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**Original Article**

# Assessing Climate Change and Heat Stress Responses in the Tarai Region of Nepal

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**Abstract: This paper intends to analyse responses of the working people to heat stress in Nepal's Tarai region. Here, the heat stress responses refer to the working environments– indoor and outdoor settings, prevailing diseases, and adaptive measures by the workers. Data were gathered from the sample households by using household survey, observation, and informal discussions. Environmental conditions in terms of heat exposure in the working areas have been measured with heat index, humidity index, and WBGT, based on the HOTHAPS approach. The findings are that: the average temperature during the peak hot months reached to over 39 °C and the environmental conditions in the selected factories during the hot summer months were too hot to the workers to work continuously during the day, where there was inadequacy of facilities to combat against the hot. Males were more exposed than females to the heat due to heavy type of works in outdoor settings. Few workers found to have adapted coping measures such as shift in working time, wearing thin cotton clothes, etc but they were inadequate against the heat stress. More quantitative measurements of workers' health effects and productivity loss will be of interest for future works.**

**Key words:** Heat stress, Rising temperature, HOTHAPS, Working environments, Adaptive strategies

## Introduction

Heat stress is an unusual phenomenon that occurs especially in the areas, where environment temperature is excessively hot and affects on the people who work without any precaution against such excessive heat. The people response differentially to heat stress and some of them are more susceptible to it than others. Typical symptoms of heat stress are many, such as muscle cramps, heat rash, severe thirst, faint, heat exhaustion, fatigue, giddiness, nausea, headache, heat stroke, hot dry skin, confusion, convulsions, and eventual loss of consciousness[1, 2]. Direct response of heat stress is the failure of temperature control of body[3]. McMichael *et al.* (2003), Costello *et al.* (2009), Kjellstrom (2000, 2009)[4–7] have concerned in their studies with the increasing health risks due to direct heat exposure across different parts of the world.

Nepal has been experiencing a warming temperature at 0.6 °C per decade over the last few decades[8]. It is recorded that the health of general people, particularly in Nepal's hot region has been affected due to the heat stress during hot summer season[9], but no studies are available on heat

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exposure and its effects on the health of different working groups of the people. This paper intends to portray the responses of the working groups to heat stress in Nepal.

## Subjects and Methods

The data and information related to the working groups' responses to the heat stress were acquired by using questionnaire survey, observation checklist and data logger from two districts such as Bara and Parsa located in the south-central Tarai region of Nepal (Fig.1).

*Household survey*

Altogether 120 out of 550 total households from four villages lying in the peri-urban areas; two villages each of those two districts were selected randomly during the field survey in 2010. The total household heads contained 61 males and 59 females and represented the people working in both indoor and outdoor environments (Table 6). The questionnaires administered to the sample household heads acquired data on economic activities, type and duration of works, working environments, and knowledge and responses such as diseases, work efficiency, disturbances in work, and coping strategies to the heat stress.

*Observation survey*

Two important types of factories such as iron and soap; two each located in the two districts were selected for case studies. The working environments and facilities of those factories such as ventilation, fans/air condition, drinking water tap, resting places, and surrounding environments (open space, shade, greenery, and garden) were observed and recorded on the observation protocols, while the information on clothing, duration of works, working breaks, precaution measures, and problems of the workers were gathered from the checklist.

In addition, informal discussions were also held with the authorities of the concerned factories and health institutions about the heat stress and health of the workers.

Prior to the surveys, informed consents from the respondents, including the sample household heads, factory owners, health care departments, and department of community medicine and public health of Tribhuvan University were taken to collect required information.

*Data logger and recording of data*

The data logger[1] was used to record temperature, humidity and dew point by hour at the working sites during the summer season from May (dry month) through September (wet month). One data logger was set up in each of those two factory-houses for a week and likewise six data loggers were set up randomly in six houses of the sample households; three each in the two districts for a week. One data logger was hung up in each house of the two districts for six months.


**Fig. 1. Study districts in Tarai region of Nepal.**

*Methods of Analysis*

The environmental conditions of both indoor and outdoor settings have been measured and analysed. Each of those data-loggers was plugged into the USB port of the computer. The data were processed and the data outputs were analysed by Excel programme to show distribution, mean, coefficient of variation, trend by time/day intervals, and co-relations. Heat index and humidity index were obtained by HOTHAPS (High Occupational Temperature Health and Productivity Suppression) approach to measure the state of the heat stress[10)]. The results such as heat stress, diseases and probable impacts have been compared to the already established references of Heat Index (HI), Humidex and the Wet Bulb Global Temperature (WBGT). The reference tables such as International Standards Organization (ISO) (1982) and NIOSH (1986) are given in appendixes 1–3.

