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URBAN RESILIENCE: CLIMATE, FLOODS AND MALARIA IN SMART CITY SURAT, INDIA

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ABSTRACT

The aim of this contribution was to investigate the likely influence of temperature, and relative humidity on malaria during high transmission season (July to October) for flood and non-flood years from 1988 to 2014 for urban population of Smart City Surat. Retrospective analysis of the malaria cases with temperature and relative humidity was performed for high malaria transmission season from the period of 1988 to 2014 in relation to flood and non-flood years and high and low malaria transmission phases. Bivariate analysis was conducted. A total of malaria cases for all eight (8) flood years and 19 non-flood years were 74,478 and 186,169 respectively from July to October (high malaria transmission season). Average monthly malaria cases were more likely to occur when the maximum temperature is <35°C vs ≥35°C (OR 2.2), minimum temperature is ≥22°C vs <22°C (OR 1.3) and HI ≤54°C vs HI >54ºC (OR 1.7) for flood years. During high and low malaria transmission phases the average monthly malaria cases were more likely to occur when minimum temperature is ≥22°C vs <22°C (OR 1.01, p 0.075.The study concludes that the minimum (low) temperature and relative humidity are the important factors for deciding malaria case load in Surat city. However, further exploration is required.

KEYWORDS : Malaria, Flood, Temperature, Smart City, Surat

INTRODUCTION:

Globally, changing climate has influenced the pattern of some of the diseases including malaria [1].Precipitation, flood, temperature and humidity have been connected with mosquito and spread of malaria infection [2]. On an average, floods represented around 40-50% of all natural disasters happening in the middle of 2001 to 2010 globally[3,4]. Malaria epidemics in the wake of flooding are perceived marvel and stays a standout amongst the most imperative wellbeing impacts of flooding or water-logging bringing on horribleness and mortality with huge medical and financial burden[5]. Precipitation and flooding provide reproducing destinations to malaria vectors to lay their eggs and guarantees a suitable humidity of no less than 50-60% to amplify mosquito expansion [6]. Nonetheless, flooding may wash away existing mosquito-rearing destinations yet far reaching territories of pooled sediments because of substantial precipitation water or flood of streams can make new rearing site which thus brings about growth in the mosquito population and henceforth build the possibilities of malaria transmission. Studies have reported expanded mosquito rearing and epidemics of malaria as a result of floods in Mandla[7] and Cotonou (Benin) [8]. There is a strong body of evidence indicating expanded malaria transmission in urban ranges of India [9-10].

According to World Malaria Report-2013, around 90% Indian population is at risk of malaria[11] and it is further compounded by heavy rain which may cause flooding and mosquitoes start reproducing as the flood water subside. Surat has encountered a sum of 24floods (river and creek) somewhere around 1914 and 2013, out of which 19 floods were in the middle of 1914-1998 and 4 amid the period of 2002-2013. The most devastating flood was from 6 August to 11 August 2006(duration of 6 days). This flood is gone before by overwhelming rains in the catchment territories of Ukai Dam, and resulting enormous arrivals of water from the dam immersed the city up to 80% with water logging disaster. It additionally brought an economic loss of around US$ 4,200 million along with 150 human lives [12].

Surat city has a favourable climatic condition to profound its effect on the life cycle of a mosquito and the development of malaria parasites. The important factors are temperature and humidity, which is also ideal to speed up the disease dynamics. Through epidemiological investigation, it is quite evident that the reasons for high malaria incidence during August and September were high humidity of above 60%, mean temperature of 25-30°C along with the continuous but low dense rain fall[13]. In spite of the above situation meticulous actions are being taken in a time bound manner with effective supervision and monitoring, SMC is able to reduce the malaria incidence. Wealth of information is available about the effect of flooding on malaria for developed and developing cities [14-17]. Nonetheless, comprehensive studies in context to climate change and its impact on malaria in relation to flood are scant for Smart cities of India despite being a massive disease burden. This analysis was, accordingly, launched to investigate the likely influence of temperature and humidity on malaria during high transmission season (July to October) for flood and non-flood years.

