2017). In the present study, chloride concentrations were reported to be in the range of 05.99-903.71 mg/L (Table 3). Near-minimum and maximum values were observed by Tyagi and Malik. 2018; Arya and Gupta, 2013. Hardness is the soap-consuming capacity of water (WHO, 2009). The total hardness of the study region ranged from 144-1000 mg/L (Table 3), which supports the results of Kamboj *et al.* (2018). Calcium occurs in the presence of gypsi-ferrous material, limestone, and gypsum dolomite. The calcium hardness of the groundwater during the study period ranged from 60-644 mg/L (Table 3). These approximate results were also reported by Arya and Gupta (2013). In the present investigation, the magnesium salt concentration in the groundwater was found to be in the range of 8-676 mg/L (Table 3). These approximate results were also reported by Arya and Gupta (2013). Sulfate is a natural observing mineral and is used in various chemical industries. It is discharged in water by industrial wastes that increase the sulfate concentration (Ingham, 2013). In the present study, groundwater sulfate concentrations were found to be within this

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range. Natural spreading salts such as KCl, NaCl and $CaCl_2$ are chloride-containing compounds. The weathering process absorbs chloride from rocks into water and soil (WHO, of 1-198 mg/L (table 3), and similar results were observed by Dandge and Patil, 2022. The concentration of bicarbonate increases in groundwater due to weathering (Srinivasamoorthy *et al*., 2008). The concentration of uranium in groundwater is governed by the availability of HCO_3 ions in solution (Thivya, *et al*., 2021). In this research, the bicarbonate concentration was found to be in the range of 0.8-67.6 mg/L (Table 3). Similar results were observed by Chandrashekhar *et al*., 2021**.** The consumption of groundwater with a high concentration of fluoride causes dental fluorosis. In this research, the concentration of fluoride in groundwater was found to be in the range of 0.3-15.5 mg/L (Table 3). Supporting results were reported by Kumar *et al*., (2018) and Panda *et al*., (2019). The long-term consumption of elevated concentrations of uranium causes chronic health effects such as neurotoxicity, reproductive toxicity, pulmonary toxicity and hepatotoxicity (Ma, *et al*., 2020). In the present research, the concentration of uranium was found to be in the range of 0.01-135.98 ppb (Table 3). Supportive results were observed by Rani *et al*., 2013 in northern Rajasthan.

Table 1: Water quality index, status and possible usage of the water (Chatterji and Raziuddin ,2002)

Water Quality Index Level	Water Quality Status	Possible Usages
0-25	Excellent water quality	Drinking, irrigation and industrial
26-50	Good water quality	Drinking, irrigation and industrial
51-75	Poor water quality	Drinking and industrial
76-100	Very poor water quality	Irrigation
>100	Unsuitable for drinking	Proper treatment required before use

Water quality index

The water quality index represents information about water bodies in the most understandable form to the general public and classifies water into excellent to unsafe forms (Dandge and Patil, 2022). During thisThe investigation WQI of the study area was calculated and is shown in Table 4. A WQI ranging from 0-25 indicates excellent water quality, from 26-50 indicates good water quality, from 51-75 indicates poor water quality, from 76-100 indicates very poor water quality and above 100 indicates unsuitable water quality. As a result, 77% of the samples were unsuitable for drinking purposes. The values indicate that the groundwater quality in the Chandrapur district in the study area belongs to the good to unsuitable class. Similar results were observed by Ram *et al*. (2021) for groundwater quality assessment using the water quality index (WQI) and Batabyal and Chakraborty (2015) for hydrogeochemical and water quality indices in the assessment of groundwater quality for drinking purposes.

Assessment of excess cancer risk

During this investigation, the ECR for morbidity and mortality was calculated for a 70-year-old adult. The results of the investigation are shown in Tables 5 and 6. According to the AERB, 1.6710^{-4} g/kg/day is the permitted maximum limit for ECR (AERB, 2004). During this investigation, all ECR values were below the permissible limits for water samples. The results of the 116 samples for ECR for mortality and morbidity were calculated for a 70-year-old adult and ranged from 1.002E-05 to 4.19E-05 and 1.010E-06 to 8.92E-05, respectively, with average values of 1.37E-05 and 1.47E-05, respectively. All these ECR values were well below the permissible limit of the AERB.In the present study, the LADD ranged from 0.001 to 2.68, with an average value of 0.3159 for adults; these data are displayed in Tables 5 and 6. The allowable limits of the lifetime average daily dose (LADD) are 4.53 µg/kg/day and 1 µg/kg/day according to the AERB (2004) and WHO (2011), respectively. The obtained postmonsoon LADD values were well below the AERB allowable limit, but 8.62% of the sample values were above the WHO limit.

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Table 2: Observed values at the hydro stations