*(i) Wet Bulb Global Temperature*[11)]

The WBGT has been obtained by using the following equation:

$$WBGT = 0.567 \times Ta + 0.393 \times e + 3.94$$

Where,

[1] The logger of the Lascar EL-USB-2-LCD (Kjellstrom *et al.* 2009) measures and stores up to 16,379 relative humidity (RH) and 16,379 temperature readings over 0 to 100% RH and −35 to +80°C (−31 to +176°F) measurement ranges. It can easily set up and the data and view can be downloaded by plugging the module into a PC's USB port and using the supplied software. It has capacity to measure hourly data over a year.

**Table 1. Heat status of the factories**

| Parameters | Soap Industry (°C) | | | | Iron industry (°C) | | | |
|---|---|---|---|---|---|---|---|---|
| | Temp | WBGT | HI | Humidex | Temp | WBGT | HI | Humidex |
| Maximum | 40 | 34 | 51 | 52 | 44 | 36 | 50 | 53 |
| Minimum | 31 | 30 | 36 | 41 | 33 | 31 | 38 | 42 |
| Average | 34 | 32 | 43 | 47 | 36 | 34 | 42 | 47 |
| SD | 2 | – | – | – | 3 | – | – | – |
| CV (%) | 6 | – | – | – | 7 | – | – | – |

Temp = temperature; SD = standard deviation; CV = coefficient of variation; WBGT = Wet Bulb Global Temperature; HI = Heat Index; HMD = Humidex.

Ta = Dry bulb temperature (°C)
e = Water vapour pressure (hPa) (humidity)
The vapour pressure has been calculated from the temperature and relative humidity using the equation:
e = rh / 100 × 6.105 × exp (17.27 × Ta / (237.7 + Ta)
Where,
rh = Relative humidity (%)
*(ii) Heat index*(HI) has been calculated only if the actual temperature was above 27 °C, dew point temperatures greater than 12 °C, and relative humidity higher than 40 per cent. The formulae for heat index[12]:
$HI = 16.923 + (1.85 \times 10^{-1} + T) + (5.379+RH) - (1.003 \times 10^{-1}*T*RH) + (9.412 \times 10^{-3}*T^2) + (7.289 \times 10^{-3}*RH^2) + (3.454 \times 10^{-4}*T^2*RH) - (8.149 \times 10^{-5}*RH^3) + (1.021 \times 10^{-5}*T^2*RH^2) - (3.864 \times 10^{-5}*T^3) + (2.915 \times 10^{-5}*RH^3) + (1.427 \times 10^{-6}*T^3*RH) + (1.975 \times 10^{-7}*T*RH^3) - (2.184 \times 10^{-8}*T3*RH^2) + (8.433 \times 10^{-10}*T2*RH^3) - (4.819 \times 10^{-11}*T^3*RH^3)$
*HI* = Heat Index
*T* = Temperature
*RH* = Relative Humidity (%)
*(iii) Humidex*[13]
The formula for the Humidex as below:
Humidex = (air temperature in Celsius) + *h*
h = (0.5555)*(e − 10.0)
e = 6.11 * exp [5417.7530 * (1/273.16) − (1/dew point in kelvins)]

## Results

*Brief introduction to the study area*

The Tarai of Nepal is a plain region (<300 masl), lying in the sub-tropical climatic zone, where the summer temperatures remain always above 30°C[14]. The climate across the Tarai region is characterised by fluctuation in air temperature between hot summers and cool winters. While hot waves, locally known as "*loo*" prevail during the dry hot summer months, cold waves or "*sheet lahari*" occur during the peak cool winter months. Humidity remains excessively high during the Monsoon rainy summers. It is the important economic region of Nepal in terms of the agricultural and manufacturing productions.

The study area comprising two adjoining districts of Bara and Parsa shares about 13 per cent of the country's total manufacturing industries and 15 per cent of the total factory workers[15]. In 2001, Bara and Parsa districts had population of 559,135 and 497,219, which grew from 415,718 and 372,524 respectively in 1991 (CBS 2003). The densities of population of the two respective districts were 470 and 367 per km$^2$ in 2001. These densities show much higher over the national population density of 157 persons per km$^2$. Kalaiya and Birganj are the headquarters as well as the municipal towns (urban areas) of Bara and Parsa districts respectively and Birganj is the fifth largest sub-metropolis of Nepal.

*Characteristics of the sample households*

The average household size of the sample households (n=120) was 7.3, which was quite higher than the national average of 5.6 (CBS 2003). The males were higher (50.8%) than the females (49.2%) in the sample household heads. Over 62 per cent household heads derived their living from agriculture, mostly of subsistence nature and some earned supplementary income from selling of vegetables, milk, labours and rickshaw pulling, and so on. About 21 per cent household heads were factory workers and coolies (Table 6).

