Review of Existing Diseases Surveillance System in Nepal from Climate Change Perspective

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Acronyms

AGE: Acute Gastroenteritis

AR5: Assessment Report 5

BRACE: Building Resilience against Climate Effects

DHM: Department of Hydrology and Meteorology

DHO: District Health Office

DoHS: Department of Health Services

DPHO: District Public Health Office

EDCD: Epidemiology and Disease Control Division

EHP: Environment Health Project

ET: Epidemiological Transition

EWARS: Early Warning and Reporting System

EWS: Early Warning System

HMIS: Health Management Information System

IDSR: Integrated Disease Surveillance and Response

IPCC: Intergovernmental Panel on Climate Change

IVM: Integrated Vector Management

MoHP: Ministry of Health and Population

PEN: Polio Eradication Nepal

RH: Relative Humidity

RHD: Regional Health Directorate

RRT: Rapid Response Team

SARI: Severe Acute Respiratory Infection

VBDRTC: Vector-Borne Disease Research and Training Center

VDC: Village Development Committee

VPD: Vaccine Preventable Disease

WHO: World Health Organization

WMO: World Meteorological Organization

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Background

Climate change is expected to exacerbate the environmental determinants of health and has impacts on the communicable and non-communicable diseases including injuries. Malnutrition, diarrheal disease and vector-borne diseases such as malaria and dengue are all likely to increase as a consequence of climate change. Between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths per year, from malnutrition, malaria, diarrhea and heat stress (WHO, 2018). It is estimated that the annual cost of health impairment caused by climate change is $1.5-4 billion by 2030. Water, sanitation and hygiene have a very significant impact on health and in particular influence those diseases most likely to be exacerbated by climate change. Climate change impacts are likely to result in complete loss of WASH services, contamination of water and increase in the rates of WASH-related diseases such as cholera and leptospirosis, and vector borne diseases such as malaria and dengue (Howard et al., 2016).

Situated in the southern slope of the Himalayas, Nepal is one of the most vulnerable mountainous country to climate change. Emerging and re-emerging diseases are rampant in Nepal (DoHS, 2018). Some of the emerging and reemerging diseases prevalent in Nepal over the period of time are malaria, lymphatic filariasis, leishmaniasis, dysentery, Hepatitis, respiratory infections, cholera, typhoid, intestinal parasites etc. Several preparedness, pre-elimination, elimination and control programs for these diseases have been planned and executed at the governmental, non-governmental and academics level in the country (EDCD, 2016 and 2017).

Surveillance is the ongoing and systematic collection, analysis of disease related data and dissemination of the information to the people who need it, and application of it to disease prevention and control. So, it is composed of reportable disease; system of data collection, analysis, distribution and co-operation of medical institution with public health organization and effective control. Surveillance encompasses a variety of goals such as eradication or elimination of communicable diseases.

Objectives

The main objectives of this study are to review existing surveillance systems in order to strengthen the health-related adaptations to climate change in Nepal and to determine whether additional efforts are warranted. The specific objectives are to:

1. Review existing disease surveillance systems and EWARS
2. Identify/update the climate sensitive diseases
3. Select/prioritize the diseases (e.g. cholera, malaria, etc.) for integrated disease surveillance and/or EWARS
4. Determine whether modification in the existing system or new system be required and developed for the diseases as stated above (#3)
5. Propose key measures to address selected diseases in the surveillance system
6. Define scope of intervention or piloting and provide information on the geographical scopes (sites, population coverage, etc.) of the integrated surveillance/EWS.
7. Update status of the existing meteorological and health data for collection (as per WHO/WMO assessment tool)

Findings

1. Review existing disease surveillance system and EWARS

Public health surveillance is defined as the ongoing systematic collection, analysis, and interpretation of data on the specific health events affecting population, which is closely integrated with the timely dissemination of these data to those responsible for prevention and control of the diseases (Thacker and Stroup, 1994). Hence surveillance has multiple tasks in controlling and preventing diseases such as epidemic (outbreak) detection, epidemic (outbreak) prediction, monitoring trends in disease, to identify changes in agent and host factors, evaluating an intervention, monitor progress towards a control, monitor program performance, estimate future disease impacts, etc.

Types of early warning and reporting system in Nepal

In Nepal the Early Warning and Reporting System (EWARS) was established in 1996 to strengthen the flow of information on vector-borne and other outbreak prone infectious diseases from the district to Epidemiology and Disease Control Division (EDCD) and Vector-Borne Disease Research and Training Center (VBDRTC), Hetauda (EDCD, 2016). Rapid Response Teams (RRTs) can be mobilized at short notice to facilitate prompt outbreak response at Central, Regional and District level. RRTs can also support local level health institutions for investigation and outbreak control activities. The (EWARS) is a hospital-based sentinel surveillance system currently established in 118 hospitals covering all 77 districts of Nepal. It mainly focuses on the weekly reporting of detailed line list of cases and deaths (including "zero" reports) of six priority diseases/syndromes—Malaria, Kala-azar, Dengue, Acute Gastroenteritis (AGE), Cholera and Severe Acute Respiratory Infection (SARI), and other epidemic potential diseases/syndromes (like Enteric fever, Leptospirosis, Hydrophobia, Chikungunya etc.). It equally focuses on immediate reporting (to be reported as soon as possible within 24 hours of diagnosis) of one confirmed case of Cholera, Kala-azar, Severe and complicated Malaria and one suspect/clinical case of Dengue as well as 5 or more cases of AGE and SARI from the same geographical locality in one-week period. The EWARS has not covered all the tropical disease like Snake bite, Rabies etc. Moreover, the Multi-sectoral NCD action plan of Nepal has also envisioned establishment of surveillance system including diseases registry of NCDs (MoHP, 2017b).

Climate change poses a host of serious threats to human health which however can be addressed tracked by adopting robust public health surveillance systems. It is unknown, however, whether existing surveillance systems in Nepal have adequate capacity to serve that role, nor the actions being undertaken can help to develop adequate capacity. Hence, this study is aimsed to assess existing surveillance system of Nepal in the context of climate change in Nepal, using scoping review exercise including Nepal's climate change and health vulnerability and adaptation report (MOHP 2015) and stakeholders' consultation workshops.

The progress of EWARS is consistent and exists in all districts of Nepal, as shown in table 1.

