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Assessment of physicochemical and radon-attributable radiological parameters of drinking water samples of Pithoragarh district, Uttarakhand

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Abstract

This study evaluates the quality of drinking water samples (sample size=52) taken from various locations of Pithoragarh district, Uttarakhand. The parameters include physiochemical properties viz. total dissolved solids (TDS in mg/L), electrical conductivity/salinity ($\mu\text{S}/\text{cm}$), pH and radiological dose attributable to radon in water ($\mu\text{Sv}/\text{y}$). TDS values for the tested samples varied within the range of 18-434 mg/L with average value of 148 mg/L. Electrical conductivity and pH for these samples was measured as 36-868 $\mu\text{S}/\text{cm}$ (average: 296 $\mu\text{S}/\text{cm}$) and 6.8-8.2 (average: 7.2), respectively. Radon activity concentration for these water samples was measured using scintillation-based radon monitor, immediately after sampling at the location site. Radon activity concentration was measured as 0.6-81.9 Bq/L with an average value of 17.8 Bq/L. The

paper also estimates the annual effective ingestion dose ($\mu\text{Sv/y}$), annual effective inhalation dose ($\mu\text{Sv/y}$) and total effective dose ($\mu\text{Sv/y}$) attributable to radon in drinking water samples. Spatial patterns for the observed variations have also been interpreted for the dataset obtained over the terrestrial region.

Keywords

Annual effective dose; Groundwater; Radon activity; Spatial distribution; TDS.

Introduction

Water quality is one of the important parameters determining the health risks to humans. Measurement of various characteristics of water, associated interpretations and hazard estimations have been performed worldwide at different places of relevance. It is a fact that numerous contaminants pollute water sources and this impacts human health risks. The source of contaminants could be natural or anthropogenic and the level of degradation of water quality depends on their source-term. Radioactive contamination is also a serious issue around the globe. While the mineralogy acts as the source term for physicochemical parameters, natural radio-nuclides present in the earth crust acts as the main source for radiological impurity of ground and surface water [1]. Total dissolved solids (TDS), salinity/electrical conductivity and pH are three vital physicochemical parameters which vary for different water sources and also get affected due to human activities. Similar to the air matrix, radon/thoron gases and its decay products primarily released from the natural radio-active precursors (decay chains) determines the radioactivity concentration profile of water. Rn^{222} and Rn^{220} are two isotopes of radon with different half-life (Rn^{222} has a half-life of 3.82 days and Rn^{220} has a half-life of 55.5 seconds) [2]. Due to its gaseous nature, it travels through cracks and pores between the grain in the soil and easily escape into the ground and surface water. Previous studies in other parts of Uttarakhand Himalaya indicate the presence of a significant amount of natural radioactivity in the air, soil, and water [6-12]. Pithoragarh is a high-altitude terrestrial region and groundwater is the main source of water to be used for domestic as well as industrial purposes. Most of the population in the region depends on natural spring sources for drinking water [13]. Rn^{222} emits alpha particles and its short-lived progenies (Po^{218} , Po^{214} , Pb^{214} and Bi^{214}) interact with atmospheric particles. Previous studies in Kumaun Himalayas reported radiological dose levels due to Rn^{222} activity concentration. [15-18]. Such measurements, their usage in the estimations of radiological doses

and the interpretations are highlighted as an important data-base by standard international commissions. Therefore, measurement of radioactivity concentration and the estimation of radiological doses due to the ingestion of Rn^{222} has been done by several researchers in past as well [19-21].

This study focuses on the measurement of physicochemical properties and Rn^{222} concentration in drinking water samples of Pithoragarh district, Uttarakhand, India. Rn^{222} concentration was measured using a portable Rn^{222} monitor on the spot of sampling right after the sample is collected. The physicochemical properties (TDS, Electrical Conductivity, and pH) were measured in the laboratory. Statistical analysis of the obtained data is discussed in detail in this work. QGIS (Quantum GIS) 3.4 Madeira LTS (Long Term Support) is used for the spatial or geological analysis of the data over the study region.