*Working environments*

The working environments refer to the conditions and the facilities within the factories and the living houses (indoor), as well as of the farm-fields, the bazaars and other activities (outdoor).

Indoor – factories

The average temperatures and environmental conditions

**Table 2. Heat status of living house**

| Parameters | Living house (°C) | | | |
|---|---|---|---|---|
| | Temp | WBGT | HI | HMD |
| Maximum | 34 | 32 | 43 | 47 |
| Minimum | 32 | 31 | 40 | 44 |
| Average | 33 | 32 | 41 | 46 |
| SD | 0.9 | | | |
| CV (%) | 2.8 | | | |

Temp=temperature; WBGT=Wet Bulb Global Temperature; HI=Heat Index; HMD=Humidex.

**Table 3. Heat status of Agricultural fields**

| Parameters | Agricultural fields (°C) | | | |
|---|---|---|---|---|
| | Temp | WBGT | HI | HMD |
| Maximum | 42 | 35 | 52 | 53 |
| Minimum | 31 | 31 | 39 | 44 |
| Average | 34 | 33 | 45 | 48 |
| SD | 3.3 | – | – | – |
| CV | 9.7 | – | – | – |

Temp=temperature; WBGT=Wet Bulb Global Temperature; HI=Heat Index; HMD=Humidex.

**Table 4. Heat status of bazaar (market place)**

| Parameters | Market place fields (°C) | | | |
|---|---|---|---|---|
| | Temp | WBGT | HI | HMD |
| Maximum | 36 | 33 | 47 | 50 |
| Minimum | 31 | 31 | 39 | 44 |
| Average | 33 | 32 | 42 | 46 |
| SD | 1.3 | – | – | – |
| CV | 3.9 | – | – | – |

**Table 5. Duration of working hours**

| Description | % of working hours (n = 50M +50F)* | | | |
|---|---|---|---|---|
| | Outdoor | | Indoor | |
| | Male | Female | Male | Female |
| (i) Working hours | | | | |
| 1–3 | 30 | 70 | 40 | 20 |
| 4–8 | 50 | 20 | 35 | 60 |
| > 9 | 20 | 10 | 25 | 20 |
| (ii) Type of works by gender | | | | |
| Light | 20 | 40 | 10 | 50 |
| Mild | 40 | 30 | 40 | 45 |
| Heavy | 40 | 30 | 50 | 5 |

*Includes only those responded to our questions out of 61 males (M) and 59 females (F).

vary between the soap and iron factories (Table 1). In all five parameters of temperature, viz. maximum, minimum, average, SD, and CV, the iron factory exceeds the soap factory. Likewise, the WBGT and Humidex also are higher in the former than in the latter factory, while in HI there is mixed result.

Indoor – living houses

Compared to the temperature parameters and environmental conditions of the factories, they are quite low in the living house. As shown in Table 2, the heat status of the living houses is measured at 34 °C average temperature with quite low variation.

Outdoor – agricultural fields

The heat status of the agricultural fields is measured at 34 °C, with maximum temperature of 42 °C and there is quite variation in the temperature recorded among the sites and during the whole 24 h duration (Table 3).

It was obtained from the informal discussions with the farmers that they were used to work in the morning and in the late afternoon for the summer crops, including the paddy crop, which is the principal staple crop of all farmers.

Outdoor – bazaars (Market place)

The average temperature of the bazaars including both permanent shops and hāts (periodic markets) is measured at 33 °C (Table 4), which is lower than that of the agricultural fields. The variation in temperature condition is also less in the bazaars than in the agriculture field.

However, it was observed that the bazaars remained to be deserted during the hot mid-day and the marketing activities found to be slowly disappeared before dusk, due to long way walk back to village-homes.

Works by gender perspective

The duration of the working hours found to be varied between males and females in both indoor and outdoor environments. Table 5 shows that the average duration of working hours at outdoor was higher for the males than for the females, and that at the indoor setting the reverse was the case between males and females.

Similarly, the types of work also varied considerably between males and females. Of the 50 females responded, majority of them appear to have engaged in light works (household chores– indoor environment) and mild works (animal grazing, cutting grass, fetching drinking water–

**Table 6. Average hours work per day by seasons (n=120)**

| Occupation types | f* | Average working hour | | Comparison of work efficiency |
|---|---|---|---|---|
| | | Winter | Summer | |
| Pottery worker | 5 | 10 | 10 | Equal |
| Iron-grill worker | 8 | 8 | 10 | Greater in winter |
| Brick kiln worker | 4 | 8 | 12 | Greater in winter |
| Factory worker | 15 | 8 | 12 | Intermittent |
| Coolies | 10 | | | |
| Rickshaw driver | 28 | 10 | 12 | Greater in winter |
| Cook | 6 | 9 | 10 | Good in winter |
| House wife | 50 | No limitation | No limitation | No change |
| Farmer | 75 | Intermittent | | More in winter |
| Teacher | 10 | 8 | 8 | Equal |
| Student | 20 | No fixed | | |
| Shopkeeper | 18 | 14 | 16 | Equal |

*Multiple responses to the occupations.