Hydrostation	Lat.	Long.	pH	EC (µS/cm)	TDS ppm	DO mg/L	Al mg/L	Cl mg/L	TH mg/L	CH mg/L	MH mg/L	SO_4 mg/L	F mg/L	U ppb	HCO_3 mg/L
Chichpalli	20.00136	79.47949	5.13	375	250	2.09	344	103.96	212	120	92	63.92	0.3	12.83	9.2
Ajaypur	20.00321	79.49718	5.65	2840	1842	2.19	272	453.85	472	420	52	150	1.6	0.82	5.2
Chiroli	20.01055	79.60836	5.7	1345	870	1.69	180	211.93	476	340	136	54	1.9	35.83	13.6
Khalvaspeth	20.01017	79.60828	5.51	1704	1106	2.5	212	325.89	612	508	104	74	1.3	9.08	10.4
Dahegao	19.97833	79.65044	5.78	741	480	1.99	240	53.98	416	260	156	25	1.3	91.85	15.6
Bejgao	19.98646	79.68993	6	1633	106	2.6	448	155.95	428	380	48	105	0.6	32.27	4.8
Dugala	19.97230	79.70508	5.88	938	609	1.79	304	63.98	412	412	0	27	1.1	88.8	0
Fiskuti	20.01555	79.72163	5.66	710	462	1.59	248	69.97	420	420	0	26	1	9.97	0
Buruchundhi	20.04021	79.72327	5.75	1367	889	1.99	336	139.95	664	620	44	98	0.8	69.48	4.4
Tadala	20.03562	79.67336	5.6	2290	1488	2.09	304	301.9	728	636	92	140	1.3	6.49	9.2
Chitegao	20.10162	79.69780	5.8	808	525	2.08	360	37.98	500	472	28	23	1.5	0.03	2.8
Hirapur	20.11285	79.83896	5.83	1562	1014	2.64	504	197.93	436	372	64	63	1.6	9.2	6.4
Bothali	20.11636	79.81754	5.73	1239	805	2.8	320	123.96	580	528	52	79	2.3	11.09	5.2
Saimara chak	20.19729	79.81061	5.69	1425	924	2.35	368	201.93	604	572	32	46	1.3	63.31	3.2
Pawana chak	20.28552	79.80236	5.56	1417	923	1.53	384	177.94	920	640	280	84	0.5	9.04	28
Dhanora	20.27347	79.72365	5.95	370	242	1.45	216	71.97	688	200	488	1	1.1	9.57	48.8
Karghata	20.31646	79.69891	5.14	541	352	1.69	660	35.98	280	172	108	3	1.8	20	10.8
Sindewahi	20.29218	79.65946	5.66	1152	748	1.89	264	127.96	516	276	240	53	2	45.21	24
Palsgao	20.29846	79.65667	5.6	1704	1107	2.54	316	377.88	840	364	476	56	3.4	38.23	47.6
Chitmara	20.22694	79.77354	5.56	1323	861	1.56	432	115.96	628	304	324	19	2.3	0.03	32.4
Navargao	20.36433	79.58729	5.53	1068	694	1.56	276	129.95	544	276	268	43	1	13.4	26.8
Sawargao	20.41238	79.65227	5.7	1101	714	1.89	264	141.95	644	264	380	59	1.3	39.83	38
Talodhi	20.44603	79.66542	5.64	1321	860	1.76	280	187.94	660	280	380	63	0.8	10.14	38
Nagbhid	20.58150	79.68920	5.78	1596	1035	1.85	324	257.92	616	352	264	99	1.2	0.01	26.4
Mindhala	20.53738	79.71642	5.61	1270	825	1.45	252	283.91	660	272	388	54	2.4	4.51	38.8

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Bramhpuri	20.60691	79.85920	6.12	1015	661	2.56	288	173.94	420	164	256	38	0.8	6.93	29.2
Maldongri	20.57757	79.86195	5.62	1309	853	2.48	332	195.93	504	212	292	41	1	0	47.2
Dhamangao	20.46796	79.82911	5.44	1321	858	1.89	260	171.94	732	260	472	43	0.4	71.01	30
Mendki	20.46830	79.82812	5.79	1368	829	1.42	408	159.95	472	172	300	21	1.5	0.01	14.8
Ekara	20.38183	79.79743	5.19	476	311	1.56	160	73.97	272	124	148	4	1	8.68	4
Kothari	19.78826	79.49321	4.7	429	259	1.45	96	53.98	308	268	40	11	2.2	8.67	18
Parsodi	19.55088	79.51307	5.68	2090	1357	2.56	424	173.94	544	364	180	84	0.8	0.01	15.2
Tohgao	19.68336	79.49633	5.66	1188	1188	1.25	416	69.97	648	496	152	42	1.6	0.01	39.2
Wejgao	19.60207	79.50127	5.4	1543	1543	2.56	328	179.94	660	268	392	147	0.8	10.22	5.2
Lathi	19.51391	79.49130	5.17	570	570	1.49	120	51.98	360	308	52	24	1.3	0.02	0.8
Sonapur deshpande	19.54159	79.56361	5.6	1133	1133	2.45	284	129.95	672	644	8	84	1.7	10.4	26.4
Nawegao Chak	20.21761	79.69987	5.63	1863	1863	2.06	380	233.92	732	468	264	119	1.9	0.19	2.8
Adegao	19.60239	79.71480	5.6	1055	1055	2.05	240	99.98	552	524	28	76	0.3	38.93	11.2
Bhangaram Talodhi	19.66196	79.72965	5.82	1478	1478	2.56	400	139.95	664	552	112	99	0.9	49.55	36
Chak Gadholi	19.70469	79.71954	5.58	1418	1418	2.85	352	183.94	792	432	360	49	0.6	0.02	4
Gondpipari CT	19.71680	79.68470	5.48	1689	1689	1.59	364	215.93	600	560	40	82	4.35	55.07	11.6
Chintaldhaba	19.80077	79.63821	5.65	1196	1196	1.96	300	155.95	408	292	116	61	5.1	2.46	1.6
Pombhurna	19.86576	79.63490	5.6	1547	1547	1.94	336	169.94	340	324	16	89	7.85	11.42	10.8
Jam Tukum	19.92269	79.63259	5.65	3260	326	2.09	460	187.94	484	376	108	34	5.75	7.92	21.6
Pipari Deshpande	19.86482	79.76511	5.55	3170	317	2.56	464	59.98	636	420	216	150	9.3	0.78	16
Gatkul	19.79035	79.73468	5.69	2670	267	1.99	412	35.98	480	320	160	150	3.9	0.02	1.2
Rajura	19.77690	79.36502	5.71	1272	1272	1.56	368	125.96	320	308	12	62	15.35	7.14	27.2
Vihirgao	19.72598	79.45766	5.1	1219	1219	2.6	224	169.94	500	228	272	92	12.25	67.5	9.6
Nalpalli	19.67514	79.45317	5.26	738	469	2.58	280	63.98	328	232	96	45	13.7	0.01	67.6
Virur Station	19.64265	79.43100	5.74	991	644	2.56	400	33.98	924	248	676	19	8.95	0.06	26
Tembhurwahi	19.69171	79.35643	5.73	1423	861	2.08	304	135.95	440	180	260	82	12	0.7	31.6
Kapangao	19.77222	79.34174	5.94	2470	1604	2.5	544	293.9	572	256	316	150	5.45	11.08	34.8
Sasti	19.82014	79.32980	5.51	2170	1422	2.46	420	121.96	600	252	348	150	4.9	0	36.8
Ballarshah	19.85209	79.35169	5.56	1036	673	2.17	240	85.97	540	172	368	101	5.15	0.97	4
Babupeth	19.86256	79.34894	4.88	382	271	2.16	100	39.98	336	296	40	28	5.1	4.54	38
Junona	19.92930	79.38683	5.46	1287	844	1.98	304	81.97	736	356	380	56	1.15	0	5.6