Geology of Study Area

Pithoragarh is the easternmost district of Uttarakhand state of India. It confines higher Himalayan mountain ranges, passes, valleys, alpine meadows, forests, waterfalls, rivers, glaciers, springs, and snow-capped peaks. The geographical area of Pithoragarh is 7,110 square Km. The district is located in the Kumaun division of Uttarakhand. The northern part of the district is attached to the Tibetan plateau and Nepal is on its eastern border that is separated by the Kali river also known as Sharda river. The elevation from sea level ranges between 500 to 6400 m. Variation of temperature is considerable from area to area depending upon the altitude. The lower Himalaya is confined by the Main Boundary Thrust (MBT) in the southern part and Main Central Thrust in the Northern part. It consists of the late Proterozoic to early Cambrian sediments intruded by some granites and volcanic rocks [22]. The rock types in this land are quartzites, siltstone, carbonates, Phyllite, schist with subordinate impure marbles, metamorphic rocks, and orthogneisses [23]. Almost 50 % of the area is occupied by snowy Himalayan mountain ranges in the north forming several glaciers in the region. Therefore, at lower reaches, numerous natural springs are available for domestic and irrigation purposes. The district receives a good amount of rainfall, which infiltrates into the ground through the soil matrix and recharges the groundwater level. During the post-monsoon period, the water level reduces gradually affecting running water inventory for the pre-monsoon phase. The radon exhalation and water discharge rate are largely influenced by the meteorological parameters like pressure,

temperature, relative humidity etc. Radon level in water was found to be higher in monsoon and post-monsoon season in comparison to pre-monsoon season in a study conducted in Garhwal region [27]. The concentration of radon is linked to water quality in terms of radiological considerations. This study was performed for the post-monsoon season only and the results are interpreted in terms of water quality characterization using the results obtained from the measurements made in this season. Whereas physicochemical properties represent the parameters mainly for post-monsoon season, annual inferences are also made for radiological dose estimations. As the radon concentration values remains in mid-level (maximum in pre-monsoon and minimum in monsoon period) range, these can be assumed as representing yearly averaged values for calculations.

Figure 1: Sampling locations on the map of the study area (Pithoragarh district of Uttarakhand state of India).

Experimental Techniques and Methodology

Sample collection

52 water samples of drinking water were collected from different villages of the study area from various sources like natural springs (49) and hand pumps (3) in the month of December. Radon concentration profile follows a seasonal pattern due to the change in the water level as the function of rainfall. Radon concentration is expected to be at maximum level in the summer season while it reduces in monsoon period due to the increase in water level. The water samples that have been taken from the locations represent water which is used by the local population for domestic purpose as well as for drinking. Water samples were collected in polypropylene double capped sampling bottles. The bottles were washed thoroughly prior to sampling to reduce external contamination. Before pouring the sample into the bottles, a container is used to collect the water. The polypropylene sample bottle was then immersed into the container. One end of a polypropylene pipe is immersed into the opening of water source. After ensuring that no air bubble is forming inside the pipe, the other end of the pipe is purged into the sampling bottle, replacing the water in the sample bottle. To collect water sample from the hand-pump, the pipe was plunged inside the pumping cylinder of hand-pump up to the water level and hand-pump lever was operated to pump out water. After ensuring that there are not any bubbles forming inside the pipe, the other end of pipe then plunged inside the sample bottle that was immersed inside the water in large container. The sample bottle was capped inside the container to prevent the atmospheric contaminants. This sampling methodology was used to reduce the chance of instant degassing of radon while pumping the water out from the handpump, and to reduce external contamination from the atmosphere. After sampling, these water samples were analyzed for Rn^{222} on the spot with a portable Rn^{222} monitor. After the Rn^{222} measurement, water samples were taken to the laboratory for physiochemical analysis.

Measurement of Rn^{222} concentration

Water samples were analysed for Rn^{222} concentration with Smart RnDuo using a bubbler kit. Smart RnDuo is an online active Rn^{222} monitor that is developed by Bhabha Atomic Research centre, Mumbai. The working of Smart RnDuo is based on the alpha scintillation method. An Ag:ZnS coated cell (Lucas cell) is connected to a photomultiplier tube that records scintillation counts when an alpha particle hits the wall of the lucas cell [28]. The basic set-up for the measurement of radon concentration in water involves 50 ml glass sample bottle attached to a bubbler. The bubbler is connected to the radon monitor using polypropylene pipes and a particle filter. The air pump is used to circulate the air within the sample through the Lucas cell to obtain

escaping Rn^{222} from the sample inside the Lucas cell. For 15 minutes of the measurement cycle, a pump is set to on for 5 minutes and for the rest 10 minutes, the alpha count continues. After completing one cycle, average Rn^{222} activity concentration is displayed on the monitor. Figure 2 shows the schematic diagram for the setup for the measurement of Rn^{222} activity concentration using the bubbler method [29]. This instrument gives Rn^{222} concentration in the air volume having unit Bq/m^3 . To calculate Rn^{222} activity concentration in water volume (liquid) one can use the following equation 1 for the setup [30].