**Table 7. Monthly average temperature, relative humidity and dew point**

| Months | Temperature (°C) | | | | | Relative humidity (%) | | | | | Dew point (°C) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MX | MN | AV | SD | CV | MX | MN | AV | SD | CV | MX | MN | AV | SD | CV |
| May | 41 | 29 | 33 | 3 | 8 | 77 | 41 | 62 | 9 | 14 | 25 | 25 | 25 | 1 | 3 |
| June | 41 | 27 | 33 | 2 | 7 | 84 | 46 | 66 | 10 | 15 | 27 | 25 | 25 | 1 | 5 |
| July | 43 | 26 | 31 | 3 | 10 | 95 | 40 | 77 | 11 | 14 | 26 | 25 | 26 | 1 | 3 |
| Aug | 43 | 25 | 31 | 3 | 10 | 96 | 49 | 79 | 11 | 13 | 29 | 25 | 27 | 1 | 3 |
| Sep | 39 | 27 | 31 | 3 | 8 | 87 | 56 | 80 | 7 | 9 | 29 | 25 | 27 | 1 | 4 |

MX=maximum, MN=minimum, AV=average, SD=standard deviation, CV=coefficient variance.

outdoor environment), while the most males found have worked in heavy works (factories, cook in hotel and restaurants, rickshaw pulling, coolies– outdoor environment) and mild works such as building construction − mason, carpenter (Table 6).

It was obtained from the informal discussions and observation that, the social features of the female workers were that, those with above 15 yr of age were used to work mainly with the household chores such as cooking, cleaning, and washing, taking care of children and older people, fetching the livestock for grazing, and occasionally planting, weeding and harvesting in the agriculture fields. Some of those with below 15 yr of age were also found to be involved in raising goats, fetching fodder grasses for livestock and helping in cleaning and washing at home.

Work efficiency

Based on the discussions with the concerned authorities, the information shown in Table 6 is that, the duration of works is longer in summer than in winter in some of the wage workers, due to longer days, taking frequent rests, or longer mid-day off by the workers. As per the factory production record and the workers' experience, the work efficiency is indeed higher in the winter than in the summer.

*Heat stress exposures*

Heat stress pattern

The monthly average temperature is 31 °C and above (Table 7). The maximum temperature has gone up to 43 °C in July-August, with coefficient of variance being ranged from 7 to 10 percent. Two months such as July and August were characterised by lowest minimum temperatures, highest coefficient of variance, highest maximum relative humidity, and maximum dew point. Figs. 2 and 3 exhibit hourly temperature, relative humidity and dew point recorded at the headquarters towns, viz Birganj and Kalaiya of the two study districts − Parsa and Bara respectively.

The diseases

The heat stress syndromes in the study region were faint, tension, irritation, and laziness. The people used to