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Karwa	19.91115	79.38602	5.52	751	487	1.79	260	91.97	548	492	56	20	5.4	1.87	10.8
Ballarshah Tekadi	19.92320	79.31857	5.03	1359	949	1.53	240	173.94	528	420	108	125	7.8	0.3	31.2
Pandhar Pawani	19.74721	79.27447	5.71	1205	783	2.46	288	105.96	516	204	312	108	6.35	16.03	28.8
Bibi	19.76231	79.14222	5.82	988	640	2.86	224	93.97	708	420	288	38	6.8	0.01	9.2
Awalpur	19.77975	79.13397	5.76	873	568	2.06	304	43.98	396	304	92	22.08	5.15	23.5	11.2
Naranda	19.78319	79.05864	5.54	700	488	1.79	280	81.97	424	312	112	20.36	5.75	97.07	3.2
Dhoptala	19.76101	78.99659	6	967	629	1.99	220	61.98	200	168	32	29	4.25	1.2	8.8
Korpana	19.74222	78.98784	5.59	1790	1166	1.56	320	341.89	508	420	88	27.96	4.25	20.98	16
Pardi	19.73584	78.91412	5.84	913	595	2.56	288	27.99	524	364	160	18.64	6.95	35.34	17.2
Umarchira	19.68005	78.90519	5.7	662	430	2.2	256	31.99	416	244	172	18.28	6	7.16	13.2
Durgadi	19.71237	78.86763	5.39	876	570	1.99	280	25.99	456	324	132	12.4	6.5	103.67	22
Kargao khurd	19.68390	79.05155	5.33	879	572	1.99	388	13.99	512	292	220	17.24	4	9.42	11.2
Jivati	19.61510	79.07036	5.7	783	510	1.56	256	29.99	220	108	112	15.2	4.2	9.47	16
Manguda	19.58184	79.00801	5.79	720	466	1.98	336	5.99	392	232	160	12.76	4.45	0.02	0
Wani BK	19.57696	78.99747	6.66	1028	716	2.06	284	91.97	552	356	196	19.68	5.05	10.11	4
Dewalguda	19.60091	79.06269	8.11	550	330	2.35	84	123.96	304	60	244	17.96	4.75	11.86	4.8
Shengao	19.58583	79.14031	5.61	437	269	2.21	136	45.98	144	144	0	12.76	7.4	6.04	24.4
Rahpalli	19.56038	79.13901	5.84	1004	658	2.24	384	125.96	336	296	40	17.96	6.3	7.09	23.6
Bhari	19.50486	79.18319	7.78	955	577	2.1	288	61.98	320	260	60	17.24	1.5	0	32.4
Shedwahi	19.46820	79.19406	5.95	752	488	2.07	348	25.99	180	132	48	15.2	7.05	135.98	62.8
Ranvelli	19.69903	79.30871	5.51	863	523	1.98	288	31.99	356	112	244	15.2	6.7	6.33	16
Visapur	19.88798	79.33008	5.33	951	665	1.82	240	141.95	324	88	236	21.04	9.2	5.94	21.2
Nandgao pode	19.89990	79.30497	5.62	1589	1034	2.03	304	177.94	484	160	324	24.16	2.8	1.56	30
Mana tekadi	19.89981	79.30381	5.56	2400	1551	2.05	368	85.97	760	132	628	198	5.9	13.83	38
Lakhamapur	19.99245	79.26527	5.45	994	713	1.96	296	79.97	368	208	160	30.04	4.95	10.16	9.2
Kiloni	20.15243	79.08996	5.72	2820	1832	1.23	404	453.85	528	316	212	76	3.35	0	22.4
Chalbardi	20.14146	79.05387	5.65	2380	1546	2.01	424	263.91	592	292	300	43.52	6.3	30.21	13.6
Naglon	20.14461	79.01353	5.75	3400	221	1.97	404	527.83	680	300	380	42.84	5.65	0.28	2.8
Kawadsi	20.39122	79.15424	5.72	1765	1149	2.35	440	251.92	392	300	92	16.24	12.15	12.37	14

