

Role of Government in Ensuring Safe Drinking Water after a Natural Disaster - A Case Study of Kerala Flood

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Abstract Floods are one of the major natural disasters, resulting in the contamination of drinking water sources such as ground water and drinking water. Kerala had an abnormally high rainfall during 1st June 2018 to 19th August 2018. It resulted in the heavy loss of life and many people were evacuated and nearly one sixth of the total population were affected. Contamination of drinking water by floods results in water-borne illnesses. Alappuzha district of Kerala was one of the worst hit districts by flood. Economically backward sections of the population are usually more affected by any natural disaster particularly flood. Hence a study was made on the socio-economic status of the flood affected people and role of government in ensuring safe drinking water. The water samples were collected from the ground water sources (wells) of flood affected Mannar panchayath of Chengannur taluk. The water quality of households affected due to flood were subjected to various physico-chemical and microbiological analysis. Also the quality of water collected from flood affected areas were calculated using two indices - WQI and OPI. Based on the results, the recommendations were made to improve the performance of the government in ensuring safe drinking water after a flood.

Keywords: bacteriological analysis, flood, socio economic survey, water quality, WQI and OPI

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1. Introduction

Natural disasters, such as floods, hurricanes, tsunamis, tornadoes *etc.* can lead to the contamination of water supplies [1]. More than 90% of all natural disasters are related to water. According to United Nations, over the period 1995-2015, floods accounted for 43% of all documented natural disasters, affecting 2.3 billion people, killing 157,000 and causing US\$662 billion in damage. UNESCO has observed that, Asia is the region most vulnerable to water-related disasters [2].

One of the important consequence of a water-related disaster particularly flood is the contamination of drinking and ground water. Economically backward sections of the population are usually more affected by any natural disaster particularly flood [3]. The location of their houses may be in environmentally fragile areas, in marshy places or in low lands which are more susceptible to heavy damage due to rain and flood. They may be less informed about the hazards of drinking contaminated water. They may not know how to disinfect contaminated water. They are financially incapable to make arrangements to get their water resources cleaned. Moreover, since they don't have any regular salaried employment, their means of

livelihood may be temporarily hindered by the disaster. The public authorities have a significant role in ensuring safe drinking water supply to the victims of such calamities.

Kerala is the southernmost state of India. Kerala had an abnormally high rainfall during 1st June, 2018 to 19th August, 2018. This led to severe flooding in 13 out of 14 districts in the State. According to Indian Meteorological Department (IMD) data, Kerala received 2346.6 mm of rainfall from 1st June, 2018 to 19th August, 2018. Expected rainfall for the period was 1649.5m [4]. About 483 people died. More than a million people were evacuated. One-sixth of the total population of Kerala were directly affected by the floods [5].

Alappuzha district of Kerala was one of the worst hit districts by flood. According to the technical report by Central Ground Water Board, ground water in a major part of the Alappuzha district suffered from bacteriological contamination, making it unsuitable for drinking even before the floods [6]. Mannar which is the study area (Figure 1), is a Panchayat in Chengannur Taluk in Alappuzha District of Kerala state, India, located on the banks of the river Pamba. The geographical coordinate of Mannar panchayath of Alapuzha district is 9.3171° N, 76.5344° E. The main drinking water source for the population of the region is the ground water.

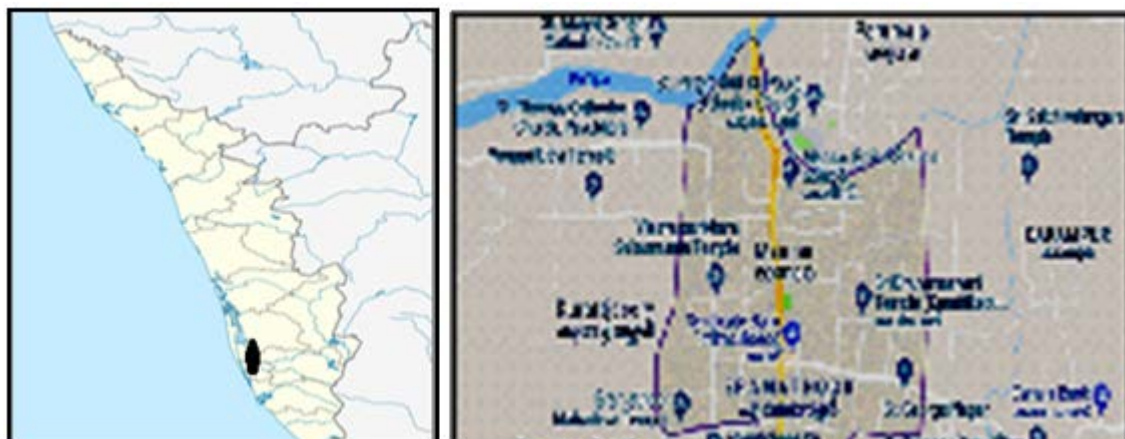


Figure 1. Map of the study area

The objectives of the study includes the following:

1. To understand the role of government in ensuring safe drinking water to people after flood.
2. To analyze the quality of water collected from flood affected areas using two indices - WQI and OPI
3. To make recommendations to improve the performance of the government in ensuring safe drinking water after a flood.

2. Materials and Methods

We carried out a detailed investigation about drinking water in the study area during October - November, 2018 *i.e.*, two months after the flood. With the help of a well-structured questionnaire, information was collected from 30 flood affected households who were depending on well water before flood. The information secured included the difficulties faced by the households due to non-availability of pure drinking water and the role played by the government to address the situation. A total of 30 water samples were collected from the ground water sources (wells).

The water quality of households affected due to flood were subjected to various physico-chemical and microbiological analysis and based on standard procedures [7]. The parameters selected for analysis were temp ($^{\circ}\text{C}$), pH, DO (ppm), BOD_5 (ppm), Turbidity (NTU), MPN, Hardness (mg/l) and Total coliforms, Standard Plate count and Faecal coliforms. The standards are designated based on WHO guidelines for drinking water quality assessment. Based on the results, the quality was classified based on two major pollution indices - National sanitation foundation water quality index (NSF-WQI) and Overall Index of Pollution (OIP).

NSF-WQI can be used to assess the water quality of water body and is mathematically expressed as $\text{WQI} = \sum W_i Q_i$; where, Q_i : Sub Index of i^{th} water quality parameter, W_i : Weight (in terms of importance) of water quality parameter and N : Number of water quality parameters [8].

$$\text{OIP} = \sum i P_i / n$$

Where P_i is the pollution index for i^{th} parameter, i is 1,2,-----, n and n is the number of parameters. The (P_i) called pollution index can be obtained for each parameter using mathematically expressions developed [9].

3. Results and Discussion

Water contamination may be caused by livestock waste, human sewage, chemicals and excessive increase in the turbidity of water, or pollution from other types of contaminants. Contamination of drinking water by floods results in water-borne illnesses [10,11]. Kerala has the highest chemical/bacterial contaminated drinking water among 28 tested states in the country, as per the Union Ministry of Drinking Water and Sanitation [12]. According to a report by the National Sample Survey Organization, only 29.5% rural households in Kerala have access to safe drinking water as compared to the national average of 88.5% [13,14].

From the study, it is found that the highest income earner of the households surveyed was either self-employed or casual labourer. 66 % of the households had to change their drinking water sources after flood. The main source of drinking water was own well for all the households before flood. But after flood, they had to shift their drinking water source to public well, public tap, mineral water, neighbours' well, packet water *etc.*

Table 1. Source of Drinking Water before and after Flood

Source of water	No. of households (Before flood)	No. of households (after flood)
Own well	30	10
Public well	0	4
Public tap	0	9
Mineral water	0	1
Neighbours' well	0	4
Packet water	0	2

(Source: Primary survey).

The incidence of water borne diseases like Dysentery, Diarrhoea were reported in 27% of the households after the flood (Table 2).

3.1. Role of Government

In the event of a natural disaster like flood, the government has a significant role in taking decisions, implementing policies and enforcing regulations to ease the impact of the disaster. The ability of the public authorities to respond to such emergencies decides the extent of casualties, damage to assets and the speed at

which the civil society recovers from the disaster. These should be assessed in terms of management capacity for coordination and strategy and technical professional knowledge and finally on community participation and development.

Ensuring adequate drinking water services is more important during disasters than during normal times. During natural disasters, people often leave their homes, and even at home, have inadequate access to safe drinking water. This view is supported by many authors [15,16].

Table 2. Incidence of water borne diseases after flood

Disease	No. of households	Percentage (%)
Fever	4	13
Dysentery	2	7
Diarrhoea	2	7
No incidence	22	73
Total	30	100

(Source: Primary survey).

