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Potential implications of climate change on water quality and water-borne diseases in Hoshangabad district (Madhya Pradesh, India)

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Present study is to determine the potential public health risk of climate change parameters (temperature and precipitation) based on its effect on drinking water quality of Narmada River, an important multipurpose river in west India, in the Hoshangabad district, Madhya Pradesh. This study was done by collecting the past data of air temperature and precipitation and analyzing its total coliform impact using the multiple linear regression model. The study found the variation in public health risk towards water borne diseases with variation in the temperature and precipitation with significant risk during monsoon season.

[**Keywords:** Narmada Water quality; Water borne disease; Climate change; Total Coliform Count]

Introduction

Narmada is the major river of the west India that spans 1312 kms with total basin of 98, 796 sq. km total. It is a sacred river originating from Amarkantak in Shahdol district, at an elevation of 1057 meter above mean sea level. Its 87% of basin lies in Madhya Pradesh and Hoshangabad city is the largest city on this basin[1-2]**.** Other urbanized centres are Khandawa and Dewas of Madhya Pradesh. The Narmada basin lies between east longitudes 72°32' to 81°45' and north latitudes 21°20' to 23°45'. It flows through Deccan trap in between Vindhya and Satpura ranges of hills before flowing into the Gulf of Cambay in the Arabian Sea about 10 km north of Bharuch district of Gujarat[1-2]**.** For the first 1,079 km, it runs in Madhya Pradesh and thereafter it forms the common boundary between Madhya Pradesh & Maharashtra for 35 km and Maharashtra & Gujarat for 35 km. In Gujarat State, it stretches for 159 km. There are 41 important tributaries to the Narmada River. Significant among them are Burhner, Banjar, Hiran, Tawa, Chhota Tawa, Orsang and Kundi that are major tributaries having catchment area of more than 3,500 sq km each. The remaining tributaries are having catchment area ranging from 500 to 2,500 sq km. Temperature of Narmada basin is like any other part of Central India. The upper Narmada basin records lower temperature as compared to middle basin.

It has several major irrigation projects namely Karjan, Sukhi, Sardar Sarover, Jobat, Man, Upper Beda, Maheshwar, Narmada Sagar, Sukta, Kolar, Tawa, Varna, Bargi, Samrat Ashoksagar (Halali), Matiyari and Thanwar in the catchment areas of the river basin. There are 2 medium irrigation projects of Gujarat and 21 medium irrigation projects of Madhya Pradesh in the catchment area of Narmada basin. There are about 40 large scale and 70 small-scale industries in the area. Important minerals found in the basin are bauxite, clay, coal, dolomite, graphite, iron ore, manganese, talc & limestone, etc. There are 18 Water Quality observation sites in the basin. Sediment observations are also made at 11 of these stations. Further, there are 31 gauge and discharge sites being maintained by State Government of Gujarat in Narmada basin.

It has been proposed in various studies about the potential impact of climate change on the human diseases[3-6] and one of the applications of such studies has been proposed in the field of geographical area planning[3]**.** Climate change impacts the health through various routes like change in water quality and quantity, air quality, climatic variations and infection disease ecology[6-8]. However, different studies on different geographical regions have showcased different level of climate change impact on the health of the regional human population[3-6,8-9]. This makes it important to study the climate change impact on the region directly before making any recommendation for regional planning.

In India, studies have been done on the Ganges basin to determine the impact of the climate change on the human health but showed variation in impact in different areas of Ganga basin[6]. The study provides more macro-level analysis to understand the impact of the climate change on the human health. India is a country with several agro-climactic conditions and water basins and it is important to study other basins to understand the overall impact of the climate change on Human health in India. This study is done on Hoshangabad District, Madhya Pradesh that is the part of the Narmada basin to determine the impact of the climate change on the human health. The study tries to determine the climate change impact on human health in the area through the change in Narmada river water quality.

Materials and Methods

Study area and data set

Data Narmada River is located in Hoshangabad district of Madhya Pradesh, at latitude 22°23' 40" North and longitude 77° 58' 30" East. It flows along the Northern boundary of the district. The area of Hoshangabad district is 10,016 sq. km. topography of the district is marked by the plateau and hills of the Satpura in South all its length. The range of Satpura hills runs east to west between the Narmada river. The Narmada basin is about 1288 km. long and 80 km. broad running from east to west in Madhya Pradesh, occupies a central position in the country and empties into the Gulf of Cambay below Broach. Its catchment area is shown in Figure 1.

Monthly multi-parametric data of Hoshangabad district was collected to understand impact of the climate change on public health through change in water quality. The parameters used to study climate change are average monthly air temperature and total monthly precipitation[6]. Parameter related to water borne infectious diseases used for measuring Narmada water quality parameters was total coliform count[10]. Parameter total coliform count is associated with the increased public health risk of water borne diseases[3,6,9]. The various other climatic and non-climatic parameters can have effect on the water quality but was not considered owing to lack of data availability[11-13].

Graphical Flow Diagram of the data collection and analysis is shown in Figure 2. The method used to collect the data for climate change parameters was by performing the secondary literature review and data collected was from 1901 to 2002 for each month[14]. The multi-parametric climate change data collected was fitted on the modified version of Kay and McDonald multiple linear regression form[15]. The model originally developed used around 20 parameters to develop the model. In this study, the coefficients of all parameters other than the water surface temperature and four-week rainfall was added to the constant. The final equation is as given below:

$$Y = 4.09091 + (-0.16716 * ST) + (0.01088 * R) \quad (1)$$

Where, Y stands for the Log10 value of total coliform count per 100 ml, ST stands surface water temperature in degree Celsius and R stands for the total monthly rainfall in mm. Surface water temperature was calculated from air temperature data using the average slope and y-intercept values i.e. 0.71 and 2.56 respectively obtained by Morill *et al* for 43 rivers across the globe[16]. The public health risk to water borne disease is considered when the log10 value of total coliform count is found more than 3.3.