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Wadhada	20.37465	79.15826	5.84	1695	1183	1.36	384	243.92	568	344	224	30.4	6.8	2.2	15.2
Waigao	20.38228	79.20904	5.46	2760	1785	2.26	484	271.91	488	352	136	53.2	6.6	0.63	43.2
Nimdhela	20.41998	79.21153	6.07	1448	940	1.96	408	143.95	216	192	24	21.4	2.8	28.17	32.4
Akola	20.42357	79.19001	5.8	970	633	2.31	296	53.98	268	240	28	16.92	3.15	7.26	1.6
Bothali	20.46249	79.22014	5.8	2670	1732	2.41	536	363.88	404	264	140	46.96	5.65	9.57	10.8
Sonegao	20.50801	79.24696	5.54	2570	1682	1.97	464	361.88	648	496	152	25.56	2.8	23.03	64
Parsodi	20.51187	79.22206	5.82	2210	1512	1.54	312	239.92	700	268	432	55.6	10.85	11.62	0.8
Khadsangi	20.50523	79.26435	5.54	1861	1209	2.3	444	223.93	668	344	324	22.08	5.6	11.82	3.2
Shedgao	20.50707	79.32572	5.59	1228	864	2.14	312	179.94	316	310	16	22.08	4.7	10.54	8.8
Chimur	20.49197	79.37476	5.54	1068	695	2.19	336	113.96	460	352	108	17.6	3.75	0.69	37.2
Kolara	20.40538	79.36829	5.63	5260	342	2.6	396	903.71	1000	360	640	102.96	8.85	5.41	6.4
Neri	20.46699	79.44361	5.62	1182	780	1.35	308	127.96	320	312	8	15.52	10.25	4.42	2.4
Amboli	20.64576	79.48965	5.59	1058	687	1.97	204	143.95	448	416	32	13.44	9.8	3.66	1.2
Bhisi	20.63038	79.40188	6.13	3050	1981	2.79	240	67.97	1000	388	612	51.48	8.7	0.63	26.8
Chargao Khurd	20.36111	79.18265	5.67	1129	726	1.78	344	63.98	392	304	88	17.6	8	16.84	33.6
Arjuni	20.36218	79.18148	5.5	1441	221	2.46	380	273.91	800	428	372	29	10.65	5.43	22.8
Shegon	20.32967	79.14417	5.44	1854	1206	1.97	380	281.91	512	448	64	25.56	12.85	0.31	9.6
Warora	20.22690	79.01031	5.64	1164	758	1.58	460	107.96	224	200	24	19.68	12	0	27.6
Bhadrawati	20.10653	79.12055	5.3	1162	755	2.56	248	169.94	400	388	12	18.28	8.5	0.58	15.2
Lonara	20.06934	79.09795	5.66	5050	326	2.47	632	731.77	640	372	268	105.04	12.55	6.01	7.2
Durgapur	20.00187	79.30308	5.52	2170	1394	1.99	324	317.9	680	344	336	25.2	15.5	0.12	4.8
Khergao	20.02828	79.28093	5.52	2930	1907	1.94	444	403.87	484	256	228	41.44	2	0	26.8
Wandhari	19.98239	79.20995	5.53	1208	783	2.45	404	107.96	324	228	96	19	3.35	1.39	50
Yerur	19.99625	79.19051	5.54	2790	1814	2.13	432	323.89	564	288	276	59.08	1.48	3.42	47.2
Sonegao	19.95890	79.12109	5.49	1373	890	2.26	332	87.97	544	392	152	27.64	1.28	3.34	59.6
Matardei	19.93900	79.11227	5.95	1191	774	2.15	368	79.97	420	348	72	68.2	4.92	0.58	9.2
Ghugus	19.91931	79.11000	5.4	1043	677	2.17	268	113.96	348	300	48	28.32	1.2	12.83	5.2
Nakoda	19.97234	79.17515	5.69	1842	1195	1.98	316	293.9	620	352	268	34.2	1.72	0.82	13.6
Dhanora	19.91398	79.17938	5.62	3600	235	1.97	428	393.87	852	352	500	43.88	1.76	35.83	10.4
Pipari	19.90687	79.20386	5.57	2530	1643	2.3	360	193.93	812	340	472	85.5	1.2	9.08	15.6
Sidur	19.94217	79.21196	5.71	4920	320	2.4	456	293.9	1000	404	596	116.6	4.89	91.85	4.8

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Table 3: Values used for calculation of the WQI (Bhutiani *et al.*, 2018)

Parameter	Minimum-maximum value	Standard Value	Ideal value
pH	**4.7-8.11**	**6.5-8.5**	**7**
EC (µS/cm)	**370-5260**	**3000**	**0**
TDS (ppm)	**106-1981**	**500**	**0**
DO (mg/L)	**1.23-2.86**	**5**	**14.6**
Alkalinity(mg/L)	**84-660**	**200**	**0**
TH(mg/L)	**144-1000**	**200**	**0**
CH(mg/L)	**60-644**	**200**	**0**
MH(mg/L)	**8-676**	**100**	**0**
HCO_3(mg/L)	**0.8-67.6**	**600**	**0**
SO_4(mg/L)	**1-198**	**250**	**0**
Cl(mg/L)	**5.99-903.71**	**250**	**0**
F(mg/L)	**0.3-15.5**	**1.5**	**0**
U(ppb)	**0.01-135.98**	**30**	**0**

Table 4: Water quality indices and classes of various hydrostations

Sr. No.	Hydrostation	WQI Value	Class
1.	Chichpalli	27.6301	Good water quality
2.	Ajaypur	86.8860	Very poor water quality
3.	Chiroli	104.0798	Unsuitable for drinking
4.	Khalvaspeth	73.7524	Poor water quality
5.	Dahegao	84.2618	Very poor water quality
6.	Bejgao	48.8395	Good water quality
7.	Dugala	75.7393	Very poor water quality
8.	Fiskuti	61.8337	Poor water quality
9.	Buruchundhi	61.6179	Poor water quality
10.	Tadala	75.8559	Very poor water quality
11.	Chitegao	82.7470	Very poor water quality
12.	Hirapur	87.8357	Very poor water quality
13.	Bothali	116.4644	Unsuitable for drinking
14.	Saimara chak	80.6161	Very poor water quality
15.	Pawana chak	45.1653	Good water quality
16.	Dhanora	72.9950	Poor water quality
17.	Karghata	93.4928	Very poor water quality
18.	Sindewahi	109.5435	Unsuitable for drinking
19.	Palsgao	169.9456	Unsuitable for drinking
20.	Chitmara	118.8379	Unsuitable for drinking
21.	Navargao	64.0633	Poor water quality
22.	Sawargao	81.3981	Very poor water quality
23.	Talodhi	57.2573	Poor water quality
24.	Nagbhid	73.2078	Poor water quality
25.	Mindhala	124.5887	Unsuitable for drinking
26.	Bramhpuri	56.7676	Poor water quality
27.	Maldongri	61.7826	Poor water quality
28.	Dhamangao	45.9601	Good water quality
29.	Mendki	86.1959	Very poor water quality
30.	Ekara	58.3181	Poor water quality
31.	Kothari	104.6748	Unsuitable for drinking
32.	Parsodi	53.4776	Poor water quality
33.	Tohgao	89.6161	Very poor water quality
34.	Wejgao	54.4678	Poor water quality
35.	Lathi	69.7728	Poor water quality
36.	Sonapur deshpande	90.9675	Very poor water quality
37.	Nawegao Chak	102.1828	Unsuitable for drinking
38.	Adegao	35.0986	Good water quality
39.	Bhangaram Talodhi	63.9966	Poor water quality