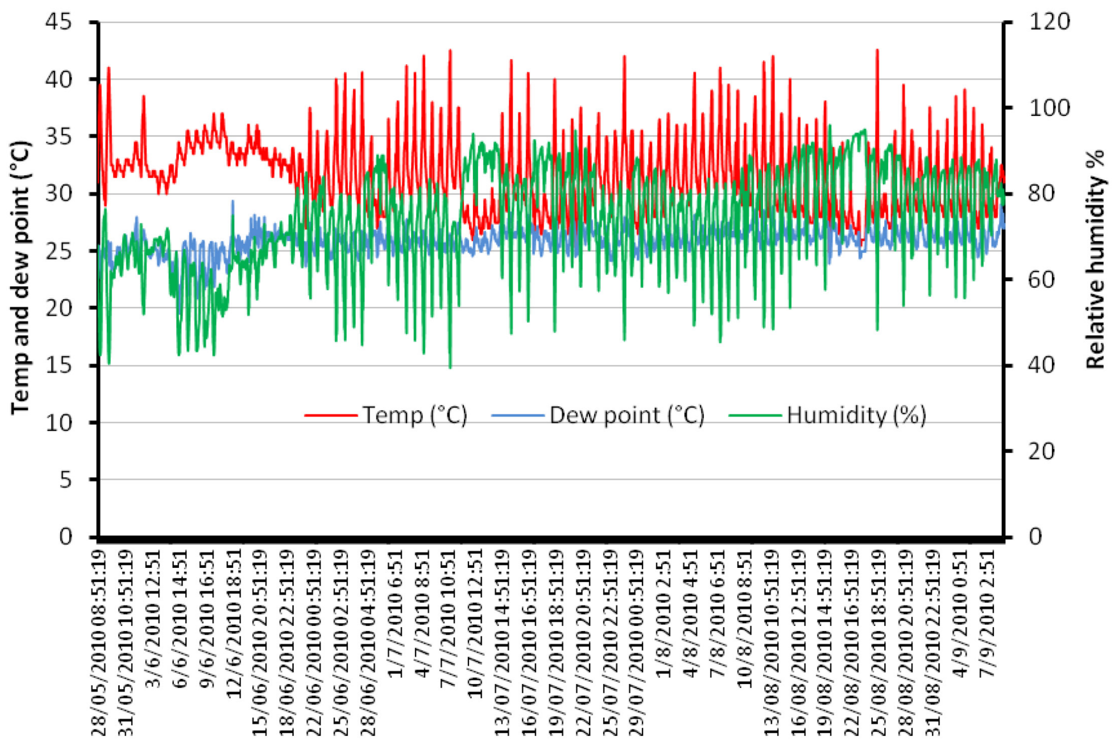


**Fig. 2. Daily hourly record of temperature, relative humidity and dew point, Birganj.**

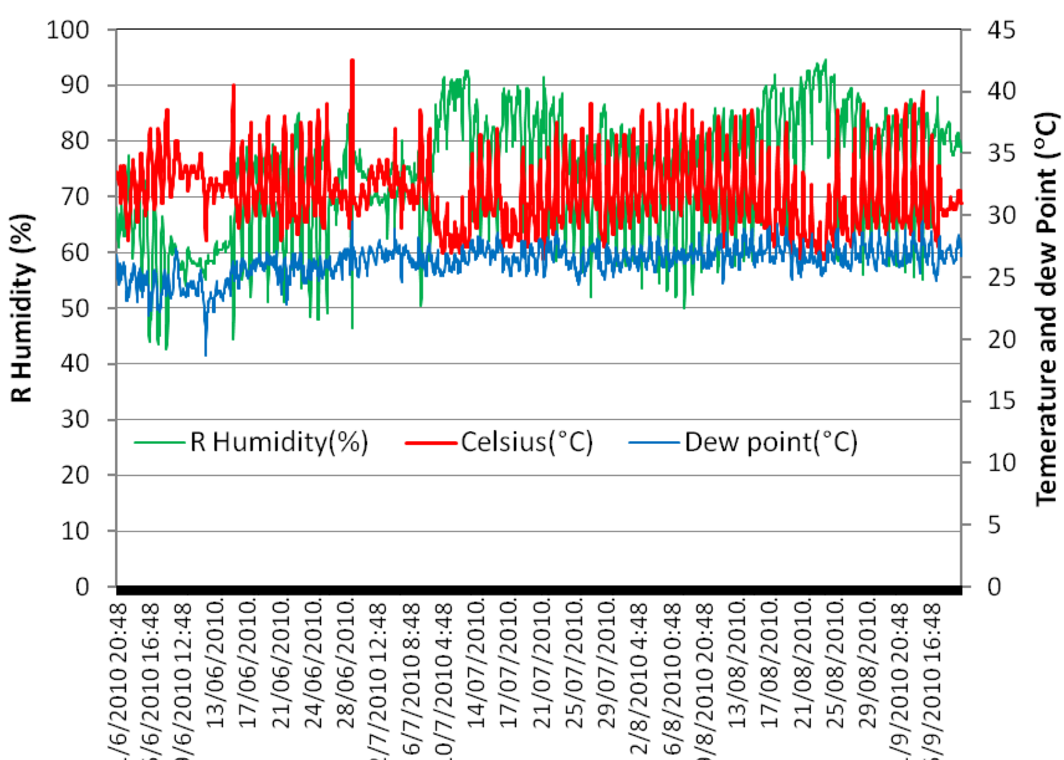


**Fig. 3. Daily hourly record of temperature, relative humidity and dew point, Kalaiya.**

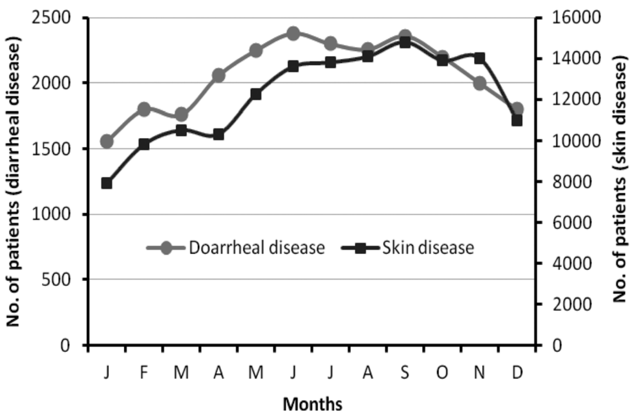


**Fig. 4. Diarrheal and skin diseases by month.**

**Table 8. Adaptation measures (n=120)**

| Coping measures | *f* | % |
|---|---|---|
| Run fan | 105 | 87.5 |
| Drink cold water | 104 | 86.7 |
| Use wet clothes | 100 | 83.3 |
| Bathing in cold water | 99 | 82.5 |
| Wear thin cotton clothes | 70 | 58.3 |
| Cover face by wet white clothes | 60 | 50.0 |
| Change work time | 45 | 37.5 |
| Avoid work | 43 | 35.8 |
| Sleeping/rest | 40 | 33.3 |
| Sitting under tree shade | 27 | 22.5 |

*f* = Frequency.

feel doing nothing and spend most of the nights without sleep due to intensified heat. They used to get sleep only in the early morning between 4–6 am. Other common syndromes due to heat stress included mental irritation, regular dehydration, and giddiness.

During the peak hot months, the people used to get the heat stress induced by heat waves. The survey indicates that about 20 per cent of the people were estimated to have harshly affected by heat waves during the hot season. One instance during the field survey was that one man got to be hospitalized and was on the verge of death due to heat stress and dehydration. The main syndromes prevailed during the extreme hot season were rash, diarrhoea, typhoid, eye infection, appetite loss, urinary tract infection, unconsciousness, fit, hypertension, irritation, fever, leg swelling, boils, and malaria. The outpatients' record at hospitals of Birganj[16)] showed higher frequency with diseases of diarrheal and skin during the hot and rainy summer months (Fig. 4).

*Coping strategies adapted*

The customary coping measures adapted by the respondents against the heat stress syndromes as depicted in Table 8 indicate that they found to have used multiple options to get rid of the heat stress. In terms of relative frequency, two of the most frequently used practices were running fan (if not load shedding) and drinking water.

