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Impact of climate variability on human health: A pilot study in tertiary care hospital of Eastern Uttar Pradesh, India

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सार–इस शोध पत्र में पूर्वी उत्तर प्रदेश में जलवायु विभिन्नताओं के श्वास, हृदय संवहनी वायु-जनित एवं अतिसार रोगों पर पड़ने वाले प्रभाव का पता लगाने के लिए सर सुन्दर लाल हॉस्पिटल वाराणसी, उत्तर प्रदेश के वर्ष 2004-2013 के आँकड़ों का अध्ययन किया गया है। इस अध्ययन से पता चलता है कि पुरानेविध्नकारी फुप्फुसीय रोग (COPD)और हृदय संवहनी रोगों (CVD) से संबंधित मामलों का जलवायुविभिन्नताओं के साथ कोई महत्वपूर्ण संबंध नहीं रहा है। अधिकतम औसत मासिक तापमान में 1° सेल्सियस वृद्धि होने से यक्ष्मा (TB) रोगियों की संख्या में 4 की गिरावट हुई (95% CI = 4.95-3.05) जबकि मासिक न्यूनतम तापमान में 1° सेल्सियस की वृद्धि होने से यक्ष्मा (TB) रोगियों की संख्या में 4 (95% CI = 4.95-3.05) की वृद्धि हुई। मासिक औसत सापेक्षिक आर्द्रता में एक प्रतिशत की वृद्धि होने पर किसी भी माह का आकलन किए जाने पर न्यूमोनिया के एक रोगी की संख्या में वृद्धि हुई (95% CI = 1.95-0.05)। किसी भी दिए गए माह के मासिक तापमान में 1° की वृद्धि होने पर अतिसार (डायरिया) के रोगियों की मासिक संख्यामें एक की वृद्धिहो जाती है। (95% CI = 1.95-0.05) न्यूनतम मासिक तापमान में 1° सेल्सियस के बढ़ने से डेंगू और मलेरिया के रोगियों की संख्या दर्शाती है कि मलेरिया के मासिक रोगियों की संख्या 5 तक (95% CI = 5.95-4.05) बढ़ जाती है और सापेक्षिक आर्द्रता में 1% की वृद्धि होने से 1 रोगी (95% CI = 1.95-0.05) की संख्या बढ़ जाती है। अधिकतम तापमान में 1° सेल्सियस की मासिक वृद्धि होने से मस्तिष्क ज्वर के रोगियों की संख्या में एक रोगी की वृद्धि (95% CI = 1.95-0.05) देखी गई है। इस शोध से स्वास्थ्य सूचना का अच्छा ज्ञान मिलता है, ऋतुओं के अनुसार दशकों पहले स्वास्थ्य संबंधी उपायों की प्रभावी योजना बनाई जा सकेगी और स्थानीय एवं क्षेत्रीय स्तर पर आधारभूत ढांचे तैयार किए जा सकते है।

ABSTRACT. This study is an attempt to find out the effect of climate variables on respiratory, cardiovascular, vector-borne and diarrheal diseases from 2004-2013 carried out at Sir Sunder Lal hospital, Varanasi, Uttar Pradesh with focus on eastern Uttar Pradesh. The study shows that cases of Chronic Obstructive Pulmonary Disorder (COPD) and Cardiovascular Disorders (CVD) didn't show any significant relation with any of the climate variables. With increase of 1 °C mean maximum monthly temperature the estimated decrease in number of Tuberculosis (TB) patients was 4 (95% CI = 4.95-3.05) while a 1°C increase in minimum monthly temperature showed increase of TB patients by 4 (95% CI = 4.95-3.05). One percent increase of monthly averaged relative humidity is estimated to increase the one pneumonia patients (95% CI = 1.95-0.05) at any given month. One-degree increase in given monthly temperature will increase the load of one diarrhea patients (95% CI = 1.95-0.05) monthly. Dengue and Malaria patients showed increasing monthly malaria cases by 5 (95% CI = 5.95-4.05) with 1°C rise in minimum monthly temperature and by 1 patient (95% CI = 1.95-0.05) with increase in 1% relative humidity. Encephalitis showed an increase of one patient load (95% CI = 1.95-0.05) with monthly increase of 1°C in maximum temperature. The study shows advance knowledge of health information, on timescales of seasons to decades ahead, would aid effective planning of health response measures and infrastructure at local and regional scale.

Key words – Human health, Climate variability, Climate change, Extreme events.