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40.	Chak Gadholi	45.9941	Good water quality
41.	Gondpipari CT	208.6186	Unsuitable for drinking
42.	Chintaldhaba	234.3763	Unsuitable for drinking
43.	Pombhurna	350.1319	Unsuitable for drinking
44.	Jam Tukum	262.4741	Unsuitable for drinking
45.	Pipari Deshpande	411.1263	Unsuitable for drinking
46.	Gatkul	184.3235	Unsuitable for drinking
47.	Rajura	667.0532	Unsuitable for drinking
48.	Vihirgao	538.6308	Unsuitable for drinking
49.	Nalpalli	591.4144	Unsuitable for drinking
50.	Virur Station	402.0643	Unsuitable for drinking
51.	Tembhurwahi	526.3954	Unsuitable for drinking
52.	Kapangao	254.4234	Unsuitable for drinking
53.	Sasti	226.6933	Unsuitable for drinking
54.	Ballarshah	237.2730	Unsuitable for drinking
55.	Babupeth	226.5424	Unsuitable for drinking
56.	Junona	69.3962	Poor water quality
57.	Karwa	246.0375	Unsuitable for drinking
58.	Ballarshah Tekadi	344.5795	Unsuitable for drinking
59.	Pandhar Pawani	289.6649	Unsuitable for drinking
60.	Bibi	307.3705	Unsuitable for drinking
61.	Awalpur	238.6345	Unsuitable for drinking
62.	Naranda	270.8064	Unsuitable for drinking
63.	Dhoptala	198.7871	Unsuitable for drinking
64.	Korpana	201.4041	Unsuitable for drinking
65.	Pardi	316.3791	Unsuitable for drinking
66.	Umarchira	272.4825	Unsuitable for drinking
67.	Durgadi	301.8321	Unsuitable for drinking
68.	Kargao khurd	187.2369	Unsuitable for drinking
69.	Jivati	196.8041	Unsuitable for drinking
70.	Manguda	207.4683	Unsuitable for drinking
71.	Wani BK	241.2595	Unsuitable for drinking
72.	Dewalguda	237.5980	Unsuitable for drinking
73.	Shengao	327.8288	Unsuitable for drinking
74.	Rahpalli	285.3001	Unsuitable for drinking
75.	Bhari	96.6893	Very poor water quality
76.	Shedwahi	330.6584	Unsuitable for drinking
77.	Ranvelli	301.2526	Unsuitable for drinking
78.	Visapur	405.4523	Unsuitable for drinking
79.	Nandgao pode	138.7712	Unsuitable for drinking
80.	Mana tekadi	274.1699	Unsuitable for drinking
81.	Lakhamapur	227.1472	Unsuitable for drinking
82.	Kiloni	164.5687	Unsuitable for drinking
83.	Chalbardi	290.5314	Unsuitable for drinking
84.	Nagion	261.6522	Unsuitable for drinking
85.	Kawadsi	532.4228	Unsuitable for drinking
86.	Wadhad	310.4044	Unsuitable for drinking
87.	Waigao	296.7628	Unsuitable for drinking
88.	Nimdhela	141.8098	Unsuitable for drinking
89.	Akola	151.3937	Unsuitable for drinking
90.	Bothali	259.7564	Unsuitable for drinking
91.	Sonegao	141.0366	Unsuitable for drinking
92.	Parsodi	483.6586	Unsuitable for drinking
93.	Khadsangi	258.0531	Unsuitable for drinking
94.	Shedgao	216.3277	Unsuitable for drinking
95.	Chimur	175.9898	Unsuitable for drinking
96.	Kolara	398.9837	Unsuitable for drinking
97.	Neri	451.1582	Unsuitable for drinking
98.	Amboli	431.1817	Unsuitable for drinking
99.	Bhisi	394.1907	Unsuitable for drinking
100.	Chargao Khurd	358.0595	Unsuitable for drinking
101.	Arjuni	470.1089	Unsuitable for drinking
102.	Shegon	559.6283	Unsuitable for drinking
103.	Warora	524.1276	Unsuitable for drinking

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104.	Bhadrawati	372.5630	Unsuitable for drinking
105.	Lonara	551.3920	Unsuitable for drinking
106.	Durgapur	674.5642	Unsuitable for drinking
107.	Khergao	104.6903	Unsuitable for drinking
108.	Wandhari	158.0813	Unsuitable for drinking
109.	Yerur	83.4766	Very poor water quality
110.	Sonegao	72.4299	Poor water quality
111.	Matardei	228.0912	Unsuitable for drinking
112.	Ghugus	67.6882	Poor water quality
113.	Nakoda	94.3253	Very Poor water quality
114.	Dhanora	102.0337	Unsuitable for drinking
115.	Pipari	74.3265	Poor water quality
116.	Sidur	241.1126	Unsuitable for drinking

Table 5: Carcinogenic and noncariogenic risk due to uranium in the postmonsoon season