Table 1: Progress of EWARS in DOHS, Nepal

1996	EWARS guidelines, selection of sentinel sites and training
1997	EWARS started functioning with 8 hospital-based sentinel sites
1998	Expanded to 24 sites
2001	Environment Health Project (EHP) assessment
2002	26 sentinel sites and re-orientation and revised formats
2003	28 sentinel sites
2008	40 sentinel sites
2015	81 sentinel sites
2018	83 sentinel sites throughout the country covering all districts of Nepal
2019	Additional 35 sentinel sites are expanded and linked with DHIS2

Since its establishment, the EWARS has been focusing on six diseases, consisting of three vector borne diseases and three Vaccine Preventable Diseases (VPDs). After five years of its implementation, the evaluation of EWARS system was carried out by the Environment Health Project (EHP), which provided some recommendations, as follows (Pyle et al., 2004):

1. Establish and sustain an effective, integrated Early Warning and Rapid Response System
2. MOHP should explore the possibility of an integrated disease surveillance system with capacity for early warning and incorporating an effective rapid response mechanism
3. Drop Vaccine Preventable Diseases (VPD) reporting, leave to Polio Eradication Nepal (PEN)
4. Expand community-based malaria and kala azar early warning and response system
5. Expand to include other epidemic prone diseases, including emerging/re-emerging diseases and diseases of unknown origin
6. Move EWARS to Public Health structure
7. Data should be originated at periphery VDC
8. To ensure an effective early warning system, build district capacity to collect, analyze data and institute a prompt effective response.

Still, MOHP is in the process of implementing these recommendations except a few were implemented such as the diseases considered for EWARS.

The present communicable disease surveillance under EDCD, DoHS is hospital-based sentinel surveillance system. It is currently collecting information from 82 hospitals covering all provinces of Nepal (DoHS, 2018). The surveillance system is designed to complement the country's Health Management Information System (HMIS) by providing timely reporting for early detection of selected vector-borne, water-borne and food- borne diseases with outbreak potential. The system focuses on six priority diseases such as malaria, kala-azar, dengue, acute gastroenteritis (AGE), cholera and severe acute respiratory infection (SARI). Besides, it also includes other epidemic potential diseases like enteric fever, Leptospirosis, Hydrophobia, Chikungunya, etc. (EDCD, 2019).

The weekly reporting system contains a detailed list of cases and deaths (including "zero" report). It also focuses on immediate reporting (within 24 hours of diagnosis) such as one confirmed case of cholera, Kala-azar, severe and complicated malaria, one suspect/clinical case of dengue and five or more cases of AGE and SARI from the same geographical locality in a week (EDCD, 2017). This is however a traditional type of surveillance system, where mainly disease outcomes are considered (Hall et al. 2012). Recently, in addition to six priority diseases: malaria, kala-azar, dengue, acute gastroenteritis (AGE), cholera and severe acute respiratory infection (SARI), additional 26 notifiable diseases are proposed in the Public Health Regulation.

EWARS bulletin is published every week on Sunday, covering information obtained from all medical recorders, EWARS focal persons, rapid response team members, DHOs, DPHOs, RHDs, and all DoHS divisions and centers, and personnel such as Secretary, MoHP chief-secretary, and stakeholders through email. The bulletin has been maintained by EDCD with updated regular information.

In Nepal, Integrated Disease Surveillance and Response (IDSR) system (WHO and CDC, 2010) has not yet been implemented. However, there are integrated surveillance of common group of diseases or risks such as Integrated Vector Management (IVM), integrated entomological surveillance, integrated surveillance of vectors of Malaria, Kala-azar, Dengue, and LF & JE, and integrated surveillance of VPDs, etc. (DoHS, 2018; Acharya, 2018). The IDSR system is a strategy for multi-disease surveillance of selected priority diseases or conditions. It links the community and health facility at the district and national levels, allowing the rational use of resources for disease control and prevention (WHO and CDC, 2010; Nsubuga, 2010). Integrated Vector Management (IVM) is a rational decision-making process for the optimal use of resources for vector control with the main aim of preventing the vector borne disease transmission. The approach seeks to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease-vector control. The driving forces behind a growing interest in IVM include the need to overcome challenges experienced with conventional single-intervention approaches to vector control as well as recent opportunities for promoting multi-sectoral approaches to human health (EDCD, 2017). The major stakeholders for IDRS are

- Ministry of Health and Population, Government of Nepal
- Epidemiology and Diseases Control Division, Department of Health Services
- Vector-borne Diseases and Research Training Centre (VBDRTC)
- Nepal Health Research Council (NHRC) and Academic Institutions
- Provincial and Local Governments
- World Health Organization (WHO)
- External Development Partners such as DFID, GIZ etc.

Lessons from International Experiences

Elsewhere across the world**,** several countries have adopted disease surveillance systems. For instance, WHO/UNDP in 2010 launched the first global project on public health adaptation to climate change in seven countries: Barbados, Bhutan, China, Fiji, Jordan, Kenya, and Uzbekistan, with the main aim of increasing the adaptive capacity of the national health system including the field level response to climate-sensitive health risks. Each country has focused on different components of public health adaptation as per their need. For example, China focuses on strengthening early warning and response systems to extreme heat in urban settings, Jordan focuses on diarrheal disease control through safety of wastewater reuse as a response to water scarcity etc. The measures adopted by the countries to address these challenges can be categorized as: (i) enabling environment (ii), capacity, and (iii) data base (WHO 2011). In Nepal, the climate sensitive diseases and the adaptation measures to combat their impacts are well reflected in its existing policies, plans and strategies, but their implementation part is weak (Dhimal et al. 2017). However, the experiences of the global project on public health adaptation to climate change of those seven countries can be used in establishing climate sensitive diseases surveillance system in Nepal.

A comprehensive public health surveillance system can address the adverse impacts of climate change by identifying appropriate mitigation and adaptation measures (Moulton and Schramm, 2017). The comprehensive health surveillance needs to address the four key components of surveillance: comprehensive data base on health and non-health sectors including long terms meteorological data base, workforce, finance and policy which can be expressed in measurable indicator in seven domains such as Environmental, Vulnerability, Health, Climate change mitigation, Climate change adaptation and Policy. A coordinated, multisector strategic plan can create and sustain surveillance system to address climate change health issue (Moulton and Schramm, 2017). A study from Europe has shown the evidence of a link between vector-borne disease outbreaks and El Niño driven climate anomalies, suggesting early warning systems developed based on climatic information can lead to improved outbreak control and management (Morand et al., 2013). Other different studies have also highlighted the ways of designing a reliable surveillance system for example with the use of long-term meteorological data (Vairo et al., 2018) (Descloux et al., 2012).

The framework of the Building Resilience against Climate Effects (BRACE) provides the systematic use of climate projections to inform public health adaptation efforts at local or regional level. The framework incorporates an assessment of (a) climate change impacts and vulnerability assessment, (b) projection of the disease burden/health impacts, (c) assessment of public health interventions, (d) development and implementation of a climate and health adaptation plan, and (e) evaluation of impact and improved quality of activities. Broad stakeholder engagement, adaptive management, and a long range-planning frame are key elements of BRACE (Marinucci et al., 2014). The adaptive management framework calls for the periodic revisions to the stakeholder network in order to better align with the specific goals of each step. A second point to consider is that implementation of BRACE is the temporal scope for assessing changing climatic conditions and for choosing adaptations or key interventions. BRACE pragmatically recognizes that public health and climate change are two of many considerations for making adaptation policy decisions. The level of specificity needed for disease projections will become more apparent as this information informs public health adaptations going forward. How successfully public health agencies navigate this challenge depends on the collaborations built with agencies involved in developing climate projections (Moser and Ekstrom, 2010).