The role of government during disasters covers: a) Pre-disaster steps: steps to be taken when the disaster is anticipated; b) During disaster: steps to be taken when the disaster actually strikes; and c) After disaster: corrective steps to be taken after the disaster. In this paper, we are concentrating on the role of government after disaster. After a natural calamity like flood, government authorities will have to ensure pure drinking water supply to the affected people. Arrangements will have to be done to test the quality of water used for drinking. Even though, water may be clear, it does not necessarily mean that it is safe to drink. It is important to judge the safety of water by taking the following three qualities into consideration:

1. Microbiological parameters like coliform tests, SPC counts, Detection of pathogens
2. Chemical parameters like pH, minerals, metals, hardness and chemicals.
3. Physical parameters like temperature, colour, smell, taste and turbidity

At the time of the flood, the households surveyed were shifted to relief camps. There, safe drinking water was supplied in the form of mineral water bottles, packets *etc* by the local self-government. After the flood when people reached their houses, they found that the water in their wells were not worth to drink. In the relief camp, instructions were given to the people regarding how to clean their wells. They were asked to put chlorine in the

wells. Representatives from the local self-government visited their house and instructed them to drink water only after boiling. Cleaning the wells became very difficult as pumps were damaged. Apart from the difficulty in drying the wells, dead reptiles, insects, e-waste and garbage floating in the water also hindered the cleaning process. Two sample households got the support of volunteers to help with the sanitizing process. But rest of them had to do it by themselves.

In tanker lorries drinking water was brought to the village by the governmental authorities occasionally. There would be a long queue of people for water. Each family got just enough water for drinking. Even two months after the flood, many of them went to the relief camp daily for getting safe water which was distributed by NGOs.

After a natural disaster, especially flood, government authorities are supposed to test the quality of water in the water sources of the people. On the basis of the results of the test, government should either declare water to be safe to consume or purify the water if it is unsafe. But in the case of the households surveyed no such action had come from the part of the authorities. The charge for testing water quality in government labs was not affordable to the sample households as flood had adversely affected their livelihood. Eleven sample households reported to the researchers that they didn't have any information regarding the existence of water quality testing labs in the public sector. Researchers could find clear laxity from the side of the public authorities in ensuring pure drinking water to the sample households.

3.2. Water Quality Analysis

The physico- chemical and microbiological analysis of the water samples were carried out in all the samples collected and the results are given in Table 3. Based on MPN analysis of the water samples, they are not potable since the MPN index values are above the permissible limit of WHO and ICMR standards and some of the samples are reported to contain faecal contamination [17,18]. Hence these ground water samples should not be used for drinking purposes. The water quality based on National sanitation foundation water quality index (NSF WQI) [19] is given in Table 4 (Figure 2). Only 10 percent of the samples are of good quality. 76.6 percent of the samples belong to medium range, 13.33 percent are of bad quality.

Table 3. Analysis of water quality after flood

SSample No.	Physical parameters				Chemical parameters					Microbial parameters			Quality indices	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	28	10	7.01	201.3	5.6	4.3	144	0.1	65	2400	346	2	64	2.45
2	29	10	6.76	293.4	5.6	2.6	256	0	75	150	216	12	60	3.72
3	26	10	7.02	303.5	6.0	4.2	304	0	145	2400	177	1	72	2.90
4	24	5	6.37	393.5	5.6	2.3	136	0	65	150	95	11	667	2.09
5	28	100	6.52	300.2	7.2	6.4	312	0.2	70	28	>500	54	554	3.90
6	26	5	6.71	312.9	4.8	3.5	256	0	80	2400	103	2	63	2.45
7	24	100	7.03	438.2	6.0	4.6	280	0	130	1100	>500	2	60	3.63
8	27	100	7.04	248.4	4.8	3.7	312	0	80	2400	>500	17	442	4.90