Sampling Location	*U (ppb)*	*Average Conc. (Bq/L)*	*R Mortality*	*R (Morbidity)*	*ECR (Mortality)*	*ECR (Morbidity)*	*LADD (µg/kg/Day)*	*HQ*	*DE (µSv/Yr)*	*Cumulative Dose (µSv*Lifetime)*
Chichpalli	12.826	0.3206	4.19E-05	6.48E-05	1.343E-05	2.07E-05	0.252	0.0049	7.266E-06	0.000
Ajaypur	0.820	0.0205	4.19E-05	6.48E-05	8.589E-07	1.328E-06	0.016	0.000	4.646E-07	3.252E-05
Chiroli	35.834	0.8959	4.19E-05	6.48E-05	3.753E-05	5.805E-05	0.706	0.013	2.030E-05	0.001
Khalvaspeth	9.080	0.227	4.19E-05	6.48E-05	9.511E-06	1.470E-05	0.179	0.003	5.147E-06	0.000
Dahegao	91.845	2.2961	4.19E-05	6.48E-05	9.620E-05	0.000	1.8106	0.035	5.204E-05	0.003
Bejgao	32.271	0.8068	4.19E-05	6.48E-05	3.380E-05	5.227E-05	0.6362	0.012	1.828E-05	0.001
Dugala	88.799	2.2199	4.19E-05	6.48E-05	9.301E-05	0.00	1.750	0.034	5.031E-05	0.003
Fiskuti	9.973	0.2493	4.19E-05	6.48E-05	1.044E-05	1.615E-05	0.196	0.003	5.650E-06	0.00
Buruchundhi	69.480	1.737	4.19E-05	6.48E-05	7.278E-05	0.000	1.369	0.027	3.937E-05	0.002
Tadala	6.486	0.1621	4.19E-05	6.48E-05	6.794E-06	1.050E-05	0.127	0.002	3.674E-06	0.000
Chitegao	0.0317	0.0007	4.19E-05	6.48E-05	3.320E-08	5.135E-08	0.000	1.243E-05	1.586E-08	1.11E-06
Hirapur	9.203	0.2300	4.19E-05	6.48E-05	9.640E-06	1.490E-05	0.181	0.003	5.215E-06	0.0
Bothali	11.093	0.2773	4.19E-05	6.48E-05	1.161E-05	1.797E-05	0.218	0.004	6.285E-06	0.00
Saimara chak	63.305	1.5826	4.19E-05	6.48E-05	6.631E-05	0.000	1.248	0.024	3.587E-05	0.002
Pawana chak	9.039	0.2259	4.19E-05	6.48E-05	9.468E-06	1.464E-05	0.178	0.003	5.120E-06	0.00
Dhanora	9.573	0.2393	4.19E-05	6.48E-05	1.002E-05	1.550E-05	0.188	0.003	5.424E-06	0.00
Karghata	19.998	0.4999	4.19E-05	6.48E-05	2.094E-05	3.239E-05	0.394	0.007	1.133E-05	0.00
Sindewahi	45.210	1.1302	4.19E-05	6.48E-05	4.735E-05	7.324E-05	0.891	0.017	2.561E-05	0.001
Palsgao	38.228	0.9557	4.19E-05	6.48E-05	4.004E-05	6.192E-05	0.753	0.014	2.166E-05	0.001
Chitmara	0.025	0.0006	4.19E-05	6.48E-05	2.618E-08	4.05E-08	0.000	9.716E-06	1.359E-08	9.519E-07
Navargao	13.399	0.3349	4.19E-05	6.48E-05	1.403E-05	2.170E-05	0.264	0.005	7.591E-06	0.00
Sawargao	39.827	0.9956	4.19E-05	6.48E-05	4.171E-05	6.451E-05	0.785	0.015	2.256E-05	0.001
Talodhi	10.140	0.2535	4.19E-05	6.48E-05	1.062E-05	1.642E-05	0.199	0.003	5.745E-06	0.000
Nagbhid	0.012	0.0003	4.19E-05	6.48E-05	1.257E-08	1.944E-08	0.000	4.663E-06	6.799E-09	4.759E-07
Mindhala	4.506	0.1126	4.19E-05	6.48E-05	4.720E-06	7.299E-06	0.088	0.001	2.552E-06	0.00
Bramhpuri	0.010	0.00025	4.19E-05	6.48E-05	1.047E-08	1.62E-08	0.000	3.886E-06	4.533E-09	3.173E-07
Maldongri	6.929	0.1732	4.19E-05	6.48E-05	7.258E-06	1.122E-05	0.136	0.002	3.925E-06	0.000
Dhamangao	0.001	0.00002	4.19E-05	6.48E-05	1.047E-09	1.62E-09	1.971E-05	3.886E-07	0	0
Mendki	71.0127	1.7753	4.19E-05	6.48E-05	7.438E-05	0.000	1.399	0.027	4.023E-05	0.002
Ekara	0.011	0.00027	4.19E-05	6.48E-05	1.152E-08	1.782E-08	0.000	4.275E-06	4.533E-09	3.173E-07
Kothari	8.682	0.2171	4.19E-05	6.48E-05	9.094E-06	1.406E-05	0.171	0.003	4.918E-06	0.00
Parsodi	8.671	0.2168	4.19E-05	6.48E-05	9.082E-06	1.404E-05	0.170	0.003	4.911E-06	0.00
Tohgao	0.007	0.00017	4.19E-05	6.48E-05	7.332E-09	1.134E-08	0.000	2.720E-06	2.266E-09	1.58E-07
Wejgao	0.006	0.00015	4.19E-05	6.48E-05	6.285E-09	9.72E-09	0.000	2.331E-06	2.266E-09	1.58E-07
Lathi	10.219	0.2555	4.19E-05	6.48E-05	1.070E-05	1.655E-05	0.201	0.003	5.789E-06	0.00
Sonapur deshpande	0.021	0.00052	4.19E-05	6.48E-05	2.199E-08	3.402E-08	0.000	8.161E-06	1.133E-08	7.933E-07
Nawegao Chak	10.400	0.26	4.19E-05	6.48E-05	0.000	0.00	0.205	0.004	5.893E-06	0.00
Adegao	0.185	0.0046	4.19E-05	6.48E-05	1.937E-07	2.997E-07	0.003	7.190E-05	1.042E-07	7.298E-06
Bhangaram Talodhi	38.931	0.9733	4.19E-05	6.48E-05	4.078E-05	6.306E-05	0.767	0.015	2.205E-05	0.001
Chak Gadholi	49.554	1.2389	4.19E-05	6.48E-05	5.190E-05	8.027E-05	0.976	0.019	2.807E-05	0.001
Gondpipari CT	0.024	0.0006	4.19E-05	6.48E-05	2.514E-08	3.888E-08	0.000	9.327E-06	1.359E-08	9.519E-07