An early warning system for climate sensitive diseases helps to prevent an outbreak by predicting the rise in number of cases of those sensitive diseases which can then help the local authorities to take timely preventive measures. Here are some cases studies of warning systems and the predictive models. Some case studies of surveillance and early warning systems for climate sensitive diseases are provided in the ANNEX 1.

2. Identify or update the climate sensitive diseases

Nepal has experienced global warming and its impacts on forming climate extremities (like droughts, landslides and floods), ill health of the people, change in agricultural production patterns, etc. over the past recent decades. The public health sector is one of the sectors, which is the most vulnerable to climate change and there are increasing evidences of the impacts of climate variability on health outcomes in Nepal (MOE, 2010). The climate sensitive health diseases in the country have been identified by different government policy documents. The MOHP/WHO (2015) in the report of vulnerability and adaptation assessment of health impacts due to climate change in Nepal has identified climate sensitive diseases, which have been categorized into three groups based on Assessment Report 5 (AR5) of IPCC. They are: (a) extreme weather related health impacts, such as heat wave, cold wave and floods, (b) environmental and ecosystem mediated health impacts such as vector borne diseases including Japanese Encephalitis (JE), malaria, Kala-azar (Visceral leishmaniasis) and dengue, and diarrheal disease, and (c) societal systems change impacts like under-nutrition and mental illness and other environmental stresses (Smith et al.,2014).

Entomological and epidemiological studies carried out in Nepal show early effects of climate change on vector-borne diseases, which together with their vectors appear to have shifted clearly to high altitude (mountain) region of Nepal (Dhimal et al. 2014). The data from 1963 to 2012 indicates a fluctuating trend of malaria incidence, and an increasing trend of P. falciparum infection cases and clinically suspected malaria (Dhimal et al., 2014a). This is a challenging result for the country's malaria eradication strategy for the years 2011-2026 (Dhimal et al., 2014a). Similarly, the first vertical distribution of species composition, seasonal occurrence, habitat preference and altitudinal distribution of malaria and other disease vectors in the eastern Nepal has also indicated that the vectors of malaria and other diseases have already established their populations in the highlands due to climatic and other environmental changes (Dhimal et al., 2014a). This is alarming information to the people and the government where VBD control programs have not been focused.

The study carried out in central Nepal about knowledge, attitude and practice regarding dengue fever among the healthy populations of highland and lowland communities shows that only 12% of the samples had good knowledge about dengue fever (Dhimal et al, 2014b). It means that massive awareness programs are urgently required to protect the health of people from dengue fever and to limit its further spread in the country.

The study on the spatio-temporal distribution of dengue and lymphatic filariasis vectors in the central Nepal exhibits that the dengue virus vectors have already established stable populations in the middle mountains while the lymphatic filariasis vectors are found in the high mountains (Dhimal et al 2014c). The findings of their study suggest a better planning and scaling-up of mosquito-borne diseases control programmes in the middle mountain region of Nepal.

The review paper on “dengue periodic outbreaks and epidemiological trends in Nepal" based on the information of the last one decade indicates that its endemics have expanded to new territories in the country’s hill region (Gupta et al. 2018). This is a serious concern. As there is lacking of basic health related infrastructure in the rural areas as well as of stringent health care policy, their paper suggests concerted and timely public health interventions to minimize the deleterious effects of the disease in the country.

Another emerging disease in Nepal is Japanese encephalitis (JE). The study on spatio-temporal epidemiology from 2007 to 2015 in the country found a strong seasonal pattern and age specific of JE (Pant et al. 2017). The JE cases were most commonly reported in the age group of 1-14 years. The occurrence of its cases has reached at peak in August and declined by October each year, corresponding to the monsoon rainy season. Spatially, the JE cases were reported in the country’s 63 districts, expanding even in the hills and mountains. Their study recommends that the JE surveillance system should be improved to better understanding of the drivers of this disease expansion in the country for instituting a control program.

Diarrhea diseases are common across different parts of Nepal. Besides consumption of contaminated food and water, the diarrhea disease can occur also due to climate change. For instance, the study on effects of climate factors on diarrheal diseases across Nepal utilizing climate data from 1970 to 2014, diarrheal data between 2002 and 2014, and water supply and sanitation coverage data from 2001 to and 2015 indicated that an increase of 1˚C temperature caused to increase an average of 4.39%) rise in diarrheal cases, with highest (5.05%) in the mountain region and lowest (0.85%) in the Terai region (Dhimal et al., 2016). Similarly, they also found a straight relationship between diarrhea disease rate and precipitation rate. According to their study, the disease rate grew at the range of 0.40% to 0.80% among the under-five children population with an increase of 1 cm rainfall. The diarrhea diseases pattern shows a distinct seasonality effect, which can be addressed with appropriate surveillance system with early warning system (Babji et al., 2014). Similarly, the multi-center surveillance of rotavirus diarrhea in hospitalized children <5 years of age is found effective in the management of disease which do not show any seasonal variation in the disease pattern.

3. Select/prioritize the diseases (e.g. cholera, malaria, etc.) for integrated disease surveillance and/or EWARS

Based on review of scientific literature, grey literature, disease burden and consensus developed in various stakeholders' meetings, following diseases are recommended for integrated diseases surveillance for developing early warning system in Nepal

- Vector-borne diseases (malaria, dengue and leishmaniasis)
- AGE including cholera

Further Criteria for selection were

- diseases which have high epidemic potential
- diseases of international concern/HR 2005
- diseases targeted for eradication or elimination
- diseases of public health importance
- diseases which have effective prevention and control measures

4. Define whether modification in the existing system or new system should be developed for those diseases

It is evident from the review of empirical studies made above that the prevention and control of climate sensitive diseases calls for climate health surveillance measure. Further, the need of climate health surveillance measure for prevention and control of climate sensitive diseases can be furnished by additional studies, as follows:

The epidemiological transition (ET) theory postulated in 1971 deals basically with disease burden and transition of morbidity and mortality patterns with the improvement of socioeconomic development. The theory is largely being a generalisation of mortality experiences drawn from some low-income and middle-income countries. It however has not considered wide-ranging aspects of the determinants of mortality, including risk factors, lifestyle changes, socio-economics, and macro factors such as climate change. Further, the theory has largely neglected the critical role of social determinants in diseases (Santosa et al, 2014). Furthermore, the challenges with this theory remain in its limited applications to generate the health-related empirical databases, to the effect of climate variability on public health, and to the prediction of uncertainties (Forastiere, 2010).