Results

The The monthly temperature and precipitation values for the Hoshangabad district, Madhya Pradesh was varying over the months in the year as shown in Table 1 and Table 2. The district climatic parameters followed the tropical climate conditions with monthly values of temperature and precipitation ranging from 17.13-35.55°C and 0.00-753.17 mm respectively over the 1200 months.

The variation in values was observed for the same months over the years (Table 3) with maximum temperature variation and precipitation variation happening for February and November and November and December respectively. The variation in temperature has been less than the precipitation variation. The correlation coefficients of different months over the years indicated that temperature parameter seems to have stronger correlation with years as compared to precipitation.

The study found variation in the total coliform count with change in temperature and precipitation value as shown in Figure 3. The study was performed to determine the months that are at risk for public health are as shown in Table 1. The study found consistent pattern of high total coliform content in the water during monsoon. Moors *et al* have also indicated that the monsoon season is water disease prone as higher precipitation lead to surface water runoff from nearby areas into water bodies that deteriorates the water quality.

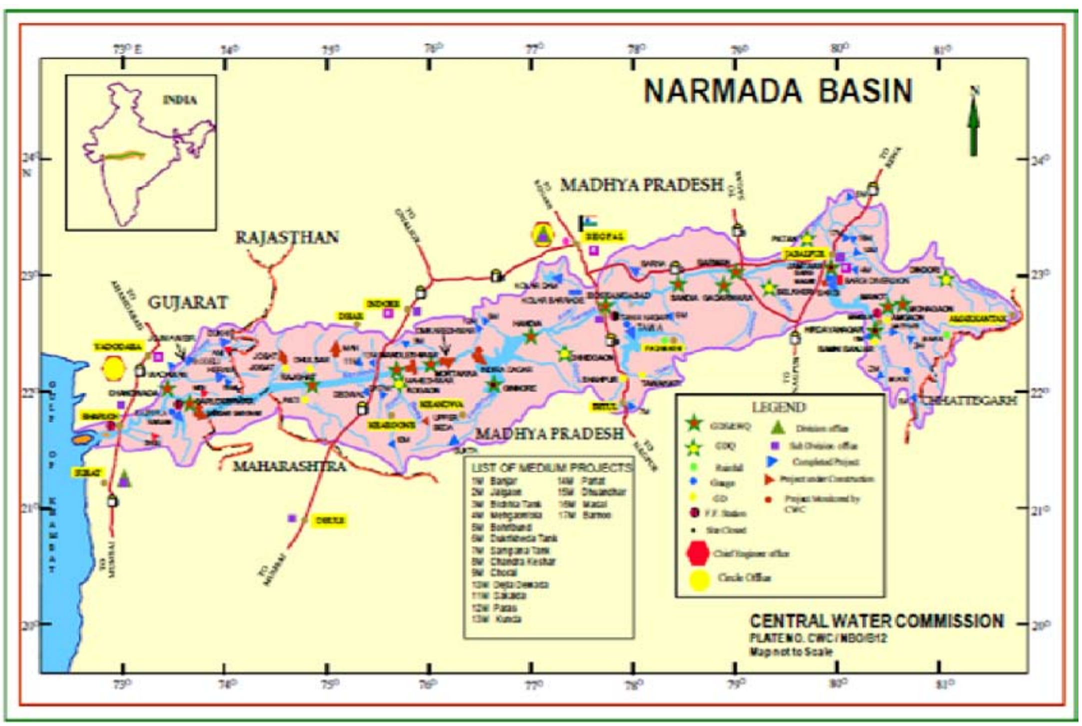

Fig. 1—Map showing Narmada River basin catchment

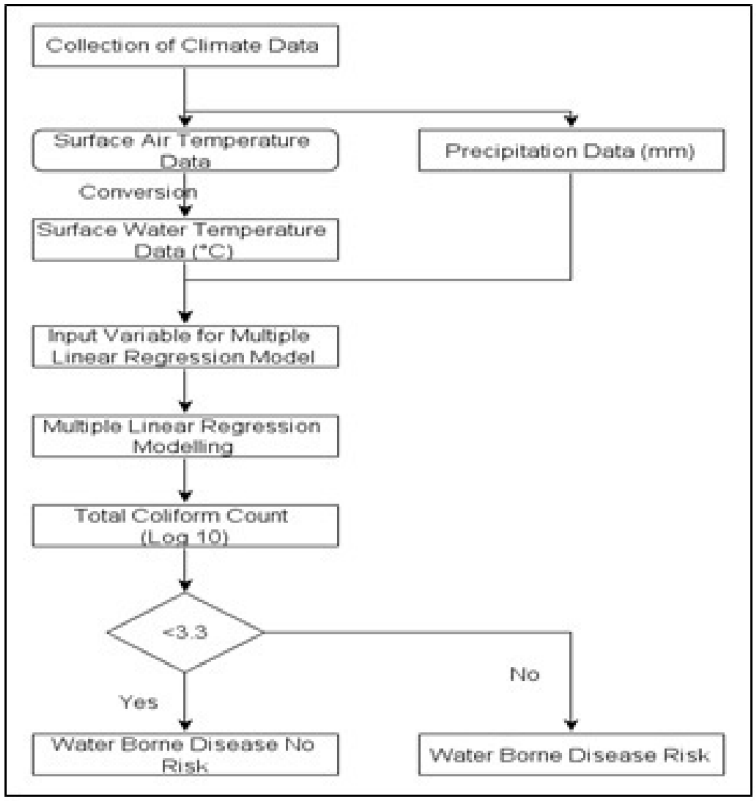

Fig. 2—Graphical Flow Diagram of data collection and analysis

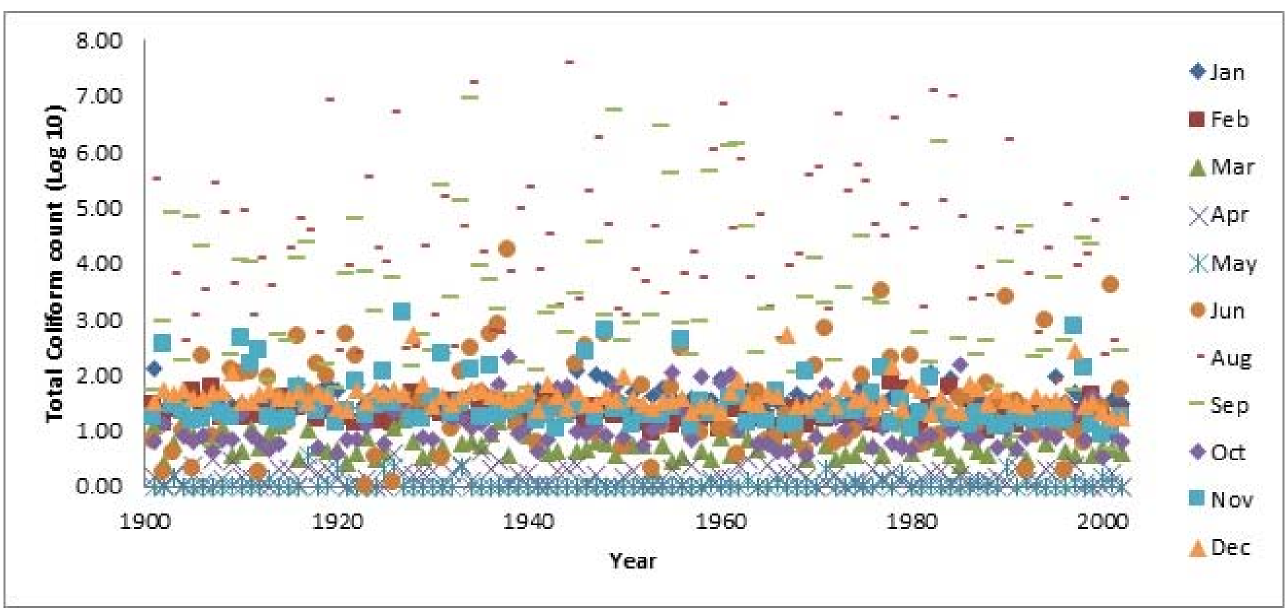

Fig. 3 - Total coliform count (Log 10) from 1901 to 2002 with change in temperature and precipitation