METHODS:

Study area:

Surat, the historical trade city,4th-fastest [18]developing cities with population of 5 million plus. Surat is known for its textile and

Diamond cutting business. Surat city is located on the bank of Tapi River which terminates in Arabian Sea on West coast [19]. This coastal city is flood prone and has experienced 24 river floods in last century [18].However, it had a total transformed Governance post flood outbreak of Plague in 1994.

The climate of Surat city is hot and humid because of closeness of Sea with summer temperatures ranging from 37°C to 44°C. The monsoon generally starts during the third week of June and lasts till September. Annual rainfall ranges from 1,000 to 1,200 millimetres, [20] and the relative humidity varies from 50%-80%. There is a vigorous house-to-house surveillance system for controlling mosquitoes and parasite for prevention of vector borne diseases by Vector Borne Disease Control Department (VBCD) of Surat Municipal Corporation (SMC).

Study Design, Data Collection and statistical analysis: Retrospective study was conducted to determine the influence of temperature and relative humidity on malaria with relation to flood. Daily meteorological data were obtained from Tutiempo Network, S.L website [21]. The meteorological variables included daily average temperature, daily maximum temperature, daily minimum temperature and daily average relative humidity. Because the effect of meteorological variables on the burden of malaria is not linear [22], daily average temperature, daily maximum temperature, daily minimum temperature and daily average relative humidity were transformed to categorical variables.The basis of such categorization of temperature and relative humidity was availability of the literature on the climatic conditions appropriate for malaria transmission by vector[23–26].

The data for malaria cases (monthly and yearly bases) for the period of 1988–2014 from were collected through online from SMC website[27] with official permission of concerned authority. Vector Borne Disease Control Department of SMC dividedthe city into 500 sections for VBDs surveys; each section has one Primary Health Worker (PHW), who will be approximately, assigned ten thousand populations for domiciliary house to house visit for active surveillance along with immature vector survey and follow up for previous malaria cases. Due to intensive malaria surveillance by VBDC Department of SMC, it is less likely to miss the malaria cases.

The data were processed in Microsoft Excel and analyzed through SPSS version (16.0). Data werechecked for completeness and cleaned of any inconsistencies before conducting the analysis. Quantitative variables were summarized using mean and standard deviation. Odd Ratio (OR) and t-test were used for testing the significance of differences between the malaria cases and independent variables.

RESULTS:

The performed analysis is from 1988 to 2014 (27 years) which includes 8 flood years and 19 non-flood years. Total malaria cases for all eight (8) flood years and 19 non-flood years were 132,321 with 56.3% (74,478) and 335,616 with 186,169 (55.5%) case load from July to October (high transmission season).

Figure – 1: Epidemiology of Malaria for Surat City (1988 – 2014)

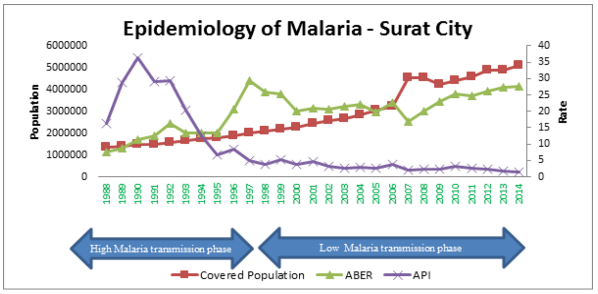
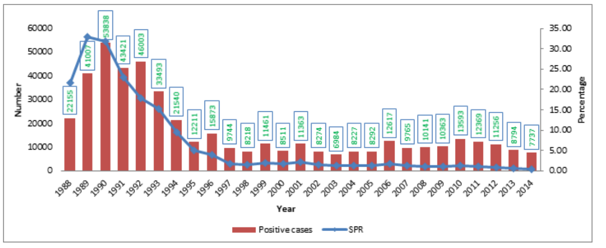


Figure-1 depicts that total population of Surat City has tripled from 1.49 million in 1991 to 4.47 million in 2011. With increase in population coverage for surveillance, Annual Blood Examination Rate (ABER) is showing an increasing trend in last two decades except in the year 2007 and againa rising trend post 2007. Annual parasite index (API) is showing the highest peak in the year 1990 and a rapid decline since 1994.