The study on causes of global warming indicates that climatic condition is warming due to heating of the surface air by greenhouse gas and changing atmospheric system due to massive extraction of energy from fossil fuels during the past two centuries (Barrett et al. 2015). This warming system has not only affected human health, but also the quality and quantity of basic social determinants.

Further, an application of spatial modelling technique to cholera disease pattern has estimated that around 2.86 million cholera cases occur globally every year, of them approximately 95,000 die and about 1.3 billion people are currently at risk of infection from cholera (Chaudhury et al. 2017). This estimation offers an impression of interplay between global warming and the pathogenicity and epidemiology of *V. cholera*. Global warming together with poor sanitary conditions, overcrowding, improper sewage disposal etc causes to promoting the growth and transmission of this deadly disease. Several distinctive features of cholera survival such as optimal thriving at 15% salinity, 30 °C water temperature, and pH 8.5 indicate a possible role of climate change in triggering the epidemic process. This process and its future outbreaks can however probably be prevented or controlled by adopting certain measures such as precise environmental signals for instance optimum temperature, sunlight and osmotic conditions; development of an effective early warning system based on climate data, etc. Moreover, integration of real-time monitoring of cholera affected regions and their climate variability and epidemiological and demographic population dynamics can be adopted to predict cholera outbreaks and support the design of cost-effective public health strategies (Chowdhury et al, 2017).

Besides cholera and rising temperature nexus, heat wave or cold wave is one of the direct impacts of climate change. Body temperature is affected by environmental temperature depending on the occupations of the people. High body temperature with ≥ 40°C (104°F) is the most frequently cited underlying cause of heat-related death of the working people, followed by heart disease, unintentional injuries, and reduced blood pressure (dizziness or fainting). Other symptoms of heat-related diseases include increasing rates of heart bit and respiration, which may damage kidneys, liver, heart, lungs, and brain. Likewise, the body temperature ≤ 35°C (95°F) exposure to excessive cold is the most frequently cited underlying cause of cold-related death, followed by unintentional injuries, heart disease, impaired blood flow and decreased metabolic activity, which alter brain function, causing confusion, memory loss, and low energy, constricted blood vessels and viscous blood increase cardiac workload, body loses heat, depleting stored energy (Seltenrich, 2015).

Several studies carried out in Nepal exhibit climate change impacts on various communicable and non-communicable diseases including mental health (MacFarlane etal, 2015; Joshi et al, Bhusal and Dhimal, 2010; Ghaffar et al., 2004; Hunter, 2003). The country is now endemic for five major vector-borne diseases (VBDs), namely malaria, lymphatic filariasis, Japanese encephalitis, visceral leishmaniasis and dengue fever (DoHS, 2018). The systematic review study indicates that there is increasing evidence about the impacts of climate change on VBDs especially in sub-tropical highlands and temperate regions (Dhimal et al, 2015). The same study also indicated that vectors are found in high mountains with over 2,000 m above sea level, which were previously non-endemic areas. The study concluded that climate change could intensify the risk of VBD epidemics in the mountain regions of Nepal if other non-climatic drivers of VBDs remain constant. Diarrhea as one of the major diseases linked with climate change in Nepal. A study carried out in Jhapa district of Nepal shows a close association between climate variables and diarrheal disease occurrence (Bhandari et al. 2013). Studies carried out in South Asia including Nepal have found increasing burden of non-communicable diseases due to climate change (Gentle et al. 2014; Gentle and Maraseni, 2012; Eriksson et al., 2009).

Thus, it is evident that different types of diseases can occur due to climate change, whether rising and decreasing in level of temperature. Nepal also needs to adopt the systems to address those causes of diseases. Indeed, the country has already climate sensitive diseases and the adaptations measures as already stated above, which need to be implemented sincerely and concomitantly, or if not, the measure of the WHO's global project on public health adaptation to climate change as mentioned above can be adopted. In a summary, Nepal needs to adopt the systems to address the causes of diseases. For example

- Consider the role of social determinants such as education, income, ethnicity, occupation, areas of residence (urban vs rural) and access to WASH, energy, healthcare facility, transportation etc.
- Using the application of spatio-temporal modelling techniques to monitor expansion of diseases. This helps to assess changes in expansion/recession of diseases with respect to time span and geographical space
- adopting measures to get precise environmental signals such as warning signs for heat waves, high pollution level, conducive environment for vector development and pathogens development etc.
- integration of real-time monitoring of disease affected regions and their climate variability and epidemiological, entomological and demographic population dynamics, and data from Department of Hydrology and Meteorology (DHM).

5. Propose key measures to address selected diseases in the surveillance system

Two major climate sensitive diseases such as malaria and diarrhea are crucial, as several studies have made attempts to analyse and explore these two diseases and their associated factors. For instance, based on the review analysis, vector borne disease basically malaria being analyzed based on the long-term data indicates that shifting of vector has taken place from low land to high land (Dhimal et al., 2014). Though this disease is in elimination phase, but more virulent species of malaria, *Plasmodium falciparum* is in increasing trend. Unlike spatial shift of malaria vector, diarrheal disease is wide spread across all parts of Nepal and during all seasons, though particularly more seen in summer rainy season (Dhimal et al. 2015). Both diseases are associated with impounded water including open sewerage, which are often seen during rainy season.

- For malaria not only human settlements, both villages and towns having impounded water including ponds in their surroundings and open defecation sites in the Tarai region, but also those in the hills and mountains having those attributes together with elevation as well as temperature and precipitation are to be recorded in the system.

- Studies show that both diseases can shift or transmit by migrant people, particularly the malaria vector. So, the features of the movement (seasonal or work type) of the people need to be recorded in the system.
- In addition to migrant people or working groups, the system should also include infant and children below 5 years of age by sex and social (race) and economic status (poverty condition), as they are most susceptible to those diseases as per the review of the studies.
- Regular monitoring of the diseases and their associated features as stated just above should be maintained in recording, at least once a week by health facility units.

In a summary,

The proposed key measures for AGE including cholera are

- Enhance disease surveillance system during high-risk seasons/periods

  Use weekly reported retrospective data of AGE and meteorological data for identifying high-risk seasons/periods as well as geographical areas and develop simple models for projecting diseases outbreaks/epidemics. This can be done in coordination between EDCD and NHRC with technical support of WHO.
- Strengthen water quality surveillance

  There is a need to expand and strengthen water quality surveillance throughout the country and need to document water quality surveillance data and these data need to link with AGE cases as well as climatic data of local stations. This can be done in coordination between EDCD and DWSS with the technical support of WHO and research institutions.
- Integrate disease, water quality and climatic data for predicting diseases outbreak in certain geographic areas

The proposed key measures for vector-borne diseases (malaria, dengue and leishmaniasis) are

- Expand the scope of diseases monitored, and monitor at the margins of current geographic distributions to detect spread and epidemic potentials of disease developing spatio-temporal risk maps using GIS techniques.
- Establish vector control measures combining knowledge socio-behavioural, ecological and biological measures. Integrated vector control surveillance could be an effective surveillance technique.
- Enhance diagnostic and treatment options for different disease at federal, provincial and local governments level. This should be clearly defined at different governments levels and an appropriate referral system should be developed.
- Establish early warning system of these diseases using climatological, epidemiological, entomological (if applicable), socio-behavioral, ecological and economic determinants.