$$C_{liq} = C_{air} \left[K + \frac{V_{air}}{V_{liq}} \right] \quad (1)$$

Where C_{air} is the Rn^{222} activity concentration of air given by the Rn^{222} monitor, K is the partition coefficient (i.e. $K=0.25$ for water and air), V_{air} and V_{liq} is the volume of air present in the setup and volume of liquid sample present in the sampling bottle, respectively.

Figure 2: Schematic diagram of measurement of Rn^{222} activity concentration using bubbler kit attached to portable Smart RnDuo active radon monitor.

Measurement of Physiochemical parameters

The measured physiological parameters for the water samples i.e., Total Dissolved Solids (TDS), pH, and electrical conductivity due to salinity were measured using standard analytical methods available at Nuclear Research Laboratory, USERC, Dehradun. The Oakton CON 550 Benchtop Conductivity/TDS meter kit was used for the measurement of TDS and Electrical Conductivity of the water samples. The instrument measure electrical conductivity/TDS through a conducting probe, and has conductivity measuring range of 0-200 mS/cm with an accuracy of $\pm 1.0\%$ full-scale ± 1 digit, and TDS measuring range of 0-100 g/L with a resolution of 0.1/1 mg/L . TDS is the

measurement of the total weight of solids dissolved in the water sample volume that is expressed in parts per million (mg/L) or milligrams per unit volume. pH shows whether the sample is alkaline or acidic. It is a negative logarithm of hydrogen ion concentration. For pH measurement, GeNai pH digital meter – 117800GB is used in the laboratory. It has pH range of 1-14 with 0.5 ± 1 digit accuracy pH. [31-33].

Estimation of radiological dose

The annual effective dose due to ingestion and inhalation of Rn^{222} has been calculated using the parameters established in the reference [34,35].

The annual effective dose via ingestion can be calculated using the following equation2:

$$E_{w.Ig} (\mu\text{Sv}.y^{-1}) = C_{Rnw} \times C_w \times (EDC) \quad (2)$$

Where, $E_{w.Ig}$ is the annual effective ingestion dose, C_{Rnw} is the Rn^{222} activity concentration in water (Bq/L), C_w is the estimation of water consumption for the average population (600 L/y) and EDC is the ingestion effective dose conversion coefficient i.e. 3.5 nSv/Bq [36]. Annual effective inhalation dose can be calculated by the equation 3:

$$E_{w.Ih} (\mu\text{Sv}.y^{-1}) = C_{Rnw} \times R_{a.w} \times F \times O \times (DCF) \quad (3)$$

Where, $E_{w.Ih}$ is the annual effective inhalation dose, C_{Rnw} is the Rn^{222} activity concentration in water (Bq/L), $R_{a.w}$ is the ratio of Rn^{222} in air and tap water (10^{-4}) [36], F is the equilibrium factor between Rn^{222} and its progenies (0.4) [37], O is average annual indoor occupancy time per person (7000 h/y) and DCF is the dose conversion factor due to Rn^{222} exposure i.e. 9 nSv/(h.(Bq/m³)) [36].

Age-dependent annual effective ingestion dose was calculated using equation 4 as follows [36,38]:

$$AED_{ing} (\mu\text{Sv}.y^{-1}) = A \times w_{ing} \times DCF_{ing} \quad (4)$$

Where, AED_{ing} is the age-dependent annual effective ingestion dose($\mu\text{Sv/y}$), A is the activity concentration of Rn^{222} in water (Bq/L), w_{ing} is average annual water intake by the local population (L.y^{-1}) and DCF_{ing} is the age-dependent dose conversion factor (nSv/Bq) [39,40].