Figure - 2: Malaria cases and Slide Positivity Rate from 1988-2014



Slide Positivity Rate (SPR) was very high from 1988 to 1993 (heavy malaria phase). Post 1993 there was a decline in SPR following which a drastic reduction is observed since 1997 and till 2014. In the last decade, highest recorded SPR was in the year of 2006 (Figure-2).

Figure – 3: Year wise distribution of Malaria cases for Phase-1 and Phase-2 of Surat City

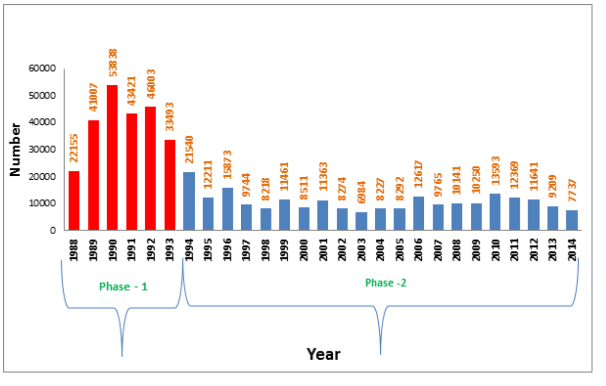


Figure-3 depicts the phase wise distribution of the malaria cases. This shows that total malaria cases for phase-I and Phase – II were 239,917 and 228,020 respectively.

Table – 1: Temperature, Relative Humidity, Heat Index and Malaria cases from 1988 to 2014, Surat, India

Climate Factor		Total Months 323* (%)	Monthly Average of Climate factor	Total Malaria Cases	Average Malaria cases/month
Max. Temperature °C	<35	83 (26)	33.39	140820	1696.63
	≥35	240 (74)	38.23	326740	1361.41
Min. Temperature °C	≥22	126 (39)	23.89	243261	1930.64
	<22	197 (61)	15.76	224299	1138.57
Average Temperature°C	≥28.5	135 (42)	29.86	213689	1582.88
	<28.5	188 (58)	25.63	253871	1350.37
Relative Humidity %	≥70 %	117 (36)	79.99	242845	2075.59
	<70 %	206 (64)	55.29	224363	1089.14
HI oC	>54	153 (47)	65.55	234692	153393
	≤54	170 (53)	45.97	232868	1369.81

***Climate Data for the month of March 2007 is not available.**

Of 323 months, 240 months were having monthly average maximum temperature of ≥35°C. The average monthly heat index was 65.55°C for 153 months out of 323 months. Average monthly malaria case load was higher at maximum temperature of <35°C, minimum temperature of ≥22°C, relative humidity ≥70% and HI

≤54°C (Table 1).]

Table – 2: Average monthly malaria cases for Flood and Non Flood Years with relation to temperature and humidity from 1988 to 2014, Surat, India

Variable		Flood 8 years (32 months)		No Flood 19 years (76 months)		OR
	°C	Months (%)	Average Malaria cases/month	Month (%)	Average Malaria cases/month	
Max. Temperature	<35	15 (47)	2974	34 (45)	2110	2.2
	≥35	17 (53)	1757	42 (55)	2725	
Min. Temperature	≥22	23 (72)	2527	49 (64)	2536	1.3
	<22	9 (28)	1817	27 (36)	2293	
Average Temperature	<28.5	20 (63)	2289	38 (50)	2304	1.1
	≥28.5	12 (37)	2391	38 (50)	2595	
Relative Humidity %	<70 %	7 (22)	2020	17 (22)	2298	1.1
	≥70 %	25 (78)	2413	59 (78)	2493	
HI	≤54	16 (50)	2910	28 (37)	2393	1.7
	>54	16 (50)	1745	48 (63)	2483	

Table-2 shows that average monthly malaria cases were more likely to occur when maximum temperature is <35°C as compared to temperature ≥35°C (OR 2.2), minimum temperature is ≥22°C as compared to minimum temperature <22°C (OR 1.3) and HI ≤54°C vs HI >54°C (OR 1.7) for flood years.