1. Introduction

Climate is a critical factor in the lives and livelihoods of the people and socio- economic development as a whole but the changing climate will have consequences for all (Patz *et al.*, 2005). The warming of 0.89 °C was mainly contributed by anthropogenic activities for the period of 1901-2012 (Attri and Rathore, 2012; IPCC, 2013) that has an important role in accelerating climate change. The result of warming is

TABLE 1

Number of morbidity cases of some prevalent diseases in India and Uttar Pradesh in recent years

	Year	Acute Diarrhoeal Diseases[a]	Acute Encephalitis cases[b]	Malaria cases[a,b]	Dengue cases[a,b]	Kala-azar cases[a,b]	Pulmonary Tuberculosis cases[a]	Acute respiratory infection[a]	Pneumonia[a]
Uttar Pradesh	2010	-	3540	64606	960	14	-	-	-
	2011	-	3492	56968	155	11	-	-	-
	2012	740328	3484	47400	342	5	178274	1552436	94237
	2013	828367	3096	48346	1409	11	256733	1720714	103416
	2014	745457*	3,329	41,612	200	11	255364*	1628014*	95414*
	2015	-	2894*	41264*	2892*	116*	-	-	-
India total	2010	-	5167	1599986	28292	29000	-	-	-
	2011	-	8249	1310656	18860	33187	-	-	-
	2012	11701755	8344	1067824	50222	20600	933905	31684628	779794
	2013	11413610	7825	881730	74168	13869	1416014	33423107	729891
	2014	11673018*	10867	1102205	40571	9241	1443942*	34814636*	709298*
	2015	-	8739*	1036629*	97740*	7720*	-	-	-

* provisional till 31st December

a: NHP, 2015, "Health status indicators", *National Health Profile*, Ministry of Health and Family Welfare, Directorate General of Health Services, Central Bureau of Health Intelligence, Government of India Available at http://cbhidghs.nic.in/writereaddata/mainlinkFile/NHP-2015.pdf-Accessed on 7June, 2017.

b: Available from -http://nvbdcp.gov.in/ (Accessed on 24 January, 2016).

TABLE 2

Change in numbers of cases with change in meteorological parameters using multiple regression model

Diseases	F value Significance level 95%	Coefficient Value (P value significant at 0.05)				
		Maximum temp	Minimum temp	Rainfall	Rainy days	Humidity
COPD	0.53	1.184(0.102)	-1.296(0.068)	0.005(0.775)	0.247(0.486)	0.005(0.968)
TB	0.00	**-4(0.003)**	**4(0.000)**	0(0.574)	0(0.790)	**-1(0.003)**
Pneumonia	0.00	1.78(0.085)	-0.86(0.389)	0.013(0.630)	0.640(0.210)	**1(0.010)**
Diarrhea	0.00	**1(0.000)**	-0.4(0.184)	0.0(0.524)	**0.3(0.017)**	0.8(0.087)
CVD	0.78	0.3607(0.555)	-0.365(0.482)	-	-	-
Malaria	0.00	-2.9(0.139)	**5(0.007)**	0.03(0.523)	-0.96(0.312)	**1.2(0.001)**
Dengue	0.00	-6.12(0.002)	**5(0.012)**	-0.00(0.96)	-0.825(0.442)	**1.2(0.002)**
Encephalitis	0.00	**2.4(0.003)**	-1.797(0.044)	-0.01(0.747)	0.544(0.196)	0.78(0.210)

increase in incidences of floods, droughts, and sea level rise, impacts on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure (Joon and Jaiswal, 2012; Unnikrishnan, 2015; Bhatt and Mall, 2015, Banerjee *et al*., 2017, Mall *et al*., 2016a). Climate change may affect multiple facets of human health. This could include direct health impacts such as heatstroke and cold stroke and indirect impacts such as increased diarrheal risk from water contamination via flooding, and other infectious diseases including vector borne diseases or higher risk of mortality from large-scale loss of agricultural yield and livelihoods (INCCA, 2010; Mirski *et al*., 2012; Dhara *et al*., 2013; IPCC, 2014; Tompkins, 2013; Bhatt *et al*., 2015; Mall *et al*., 2016b). Increase in temperature and rainfall extremes, decrease in low and medium rainfall events, frequent drought and flooding along with rising sea level increased the related mortality (De *et al*., 2005; Goswami *et al*., 2006; Guhathakurta and Rajeevan, 2008; Kovats and Hajat, 2008; INCCA, 2010; Kothawale *et al*., 2010; CDKN, 2012). Seasonal variability affects the functions of human system and increases associated stress that can lead to immune system inhibition following death in severe cases (McMichael *et al*., 2006). Recent findings specify the more prominent warming than expected that would have severe impact particularly in the tropical areas, including India (Sathaye *et al*., 2006).