During the intense hot evening, sleeping inside the house was almost impossible, while sleeping on the roof top was also difficult due to mosquitoes. To get rid off from the heat stress, the option adopted by the people in the towns was to increase the floor height (≥9 ft) with lots of cross ventilations. But in the rural areas, the people had to sleep inside the houses with limited or no windows, though thatched roofs, because of the thief and snake bite.

## Discussions

The average temperature during the hot summer season in the study region has been recorded at ≥30 °C. Baidya *et al.* (2008)[17)] show an increase of temperature up to 3 °C during the summer months between now and some decades ago. According to NAPA (2010)[18)], it is projected that the mean annual temperature with a multi-model across Nepal will increase by 1.4 °C, 2.8 °C and 4.7 °C by 2030, 2060 and 2090 respectively and that the frequency of hot days and nights in summer will increase by 15–55 per cent and 6–77 per cent respectively by 2060. The perceived feeling of the local people also indicates that the temperature has risen. Reasons for rise in temperature in the study region might include change in land use patterns such as decrease of vegetation coverage, rapid urbanization, increase of blacktop roads, increase of manufacturing industries, etc. For instance, the urban areas of Birganj and Kalaiya grew by 63 per cent and 74.4 per cent respectively during the 1991–2001 decade (CBS 2003)[2]. The average forest coverage decreased from 51 per cent in 1986 to 42.3 per cent in 2000[19, 20) 3]. The construction of road length increased from 200 km in 1990 to 545 km in 2002[21)]. The number of motor vehicles has also increased with over 10 per cent by year across the Tarai urban areas[22)].

Most of the factories in the Tarai, including the Bara and Parsa districts did not have indoor facilities for work under hot environment[23)]. The concerned government authorities have given priority neither to the provisions of health risk

[2] The population of Birganj municipality (urban area) increased from 69,005 in 1991 to 112,484 in 2001 and likewise the urban population in Kalaiya municipality grew from 18,498 in 1991 to 32,260 in 2001.

[3] The forest coverage of the study region includes the percentile area of both Bara and Parsa districts of both years: 1986 and 2000.