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Chintaldhaba	55.066	1.3766	4.19E-05	6.48E-05	5.768E-05	8.920E-05	1.085	0.021	3.120E-05	0.002
Pombhurna	2.457	0.0614	4.19E-05	6.48E-05	2.573E-06	3.980E-06	0.048	0.000	1.391E-06	9.742E-05
Jam Tukum	11.421	0.2855	4.19E-05	6.48E-05	1.196E-05	1.850E-05	0.225	0.004	6.471E-06	0.000
Pipari Deshpande	7.920	0.198	4.19E-05	6.48E-05	8.296E-06	1.283E-05	0.156	0.003	4.487E-06	0.000
Gatkul	0.779	0.0194	4.19E-05	6.48E-05	8.160E-07	1.261E-06	0.015	0.000	4.397E-07	3.078E-05
Rajura	0.020	0.0005	4.19E-05	6.48E-05	2.095E-08	3.24E-08	0.000	7.773E-06	1.133E-08	7.933E-07
Vihirgao	7.138	0.1784	4.19E-05	6.48E-05	7.477E-06	1.156E-05	0.140	0.002	4.043E-06	0.000
Nalpalli	67.495	1.6874	4.19E-05	6.48E-05	7.070E-05	0.000	1.330	0.026	3.824E-05	0.002
Virur Station	0.010	0.0002	4.19E-05	6.48E-05	1.047E-08	1.62E-08	0.000	3.886E-06	4.533E-09	3.173E-07
Tembhurwahi	0.060	0.0015	4.19E-05	6.48E-05	6.285E-08	9.72E-08	0.001	2.331E-05	3.399E-08	2.38E-06
Kapangao	0.697	0.0174	4.19E-05	6.48E-05	7.301E-07	1.129E-06	0.013	0.00	3.943E-07	2.760E-05
Sasti	11.081	0.2770	4.19E-05	6.48E-05	1.160E-05	1.795E-05	0.218	0.004	6.280E-06	0.00
Ballarshah	0.001	0.00002	4.19E-05	6.48E-05	1.047E-09	1.62E-09	1.971E-05	3.886E-07	0	0
Babupeth	0.967	0.0242	4.19E-05	6.48E-05	1.012E-06	1.566E-06	0.019	0.000	5.462E-07	3.823E-05
Junona	4.543	0.1136	4.19E-05	6.48E-05	4.758E-06	7.359E-06	0.089	0.001	2.572E-06	0.00
Karwa	0.001	0.00002	4.19E-05	6.48E-05	1.047E-09	1.62E-09	1.97E-05	3.886E-07	0	0
Ballarshah Tekadi	1.874	0.0469	4.19E-05	6.48E-05	1.963E-06	3.035E-06	0.036	0.00	1.060E-06	7.425E-05
Pandhar Pawani	0.295	0.0073	4.19E-05	6.48E-05	3.090E-07	4.779E-07	0.005	0.00	1.654E-07	1.158E-05
Bibi	16.029	0.4007	4.19E-05	6.48E-05	1.679E-05	2.596E-05	0.315	0.006	9.082E-06	0.00
Awalpur	0.011	0.0002	4.19E-05	6.48E-05	1.152E-08	1.782E-08	0.0002	4.275E-06	4.533E-09	3.173E-07
Naranda	23.495	0.5874	4.19E-05	6.48E-05	2.461E-05	3.806E-05	0.463	0.009	1.331E-05	0.00
Dhoptala	97.068	2.4267	4.19E-05	6.48E-05	0.000	0.000	1.913	0.037	5.500E-05	0.003
Korpana	1.197	0.0299	4.19E-05	6.48E-05	1.253E-06	1.939E-06	0.023	0.000	6.777E-07	4.744E-05
Pardi	20.981	0.5245	4.19E-05	6.48E-05	2.197E-05	3.398E-05	0.413	0.008	1.188E-05	0.000
Umarchira	35.335	0.8833	4.19E-05	6.48E-05	3.701E-05	5.724E-05	0.696	0.013	2.002E-05	0.001
Durgadi	7.159	0.1789	4.19E-05	6.48E-05	7.499E-06	1.159E-05	0.141	0.002	4.055E-06	0.00
Kargao khurd	103.674	2.5918	4.19E-05	6.48E-05	0.000	0.000	2.043	0.040	5.874E-05	0.004
Jivati	9.419	0.2355	4.19E-05	6.48E-05	9.866E-06	1.525E-05	0.185	0.003	5.335E-06	0.00
Manguda	9.467	0.2368	4.19E-05	6.48E-05	9.916E-06	1.533E-05	0.186	0.003	5.362E-06	0.000
Wani BK	32.452	0.8113	4.19E-05	6.48E-05	3.399E-05	5.257E-05	0.639	0.01	1.838E-05	0.001
Dewalguda	27.479	0.6869	4.19E-05	6.48E-05	2.878E-05	4.451E-05	0.541	0.010	1.556E-05	0.001
Shengao	0.021	0.0005	4.19E-05	6.48E-05	2.199E-08	3.402E-08	0.000	8.161E-06	1.133E-08	7.933E-07
Rahpalli	10.107	0.2527	4.19E-05	6.48E-05	1.058E-05	1.637E-05	0.199	0.003	5.725E-06	0.00
Bhari	33.954	0.8488	4.19E-05	6.48E-05	3.556E-05	5.500E-05	0.669	0.013	1.923E-05	0.001
Shedwahi	11.862	0.2965	4.19E-05	6.48E-05	1.242E-05	1.921E-05	0.233	0.004	6.720E-06	0.000
Ranvelli	6.041	0.1510	4.19E-05	6.48E-05	6.327E-06	9.786E-06	0.119	0.002	3.422E-06	0.000
Visapur	7.093	0.1773	4.19E-05	6.48E-05	7.429E-06	1.149E-05	0.139	0.002	4.018E-06	0.000
Nandgao pode	0.002	0.00005	4.19E-05	6.48E-05	2.095E-09	3.24E-09	3.942E-05	7.77E-07	0	0
Mana tekadi	135.98	3.3995	4.19E-05	6.48E-05	0.000	0.000	2.680	0.052	7.705E-05	0.005
Lakhamapur	6.329	0.1582	4.19E-05	6.48E-05	6.629E-06	1.025E-05	0.124	0.002	3.585E-06	0.00
Kiloni	5.939	0.1484	4.19E-05	6.48E-05	6.221E-06	9.621E-06	0.117	0.002	3.363E-06	0.00
Chalbardi	1.562	0.0390	4.19E-05	6.48E-05	1.636E-06	2.530E-06	0.030	0.00	8.862E-07	6.203E-05
Naglon	13.834	0.3458	4.19E-05	6.48E-05	1.449E-05	2.241E-05	0.272	0.00	7.838E-06	0.0
Kawadsi	10.159	0.2539	4.19E-05	6.48E-05	1.064E-05	1.645E-05	0.200	0.003	5.755E-06	0.0
Wadhada	0.0001	0.00000	4.19E-05	6.48E-05	1.047E-10	1.62E-10	0	0	0	0
Waigao	30.214	0.7553	4.19E-05	6.48E-05	3.164E-05	4.894E-05	0.595	0.011	1.712E-05	0.00
Nimdhela	18.184	0.4546	4.19E-05	6.48E-05	1.904E-05	2.945E-05	0.358	0.00	1.030E-05	0.00
Akola	0.278	0.0069	4.19E-05	6.48E-05	2.912E-07	4.503E-07	0.005	0.000	1.563E-07	1.09E-05
Bothali	12.374	0.3093	4.19E-05	6.48E-05	1.296E-05	2.004E-05	0.243	0.004	7.010E-06	0.00
Sonegao	2.202	0.0550	4.19E-05	6.48E-05	2.306E-06	3.567E-06	0.043	0.000	1.248E-06	8.74E-05
Parsodi	0.625	0.0156	4.19E-05	6.48E-05	6.546E-07	1.012E-06	0.012	0.000	3.535E-07	2.47E-05
Khadsangi	28.168	0.7042	4.19E-05	6.48E-05	2.950E-05	4.563E-05	0.555	0.010	1.595E-05	0.00
Shedgao	7.260	0.1815	4.19E-05	6.48E-05	7.604E-06	1.176E-05	0.143	0.002	4.113E-06	0.00
Chimur	9.569	0.2392	4.19E-05	6.48E-05	1.002E-05	1.550E-05	0.188	0.003	5.421E-06	0.00
Kolara	23.026	0.5757	4.19E-05	6.48E-05	2.411E-05	3.730E-05	0.453	0.008	1.304E-05	0.00
Neri	11.615	0.2904	4.19E-05	6.48E-05	1.216E-05	1.881E-05	0.229	0.004	6.580E-06	0.0
Amboli	11.815	0.2954	4.19E-05	6.48E-05	1.237E-05	1.914E-05	0.232	0.004	6.693E-06	0.000
Bhisi	9.250	0.2312	4.19E-05	6.48E-05	9.689E-06	0.0000	0.182	0.003	5.240E-06	0.00
Chargao Khurd	10.535	0.26337	4.19E-05	6.48E-05	1.103E-05	1.706E-05	0.207	0.004	5.968E-06	0.00
Arjuni	0.687	0.0171	4.19E-05	6.48E-05	7.196E-07	1.112E-06	0.013	0.00	3.875E-07	2.71E-05
Shegon	5.410	0.1353	4.19E-05	6.48E-05	5.666E-06	8.764E-06	0.106	0.002	3.064E-06	0.00
Warora	4.418	0.1104	4.19E-05	6.48E-05	4.627E-06	7.157E-06	0.087	0.001	2.502E-06	0.00
Bhadrawati	3.663	0.0915	4.19E-05	6.48E-05	3.836E-06	5.934E-06	0.072	0.001	2.073E-06	0.000
Lonara	0.632	0.0158	4.19E-05	6.48E-05	6.620E-07	1.023E-06	0.012	0.000	3.581E-07	2.50E-05
Durgapur	16.844	0.4211	4.19E-05	6.48E-05	1.764E-05	2.728E-05	0.332	0.006	9.544E-06	0.00
Khergao	5.434	0.1359	4.19E-05	6.48E-05	5.692E-06	8.803E-06	0.107	0.002	3.078E-06	0.00