6. Define scope of intervention or piloting and provide an information on the geographical scope (sites, population coverage etc.) of the integrated surveillance/early warning system (EWS)

Following sites for interventions or piloting for of the integrated surveillance/EWS
have been recommended based on findings of desk review, experience of programme managers and the feedback from stakeholders:

- Select geographic area/district (Jhapa, Chitwan, Pokhara, Jumla) for piloting integrated disease surveillance
- Develop guidelines for establishing integrated surveillance and early warning system including detail data analysis and reporting plan
- Use of early detection tools (eg., rapid diagnostics, syndromic surveillance) to identify changing incidence and early action triggered
- Surveillance of water quality or diseases vectors as appropriate
- Spatio-temporal risk mapping of defined climate sensitive diseases using GIS techniques

- Predicting disease outbreaks/early warning systems using both climatic and non-climatic variables

7. Update status of meteorological and health data collection (as per WHO/WMO assessment tool)

In regard to the meteorological data, the DHM operates 438 meteorological stations network distributed across the country for the collection of weather data. Table 1 depicts the parameters such as measurement variables, frequency and application by type.

Table 1: Parameters observed in different station types

Station Type	Number	Observed Parameters	Observed Frequency	Observed Time (UTC)
Precipitation only	306	Precipitation (P)	Once a week	03
Climate: three elements	103	Temperature (T), Precipitation, Relative Humidity (RH)	Twice a week	03, 12
Agro-meteorological	13	T, P, RH, Evaporation (E), Sunshine (S), Soil Temp (ST), Wind (W)	Twice a week	03, 12
Synoptic	9	T, P, RH, S, W, Cold type (C), Visibility (V), Present Weather (PW), Atmosphere Pressure (PR)	Three hourly daily	00 to 12

Aeronautical (aero-synoptic)	7	T, P, RH, S, W, C, V, PW, PR	Hourly	00-23

Source: Bhetuwal et al. 2016

The DHM website (https://www.dhm.gov.np/) has described several aspects including accessibility of data and methods of purchasing the data, as per the requirement.

Unlike the meteorological data, the health data accessibility is not easy at all. There is not clearly mentioned how one can acquire the health facility data, whether free of cost or purchase. The format of availability health data is also not clear. The health annual report available to the users shows data in annual aggregate. The surveillance data of six diseases through EDCD is available on a weekly basis.

For climate health surveillance, the health data should also be available on daily or weekly basis as make it compatible to the meteorological data. These offer flexibility in analysis including prediction and so formulation of specific policy measures and programs.

The CDC has come up with concept of health surveillance for the 21st century considering the multifactorial determents of health including environmental and climate change (Buehler, 2012). A traditional interpretation of key concepts leads to a narrow definition of the scope of public health surveillance systems to include morbidity and mortality of diseases or specific health events. Conversely, a more expansive interpretation opens the field of public health surveillance to new areas of public health inquiry using innovative data sources, methods of data collection and analysis, and application to several public health concerns. This latter interpretation of key concepts was adopted because it was considered essential to adapt to the health information needs and the advancement of public health surveillance in the 21st century (Hill et al. 2012). Health information needs for the 21st century as suggested (CDC 2012) are as follows:

- Preparedness
- New information systems/technologies

- Availability of more and new data/new data sources/databases
- Health-care reform
- Electronic health/medical records
- Performance accountability
- Comparative effectiveness of medical interventions
- Measuring positive indicators
- Infrastructure and capacity
- Globalization
- Interoperability
- Changes in the economy
- Expanding scope of public health practice
- Data privacy issues
- Data security
- Public participation in public health activities

In the context of Nepal,

- In regard to the meteorological data, the DHM operates 438 meteorological stations network distributed across the country for the collection of weather data and daily data are available. For health sector, temperature, precipitation, humidity and wind data are important.
- Unlike the meteorological data, the health data accessibility is not easy and the process of obtaining the data is not clear. Hence, health sector data maintaining in minimum spatial and temporal scale is important such as daily data of municipality levels.
- For climate health surveillance, the health data should also be available on daily or weekly basis as make it compatible to the meteorological data as well as provide robust prediction

- These offer flexibility in analysis including prediction and so formulation of specific policy measures and programs.
- MOU need to sign between MOHP and Department of Hydrology and Meteorology, Ministry of Energy and Water Resources for data sharing. DHM can share daily data of temperature, precipitation, humaidity and wind data and EDCD/MOHP share daily/weekly reported cases of climate sensitive diseases and risks.

Key challenges

- Accessing long term retrospectives health data for developing reliable models. For example, more than four years weekly health/disease data is not available from existing EWARS in Nepal. Hence, data recording and reporting system need to be strengthen
- High cost of purchasing meteorological data. In order to purchase daily and monthly meteorological data is very costly especially for students and government bodies. Hence, there should be MOU between government bodies for free access of meteorological data for research and developing early warning system.
- Inadequate human resources for working on diseases surveillance such as entomologists, environmental epidemiologists, environmental health experts and modelling expert.
- Lack of conducive environment for integrated diseases surveillance and early warning system. There is lack of clear institutional mandate and some overlapping mandate for working on integrated diseases surveillance system including on international health regulation

Way forward

Surveillance is a systematic use of data for action. If meteorological parameters are used as per the diseases data available, the adverse effects of climate change can be addressed by adopting appropriate adaptation and mitigation measures to combat the impacts of climate change. Effective disease control relies on effective disease surveillance. It is a key part of public health decision-making. Hence, further actions may be required, as follows:

- Create enabling environment for integrated disease surveillance by assessing the internal and external environments of the health system, implementing the existing policy, or revising the existing policy if required, and ensuring the adequate resources, including capital and human
- Strengthen capacity of the organizations such as ministries, departments, etc for diagnosis, recording reporting, and analysis and interpretation of climate sensitive diseases
- Strengthen health data by enhancing the resolution of recording and reporting data to daily or weekly by revising the existing reporting systems such as weekly, monthly and yearly and also develop the data repository in public domain for research and development
- Require research studies such as malaria, dengue, AGE, Cholera etc for better understanding the relationships of diseases with climatic and non-climatic variables using weekly data available at EDCD (research on identified climate sensitive diseases in this review report)
- Develop early warning systems of climate sensitive diseases by updating the existing EWRS data base and climatic data

Recommended actions

- Development of tools for recording and reporting of climate sensitive diseases and risks by adding the climate parameters like temperature and precipitation into the existing tool of surveillance, which are based on the trend of diseases recorded by EDCD and other environmental and social determinants of health.