**Table 9. Measuring heat stress by heat index, Humidex, and WBGT**

| Month | Heat index (°C) | | | Humidex (°C) | | | WBGT (°C) | | |
|---|---|---|---|---|---|---|---|---|---|
| | AV | MX | MN | AV | MX | MN | AV | MX | MN |
| May | 41 | 51 | 30 | 45 | 53 | 40 | 31.5 | 34 | 29.8 |
| June | 43 | 60 | 30 | 46 | 55 | 38 | 32.7 | 34.8 | 28.9 |
| July | 41 | 53 | 31 | 44 | 56 | 38 | 32.5 | 35.2 | 29.2 |
| Aug | 42 | 55 | 30 | 45 | 61 | 36 | 31.8 | 36.8 | 28.4 |
| Sept | 41 | 59 | 32 | 45 | 55 | 39 | 31.9 | 34.9 | 29.2 |

Source: Field survey 2010.

mitigation of the working groups[24] nor monitored about the provision of facilities in the working areas, particularly the factories. In our study, the workers with different occupations, irrespective of gender have worked more than 8 h a day. According to the Nepal Labor Act (1992), the daily working hours has been fixed at 8 h irrespective of the seasons − hot and cold. This could be reasonable, if the indoor facilities were provided to work under extreme hot and cold, or alternatively there should be provision of shifts of work suitable to working environment. But there is neither an approach such as shift of work schedule such as morning and evening nor is provision of facilities for work in most cases in our study region. Under no such circumstances, if the workers work for 8 h continuously during the peak hot summer months, their health condition and work productivity will be deteriorated due to heat stress.

The living houses in the rural settings were mostly of traditional types, made up of thatched roofs and *khapada* (clay curved tiles) and brick walls with mud plaster. These housing structures are primarily for protecting and preventing from intense heat. The rural traditional houses were mostly of one storey having a single room and a single door without ventilated windows. As such, they were made primarily to keep away from poisonous snakes, flies and other insects. Living, cooking, etc were held in the same room. Few houses in the rural villages were of modern concrete buildings.

The houses in Nepal are classified into three types: *Kachchi, semi-Pakki*, and *Pakki* in terms of vulnerability of physical structure (CBS 2003). The Kachchi houses, the most vulnerable for living in Kalaiya and Birganj shared 29 and 13 per cent respectively and the rest 71 and 87 per cent comprised of *Pakki* (less vulnerable) and *semi-Pakki* houses (CBS 2003). Majority of the houses in rural areas are of *Kachchi* and that also belonged to poor workers.

Heat stress affects human health. Excessive rise of temperature above the core body temperature may affect on work and health of the people in both indoor and outdoor environments. Work load also affects the work productivity and health under excessive hot condition. If high work intensity in the workplaces with high heat exposure continues, serious health effects including heat stroke and death can occur. Excessive dehydration during the work also affects health. Morbidity and mortality due to heat stress record was not given in priority[25]. Due to poorness, the workers were not even aware or able enough to adapt coping measures to the heat stress and its health consequences such as morbidity and mortality, but to work in the factories. According to ISO (1982)[26]and the National Institute for Occupational Safety and Health (1986; 1992)[27, 28], some measures to exposed workers to reduce the impact of heat stress are temperature control, provision of mechanical aids (fan, air condition), dehydration prevention, provision of personal protective equipment, allowing workers to acclimatize, etc.

However, our informal discussions with the workers indicate that some of them found to have adopted simple local measures such as the working hours being divided into two shifts to escape from the extreme heat during the hot summer months, such as: (i) 6−11am and (ii) 3–7 pm. During the winter, there was only one shift of working hours that ranged from 9 am to 5 pm.

In some cases, our data also show an unlimited working hour to the workers in the agricultural fields even during the hot summer months. The working people with low and middle-incomes were the most vulnerable, because most of them were involved in heavy physical work, either in outdoor settings under strong sunlight or indoors without effective cooling.

Also found in our study region was that the children with below 15 yr of age were involved in raising goats, fetching fodder grasses for livestock and helping in cleaning and washing at home. It has a serious implication to child education. It was found that about 80 per cent of the school aged children got admission in the schools, but 50 per cent of them used to go to school[29]. Dropout rate was higher among the girls, especially the adolescent age (80%) than the boys at the lower secondary levels (6–8 grades).

WBGT, heat index and humidex

The HOTHAPS data analysis includes Heat Index (HI), Humidex, and WBGT. The HI combines air temperature and relative humidity to determine the human-perceived equivalent temperature[30]. The Humidex differs from the heat index that uses dew point over the relative humidity. Its value is computed to assess the impact of the heat. In WBGT, the vapour pressure is calculated from temperature and relative humidity, indicating work intensity (Table 9).

The three indices − heat index, Humidex and WBGT and their reference values are to verify the heat stress, working conditions, possible consequences of heat stress and some adaptive measures against to the heat stress in the study region. The tables with reference values are provided in annexes 1–3.

The observation of maximum temperature record does not allow the laborers to do any kind of work. The minimum temperature recorded at the sites is recommended to do light work and medium work with 25 per cent rest/hour. The average temperature indices fall into high status. The average monthly HI value ranges from 40° to 43 °C. All the values from May through September except June lie in the zone of extreme caution. The heat index values for June lie in a danger state where heat cramps, and heat exhaustion are likely to occur and if work continues, probability of heat stroke would be very high. The maximum heat index value is in extreme danger state. If proper precaution is not taken the chance of heat stroke is high.