India's food production and water resources is already under threats due to climate change that needs better policy and planning for disaster risk reduction in future (Mall *et al*., 2006; Mall *et al*., 2011 a&b). Further, the impact on health will have additional burden to cope up. Some prevalent communicable diseases responsible for major disease burden in India and Uttar Pradesh are shown in Table 1. India have considerably high disease incidence with Disability Adjusted life Years per one thousand capita (DALYs/1000cap) of 65 and total disease burden of 24% of which diarrhea and malaria contribute about 10% (WHO, 2009; NHP, 2012). Unfortunately, satisfactory attention has not been given in studying disease pattern and epidemiological transition in India and its impoverished states like UP where Diarrhea, Pneumonia and other infectious diseases are the major cause of mortality among children aged 5 to 14 year in UP (Morris *et al*., 2011). In light of the above, this preliminary study is an attempt to review the present status of the prevalence of diseases and its seasonal association with climate variables and to estimate the health status of eastern Uttar Pradesh region using secondary hospital data from Sir Sunder Lal hospital, Varanasi, Uttar Pradesh (UP).

2. Some prevalent diseases that are influenced with climatic variability

2.1. *Respiratory diseases*

Climate change revises the intensity and distribution of air pollutants and increased temperature in winter and spring induce early pollination and increased summer temperature induces extended pollination causing asthma and chronic obstructive pulmonary disorders (D'Amato *et al*., 2010). Contaminated airborne droplets help in dissemination of tuberculosis (TB) and pneumonia therefore humidity plays an important role in its dissemination whereas, low humidity aids the development of pathogen laden dust and increase the aerial transport. Pneumonia and TB catches easily mainly due to weak immune system while pneumonia is the ultimate cause of death in extreme ages.

2.2. *Diarrheal diseases*

Almost every developing country faces a cholera outbreak or threat of an epidemic after the advent of flood. Continuing as second most common cause of mortality in children, it caused over 200,000 deaths in India during 2010 (Liu *et al*., 2012). Meteorological conditions manipulate the transport, diffusion, reproduction and persistence of pathogens causing diarrhea and define environmental reservoirs of pathogens and govern the timing and intensity of seasonal outbreaks (Moors *et al*., 2013). Flood contaminates the food and drinking water through animal and human wastes that causes increased rate of fecal-oral transmission of diarrheal disease and other bacterial and viral illnesses (Biswas *et al*., 1999; Mondal *et al*., 2001; Hamner *et al*., 2006; Chou *et al*., 2010; El-Fadel, 2012; Kazama *et al*., 2012).

2.3. *Cardio vascular diseases*

Impact of extreme temperature and related mortality has been observed in cardiovascular (CVA) patients (Basu & Samet, 2002; Majra & Gur, 2009). Decrease in winter temperature causes significant increase in incidence of cardiac diseases due to arterial spasm causing decreased blood circulation in the body, and the heart needs to put in extra pressure that leads to heart failure. A study by Bull and Morton (1975) showed that temperature before 1 to 2 days of death is most significant in the case of myocardial infarction, and before 3 to 4 days of death in strokes.