Table 1 - Monthly Air Temperature (°C) from 1901-2002

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1901	18.05	19.72	25.90	30.75	34.04	33.25	27.80	25.06	26.27	26.14	21.21	18.98
1902	20.44	22.32	28.47	31.94	34.55	33.08	27.47	27.02	25.90	25.06	20.07	17.82
1903	19.58	20.22	25.19	30.28	32.35	33.67	28.13	26.03	25.77	23.92	19.57	17.74
1904	19.61	20.91	25.16	31.62	33.63	30.91	25.83	25.42	25.54	25.27	20.29	18.75
1905	18.27	17.81	24.35	28.79	35.20	33.48	27.12	26.56	25.92	24.99	21.96	18.18
1906	18.21	20.08	25.37	31.33	35.22	30.76	26.47	26.44	24.99	24.25	21.70	19.05
1907	19.83	20.28	24.93	28.81	32.35	31.93	28.65	24.88	26.69	26.67	22.41	17.49
1908	18.40	21.37	25.05	31.92	33.90	32.47	25.78	25.12	26.49	25.24	20.96	17.48
1909	19.86	21.26	27.23	29.15	33.66	29.99	25.85	25.89	25.38	24.68	21.45	18.55
1910	19.07	21.26	26.43	30.68	33.78	29.91	26.77	25.83	25.74	23.75	19.26	18.77
1911	20.57	20.77	24.30	30.72	34.96	29.50	27.61	25.64	25.35	25.30	21.23	18.98
1912	19.84	22.42	26.00	31.01	34.37	33.67	27.44	25.69	25.82	25.17	20.26	17.69
1913	18.85	21.60	24.69	32.21	32.68	29.31	26.58	25.59	26.71	26.45	21.45	18.71
1914	20.66	21.79	25.21	30.29	33.62	30.46	26.29	25.94	26.33	25.56	22.60	18.68
1915	19.32	20.00	25.45	30.22	34.45	33.68	28.04	25.73	26.77	25.68	22.10	18.60
1916	19.18	20.48	27.85	31.85	34.30	28.48	27.39	25.74	26.14	24.44	19.94	17.41
1917	19.33	20.26	25.04	28.96	31.13	29.66	25.91	25.86	25.56	24.30	19.45	18.78
1918	17.42	21.82	26.27	29.87	34.37	30.02	28.13	25.81	26.74	26.13	22.30	18.12
1919	19.58	20.86	26.70	30.31	33.21	30.70	25.79	25.12	25.96	24.28	21.71	18.24
1920	19.21	20.85	26.59	30.90	31.20	31.06	25.97	25.84	27.07	26.92	22.31	19.80
1921	20.26	21.50	28.36	32.66	34.99	30.61	28.26	25.43	25.16	24.77	20.38	20.02
1922	18.48	22.78	27.02	31.58	34.17	30.37	26.28	25.50	25.55	24.65	20.48	17.35
1923	19.07	20.66	26.65	31.15	33.11	34.01	26.97	24.94	26.04	24.03	21.06	19.47
1924	19.33	22.08	27.93	32.20	33.23	32.71	26.74	25.92	25.64	23.84	19.62	18.42
1925	17.21	20.13	26.59	32.30	32.06	29.30	25.20	26.03	26.34	25.79	20.82	17.72
1926	19.51	22.54	25.30	27.71	32.48	33.95	27.32	25.63	25.76	23.68	19.11	17.13
1927	18.18	19.76	24.44	30.22	33.51	31.57	26.24	25.66	26.45	24.35	18.59	18.66
1928	18.81	21.09	25.99	30.42	34.22	30.93	25.99	26.15	26.38	25.01	21.78	17.61
1929	18.43	19.86	27.33	30.44	34.32	30.69	26.14	25.28	26.34	24.57	21.72	17.99
1930	19.25	20.20	26.92	30.20	33.43	31.46	25.70	25.40	26.11	26.04	20.31	19.46
1931	20.93	21.24	26.08	32.54	34.44	33.15	27.45	25.92	25.60	23.56	20.51	18.34
1932	20.87	19.87	25.52	30.21	33.86	31.98	26.33	25.87	25.91	25.51	20.96	19.06
1933	18.91	22.16	26.60	29.97	30.94	30.04	27.14	25.74	25.28	24.23	20.98	18.49
1934	17.93	21.66	25.52	31.09	33.60	31.28	26.10	25.40	25.01	23.74	19.92	18.53
1935	17.48	20.95	25.68	28.30	34.04	31.70	25.94	25.23	25.40	24.67	21.44	18.99
1936	18.12	20.90	25.87	29.94	34.55	29.60	26.71	25.56	25.54	24.44	21.29	18.03
1937	17.89	21.47	24.79	29.30	33.48	31.47	26.08	25.71	25.79	24.04	21.90	18.02
1938	20.04	19.58	27.73	31.49	34.44	27.29	25.84	26.01	26.80	24.54	20.36	18.66

Table 1 - Monthly Air Temperature (°C) from 1901-2002