Table – 3: Association of Temperature and Humidity with Malaria cases in relation to high malaria transmission Phase (1988-1993) and low malaria transmission Phase (1994-2014), Surat, India

Factor		Phase 1 6 years (24 months)		Phase 2 21 years (84 months)		OR (p-value)
	°C	Months (%)	Average Malaria cases/month	Month (%)	Average Malaria cases/month	
Max. Temperature	≥35	14 (58)	5328	45 (54)	1549	1.06
	<35	10 (42)	5295	39 (46)	1625	(0.181)
Min. Temperature	≥22	16 (67)	5589	56 (67)	1660	1.01
	<22	8 (33)	4766	28 (33)	1434	(0.075)
Average Temperature	≥28.5	14 (58)	5213	36 (43)	1509	1.04
	<28.5	10 (42)	5457	48 (57)	1641	(0.347)
Relative Humidity %	≥70 %	18 (75)	5496	66 (79)	1644	0.96 (0.284)
	<70 %	6 (25)	4771	18 (21)	1365	
HI	>54	13 (54)	5370	51 (61)	1515	1.14
	≤54	11(46)	5249	33 (39)	1692	(0.009)

Table-3 depicts high and low malaria transmission phases and shows that average monthly malaria cases were more likely to occur when minimum temperature is ≥22°C as compared to minimum temperature <22°C (OR 1.01, p 0.075) and relative humidity ≥70% as compared to relative humidity <70% (OR 1.14, p 0.009).

Table – 4: Temperature and Humidity and Malaria cases for high transmission season (July – October) from 1988-2014, Surat, India

Variable		Total Malaria Cases 27 years (108 months)		
	°C	Total Cases	Months (%)	Average Malaria cases/month
Max. Temperature	≥35	144297	59 (55)	2446
	<35	116325	49 (45)	2374
Min. Temperature	≥22	182384	72 (67)	2533
	<22	78380	36 (33)	2177
Average Temperature	≥28.5	127306	50 (46)	2546
	<28.5	133338	58 (54)	2299
Humidity %	≥70 %	207432	84 (78)	2469
	<70 %	53196	24 (22)	2217
HI	>54	147075	64 (59)	2298
	≤54	113575	44 (41)	2581

Average monthly malaria case load was high at minimum temperature of ≥22°C, relative humidity ≥70% and HI ≤54°C during high malaria transmission season from July to October (Table - 4).

Table - 5: Average monthly malaria cases of flood years with comparison to pre and post flood years during 1988 to 2014, Surat, India

Flood Year			Non flood year			t-test (p-value)
Flood Year (Level in ft)	Cases for July to October	Average / Month	Pre and post Flood Year	Average of Pre and post Flood Year cases	Average / Month	
1990 (94.6)	28907	7227	1989 and 1991	40450	5056	243.77 (<0.0001)
1994 (97.7)	12322	3081	1993 and 1995	23836	2980	6.17 (<0.0001)
1998 (101.3)	4863	1216	1997 and 1999	11487	1436	-31.93 (<0.0001)
2002-2003 (91.9) &(79.2)	8730	1091	2001 and 2004	11898	1487	-63.07 (<0.0001)
2006 (106.5)	7905	1976	2005 and 2007	10249	1281	66.25 (<0.0001)
2012-2013 (89.7) & (97.0)	11751	1469	2011 and 2014	11489	1436	5.08 (<0.0001)

Table-5 shows that average monthly malaria case load during flood years of 1990 and 2006 was 30% (p <0.0001) and 35% (p <0.0001) significantly higher than monthly average of combined pre and post flood years (1989 and 1991) and (2005 and 2007). However, overall there is only difference (higher) of 0.8% for malaria cases of all combined flood years as compared to all non-flood years.

DISCUSSION:

The most frequent natural weather disaster was flooding (43%), killing almost 100,000 people and affecting over 1·2 billion people[28]. Flooding has been a problem in Surat city since decades. Some health consequences arise during or soon after the flooding (such as injuries, communicable diseases, malaria, etc). Surprisingly, the onset of flood at first lessens mosquito reproducing. In any case, as the floods subside, stagnant pools of water deserted serve as an issue rearing ground for mosquitoes. As a rule, the lag time is around 6-8 prior weeks the onset of malaria epidemic. Notwithstanding incredible advances in health and medical science over the recent decades, medical complications emerging from natural calamities are still greatly normal. These are especially dangerous for developing nations like India where assets are restricted and foundation powerless.