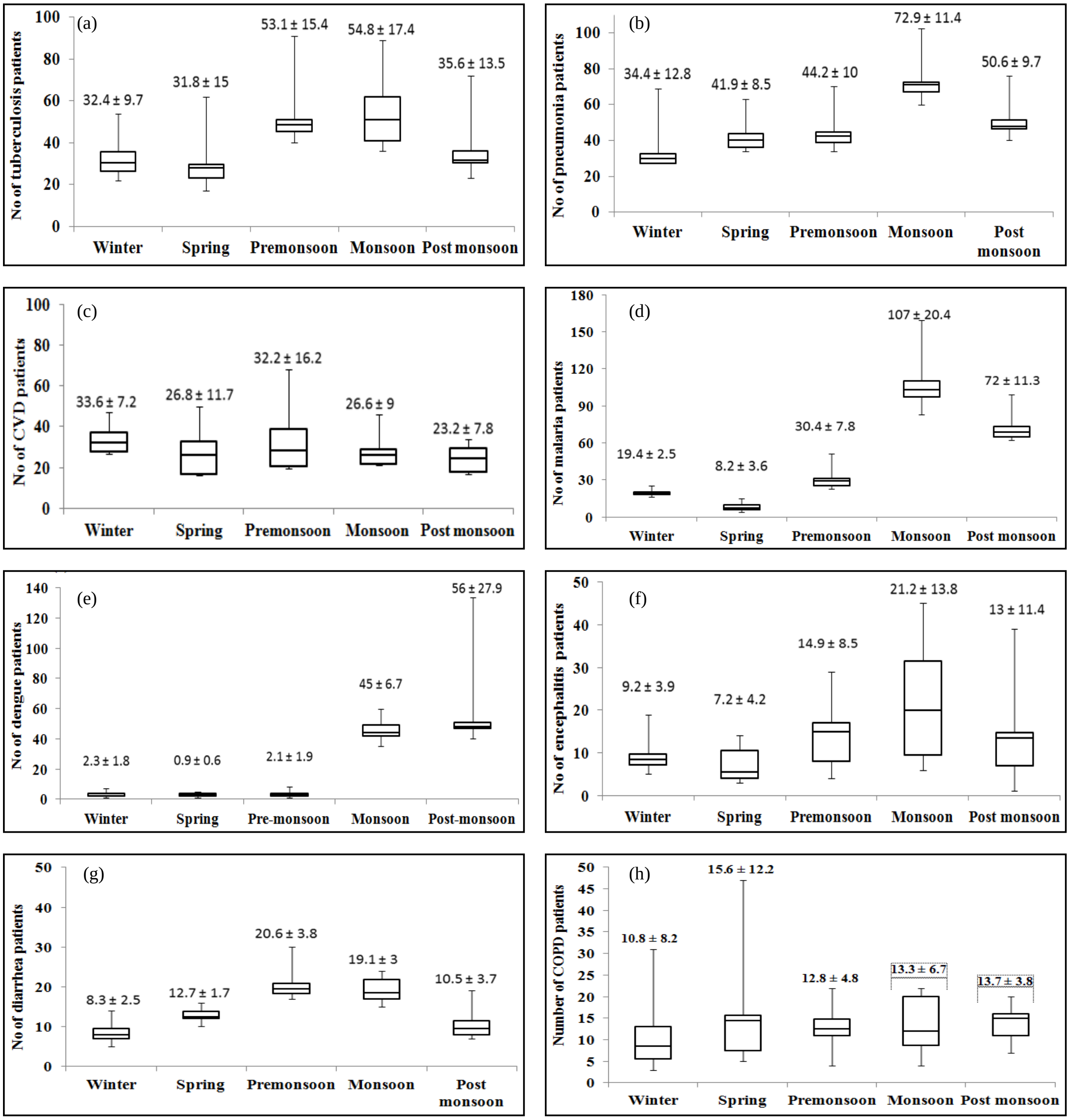
2.4. *Vector borne diseases*

Several studies have shown that the prevalence of vector diseases have increased in tropical and sub-tropical countries (Dhiman *et al*., 2010). Due to the absence of thermostatic mechanism, infectious agents like protozoa, bacteria and viruses and their vectors like mosquitoes, ticks and sand flies are affected by changing temperature that influence their reproduction and survival rates (Patz *et al.*, 2005). The outbreaks of Malaria, Dengue, kala azar is evident and particularly seen in some parts of India (Sharma *et al*., 1994; Ready, 2008). Kala azar caused by pathogen *Leishmania donovani* transmitted by female sand flies *Phlebotomus argentipes* showed association with temperature and land use (Ready, 2008). Over the last few decades the frequency of Japanese encephalitis virus (JEV) (flavivirus transmitted to human beings by *Culex tritaeniorrhynchus)* epidemics and outbreaks increased in parts of Indian subcontinent and South East Asian countries. In India, encephalitis accounts for a significant number of cases, mainly from Gorakhpur district and adjoining areas of eastern UP (Saxena *et al*., 2009). Increased temperature is found to be associated with increase in the rate of mosquito development and maturation of parasites inside the host body (Bhattacharya *et al*., 2006; Dev, 2010) along with rainfall that acts as an important factor in influencing the reproductive cycle of arthropod vectors by creating breeding ground for multiplication. The two transmission windows TW1 ($T_{max} \leq 35$ °C; $T_{min} \geq 20$ °C; RH$\geq$ 55%) and TW2 (25 °C $\leq T \leq$ 30 °C; 60% $\leq$ RH $\leq$ 80%) favourable for transmission of vector borne diseases, are found to be satisfied for many days during the south-west monsoon (June-Sept.) and the post-monsoon season (Oct-Dec) over different parts of India (Dogra and Srivastava, 2012).