Result and discussion

The statistical parameters (i.e. minima, maxima, mean, standard deviation, skewness, and kurtosis) calculated for Rn^{222} activity concentration (Bq/L), TDS (mg/L), pH, Electrical conductivity ($\mu\text{S/cm}$), age-dependent annual effective ingestion dose ($\mu\text{Sv/y}$), Annual effective ingestion dose ($\mu\text{Sv/y}$), Annual effective inhalation dose ($\mu\text{Sv/y}$) and Total annual effective dose ($\mu\text{Sv/y}$) in Table 1.

Radiological exposure due to Rn^{222} activity concentration in water

The Rn^{222} activity concentrations in the water samples are found to be in the range of 0.6 to 81.9 Bq/L with a mean value of 17.8 Bq/L . These values are within the safe limit prescribed by WHO (2008) and EU (2001a), that is 100 Bq/L [41-42].

The frequency plot regarding the data obtained for Rn^{222} activity concentration in collected water samples is shown in Figure 3(a). The frequency plot indicates that more than half (54%) of samples have Rn^{222} activity level below 10 Bq/L and in 56% samples radon level is below 11.1 Bq/L (recommended level by USEPA (1991)) [43]. All of samples have Rn^{222} levels within the safety limit recommended by WHO (2008). To obtain the best fit distribution among Lognormal, Exponential, Gamma and Weibull, K-S (modified) test and A-D test has been performed on radon dataset, and goodness-of-fit statistical parameters are shown in Table 2. Results shown in table 2 and fig. 3 suggest that except exponential distribution, all other distributions (Lognormal, Gamma and Weibull) captured the trend of the variation of the data. [44, 45]. Figure 3(b) demonstrate the probability plot generated for the radon dataset. Lognormal, Gamma and Weibull dataset lie over the fitted reference line, indicating good fit for the data. However, in the Exponential probability plot, data points outreach the reference fitted line which indicates rejection of Exponential distribution over the radon dataset.

(a)

(b)

Figure 3: (a) Frequency plot and (b) probability plot of Rn^{222} activity concentration in water samples taken from Pithoragarh, district of Uttarakhand.

Physicochemical parameters

Total dissolved solids (mg/L) values of the samples occur in the range between 18 and 434 mg/L with an average value of 148 mg/L. From frequency plot (Fig 4a), it can be seen that; the TDS concentration was below 50 mg/L in 37% samples and in 97% samples its value was below 300 mg/L. Also shown in Table 1, this dataset is not uniform with -0.2 kurtosis and lightly-tailed or non-uniformly random. Goodness-of-fit statistics using K-S (modified) and A-D test has been performed over TDS dataset, and calculated parameters are shown in the Table 2. The goodness-of-fit statistics suggest that Lognormal, Gamma and Exponential distribution are not followed by the TDS dataset. However, Weibull distribution is accepted as best fit among assumed Distributions.

Figure 4(b) demonstrate the probability plot of the TDS dataset is rejected for Lognormal, Gamma and Exponential distribution. However, it is observed that the K-S (modified) test signifies that data-points are within the reference fitted line which confirms that Weibull distribution is best fit for the dataset (Table 1), meanwhile Lognormal, Gamma and Exponential distributions are rejected for the TDS dataset.

The pH values of collected samples range from 6.8 to 8.2 with a mean value of 7.2. Thus, the samples are slightly alkaline but safe for drinking and other domestic purposes. Skewness and kurtosis values show asymmetry of the dataset distribution which indicates a lack of external parameters to affect the pH of the water samples. Electrical conductivity varies from 36 $\mu\text{S}/\text{cm}$ to 868 $\mu\text{S}/\text{cm}$, with a mean value of 296 $\mu\text{S}/\text{cm}$.

(a)

(b)

Figure 4: (a) Frequency plot and (b) probability plot of TDS present in the water samples taken from Pithoragarh, district of Uttarakhand.