SSample No.	Physical parameters				Chemical parameters					Microbial parameters			Quality indices	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
9	26	5	6.36	303.1	6.0	2.4	360	0.2	80	210	126	1	667	2.18
10	24	10	7.07	204.7	5.6	3.2	136	0	70	210	223	12	661	3.09
11	26	5	6.51	368.8	5.2	2.2	248	0.1	225	460	83	<<2	664	2.09
12	25	100	6.85	407.5	5.5	4.3	328	0	150	1100	>500	17	552	3.81
13	26	100	7.04	412.5	5.2	2.8	200	0	115	460	>500	<<2	558	3.45
14	28	5	6.83	216.9	4.8	2.3	248	0	90	75	164	1	666	2.18
15	27	100	6.76	209.2	7.6	7.0	328	0	75	2400	>500	1	664	3.45
16	26	10	6.56	242.6	5.6	3.2	312	0.5	70	240	359	12	448	3.45
17	28	100	6.52	355.1	6.4	5.8	280	1	120	1100	>500	17	448	4.09
18	26	5	6.46	245	4.8	2.6	296	0.2	80	2400	32	<<2	62	1.9
19	27	5	6.68	394	6.4	2.4	288	0	130	93	140	<<2	55	2.18
20	27	5	6.67	356.3	5.6	2.9	320	0	140	240	87	<<1	667	2.45
21	26	100	6.52	242.6	6.0	5.4	376	0.1	75	1100	>500	12	441	3.27
22	26	5	6.36	417.1	6.4	2.6	336	0.1	75	75	165	<<1	771	2.27
23	26	5	6.68	432.8	4.8	2.3	312	0.1	150	210	148	<<2	557	2.36
24	27	5	6.30	295	5.2	1.8	184	0.2	90	20	73	<<2	664	1.63
25	25	5	6.58	239.2	4.8	3.4	336	0.1	65	2400	186	<<2	662	2.18
26	28	5	7.32	386.2	6.4	1.7	368	0.1	50	7	117	<<1	775	2.27
27	27	5	6.95	214.1	5.2	1.9	328	0.1	70	210	143	12	663	3.36
28	26	5	6.42	320.5	4.8	2.1	352	0.2	65	460	125	2	663	2.18
29	26	10	6.40	420.2	6.0	2.5	320	0	140	210	328	<<2	664	3.18
30	27	100	7.1	351.8	6.4	5.7	304	0	150	2400	>500	<<2	660	3.72
Mean±SD	26.4 ±1.24	34.5 ±43.65	6.48 ±0.27	317.557 ±76.70	5.67 ±0.73	.40 ±1.44	285.33 ±66.54	0.11 ±0.20	99.5 ±39.85	903.6 ±973.11	264.53 ±173.29	5.4±6.04		

1= Temperature (°C); 2=Turbidity(NTU); 3=pH; 4= Conductivity (µs); 5= DO (ppm); 6= BOD(ppm); 7= COD (ppm); 8=Rsidual Chlorine (ppm); 9= Hardness (ppm); 10= Total coliform /100ml; 11=Standard Plate Count (CFU/ml); 12= Faecal coliform (CFU/ml); 13= WQI; 14=OIP.

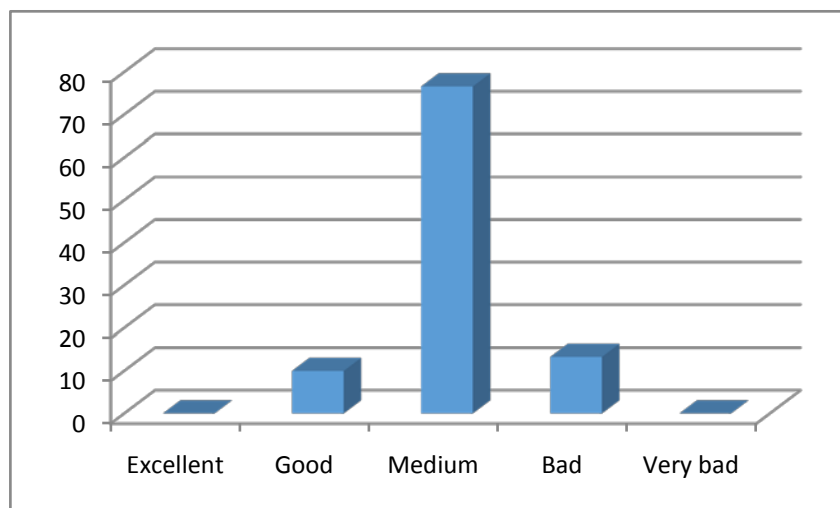


Figure 2. Water quality of Mannar Gramapanchayath after flood based on NSF-WQI

Table 4. Analysis of water quality based on National sanitation foundation water quality index (NSFWQI)

NSF WQI ranges					
Range	90-100	70-90	50-70	25-50	0-25
Quality	Excellent	Good	Medium	Bad	Very bad
Number	0	3	23	4	0
Percentage	0	10	76.6	13.33	0

The water quality based on Overall pollution index (OPI) is given in Table 5 (Figure 3). Here, 6.6 percent of the samples are acceptable, 86.6 percent of the samples are slightly polluted and 6.6 are polluted.