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1939	20.30	22.06	24.50	30.37	33.87	30.57	26.05	26.08	25.38	25.42	20.75	17.96
1940	19.04	21.31	24.44	30.27	33.89	31.23	26.29	25.32	25.91	24.98	21.47	18.37
1941	18.66	21.22	27.54	32.14	34.51	32.06	26.76	25.75	26.64	26.45	21.93	20.22
1942	18.09	21.25	27.02	32.08	34.46	32.87	25.41	25.44	25.36	24.91	21.02	18.04
1943	19.77	20.12	26.69	30.15	34.54	30.38	26.06	24.82	25.83	23.93	23.30	17.89
1944	18.55	20.45	24.65	30.02	34.58	30.90	25.89	25.40	26.07	23.94	21.08	20.19
1945	17.44	20.25	26.38	29.61	33.69	32.03	26.26	26.09	25.48	24.14	19.90	17.19
1946	19.60	22.61	26.30	32.37	33.79	29.78	26.08	25.19	25.93	25.21	19.82	19.73
1947	17.74	21.03	26.45	30.82	34.55	31.97	26.29	26.43	25.47	23.53	21.52	19.32
1948	18.78	20.45	26.01	32.15	35.37	31.03	26.73	25.65	25.34	25.65	20.66	17.78
1949	20.23	21.05	27.10	32.08	34.44	30.92	26.70	26.35	25.72	24.73	20.16	18.46
1950	19.91	20.13	25.19	30.65	34.28	32.33	26.68	26.01	26.01	24.51	19.89	18.21
1951	17.96	20.99	26.49	29.76	34.09	31.96	28.22	25.56	26.56	26.97	22.62	18.10
1952	20.20	23.08	25.84	32.16	35.20	31.37	26.77	24.98	26.64	25.83	20.96	20.23
1953	18.24	23.82	29.30	31.90	34.40	32.90	26.78	25.76	26.40	24.84	21.04	19.75
1954	17.97	22.55	26.61	31.89	35.30	32.04	27.23	25.86	24.67	23.25	21.07	18.98
1955	19.47	22.54	28.28	29.52	33.89	31.03	26.70	25.64	25.54	23.32	19.67	18.52
1956	19.50	21.51	27.37	31.66	34.06	29.06	25.37	25.04	25.49	24.11	19.63	19.03
1957	18.96	20.02	24.36	30.25	32.85	31.89	26.53	26.06	25.47	25.27	23.06	20.40
1958	20.67	21.63	26.83	32.45	34.62	33.18	26.24	26.39	25.31	24.03	21.83	19.45
1959	19.51	21.24	27.66	31.45	34.00	31.62	26.10	25.27	25.38	25.08	21.55	19.59
1960	17.95	23.23	25.72	31.17	34.47	32.06	27.04	24.64	26.32	24.31	20.76	20.37
1961	19.10	19.32	27.50	31.03	33.81	30.52	25.75	25.55	24.50	23.22	20.61	17.70
1962	17.32	20.74	25.23	30.15	33.48	31.50	26.87	25.36	24.93	23.12	21.41	19.27
1963	17.97	22.11	24.85	28.20	32.12	29.37	25.70	24.66	25.21	24.89	22.95	19.11
1964	18.43	21.72	28.14	32.57	33.38	30.92	26.96	25.56	25.82	25.68	20.93	19.29
1965	19.91	21.56	25.62	30.06	33.86	31.92	27.15	26.51	25.62	25.74	21.86	18.97
1966	19.04	23.01	25.69	30.33	32.64	30.84	28.45	25.68	27.05	26.83	23.42	18.78
1967	19.06	23.36	24.87	29.90	34.47	30.94	26.87	25.38	25.22	26.53	22.61	19.69
1968	18.31	20.72	27.02	29.55	32.28	30.42	26.52	25.04	26.85	24.87	22.26	19.49
1969	19.12	22.69	28.07	30.50	33.38	30.42	26.41	24.72	25.20	27.31	23.40	19.49
1970	19.60	21.98	27.02	33.29	35.13	29.78	27.37	25.41	25.31	24.79	20.38	18.45
1971	18.93	22.08	25.93	31.59	31.72	28.46	25.76	25.68	25.91	24.64	20.92	17.77
1972	19.10	20.47	27.68	30.33	34.08	31.91	27.64	25.31	25.67	25.39	21.74	20.00
1973	19.51	22.37	27.26	33.04	35.18	31.57	25.71	25.89	25.44	24.71	20.49	18.58
1974	18.33	21.16	27.14	31.59	32.72	31.41	27.22	25.32	27.22	25.11	20.27	18.51
1975	17.15	21.43	25.66	31.82	34.26	30.76	25.78	25.80	25.50	25.00	19.53	18.10
1976	19.01	22.10	26.72	30.75	33.71	29.62	26.93	25.38	25.77	25.94	24.18	20.25
1977	19.36	22.61	28.70	30.94	32.17	31.53	26.94	25.62	25.75	25.54	22.79	19.34