3. Materials and method

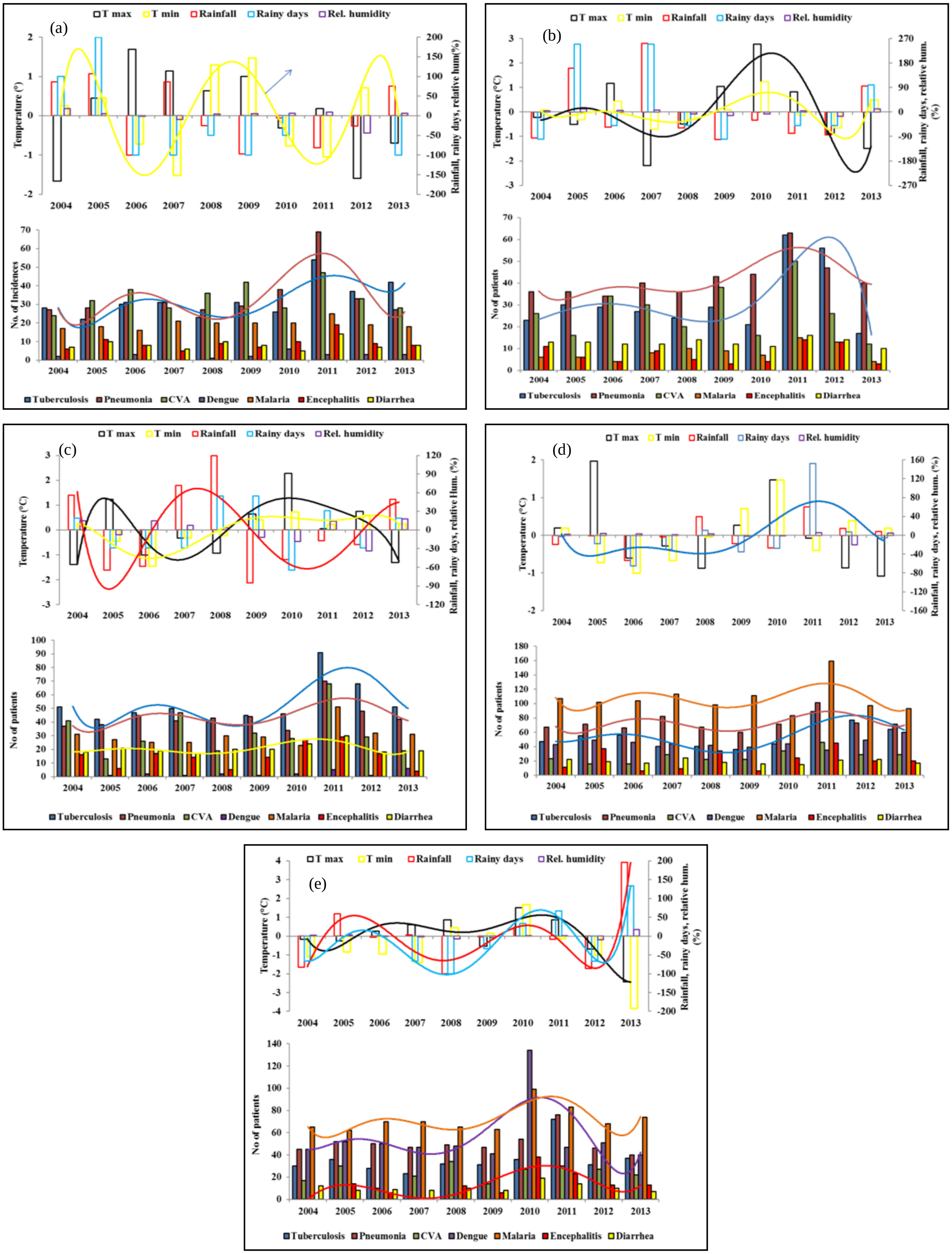
3.1. *Study area and climate description*

A pilot study was carried out at Sir Sunder Lal Hospital, BHU, Varanasi for a period of ten years from



Figs. 1(a-h). Variation in the disease incidences over different seasons (a) TB(b) Pneumonia (c) CVD (d) Dengue (e) Malaria (f) Encephalitis (g) Diarrhea (h) COPD. The boxes mark the 25 and 75% quartiles while the whiskers give the minimum and maximum values. The values above the whisker represent mean and standard deviation of the number of patients

January 1, 2004 to December 31, 2013. Sir Sunder Lal Hospital is the only Tertiary Care Hospital providing specialty and Super Specialty services to the health care needs of about 200 million populations of Eastern UP, Western Bihar, adjoining MP, Chhattisgarh and Jharkhand as well as neighboring country of Nepal. Situated in the middle Gangetic plain of the Indian sub-continent with an estimated area of 225 km^2 Varanasi is located at 25° 18′ N latitude, 83° 01′ E longitude and 82.20 m above sea level with a population of 3.4 million. The climate of Varanasi is humid subtropical and was used as a representative for the analysis. The average summer and winter temperature maximum is 37 °C and 24 °C, while minimum temperature is 23 °C and 11 °C respectively. The average rainfall and rainy days is 100 mm and 40-50 days respectively.



Figs. 2(a-e). Association between the change in trend of the meteorological parameters with the trend in disease incidences during (a) Winter (b) Spring, (c) Pre-monsoon (d) Monsoon and (e) Post-monsoon

3.2. *Data collection*

Data was collected through admission register maintained by doctors. Patient counts were obtained for eight different categories: CVD (ICD-10: I20-I25, I26-I28), COPD (J40-J44, J47), TB (ICD-10: A15-A19), Pneumonia (ICD-10: J09-J18), Diarrhea (ICD-10: A09, K59.1), Malaria (ICD-10: B50-B54), Dengue (ICD-10: A90), Encephalitis (ICD-10: A83-186, B94.1 G05). Data was collected and analyzed from 2004-2013 that include variables as month of admission and year of admission. The study has taken into account of only those patients that belongs to Varanasi. Patients from other districts were either excluded from the study or patients who belonged to other districts but are living in Varanasi for a sufficiently long time (>40 years) are also included in the study. The weather data was obtained from Indian Meteorological Department, New Delhi that includes mean daily maximum and minimum temperatures, relative humidity and rainfall.