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Wandhari	0.305	0.0076	4.19E-05	6.48E-05	3.194E-07	4.941E-07	0.006	0.000	1.722E-07	1.20E-05
Yerur	0.001	0.00002	4.19E-05	6.48E-05	1.047E-09	1.62E-09	1.971E-05	3.886E-07	0	0
Sonegao	0.580	0.0145	4.19E-05	6.48E-05	6.075E-07	9.396E-07	0.011	0.00	3.286E-07	2.30E-05
Matardei	6.011	0.1502	4.19E-05	6.48E-05	6.296E-06	9.737E-06	0.118	0.002	3.404E-06	0.00
Ghugus	0.12	0.003	4.19E-05	6.48E-05	1.257E-07	1.944E-07	0.002	4.663E-05	6.799E-08	4.75E-06
Nakoda	0.002	0.00005	4.19E-05	6.48E-05	2.095E-09	3.24E-09	3.942E-05	7.773E-07	2.266E-09	1.58E-07
Dhanora	1.394	0.0349	4.19E-05	6.48E-05	1.460E-06	2.258E-06	0.027	0.000	7.887E-07	5.52E-05
Pipari	3.416	0.0854	4.19E-05	6.48E-05	3.578E-06	5.533E-06	0.067	0.001	1.933E-06	0.00
Sidur	3.335	0.0834	4.19E-05	6.48E-05	3.494E-06	5.397E-06	0.065	0.001	1.888E-06	0.00

Table 6: Statistical data of parameters (postmonsoon)

Statistical Parameters	*U(ppb)*	*Average ww (Bq/l)*	*Mortality*	*Morbidity*	*LADD*	*HQ*	*DE*	*Cumulative Dose*
Min	0.01	0.000002	1.002E-05	1.010E-06	0.001	0.001	0.030E-05	0.001
Max	135.98	3.3995	4.19E-05	8.92E-05	2.68	0.052	7.71E-05	5.00E-03
Average	16.048	0.401	1.37E-05	1.47E-05	0.3167	0.006	8.09E-06	3.42E-04
Median	7.59	0.18975	7.34E-06	8.78E-06	0.1495	0.002	4.30E-06	0.00E+00

Conclusion

The results of the present research work clearly indicated that out of 116 samples, 110 were in the nonpotable category and unsafe for human consumption. In this context, improper disposal of waste and the presence of radioactive elements as well as other contaminants are serious concerns. The chemical toxicity of LADD in the 70-year-old age group was found to be above the permissible limit, and LADD can affect human health and can cause kidney toxicity and bone and lung toxicity. The water quality index is very helpful for simplifying the interpretation of many variables influencing water quality. The computed water quality indices showed higher percentages of fluoride, uranium and nitrate in the collected samples than in the control samples, which can increase the risk to people when ingested. The TDS, magnesium, Calcium, sulfate and chloride have organoleptic characteristics. Poor-quality water will cause organoleptic effects due to the relatively high concentrations of calcium, magnesium, chloride and sulphate. Considering the whole scenario, proper physical and chemical treatment should be preferred before utilizing these materials for drinking purposes.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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