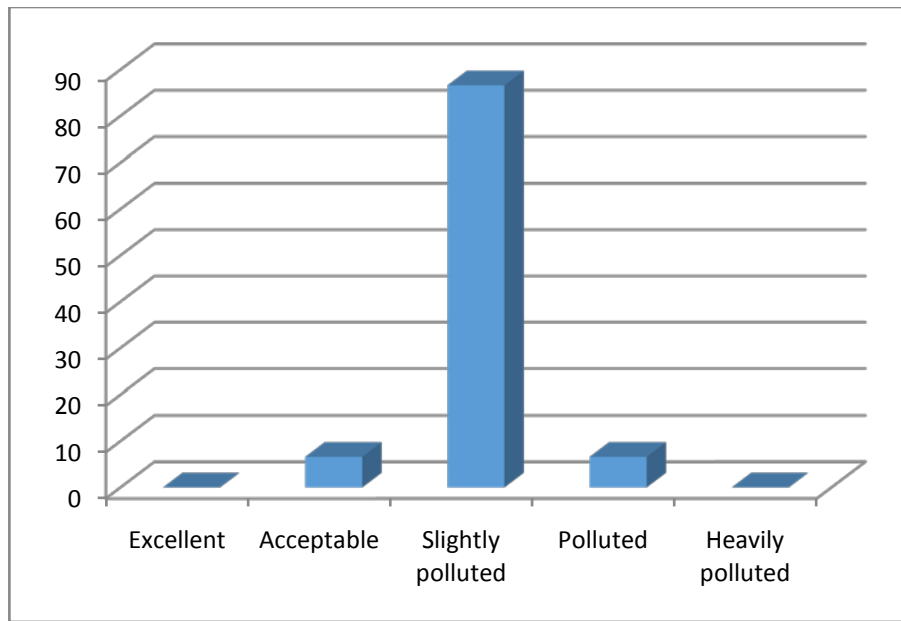


Figure 3. Water quality of Mannar Gramapanchayath after flood based on OIP

Table 5. Analysis of water quality based on Overall Index of Pollution (OIP)

OIP ranges					
Range	0-1	1-2	2-4	4-8	8-16
Quality	Excellent	Acceptable	Slightly polluted	Polluted	Heavily polluted
Number	0	2	26	2	0
Percentage	0	6.6	86.6	6.6	0

Table 6. Presence of pathogens in water samples

Sl.No	Pathogens Identified	Number of samples	Percentage (%)
1	<i>Salmonella</i> sp.	30	100
2	<i>Vibrio cholera</i>	5	16.6
3	<i>V.parahaemolyticus</i>	19	63.3
4	<i>E.coli</i>	7	23.3

The pathogenic bacteria were screened in the flood contaminated samples and the results are given in Table 6. It showed the presence of *Salmonella* sp. in all the samples. The presence of *V. cholera* is found in 16.6% of the samples tested and *V.parahaemolyticus* in 63.3% of the samples. The presence of pathogenic *E.coli* is found in 23.3% of the samples. Hence, there is a chance for the spread of water borne diseases in the area [20]. Also we can conclude that the water quality is being adversely affected and adequate steps to be taken to prevent further epidemics [21,22].

4. Recommendations

After water related natural calamities like flood the governmental authorities should make necessary arrangements for testing the quality of drinking water in the affected area. Public should be informed about the provisions available in the public sector for testing water quality. The price charged for testing the quality of drinking water should be subsidized at least at the time of such calamities. Even though, chlorination is considered as the first and immediate step of purifying drinking water after a flood, it has some hidden dangers. If chlorine is

added to water containing suspended or dissolved organic matter, the organic matter will consume chlorine and also may produce harmful by products. So such measures require expert supervision which lacked in the study area.

5. Conclusion

A study was made on the socio-economic status of the flood affected people and role of government in ensuring safe drinking water in the open water sources of flood affected Mannar panchayath of Chengannur taluk. The water quality was subjected to various physico-chemical and microbiological analysis. The quality of water were calculated using two indices - WQI and OPI. Based on the results, the recommendations were made to improve the performance of the government in ensuring safe drinking water after a flood.

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Statement of Competing Interests

The authors have no competing interests.

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