3.3. *Data analysis*

In this study multiple regression between number of patients and meteorological parameters was carried out at 0.05 significance level. All the analysis was performed using statistical software SPSS version 16.0. The time series analysis of the climate variables and diseases was done by calculating centered moving mean. The years were divided into five seasons for facilitation in analysis: Winter (December-January), Spring (February-March), Pre-Monsoon (April-June), Monsoon (July-September), Post-Monsoon (October-November).

4. Results and discussion

The disease counts showed a wide difference in occurrences for different years in different seasons [Figs. 1(a-h)]. The seasonal analysis was useful in establishing the diseases prevalence in different seasons. The hospital admissions for pneumonia were high in monsoon and post-monsoon and the admissions for TB were high in pre-monsoon and monsoon [Figs. 1(a&b)]. Another lung disease COPD admissions peaked during spring [Fig. 1(h)]. CVD expectedly showed two peaks one during winter, and another during pre-monsoon [Fig. 1(c)]. The major causes for increased cardiovascular disorders in winters is change in blood pressure, vasoconstriction, increase in viscosity of blood and RBC count and plasma cholesterol and plasma fibrinogen (Keatinge and Donaldson, 1995). Contrary, with increased temperature beyond threshold, shifting in blood flow from vital organs to under the skin takes place to provide cooling effect. This interferes with body temperature for thermoregulation along with increased viscosity of blood, cholesterol levels and higher sweating threshold impart pressure to heart and lungs (Smoyer *et al*., 2000). The vector borne diseases *viz*., malaria, dengue and encephalitis showed peaks during monsoon and post-monsoon [Figs. 1(d-f)]. Diarrhea admissions showed increased hospital admissions during pre-monsoon and monsoon [Fig. 1(g)]. The cause of diarrhea during winter is mainly due to infection of rotavirus that is common in children's (Moors *et al*., 2013). Children's have less developed immune system so that they easily catch cold and flu caused by rhinovirus during winters as winters suppresses the immune system. As a result, they suffer from diarrhea proceeding cold and flu in winters. During pre-monsoon, diarrhea admissions showed an opposite trend with the rainfall [Fig. 2(c)]. The decrease in rainfall recorded the increase in diarrhea cases [Fig. 1(a)]. Diarrhea, during pre-monsoon and monsoon is caused mainly due the bacterial pathogen. At very high temperature in pre-monsoon leads to the heavy evaporation from water resources, this water scarcity increases the concentration of bacteria in water resources and reduces the dilution (Moors *et al*., 2013). So that the consumption of contaminated food and drinking water increases the diarrhea transmission and high hospital admissions but most of them are acute diarrhea that can take a couple of days to recover in adults but children can suffer severely from this. Due to heavy rainfall during monsoon, the sewage system of the city fails to drain the additional water, as a result, the sewage water gets mixed with the drinking water and supply water. Consumption of contaminated water and food thus increases the incidences of diarrhea.

The time series analysis of maximum temperature showed an increase of 0.04 °C/decade while minimum temperature showed increase by 0.02 °C/decade and annual precipitation showed a decreasing trend of 2.5 mm/decade but insignificant. Since 2004-2013 the total number of days above 45°C were 8 and above 40 °C were 440, 44 days per year. The total extreme rainfall days above 50 mm/day were 16 from 2004-2013. On disease part, COPD showed increase of 0.9 patients/10years (insignificant), pneumonia showed 3.1 patients/10years (insignificant), and TB showed a very good trend of increase of 7.1 patients/10years (significant). CVD admissions showed increase by 2.1patients/10years (insignificant). Diarrhea admissions increased by 0.4 patients/10years. Among vector borne diseases malaria admissions increased by 2.3 patients/10 years, dengue by 1.3 patients/10years and encephalitis by 2.2 patients/10years but all insignificant.