Table 1 - Monthly Air Temperature (°C) from 1901-2002

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1978	18.63	20.88	25.23	30.86	35.41	30.44	25.91	24.67	26.34	25.92	23.36	18.04
1979	20.11	20.12	25.21	31.19	32.06	31.87	26.54	24.90	27.55	27.00	23.99	19.82
1980	20.37	22.72	27.05	32.44	33.72	29.18	26.52	25.10	26.94	26.36	23.22	18.85
1981	18.07	22.83	25.88	31.00	33.56	32.43	25.27	25.48	26.36	25.65	20.86	18.60
1982	20.23	20.93	25.08	30.20	32.25	32.04	27.60	25.49	26.61	26.24	22.12	20.78
1983	19.08	20.92	26.19	29.77	33.54	32.66	27.29	26.42	26.04	24.32	20.26	18.57
1984	19.12	19.66	27.09	31.42	35.16	30.89	27.38	24.65	25.70	25.64	21.52	20.16
1985	20.38	21.91	28.65	31.38	34.52	31.04	27.26	25.26	26.63	23.97	21.65	20.49
1986	19.65	21.56	26.42	31.22	33.81	31.07	25.88	25.34	27.37	25.32	22.60	19.09
1987	19.35	22.41	26.62	31.77	32.54	32.59	27.59	26.89	27.55	26.15	22.82	19.11
1988	20.85	23.49	27.18	31.79	35.55	31.51	26.47	26.61	27.38	24.91	21.59	19.30
1989	18.77	21.83	25.70	30.62	34.76	30.06	27.03	25.38	26.83	25.95	22.96	18.84
1990	21.27	21.84	25.08	31.44	31.73	28.79	25.63	26.23	25.73	25.47	22.61	19.57
1991	18.55	23.09	27.42	30.57	35.05	31.15	27.12	25.28	26.96	26.29	21.85	19.21
1992	19.90	21.08	27.70	31.25	33.63	32.22	28.20	25.62	26.02	25.28	21.71	19.57
1993	20.35	21.71	24.97	31.06	35.24	32.25	27.05	25.82	25.50	25.77	21.86	18.56
1994	20.32	20.93	27.56	29.54	34.87	29.84	25.49	25.06	25.85	25.48	21.80	18.77
1995	17.20	21.28	24.93	30.17	33.48	33.80	27.43	26.30	26.80	26.41	22.07	20.59
1996	20.28	22.66	27.87	31.29	34.70	32.84	27.58	25.59	26.66	24.86	21.98	18.78
1997	18.36	20.84	27.10	29.04	32.18	29.97	26.48	26.03	26.19	24.79	22.84	17.92
1998	18.83	21.66	25.18	31.41	35.26	32.63	27.31	26.91	27.09	26.50	22.20	19.61
1999	19.17	22.16	27.17	32.65	33.73	30.03	26.97	25.43	25.34	25.10	22.66	18.88
2000	20.39	20.70	25.95	33.01	32.42	29.85	26.06	26.82	26.75	27.53	23.99	20.41
2001	19.64	23.41	27.23	30.32	33.85	28.88	25.79	26.28	27.69	26.41	23.20	21.46
2002	19.20	22.88	27.53	32.40	35.03	30.99	28.44	25.17	26.07	26.57	22.66	21.61
Mean	19.14	21.37	26.34	30.90	33.81	31.20	26.69	25.65	26.02	25.13	21.42	18.89
Min.	17.15	17.81	24.30	27.71	30.94	27.29	25.20	24.64	24.50	23.12	18.59	17.13
Max.	21.27	23.82	29.30	33.29	35.55	34.01	28.65	27.02	27.69	27.53	24.18	21.61