- Developpiloting guidelines for determining the type of parameters like maximum and minimum temperature, precipitation, climate sensitive diseases (vector and water borne), social determinants (size of population, social groups, accessibility of health service, water and sanitation and energy), temporal resolution of data (hourly, daily, weekly, monthly and yearly), number and location (spatial) of sites, data validation, and preparedness to combat the effects for establishing early warning and reporting system
- Develop networking of data capture of the pilot study areas with local governmental agencies, nongovernmental health agencies and other agencies such as academic institutions, research organizations if exist, as well as with all such agencies at the provincial and central levels.
- Provision of training to health professionals including medical recorders (public and private health services and academic institutions), updating existing training materials on DHIS2/HMIS for establishing early warning system of the selected pilot areas/districts. Generic trainings on climate change and health could be also good for orientation and sensitization at the province levels through health training centers.
- Support operational cost for web based data entry (e.g. internet)
- Provide laptop and internet facility at each health facility where such facility is not available
- Orientation to key people of sentinel sites about the diseases surveillance system on climate change perspective.
- Develop mechanisms of staffs/manpower of sentinel sites providing raining on climate change and health.
- Regular supply of test kits and RDTs for strengthening the lab based diagnoses of the climate sensitive diseases.
- Review of the activities such as diseases as per the revised tools of data recording and reporting through regular monitoring and supervision systems
- Carry out research studies, particularly malaria, dengue, AGE, Cholera etc on retrospective data for establishing causal relationship to draw inference the between exposure and outcome variables.

- Analyze climate sensitive diseases with respect to climate data for at least 15 years to develop and predict climate and diseases models
- Human resources supports of multi- disciplinary backgrounds such as public health, environmental health, water sanitary health, environment science, entomology, microbiology, meteorologist, healthcare management etc.
- Quarterly dissemination of the findings and sharing of the data among the general public people who are interested in it.

ANNEX 1. Case Studies of surveillance and early warning systems for climate sensitive diseases

a. The China Infectious Disease Automated-alert and Response System (CIDARS)

CIDARS was developed by the Chinese Center for Disease Control and Prevention (Yang et al., 2017), based on the surveillance data from the existing electronic National Notifiable Infectious Diseases Reporting Information System (NIDRIS). CIDARS includes 29 infectious diseases of high burden or high public concern that are outbreak-prone and require prompt action. After the outbreak of SARS in 2003, China successfully launched web-based NIDRIS in 2004, in which all the health care institutions across China were enabled to report in real time individual cases of Notifiable infectious diseases by internet which reduced the interval between case diagnosis and case reporting to within one day on average (Yang et al., 2017).

Depending upon the type of diseases, three early warning methods are used: Fixed threshold detection method, Temporal model (moving percentile method and Cumulative Sum control chart method), and spatial temporal model. First two are extensively applied throughout China. Fixed threshold method is used for diseases like SARS, Avain influenza, filariasis, H1N1; Temporal-moving percentile method for diseases such as JE, Malaria, Dengue; Temporal-CUSUM method for hand foot and mouth diseases. Similarly, spatial-temporal model leverages MPM to detect abnormal changes in the current number of cases throughout the county/district over time, and then utilizes the spatial detection method to identify areas with possible clusters within the county/district (Yang et al., 2017).

In CIDARS, automatic analysis and calculation of the early warning algorithms for different diseases are performed and in case of abnormal situation the signals are sent to the local county/district CDCs via short message service (SMS). Upon receiving the alert signal, the staffs investigate and verify the warning and report the result in the system. This system can be logged in by the responsible epidemiological surveillance staff at CDC at any time. CIDARS is an example of successful program of a surveillance and early warning system for epidemiological surveillance staff in early detection of disease outbreaks (Yang et al., 2017).

b. Singapore: Communicable diseases live and enhanced surveillance system (CD-LENS)

After the outbreak of SARS in 2003, need to strengthen the surveillance system of Singapore was realized. To be better prepared and provide effective response, CD-LENS was launched as a part of enhancing the surveillance capabilities. It is a one-stop Internet portal developed for infectious diseases notification and outbreak management, as well as real-time information access to local and global infectious diseases events (Communicable Disease Division, 2011).

CDLENS has a simple 4-step notification system: first login to the www.cdlens.moh.gov.sg. Second, select the notification form to use. Third, complete the form with patient's address, date of diagnosis and onset of disease and prompt notification. Fourth, submit the filled form (Communicable Disease Division, 2011).

c. Study on forecasting dengue in Singapore

A study was done to forecast the evolution of dengue epidemics in Singapore to provide early warning of outbreaks and to facilitate the public health response to moderate an impending outbreak (Shi, et al., 2015).

The data on dengue cases, mid-year population size for residents and non-residents, meteorological (temperature and humidity data), trend & surveillance data from 2001 to 2011 were used. Statistical models using least absolute shrinkage and selection operator (LASSO) methods to forecast the weekly incidence of dengue notifications over a 3-month time horizon. These models were compared with other alternative methods (SARIMA and step-down linear regression). The models forecasted the data for 2013 dengue outbreak in Singapore. It was found that operationally useful forecasts were obtained at a 3-month lag using the LASSO-derived models and the forecast was more accurate than the other methods (Shi, et al., 2015).

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d. Indonesia: Prediction of Dengue Outbreaks Based on Disease Surveillance and Meteorological Data

This study was done in Yogyakarta Municipality, Indonesia. This municipality has one of the largest DHF incidence rate. Since the existing early warning system for dengue can be used to estimate the nature of next year's epidemic activities beginning in March,, this study was carried out to develop an early warning system that can estimate the nature of next one or two months' epidemic activities for the Yogyakarta province (Ramadona, et al.,2016).

Dengue data from 2001-2013 obtained from the dengue surveillance report included aggregated monthly cases of dengue fever, and dengue shock syndrome at municipality level. Similarly, meteorological data for the same period included rainfall, temperature and relative humidity data. The data from 2001 to 2010 were used to train the model whereas the data from 2011 to 2013 were used to test and validate the fitted model. Generalized linear regression models were used to fit relationships between the predictor variables and the dengue surveillance data as outcome variable.

In the models, temperature with three-month lead time, and rainfall with 2-3 month lead time were found to be the best predictors whereas relative humidity was not a strong predictor. The model in the study predicted 10 out of the 10 epidemic months during the years 2011–2013 correctly and forecasted dengue cases up to 2 month ahead and showed a consistent ability to separate months with epidemic and non-epidemic transmission in the training data, as well as in the testing data. The study found that both in outbreak and non-outbreak periods, the combinations of the meteorology and the autoregressive lag terms of dengue counts in the past have been able to predict dengue incidence quite accurately.