The estimation of effect of climate variables on hospital admissions through multiple regression showed that Chronic Obstructive Pulmonary Disorder (COPD) and Cardiovascular Disorders (CVD) didn't show any significant relation with any of the climate variables (Table 2). With increase of 1 °C mean maximum monthly temperature the estimated decrease in number of Tuberculosis (TB) patients was 4 (95% CI = 4.95-3.05) while a 1 °C increase in minimum monthly temperature showed increase of TB patients by 4 (95% CI = 4.95-3.05). One percent increase of monthly averaged relative humidity is estimated to increase the one pneumonia patients (95% CI = 1.95-0.05) at any given month. The trend analysis of disease admissions with climate anomalies in Figs. 2(a-e) shows increase in TB and pneumonia incidences with decrease in minimum temperature during winters [Fig. 2(a)]. The reason behind this trend association could be explained that during winter due to decline in temperature the immune system of a body weakens and triggers the proneness of body to catch infections or diseases (Mirski *et al*., 2012). The declined immune activity is particularly very pronouncing in the elderly and the young once and therefore large number of children die due to pneumonia while pneumonia is the ultimate cause of death in many elder ones. Also during winter, people tends to live closer to keep themselves warm or remain in a single room and therefore the chances of transmission of TB increases. During spring, TB and pneumonia shows similar trend with minimum and maximum temperature [Fig. 2(b)]. Increasing temperature during Feb and Mar increases the survival rate and multiplication of bacterial pathogens so that the transmission and admissions of TB and pneumonia cases exaggerated with increase in minimum and maximum temperature. The admissions of pneumonia and TB cases in pre-monsoon were showing a little bit of contrasting association in some years with the minimum and maximum temperature [Fig. 2(c)]. During the pre-monsoon month, a very high increase in temperature is seen that goes beyond 45 °C sometimes that will retard the growth of bacterial pathogens. Moreover, decrease in minimum and maximum temperature can help pathogens to grow and proliferate so that such a trend association was found. During monsoon, a very high increase in pilgrim's population in to the city increases the population density, so that the immigrants or the local population are in higher chances of suffering from the disease infection particularly TB that mostly disseminates through air [Fig. 1(a)]. One-degree increase in given monthly temperature will increase the load of one diarrhea patients (95% CI = 1.95-0.05) monthly. Dengue and Malaria patients showed increasing monthly malaria cases by 5 (95% CI = 5.95-4.05) with 1 °C rise in minimum monthly temperature and by 1 patient (95% CI = 1.95-0.05) with increase in 1% relative humidity. Encephalitis showed an increase of two patient load (95% CI = 1.95-0.05) with monthly increase of 1°Cin maximum temperature (Table 2). Vector borne diseases are directly affected by relative humidity. High temperature with constant dew point increases relative humidity and thus vector survival. On the other hand, rainfall creates breeding ground for the vector multiplication in long time but destroys vector larvae with high intensity rainfall (Dhara *et al*., 2013). The cases of vector borne diseases were low during the pre-monsoon because very high temperature in summers and low relative humidity don't support vector survival and multiplication. A warmer climate increases the survival time and proliferation of parasites and makes them more frequent. But, at physiological tolerance limit of temperature, small increase in temperature will kill the parasite and recorded decrease in transmission (Dhara *et al.*, 2013). Also, at higher temperature the development time of pathogen inside the vector is reduced. Vectors require peculiar climatic conditions of temperature and humidity for their adequate abundance to sustain transmission. The Fig. 2(d) shows the trend association between TB, pneumonia and malaria with that of the rainy days. More number of rainy days would sustain the humidity and thus supports pathogen survival and dissemination followed by increase in disease incidences. Hence, they showed the similar association of trend variation. During July and August months of monsoon, due to frequent rainfall the breeding sites of a pathogen is often disturbed and their larva's get washed off. During Sept and post-monsoon when the breeding sites are stagnant and the temperature is favorably appropriate for vector multiplication, a high incidences of vector borne disease is reported. This is reflected in trend analysis between rainfall, rainy days and maximum temperature with dengue, malaria and encephalitis that shows they follow a similar trend of increase and decrease [Figs. 2(e)]. Mainly, the association between vector borne diseases and climate variables is carried out with the lag period of one to two months. Because with the conducive environment is created than the vector starts breeding and development that takes time and after that it starts transmitting a parasite.

There are several confounding factors that interferes with the association of disease incidences with the climatic parameters. The diseases have a multi-factorial nature so that they cause cannot be attributed to a single factor and therefore a simple disease prediction model would fail to be worth it (Dhara *et al*., 2013). Besides meteorological conditions- population density, housing type, location, water supply, land use, irrigation system, access to health care and environmental hygiene too stimulate the disease incidences. For that reason, to establish the exact role of climate change on disease outcomes, research efforts are needed that can incorporate a surveillance system for disease outcomes with the combination of trend analysis from several sites to account local factors (Dhara *et al*., 2013).