Table 2 - Monthly Precipitation (mm) from 1901-2002

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1901	47.8	3.0	35.9	3.4	7.1	87.6	430.7	433.4	96.8	13.3	0.2	0.1
1902	4.1	1.8	0.0	3.2	0.7	34.4	368.3	181.8	209.0	28.5	106.7	9.9
1903	3.1	0.1	0.0	0.0	18.0	72.8	341.8	286.2	385.3	61.7	0.2	0.1
1904	0.0	5.6	38.3	0.0	8.3	80.2	344.9	170.2	138.8	14.0	0.2	19.1
1905	1.4	4.3	2.5	0.5	3.6	42.7	298.5	224.9	381.4	0.3	0.2	0.9
1906	0.0	6.0	12.6	0.0	2.5	201.0	466.2	265.2	321.8	1.8	0.2	7.9
1907	6.6	38.0	1.1	10.7	4.6	80.6	203.8	422.7	10.5	0.3	25.9	0.5

1908	5.0	0.5	22.1	10.0	0.0	117.0	408.0	377.3	92.7	5.1	3.9	2.0
1909	3.4	5.9	1.5	12.7	20.0	168.2	209.7	270.6	147.0	0.3	0.2	45.3
1910	0.6	0.0	0.0	1.0	1.3	161.0	192.2	387.4	306.3	30.6	108.9	0.1
1911	6.8	0.1	14.4	0.0	0.0	161.7	146.1	213.4	300.5	13.9	87.1	0.1
1912	1.4	15.6	0.0	2.4	0.4	39.9	344.1	308.3	169.1	0.6	98.0	1.7
1913	0.0	5.8	9.9	0.1	19.2	149.6	317.1	261.8	118.3	1.2	0.2	17.9
1914	0.0	5.0	29.5	10.6	14.5	130.0	382.7	185.8	189.8	1.6	6.0	5.4
1915	2.9	18.3	61.6	8.4	7.4	120.5	287.2	326.7	185.1	75.4	4.5	3.5
1916	0.0	8.9	0.0	1.1	9.9	208.9	275.6	374.0	313.0	87.6	33.3	0.1
1917	5.0	20.8	18.5	1.1	42.3	129.3	354.8	357.6	333.8	54.1	0.2	0.1
1918	0.0	3.6	2.9	0.2	16.3	178.3	170.4	187.0	78.4	1.7	19.7	9.6
1919	36.6	4.2	2.1	12.1	16.2	165.8	306.4	561.4	137.6	48.7	36.9	3.2
1920	23.4	0.0	3.0	0.8	20.4	109.0	336.6	158.7	109.9	0.3	0.2	0.1
1921	6.6	1.5	0.0	0.0	0.0	233.9	250.2	292.7	277.6	1.1	0.2	0.1
1922	24.5	5.4	0.6	0.0	1.3	196.7	386.4	152.1	371.2	1.1	50.4	4.1
1923	2.8	0.9	22.8	4.0	9.6	18.6	614.9	433.8	291.1	15.6	2.2	8.2
1924	18.5	1.2	3.0	0.4	3.3	55.5	323.6	329.3	222.5	46.9	1.7	15.3
1925	0.0	0.0	0.0	0.0	30.2	107.3	415.4	307.2	92.9	5.3	69.7	0.3
1926	10.4	2.0	24.6	10.0	37.3	27.8	292.4	548.3	276.7	35.4	0.7	1.5
1927	0.7	5.0	29.5	4.1	0.0	121.1	408.3	159.1	92.8	63.0	143.1	10.7
1928	2.2	36.2	9.7	2.0	1.5	110.9	523.8	168.5	137.0	45.9	0.4	98.8
1929	3.9	9.5	0.0	7.0	0.3	127.9	461.9	324.1	190.4	2.3	0.2	18.8
1930	0.2	1.0	0.0	5.3	2.7	125.4	539.3	212.0	160.8	14.6	21.4	0.6
1931	3.3	4.6	2.8	0.6	3.6	57.6	456.7	411.9	427.2	130.9	93.9	3.4
1932	0.0	10.2	41.3	3.4	0.6	92.8	753.2	166.5	247.7	43.9	2.1	0.1
1933	0.8	12.8	14.4	12.0	21.1	167.5	315.5	360.4	399.8	31.0	19.2	6.7
1934	5.2	0.0	4.9	0.1	0.0	217.8	348.4	595.1	563.5	10.6	61.9	17.6
1935	3.9	5.4	0.0	19.6	2.6	147.1	547.4	313.9	292.6	25.1	1.8	22.1
1936	0.6	9.0	22.2	5.3	11.2	225.4	248.6	188.2	271.5	7.6	83.0	0.2
1937	0.0	19.5	29.1	13.3	2.1	260.6	523.8	186.6	225.0	83.7	10.2	0.2
1938	13.2	0.5	5.5	1.5	23.8	339.2	369.8	288.9	97.8	136.0	0.2	0.1
1939	6.8	2.1	32.5	1.7	0.0	83.3	464.2	395.8	135.3	18.1	14.2	1.0
1940	2.4	7.0	4.7	3.9	17.8	122.9	684.9	420.7	98.2	26.8	23.1	15.2
1941	19.1	15.0	23.1	3.8	1.3	70.5	303.7	288.9	135.8	0.3	0.2	0.1
1942	11.7	29.2	1.5	3.9	2.8	140.9	675.2	345.5	214.9	3.3	0.2	20.0
1943	32.4	0.0	0.0	4.9	18.4	107.9	345.1	222.4	229.9	75.0	0.8	0.1
1944	8.3	24.8	68.4	8.3	0.9	115.6	690.1	627.5	190.0	80.7	0.8	4.5
1945	36.3	0.0	0.0	9.7	3.9	200.7	504.0	245.3	249.6	7.6	0.2	0.1
1946	0.0	7.0	0.0	9.3	3.0	207.3	313.3	412.7	68.5	16.6	93.0	6.7
1947	33.7	11.9	15.0	4.7	1.3	85.6	586.2	515.1	331.5	11.5	0.7	3.1
1948	39.0	1.0	6.0	2.1	1.2	237.9	418.3	362.5	211.7	17.9	135.1	0.1