243 Radiological Dose assessment due to Rn²²² exposure

244 The age-dependent annual effective ingestion dose (AEI_gD) estimated due to Rn²²² exposure to
245 the local population is shown in Table 1. For infants (age below 1 year), the annual ingestion
246 dose (μSv/y) varies from 2.7 to 376.6 μSv/y with an average value of 81.7 μSv/y. These values
247 estimated for the children aged between 1 and 3 years vary within the range of 0.9-125 μSv/y
248 with an average value of 27.2 μSv/y. For children aged 4 to 8 years, the value of AEI_gD ranges
249 between 1.0 and 144.9 μSv/y with an average value of 31.4 μSv/y. For toddlers (male) aged 9-13
250 years, the average value of AEI_gD is 21.8 μSv/y within the range of 0.7-100.3 μSv/y. For
251 teenagers (male) who come in the age group of 14 to 18 years, the range of AEI_gD occurs
252 between 1.2 and 171.9 μSv/y with the mean value of 37.3 μSv/y. For the adults, the AEI_gD
253 ranges from 1.5 to 209 μSv/y with an average value of 45.4 μSv/y. For Toddlers (female) aged
254 between 9 to 13, the AEI_gD values obtained within the range of 0.7-100.3 μSv/y with an average
255 value of 21.8 μSv/y. The AEI_gD value for teenagers (female) ranges between 1.2 and 171.9 μSv/y
256 with the mean value 37.3 μSv/y. For Adult females, the obtained values vary within the range of
257 1.5-209.2 μSv/y with an average value of 45.4 μSv/y. The AEI_gD values for infants and children
258 are higher than for teenagers and adults because of the high value of dose conversion factors for
259 infants and children. High dose conversion factors for infants and children indicate that this age
260 group is at relatively higher risk due to similar exposure of Rn²²² compared to other age groups.
261 For the study area, these dose values are well within the safe limits prescribed by various
262 agencies [41]. Therefore, water samplers analyzed for this region are safe for drinking for all age
263 groups. Figure 5 shows the violin plot for annual effective ingestion dose for the various age
264 groups. The violin-like graph shows the kernel densities of the dataset of age-dependent annual
265 ingestion dose. The white dots between the densities are the median value. It can be seen that for
266 infants the median as well as the span of the dataset is highest.

Figure 5: Violin plot of age-dependent annual effective ingestion dose.

The annual effective Ingestion dose ($\mu\text{Sv/y}$) due to Rn^{222} exposure through drinking water, annual effective inhalation dose ($\mu\text{Sv/y}$) due to inhalation of Rn^{222} escapes from the water and total annual effective dose ($\mu\text{Sv/y}$) are also represented in Table 2. The annual effective ingestion dose ranges between 1.5 and 209.2 $\mu\text{Sv/y}$ with the mean value 45.4 $\mu\text{Sv/y}$. The annual effective inhalation dose occurs in the investigation within the range of 1.8-258.2 $\mu\text{Sv/y}$ and the average value is 56.0 $\mu\text{Sv/y}$. The total annual effective dose due to Rn^{222} exposure ranges between 3.3 and 467.4 $\mu\text{Sv/y}$ with a median value of 44.5 $\mu\text{Sv/y}$. Figure 6 illustrates the violin plot of annual effective ingestion dose ($\mu\text{Sv/y}$), annual effective inhalation dose ($\mu\text{Sv/y}$) and total annual effective dose ($\mu\text{Sv/y}$), respectively. These values are under the recommended limits (WHO, 2004) for drinking water. The white dots in between quartiles indicate the mean value of the data and the red line demonstrates the median value. The mean value is in the second quartile for all the doses which usually happens when most of the data occur at low values. The total dose increases when the Rn^{222} concentration increases. It is also demonstrated in the study that although children drink less water than adults yet they receive more doses due to high dose

conversion factor proposed for infants. Similar conclusions are also made by other studies in past [35,39]. No significant difference is found between AED for males and females.

Figure 6: Violin plot for annual inhalation dose, annual ingestion dose and total annual effective dose.

Spatial Analysis

This study is a field survey; hence, it is imperative to analyze the dataset over terrestrial land, with available data points. QGIS 3.4 LTS software is used for spatial analysis of Rn^{222} activity concentration (Bq/L) and TDS (mg/L). It is to be noted that the sampling of water in the study was carried out on point locations of the map. The latitude and longitude were also taken by GARMIN-GPS during the measurement of the location of sampling. The pointwise data is not enough to illustrate areal distribution. Therefore, the inverse distance weighting (IDW) interpolation method is used to calculate the approximate values on the neighbouring locations where the data was not taken during fieldwork. It is an adaptive interpolation method that distributes the data values over a spatial area. The simplest weighting function that is used to

interpolate data over the area is the inverse of the distance between two points with measured data on the location of sampling. This is a good method when need to apply for fewer location points otherwise kriging should be used for interpolation [46]. However, the accuracy of the predicted values for regions other than the sample nodes increases with the increase in sample size. The study represents the spatial distribution based on chosen data nodes only for indicative purposes.