5. Extreme climatic events and its impact

Significant rising trend in extreme weather events, *i.e*., severe storms, floods, drought, heat and cold waves have caused thousands of deaths during the last few decades (Akhtar, 2010; Singh and Patwardhan, 2012). In a study more frequent extreme positive Indian Ocean Dipole (pIOD) events are expected resulting in an increase in frequency of extreme climate and weather events in regions affected by the pIOD (Cai *et al*., 2014). According to Global Climate Risk Index, published by German watch, India is one of the three countries (besides the Philippines and Cambodia) affected by the most extreme weather events in 2013 (Times of India, 2015). Some past extreme events include a heat wave in northern India and Orissa in 1998 and 2004 respectively, in 2004 a cold wave hit Uttarakhand and Uttar Pradesh, a tsunami hit the eastern coast of India in 2004, a large part of India was under the impact of flood that includes Assam, Bihar, West Bengal, Orissa, Uttar Pradesh, Himachal Pradesh, Rajasthan, Gujarat and Madhya Pradesh in the year 2003 and 2005 and Kashmir in 2014, Leh cloud burst in 2010, a cyclone Phailin in Orrisa in 2013, Hudhud in Andhra Pradesh and Orissa and Nilofar in Gujarat in 2014 are a '*wake-up call*' from technological, social and economic enhancement (Majra and Gur, 2009; Greenpeace, 2013). These events adversely affect the millions in terms of lives, agricultural and economic losses and damage to property. Therefore, an intense vulnerability assessment is needed including the details about climate, ecosystem, resources and type of pollution associated with it while understanding the anthropogenic activities and its associated governance and management practices to determine the sensitive places and their resilience capacity to climate change [Mall *et al*., 2011(a)].

6. Limitations of the study

A reliable high quality and quantity data sets are lacking to conclude the analysis with high precision. The data analyzed includes hospital admissions that represent small proportion of patients for a particular disease; nevertheless, it indirectly implies large number of patients in the hospital OPD. Furthermore, most of the epidemics are often found common in poor communities or people living in slum areas due to poverty. Such areas do lack cleanliness and provide conditions for growth and spread of vector / virus borne diseases. However, the study takes into consideration only the climatic influence on the disease prevalence.

The major confounding factors that might have interfered with the associations are:

(*i*) Varanasi is a metropolitan city with total population of 1,198,491 and population density 15,000/km^2 that is very high above the national average (COI, 2011). That indicates people live closure to each other and the infectious diseases could easily infect a large population simultaneously.

(*ii*) Of the total geographical area, the municipal corporation area covers only 78% and about 302,025 resides in slums (25.20% of total city population) (COI, 2011). This is self-explanatory for low sanitation excess to these population and high disease incidence among them.

(*iii*) Only 29% of city population is employed so that every inhabitant of the place does not have access to good live style (JNNURM, 2006).

(*iv*) Varanasi has a 125-year-old Water supply system designed for the population of 2 lakhs and most of the sewage is disposed in the river without any treatment. That creates a large number of gastrointestinal patients are generated that rely on river water for daily purpose (Hamner *et al*., 2006).

(*v*) The air quality index for Varanasi shows that the index for months November to March is very poor to severe and moderate in September-October. Thus, most of the respiratory problems take place within these months (CPCB, 2016).

7. Conclusions

This study has tried to establish a relation between disease incidences with meteorological parameters. Diseases like TB and pneumonia, malaria, dengue, encephalitis, diarrhea and cardio vascular disorders have established relation with some or the other meteorological parameters that helped in explaining their prevalence in a specific season. However, some associations were weak due to lack of sufficient data. A large dataset could help establishing a generalized association. Disease incidences are affected by a number of factors and climate is one of them, but the study deals with the climate aspect only. The study further can encourage the new research minds to work with the inclusion of all the factors possible for a disease outcome and can quantify the contribution of each and every factor. This study and several others show the linkages between climate variability and human health are complex and multi-layered and predictions of the future health impacts of climate change are still uncertain. Over India the annual/seasonal maximum/minimum temperature has increased during the last decades and projection of the future climate scenarios also shows extreme events will exhibit an increase in frequency and intensity resulting in disastrous impact on human life in terms of death toll and disease epidemic. To combat the challenges associated with climate change the

Government of India announced the constitution of a 'National Action Plan on Climate Change (NAPCC)' in 2008 that outlines the programs and policies for climate change mitigation and adaptation, sustainable development and scientific research [NAPCC, 2008; Mall *et al*., 2011(b)]. This national action plan focuses on issues like strengthening of public health care services & delivery mechanisms through early monitoring, diseases surveillance, providing high resolution weather and climate data to study the regional pattern of diseases, vulnerability mapping in areas prone to extreme weather events, response of diseases vectors to climate change, ecological studies of air pollutants and pollen and how they are affected by climate change and enhanced provision of primary, secondary and tertiary health care facilities and implementation of public health measures, including vector control, sanitation and clean drinking water supply. Moreover, there is a need for efficient and effective area-specific health programs to achieve the desired goals and a thorough, comprehensive and more intensive research in climate projections and human health is required to establish new potential relationship.

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