The Humidex (°C) value shows that the temperature has gone to dangerous discomfort level. According to the WBGT classifications, the monthly average wet bulb global temperature index is that, the value during May-September is 25 per cent rest/hour for light work. The monthly average variation recorded is not remarkable at both sites (urban areas). In rural house, the average WBGT value suggests 100 per cent rest/hour.

The average values of heat index for both soap and iron industries indicate high risk status, suggesting severally curtail of the physical activity, ensure sufficient rest/recovery time and drink a cup of water every 10–15 min. The chances of heat cramps and heat exhaustion are likely to occur and the probability of heat stroke is high if activity continues. Similarly, the comfort statuses of the Humidex value suggest that there could be intense discomfort and avoid exertion. The average WBGT values for market place and agricultural field suggest performing 50 per cent rest/hour for light work and 75 per cent rest/hour for medium work.

## Conclusions

Excessive heat in the work environments can lead to serious physical harm, and even to death. Since the average maximum temperature of the peak hot months in the Tarai region of Nepal is above 39 °C, there is more chance to affect the human health due to heat stress. Males were more exposed than females to the heat, as they found to be involved in heavy works and outdoor works. The health record of the Tarai region indicates that the mortality rate has an increasing trend over the last two decades due to heat stress. There has been little or no effort being undertaken by the concerned agencies to combat with the heat stress in the both outdoor and indoor working environments. Few workers have adapted coping strategies such as shift in working time, wearing thin cotton clothes, covering with wet cloths, etc, which however were not adequate to heat stress.

Heat stress is likely to be common during the peak hot months. To reduce its health impacts, first potential risks of the heat stress need to be recognized and then effective adaptation devices like using temperature maintenance devises, protective equipments, adequate time for acclimatization, etc should be provided. Since the heat stress does not have any indications or symptoms like other diseases do, the people having heat stress will have much risk to physical harm or even death. Awareness to the working groups as well as to the factory owner is very essential about the possible indications, health check and impacts of the heat stress. Further, conservation of greenery, reducing vehicle smoke, building housing structures to adapt to physical environments are some of the preventive measures to be undertaken for mitigating heat stress in the rapid urbanizing cities like Birganj.

This kind of study is a first attempt in Nepal's Tarai region, focusing primarily on an understanding of the workers' responses to the heat stress. There is lack of information base on heat stress responses of the laborers working in different sectors, vulnerable groups, health records, etc in Nepal.

As the next step, it will be of great interest to have more quantitative measurements of workers' health effects and productivity loss due to hourly heat levels, which can be used to formulate health policy measures against the heat stress in the contextual manner in Nepal.

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## Appendixes

**Appendix 1. Heat Index: classification and actions recommended**

| Heat Index | Status | Action Recommended |
|---|---|---|
| 30–37 | Low | Post heat stress alerts; drink water |
| 38–39 | Medium | Reduce physical activity (e.g. slower pace, more breaks); drink a cup of water every 20–30 min |
| 40–41 | Moderate | Further reduce physical activity; drink a cup of water every 15–20 min |
| 42–44 | High | Severally curtail physical activity; ensure sufficient rest/recovery time; drink a cup of water every 10–15 min |
| 45+ | Extreme | Hazardous to continue physical activities |

Source: OHSCO (2008): http://ggweather.com/101/hi.htm.

**Appendix 2. Humidex: classification and its impacts**

| Humidex (°C) | Impacts |
|---|---|
| < 30 | Little or no discomfort |
| 30–34 | Noticeable discomfort |
| 35–39 | Evident discomfort |
| 40–45 | Intense discomfort; avoid exertion |
| 46–54 | Dangerous discomfort |
| > 54 | Heat stroke probable |

Source: NIOSH (1992); http://www.hpc.ncep.noaa.gov/html/heatindex.shtml.

**Appendix 3. WBGT: Classification of work intensity**

| Metabolic rate class (work intensity) | Classification of work intensity | | | |
|---|---|---|---|---|
| | Light work WBGT (°C) | Medium work WBGT (°C) | heavy work WBGT (°C) | Very heavy work WBGT (°C) |
| 0% rest/h | 31.0 | 28.0 | 27.0 | 25.5 |
| 25% rest/h | 31.5 | 29.0 | 27.5 | 26.5 |
| 50% rest/h | 32.0 | 30.5 | 29.0 | 28.0 |
| 75% rest/h | 32.5 | 32.0 | 31.5 | 31.0 |
| 100% rest/h | 39.0 | 37.0 | 36.0 | 34.0 |

Source: NIOSH (1986)

0% rest/hour means continuous work, whereas 100% rest means no work at all.