The highest number of malaria cases were recorded in Surat during 1988 to 1993 (high transmission phase) since Slide Positivity Rate (SPR) was sustained above 10% till 1993. Post 1993 there was a decline in SPR below 2% till 2014 it is below 2%. The trend in overall burden of malaria cases from 1988 to 2014 may be attributed to other factors beyond the scope of present analysis.

Seasonal trend of anopheles mosquito density and malaria cases in

Surat city with 3-4 months of monsoon is an influence of highly conducive physical environment. Malaria (SPR) cases show rise from May with a peak between Septembers – November reaching base in December.

Despite the apparent fluctuation of malaria trends in the Surat, malaria cases occur in almost every month. Rise of malaria cases in both the flood years and non-flood years was observed during monsoon period (July to October). There is a direct relationship between rise in minimum (low) temperature, relative humidity and malaria cases during low and high malaria transmission phase and flood years. The possible explanation may be that rise in low temperature and relative humidity may increase the risk of malaria transmission to a large extent, consistent with the study by Linday SW, et.al.[29].

Limitations:

The proportion of urban population to the total population has increased in the last few decades due to pull and push factors. However, SMC's efforts for planning housing and sanitary conditions especially for urban poor resulted in few slums with efficient surveillance system of VBDC managed malaria appropriately.Analysis was based on routinely collected malaria data from SMC. Since retrospective data were used, its accuracy and completeness could not be fully verified.

CONCLUSION AND RECOMMENDATION:

The study concludes that the minimum (low) temperature and relative humidity are the important predictors for malaria case load in Smart City Surat irrespective of flood or non-flood year, high or low malaria transmission phase and high transmission season or whole year. However, further exploration is required for in-depth understanding of climate variables, flood and their impact on malaria case load and developing the different informative apps.

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REFERENCES:

1. Bhattacharya S, Sharma C, Dhiman RC, Mitra AP. Climate change and malaria in India. Curr.Sci. 2006;90(3): 369-375.
2. Reiter P. Climate change and mosquito borne diseases. Environmental Health Perspective 2001; 109:223-234.
3. Osti R, Tanaka S, Tokioka T. Flood hazard mapping in developing countries: problems and prospects. Disaster Prev Manage 2008; 17: 104-13.
4. Guha-Sapir D, Vos F, Below R, Ponserre S (2011) Annual Disaster Statistical Review 2010: The Numbers and Trends. Brussels: CRED. Available: http://www.cred.be/sites/default/files/ADSR_2010.pdf. Accessed July 2, 2016.
5. Alemu A, Abebe G, Tsegaye W, Golassa L (2011) Climatic variables and malaria transmission dynamics in Jimma town, South West Ethiopia. Parasit Vectors 2011;4: 30. Available: http://www.parasitesandvectors.com/content/4/1/30. Accessed 2016 June 14.
6. Craig MH, Snow RW, Sueur D. A climate-based distribution model of malaria transmission in Sub-Saharan Africa. Parasitol Today 1999; 15:105-111.
7. Singh N, Shukla MM, Chand SK, Sharma VP, Singh Neeru. Outbreak of falciparum malaria in submerged villages of Narayanganj PHC, District Mandla due toNarmada irrigation project, central India (MadhyaPradesh). CurrSci 1997; 73(8): 686–91.
8. Wang Shr-Jie, Christian Lengeler, Thomas A Smith,Penelope Vounatsou, Martin Akogbeto, Marcel Tanner.Rapid urban malaria appraisal (RUMA) IV: epidemiologyof urban malaria in Cotonou (Benin). Malar J 2006; 5: 45.
9. Mathur KK, Harpalani G, Kalra NL, Murthy GGK,Narasimham MVVL. Epidemic of malaria in Barmer district(Thar desert) of Rajasthan during 1990. Indian JMalariol 1992; 29: 1–10.
10. Sharma RS, Lal S, Sharma SN, Joshi RD, Dhillon GPS.Malaria outbreak in Mewat region Gurgaon district ofHaryana State. J Commun Dis 1997; 29(3): 307–8.
11. World malaria report 2013. www.who.int/iris/bitstream/10665/97008/1/9789241564694_ eng.pdfAccessed on June 9, 2016
12. Timbadiya PV, Patel PL, Porey PD. One-dimensional hydrodynamic modelling of flooding and stage hydrographs in the lower Tapi River in India. Curr.Sci 2014; 106(5):708-716
13. Surat Health Sector Study, India http://www.acccrn.org/sites/default/files/documents/5%20Surat%20Health%20Sector%20Study.pdf accessed on June 22, 2016
14. Kilian AH, Langi P, Talisuna A, Kabagambe G: Rainfall pattern, ElNino and malaria in Uganda. Trans R Soc Trop Med Hyg1999, 93:22-23.
15. Baqir M, Sobani ZA, Bhamani A, Bham NS, Abid S, Farook J, et al. Infectious diseases in the aftermath of monsoon flooding in Pakistan. Asian Pac J Trop Biomed 2012; 2(1): 76-79 doi:10.1016/S2221-1691(11)60194-9
16. Gomes Ade C, Paula MB, Natal D, Gotlieb SL, Mucci LF. Effects of flooding of the River Paraná on the temporal activity of Anopheles (Nyssorhynchus) darlingi Root (Diptera: Culicidae), at the border state of Mato Grosso do Sul and São Paulo, Brazil. Rev Soc Bras Med Trop. 2010 Sep-Oct;43(5):516-22.
17. Woube M: Geographical distribution and dramatic increases in incidences of malaria. Consequences of the resettlement scheme in Gambella, SW Ethiopia. Indian J Malariol 1997, 34:140-163.
18. Desai VK, Rathi SK, Desai H. Urban Health System and Climate Resilience – Surat case study. Journal of Health Management; July – September 2016;18(3):499-507.
19. http://www.censusindia.gov.in/pca/SearchDetails.aspx?Id=550944.
20. Bhat GK, Karanth A, Dashora L, Rajasekar U. Addressing flooding in the city of Surat beyond its boundaries. Environment and Urbanization 2013; 25(2): 1–13. DOI: 10.1177/0956247813495002
21. http://www.tutiempo.net/en/Climate/SURAT/428400.htm accessed on May 11, 2016.
22. Huang F, Zhou S, Zhang S, Wang H, Tang L. Temporal correlation analysis between malaria and meteorological factors in Motuo County, Tibet. Malar J 2011;10: 54. Available: http://www.malariajournal.com/content/10/1/54. Accessed May 7, 2016.
23. Bi P, Tong S, Donald K, Parton KA, Ni J. Climatic variables and transmission of malaria: a 12-year data analysis in Shuchen County, China. Public Health Rep 2003;118: 65–71.
24. Garg A, Dhiman RC, Bhattacharya S, Shukla PR. Development, malaria and adaptation to climate change: a case study from India. Environ Manage 2009;43: 779–789.
25. Ye Y, Louis VR, Simboro S, Sauerborn R. Effect of meteorological factors on clinical malaria risk among children: an assessment using village-based meteorological stations and community-based parasitological survey. BMC Public Health 2007; 7: 101. Available: http://www.biomedcentral.com/1471-2458/7/101. Accessed May 26, 2016.
26. Barati M, Keshavarz-valian H, Habibi-nokhandan M, Raeisi A, Faraji L, et al. Spatial outline of malaria transmission in Iran. Asian Pacific Journal of Tropical Medicine 2012;5: 789–795.
27. https://www.suratmunicipal.gov.in/e-Gov_DiseaseStatastics/DiseaseReport_malaria.aspx
28. McMichael AJ, Woodruff RE, Hales S. Climate Change and Human Health: present and future risks. Lancet 2006; 367:859-69.
29. Linday SW, Birley MH. Climate Change and Malaria transmission. Annals of Tropical Medicine and Parasitology 1996; 90(6):573-88.