References

Acharya, B. K., Cao, C., Xu, M., Khanal, L., Naeem, S., & Pandit, S. (2018). Present and Future of Dengue Fever in Nepal: Mapping Climatic Suitability by Ecological Niche Model. Int J Environ Res Public Health, 15(2). doi: 10.3390/ijerph15020187

Babji, S., Arumugam, R., Sarvanabhavan, A., Moses, P. D., Simon, A., Aggarwal, I., . . . Kang, G. (2014). Multi-center surveillance of rotavirus diarrhea in hospitalized children <5 years of age in India, 2009-2012. Vaccine, 32 Suppl 1, A10-12. doi: 10.1016/j.vaccine.2014.03.001

Barrett, B., Charles, J. W., & Temte, J. L. (2015). Climate change, human health, and epidemiological transition. Prev Med, 70, 69-75. doi:10.1016/j.ypmed.2014.11.013

Bhandari, G., Gurung, S., Dhimal, M., & Bhusal, C. (2013). Climate change and occurrence of diarrheal diseases: Evolving facts from Nepal. Journal of Nepal Health Research Council.

Bhusal, C., & Dhimal, M. (2010). Impacts of climate change on human health and adaptation strategies for Nepal. *Journal of Nepal Health Research Council*.

Bhetuwal, C., Karki, Ramchandra, Koirala, Sujan. (2016). Challenges and plans for phasing out mercury based meteorological instruments from Nepal. Department of Hydrology and Meteorology Government of Nepal

Buehler, J. (2012). CDC's vision for public health surveillance in the 21st century. Introduction. MMWR supplements, 61(3), 1.

Chowdhury, F. R., Nur, Z., Hassan, N., von Seidlein, L., & Dunachie, S. (2017). Pandemics, pathogenicity and changing molecular epidemiology of cholera in the era of global warming. Ann Clin Microbiol Antimicrob, 16(1), 10. doi: 10.1186/s12941-017-0185-1

CDC. (2012). Introduction. In: Challenges and opportunities in public health surveillance: a CDC perspective. MMWR 2012;61(Suppl; July 27, 2012):1-2.

Communicable Diseases Division.(2011).Communicable diseases live and enhanced surveillance system (CD-LENS) and the health Professionals portal (HPP). The Singapore Family Physician, 37 (2).

Dhimal, M., Ahrens, B., & Kuch, U. (2014a). Malaria control in Nepal 1963-2012: challenges on the path towards elimination. Malar J, 13, 241. doi: 10.1186/1475-2875-13-241

Dhimal, M., Ahrens, B., & Kuch, U. (2014b). Species composition, seasonal occurrence, habitat preference and altitudinal distribution of malaria and other disease vectors in eastern Nepal. Parasit Vectors, 7, 540. doi: 10.1186/s13071-014-0540-4

Dhimal, M., Ahrens, B., & Kuch, U. (2015). Climate change and spatiotemporal distributions of vector-borne diseases in Nepal–a systematic synthesis of literature. PLoS One, 10(6), e0129869.

Dhimal, M., Aryal, K. K., Dhimal, M. L., Gautam, I., Singh, S. P., Bhusal, C. L., & Kuch, U. (2014c). Knowledge, attitude and practice regarding dengue fever among the healthy population of highland and lowland communities in central Nepal. PLoS One, 9(7), e102028. doi:10.1371/journal.pone.0102028

Dhimal, M., Gautam, I., Kress, A., Muller, R., & Kuch, U. (2014). Spatio-temporal distribution of dengue and lymphatic filariasis vectors along an altitudinal transect in Central Nepal. PLoS Negl Trop Dis, 8(7), e3035. doi:10.1371/journal.pntd.0003035

Dhimal, M., Dhimal, M. L., Pote-Shrestha, R. R., Groneberg, D. A., & Kuch, U. (2017). Health-sector responses to address the impacts of climate change in Nepal. WHO South East Asia J Public Health, 6(2), 9-14.

Dhimal M, Karki KB, Aryal KK, Shrestha SL, Pradhan B, Nepal S, Adhikakri TR, Khanal M, Jha BK, Pun S, Chaudhary A, Dhungana S (2016). Effects of Climate Factors on Diarrheal Diseases at National and Sub-national Levels in Nepal. Kathmandu, Nepal: Nepal Health Research Council (NHRC) and WHO Country Office, Nepal.

Descloux, E., Mangeas, M., Menkes, C. E., Lengaigne, M., Leroy, A., Tehei, T., . . . Benzler, J. (2012). Climate-based models for understanding and forecasting dengue epidemics. PLoS Negl Trop Dis, 6(2), e1470.

DoHS (2005), Annual Report 2004/2005. Ministry of Health and Population

DoHS (2018), Annual Report 2016/2017. Ministry of Health and Population

EDCD. (2016). Early Warning and Reporting System (EWARS) Guidelines. Kathmandu: Government of Nepal, Ministry of Health, Department of Health Services, Epidemiology and Disease Control Division.

EDCD. (2017). Integrated Training Package on Emergency Preparedness and Response for Rapid Response Team (RRT). Kathmandu: MoHP.

EDCD. (2019).Early Warning and Reporting System (EWARS) Weekly Bulletin. Kathmandu: DoHS/MoHP

Eriksson, M., Xu, J., Shrestha, A. B., Vaidya, R. A., Santosh, N., & Sandström, K. (2009). The changing Himalayas: impact of climate change on water resources and livelihoods in the greater Himalayas: International centre for integrated mountain development (ICIMOD).

Forastiere, F. (2010). Climate change and health: a challenge for epidemiology and public health. Int J Public Health, 55(2), 83-84. doi:10.1007/s00038-009-0096-9

Gupta, B. P., Tuladhar, R., Kurmi, R., & Manandhar, K. D. (2018). Dengue periodic outbreaks and epidemiological trends in Nepal. Ann Clin Microbiol Antimicrob, 17(1), 6. doi: 10.1186/s12941-018-0258-9

Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. Environmental science & policy, 21, 24-34.

Gentle, P., Thwaites, R., Race, D., & Alexander, K. (2014). Differential impacts of climate change on communities in the middle hills region of Nepal. Natural Hazards, 74(2), 815-836.

Ghaffar, A., Reddy, K. S., & Singhi, M. (2004). Burden of non-communicable diseases in South Asia. Bmj, 328(7443), 807-810.

Howard, G., Calow, R., Macdonald, A., & Bartram, J. (2016). Climate change and water and sanitation: likely impacts and emerging trends for action. Annual review of environment and resources, 41, 253-276.

Joshi, H. D., Dhimal, B., Dhimal, M., & Bhusal, C. L. (2011). Public health impacts of climate change in Nepal. J Nepal Health Res Counc, 9(1), 71-75. Kathmandu.