Figure 7: Spatial distribution of (a) TDS (mg/L) and (b) Rn^{222} activity concentration (Bq/L).

Figure 7 illustrate spatial distribution of TDS (mg/L) and Rn^{222} activity concentration (Bq/L). It is observed that the most of the samples show low values over the region for TDS (mg/L) as well as Rn^{222} activity concentration (Bq/L). The water samples taken from the location of Usail, Satgad, Bisabajer and Jajardeval show comparatively higher values of TDS than other locations of the study area. The samples taken from the southern region have a TDS value of more than 160 mg/L. Figure 7(b) demonstrates the predicted Rn^{222} activity concentration values in water samples for the study region. It is observed that the northern area shows high values of Rn^{222} activity concentration in water samples although TDS is comparatively lower than 200 mg/L in the water samples taken from those nearby locations. The northern area of Pithoragarh is high altitude Terrain. More studies are needed to investigate higher Rn^{222} concentration values observed for high altitude regions. The observance of higher Rn^{222} activity concentration in low altitude regions (e.g. sampling node close to Dharchula) indicate the possibility of transportation of minerals by natural spring water, aquifers and rivers.

Conclusion

In this study, 52 samples of drinking water were collected from Pithoragarh district of Uttarakhand, India. The samples were investigated for Rn^{222} activity concentration (Bq/L) level, TDS concentration (mg/L), Electrical Conductivity ($\mu\text{S}/\text{cm}$) and pH. Age-dependent radiological doses to local population due to radon ingestion and inhalation due to water intake were also calculated and are compared with reference parameters recommended by ICRP (2002). All of the water samples have lower Rn^{222} activity concentration level than the reference limit recommended by European Commission (2001) and WHO (2008). The Rn^{222} activity concentration dataset follows Lognormal, Weibull and Gamma frequency distribution when tested with K-S (modified) and A-D tests for goodness-of-fit. Most of the samples have TDS below 250mg/L which indicates that the samples are of good quality (mineral-wise). For the case of frequency distribution of TDS, Weibull distribution was found to be best fitted as per the tests for goodness-of-fit. On average, the tested water samples were found to be slightly alkaline. Higher age-dependent annual effective ingestion dose values for the infants reflect the impact of higher dose conversion factors. No significant difference was found between annual effective ingestion doses for males and females. The estimated dose values were found to be lower than the recommended levels, wherever applicable. The spatial distribution analysis demonstrated that the water samples from the southern region have higher TDS (mg/L) values and the Northern region have higher Rn^{222} activity concentration (Bq/L) levels. This study concludes that the springs and handpumps are the source of safe drinking water in Pithoragarh district of Uttarakhand, India.

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Declaration of Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

[illegible]

Table 2: Goodness of Fit statistics for Rn²²² activity and TDS dataset in water samples.

Goodness-of-Fit Tests					
	Distribution	Goodness of Fit tests	Statistics	P-value	Decision at level (5%)
Radon	Lognormal	K-S modified test	0.075	>0.15	Accept Lognormal
		A-D test	0.477	0.225	Accept Lognormal
	Weibull	K-S modified test	0.099	>0.1	Accept Weibull
		A-D test	0.456	>=0.25	Accept Weibull
	Exponential	K-S modified test	0.184	0.022	Reject Exponential
		A-D test	2.072	0.007	Reject Exponential
	Gamma	K-S modified test	0.117	0.235	Accept Gamma
		A-D test	0.566	0.180	Accept Gamma
Total Dissolved Solids	Lognormal	K-S modified test	0.215	<=0.01	Reject Lognormal
		A-D test	2.494	2.04E-06	Reject Lognormal
	Weibull	K-S modified test	0.173	>0.1	Accept Weibull
		A-D test	2.039	<0.01	Reject Weibull
	Exponential	K-S modified test	0.193	0.014	Reject Exponential
		A-D test	1.873	0.012	Reject Exponential
	Gamma	K-S modified test	0.174	0.006	Reject Gamma
		A-D test	2.053	<0.005	Reject Gamma

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