1949	0.0	1.1	0.0	0.4	13.0	130.6	367.0	233.2	551.8	89.2	0.2	0.1
1950	6.9	5.3	10.5	0.3	1.5	68.1	381.4	218.2	176.8	1.7	0.3	34.2
1951	5.2	11.2	9.6	1.4	9.0	110.3	346.2	289.1	210.4	62.4	0.2	0.1
1952	0.0	9.5	3.7	4.3	1.5	158.6	362.7	263.2	51.9	3.5	0.2	10.2
1953	3.8	0.0	0.0	2.5	1.1	38.0	338.3	362.7	222.2	18.1	0.2	0.1
1954	14.1	7.6	9.3	0.0	0.2	96.5	348.3	252.2	515.2	14.1	0.2	0.1
1955	13.1	0.0	0.7	1.4	0.7	152.2	230.1	447.1	448.0	95.2	0.2	0.1
1956	3.6	0.0	0.3	0.5	13.8	194.7	608.4	277.3	199.5	43.2	109.7	7.1
1957	8.2	0.0	38.3	16.0	9.2	84.4	230.5	322.8	146.2	5.7	1.0	1.3
1958	3.0	0.9	3.7	2.0	6.3	99.0	429.1	284.1	201.7	98.1	32.6	0.1
1959	9.6	3.0	0.0	7.1	26.1	119.8	402.4	482.3	448.8	50.3	10.7	0.1
1960	28.6	0.0	13.4	8.1	3.3	94.2	332.9	550.3	51.7	89.3	0.2	1.0
1961	14.5	1.0	2.7	1.0	10.8	77.8	414.7	355.5	481.7	92.0	25.4	5.5
1962	4.0	8.1	23.0	14.4	4.1	46.1	398.6	468.7	488.8	1.2	37.3	38.7
1963	9.2	12.3	2.4	4.6	9.5	108.9	278.4	266.3	357.3	28.0	8.6	1.4
1964	0.0	1.0	21.5	0.0	12.0	142.7	363.0	380.1	154.9	3.5	0.2	0.1
1965	11.5	0.8	7.1	13.3	1.6	74.1	231.5	237.4	222.6	5.3	0.4	14.8
1966	2.9	0.5	7.4	0.7	11.5	69.5	302.3	175.5	96.3	2.1	63.7	7.5
1967	0.2	0.0	45.6	0.4	1.7	106.3	273.5	292.3	166.3	0.6	0.2	120.1
1968	7.8	5.6	24.1	2.9	0.0	71.0	449.3	307.9	133.5	34.1	0.2	1.0
1969	3.9	0.2	1.9	0.0	6.9	40.4	499.4	434.2	239.5	0.3	95.8	0.1
1970	13.2	7.3	34.0	1.1	15.9	173.5	185.1	456.4	305.2	5.4	0.2	0.1
1971	5.0	5.1	3.2	2.1	26.7	221.6	341.7	223.3	237.8	90.1	0.2	0.1
1972	0.0	0.4	0.0	0.4	1.9	69.8	175.3	542.0	140.8	42.7	21.6	5.4
1973	0.1	14.3	0.0	0.3	3.1	71.6	660.2	422.8	259.1	17.3	0.2	19.4
1974	0.0	2.2	0.8	2.1	15.5	83.0	235.4	458.8	63.9	75.8	0.2	0.1
1975	7.2	14.8	3.0	0.0	0.8	167.2	258.5	438.1	341.8	35.2	0.2	0.1
1976	5.1	0.1	12.4	15.5	11.4	85.1	338.9	359.6	240.9	0.3	68.6	4.3
1977	0.7	2.0	16.0	0.9	9.5	314.9	245.4	345.2	234.0	28.7	98.4	5.3
1978	7.5	52.6	42.8	10.9	0.7	193.4	329.0	527.5	129.3	6.4	10.4	49.6
1979	35.1	31.6	3.4	0.0	18.8	101.6	331.7	388.4	43.8	10.3	56.3	2.1
1980	0.9	1.8	1.1	0.5	0.0	182.8	207.3	351.1	56.8	1.0	0.2	27.9
1981	9.5	1.6	10.0	0.5	16.4	73.6	182.3	226.5	191.7	13.5	3.0	17.1
1982	62.0	12.2	4.3	2.1	6.4	80.0	270.7	581.4	145.3	22.6	72.2	0.9
1983	3.3	0.4	1.7	1.0	3.9	89.6	367.6	412.1	503.2	56.7	0.2	3.9
1984	43.5	30.4	0.0	0.1	2.4	96.5	166.3	565.2	41.9	27.3	0.2	0.9
1985	17.9	0.1	0.0	11.0	10.4	135.3	374.1	374.0	186.7	114.7	0.2	0.1
1986	4.3	31.3	16.2	0.0	8.3	140.0	387.3	238.5	62.9	13.7	1.0	32.8
1987	11.6	22.1	2.4	0.0	15.5	104.8	180.3	304.2	170.0	19.5	20.9	25.5
1988	0.0	1.4	0.3	6.1	4.2	163.0	325.7	255.9	190.7	30.0	3.3	1.9