Hall, H., Correa, A., Yoon, P., & Braden, C. (2012). Centers for Disease Control and Prevention. Lexicon, definitions, and conceptual framework for public health surveillance. MMWR Surveill Summ., (Jul 27;61(Suppl):10-4.)

Hunter, P. R. (2003). Climate change and waterborne and vector-borne disease. Journal of applied microbiology, 94, 37-46.MoE. (2010). National Adaptation Programme of Action (NAPA) to Climate Change. Kathmandu: Government of Nepal, Ministry of Environment

Smith, K.R., A. Woodward, D. Campbell-Lendrum, D.D. Chadee, Y. Honda, Q. Liu, J.M. Olwoch, B. Revich, andR. Sauerborn, 2014: Human health: impacts, adaptation, and co-benefits. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to theFifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge UniversityPress, Cambridge, United Kingdom and New York, NY, USA, pp. 709-754.MacFarlane, E. K., Shakya, R., Berry, H. L., & Kohrt, B. A. (2015). Implications of participatory methods to address mental health needs associated with climate change: 'photovoice' in Nepal. BJPsych Int, 12(2), 33-35.

Malecki, K. C., Resnick, B., & Burke, T. A. (2008). Effective environmental public health surveillance programs: a framework for identifying and evaluating data resources and indicators. Journal of Public Health Management and Practice, 14(6), 543-551.

MoHP. (2017a). National Preparedness and Response Plan for Acute Gastroenteritis/Cholera Outbreaks in Nepal July 2017 to July 2022. Kathmandu.

MoHP. (2017b). Nepal Health Sector Programme III (NHSP 3): Framework for improved management of health information in the context of federal governance structures. . Kathmandu: MOHP/DFID.

MoHP (2018). Malaria Micro Stratification. . Kathmandu: Department of Health Services, Epidemiology and Disease Control Division.

MoHP (2015). Cliamte change and health vulnerability and adaptation assessment: Ministry of Health and Population and World Health Organization

Moulton, A. D., & Schramm, P. J. (2017). Climate change and public health surveillance: toward a comprehensive strategy. Journal of public health management and practice: JPHMP, 23(6), 618

Marinucci, G., Luber, G., Uejio, C., Saha, S., & Hess, J. (2014). Building resilience against climate effects—a novel framework to facilitate climate readiness in public health agencies. International journal of environmental research and public health, 11(6), 6433-6458.

MOHP/WHO (2014). Vulnerability and Adaptation Assessment of the Health Sector in Nepal (Unpublished.)

Morand, S., Owers, K. A., Waret-Szkuta, A., McIntyre, K. M., & Baylis, M. (2013). Climate variability and outbreaks of infectious diseases in Europe. Sci Rep, 3, 1774.

Moser, S.C., Ekstrom, J.A. A framework to diagnose barriers to climate change adaptation. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 22026–22031

Nsubuga P, Nwanyanwu O, Nkengasong JN, Mukanga D, Trostle, M (2010). Strengthening public health surveillance and response using the health systems strengthening agenda in developing countries. BMC Publ Health, 10(1):S5.

Pant, Kumar, D., Tenzin, T., Chand, R., Sharma, Kumar B., & Bist, Raj P. (2017). Spatio-temporal epidemiology of Japanese encephalitis in Nepal, 2007-2015. PLoS One, 12(7), e0180591. doi:10.1371/journal.pone.0180591

Pyle, D. F., Nath, L. M., Shrestha, B. L., Sharma, A., & Koirala, S. (2004). Assessment of Early Warning and Reporting Systems (EWARS) in NEPAL. Health, Infectious Diseases and Nutrition Bureau for Global Health U.S. Agency for International Development Washington, DC 20523, EHP Project 26568/E.X.NE6.TE.SURVEIL

Ramadona, A. L., Lazuardi, L., Hii, Y. L., Holmner, Å., Kusnanto, H., & Rocklöv, J. (2016). Prediction of dengue outbreaks based on disease surveillance and meteorological data. PLoS One, 11(3), e0152688.

Shi, Y., Liu, X., Kok, S.-Y., Rajarethinam, J., Liang, S., Yap, G., . . . Chin, C. K. Y. (2015). Three-month real-time dengue forecast models: an early warning system for outbreak alerts and policy decision support in Singapore. Environmental health perspectives, 124(9), 1369-1375.

Santosa, A., Wall, S., Fottrell, E., Hogberg, U., & Byass, P. (2014). The development and experience of epidemiological transition theory over four decades: a systematic review. Glob Health Action, 7, 23574. doi:10.3402/gha.v7.23574

Seltenrich, N. (2015). Between Extremes: Health Effects of Heat and Cold. Environ Health Prospect, 123(11), A275-280. doi:10.1289/ehp.123-A275

Smith, J. B., Dickinson, T., Donahue, J. D., Burton, I., Haites, E., Klein, R. J., & Patwardhan, A. (2011). Development and climate change adaptation funding: coordination and integration. Climate Policy, 11(3), 987-1000.

Thacker, SB, Stroup, DF. (1994). Future directions of comprehensive public health surveillance and health information systems in the United States. Am J Epidemiol. 140:1-15.

Vairo, F., Di Pietrantonj, C., Pasqualini, C., Mammone, A., Lanini, S., Nicastri, E., . . . Puro, V. (2018). The Surveillance of Chikungunya Virus in a Temperate Climate: Challenges and Possible Solutions from the Experience of Lazio Region, Italy. Viruses, 10(9), 501.

WHO (2006), Joint National/International Review of Acute Flaccid Paralysis (AFP) Surveillance – Nepal. Regional office for South Asia, Delhi

WHO (2011), Nepal Malaria Program Review. Reginald office for South Asia, Delhi

WHO (2018), Climate change and health: Key factor. Available on line(https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health) [Cited on 5/5/2019].

WHO and CDC (2010). Technical Guidelines for Integrated Disease Surveillance and Response in the African Region, Brazzaville, Republic of Congo and Atlanta, USA,: 1-398. World Health Organization and Centers for Disease Control and Prevention. https://www.afro.who.int/publications/technical-guidelines-integrated-disease-surveillance-and-response-african-region-0 (Accessed on 2/1/2019)

WHO/UNDP (2010), Climate change adaptation to protect human health: global project on public health adaptation. **https://www.who.int/globalchange/projects/adaptation/en/** (Retrieved on 10 Jan 2018).

McSweeney, C., New, M., Lizcano, G., & Lu, X. (2010). The UNDP Climate Change Country Profiles: Improving the accessibility of observed and projected climate information for studies of climate change in developing countries. Bulletin of the American Meteorological Society, 91(2), 157-166.

Yang, W., Li, Z., Lan, Y., Ma, J., Jin, L., Lai, S., . . . Wang, J. (2017). China Infectious Diseases Automated-Alert and Response System (CIDARS) Early Warning for Infectious Disease Outbreak (pp. 133-161): Elsevier