1989	0.8	0.0	41.6	0.0	4.9	118.9	177.5	355.9	108.8	0.4	0.2	18.8
1990	0.2	12.9	3.6	0.0	30.0	277.6	516.5	511.2	303.9	25.5	0.7	9.8
1991	0.7	4.6	15.7	15.1	5.2	128.4	194.8	345.8	26.0	0.4	7.6	0.1
1992	2.7	3.8	0.0	0.1	26.8	28.9	72.5	281.6	366.2	10.2	0.9	0.1
1993	0.0	8.3	25.4	0.1	6.8	85.1	234.0	186.1	144.0	36.0	0.3	5.8
1994	12.1	10.6	23.9	3.2	13.9	250.7	534.1	318.9	159.4	17.0	4.2	0.1
1995	24.7	4.2	54.4	4.7	5.8	106.9	405.5	112.9	289.4	20.7	4.2	21.7
1996	15.7	5.2	13.2	16.6	5.9	33.2	303.2	396.8	184.2	47.9	1.6	0.1
1997	11.2	0.0	0.0	5.3	8.8	69.8	324.3	299.6	96.9	43.7	165.3	74.5
1998	2.5	1.1	35.3	0.2	1.4	79.0	181.9	329.5	356.7	19.4	89.8	0.1
1999	0.8	45.6	0.0	0.0	10.3	89.1	328.1	369.6	327.0	75.9	0.2	0.6
2000	0.0	2.1	0.0	0.0	21.2	107.3	564.0	163.5	58.2	2.1	0.2	0.1
2001	10.1	0.3	12.1	4.3	24.3	296.5	252.7	178.5	14.9	29.3	3.1	0.1
2002	1.0	23.9	8.2	3.7	11.4	148.1	69.1	400.1	161.7	17.0	15.3	1.9
Mean	8.8	7.8	12.0	4.0	8.9	126.4	355.5	331.9	218.0	30.3	23.6	9.4
Min.	0.0	0.0	0.0	0.0	0.0	18.6	69.1	112.9	10.5	0.3	0.2	0.1
Max.	62.0	52.6	68.4	19.6	42.3	339.2	753.2	627.5	563.5	136.0	165.3	120.1

Table 3 - Percentage Variation and correlation coefficient of Temperature and Precipitation with respect to change in year for each month over 100 years

Months	Correlation Coefficient		Percentage Variation	
	Temperature	*Precipitation*	*Temperature*	*Precipitation*
January	0.086	0.050	4.99	137
February	0.364	0.105	5.07	136
March	0.220	-0.004	4.44	126
April	0.170	-0.049	3.67	121
May	0.055	0.056	3.10	102
June	-0.111	0.012	4.38	52
July	0.004	-0.182	3.00	39
August	-0.024	0.139	2.03	35
September	0.247	-0.094	2.60	58
October	0.288	0.033	3.96	107
November	0.458	-0.074	5.58	164
December	0.466	0.065	4.92	200

Table 4 - Safety of months based on Total Coliform Log 10 count/100ml

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Health Risk Months
1901	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1902	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1903	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1904	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1905	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Risk	Safe	Safe	Safe	2

1906	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1907	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1908	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1909	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1910	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	2
1911	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	1
1912	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1913	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1914	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1915	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1916	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1917	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1918	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	0
1919	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1920	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1921	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	2
1922	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Risk	Safe	Safe	Safe	2
1923	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1924	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1925	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1926	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1927	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1928	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1929	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1930	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1931	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1932	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Risk	Safe	Safe	Safe	2
1933	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1934	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1935	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1936	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Risk	Safe	Safe	Safe	2
1937	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1938	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	Safe	3
1939	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1940	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1941	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1942	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1943	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1944	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1945	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3

1946	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1947	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1948	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1949	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Risk	Safe	Safe	Safe	2
1950	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1951	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1952	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1953	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1954	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1955	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	2
1956	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1957	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1958	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1959	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1960	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1961	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1962	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1963	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1964	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1965	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	0
1966	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1967	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1968	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1969	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1970	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	2
1971	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
1972	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1973	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1974	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1975	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1976	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1977	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Risk	Safe	Safe	Safe	Safe	2
1978	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1979	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1980	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1981	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	0
1982	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1983	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
1984	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1985	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1986	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2

1987	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1988	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1989	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1990	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Risk	Safe	Safe	Safe	4
1991	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1
1992	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	2
1993	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	0
1994	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1995	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Risk	Safe	Safe	Safe	2
1996	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1997	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	2
1998	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	2
1999	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Risk	Safe	Safe	Safe	3
2000	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	Safe	1
2001	Safe	Safe	Safe	Safe	Safe	Risk	Risk	Safe	Safe	Safe	Safe	Safe	2
2002	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Risk	Safe	Safe	Safe	Safe	1

Conclusion

A predictive modelling has been done in the study to estimate the months in which public health risk due to water borne disease will be higher. The study needs to be validated with the data collection from the hospitals on the patients reported with water-borne diseases. One of the major limitations of the study is that it used the coefficients values in the equations that were developed for the other system owing to limited data availability for the Narmada river basin.present.

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