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HEAT WAVES IN ALBANIA, THE ESTIMATION OF THOM'S THERMAL DISCOMFORT INDEX (DI), ITS GEOGRAPHICAL DISTRIBUTION, DURING SUMMER 2019

Tanja PORJA[1], Jostina DHIMITRI[2]

[1]*Department of Physics, Faculty of Natural Sciences and Mathematics, University of Tirana*
[2] *Department of Geography, Faculty of History and Philology, University of Tirana*
[*] *Corresponding author e-mail: jostina.dhimitri@unitir.edu.al*

Abstract

The air temperatures are the first the peoples feel when stepping outdoor. Their values are mainly measured and estimated on daily, monthly, annually and decadal bases, in order to have their short- and long-term changes. The daily maximum, minimum and mean temperatures are the most important values in observing long-term trends in temperature. Heat waves are related to high temperatures and demonstrate rapid periods of extreme warmth with strong impacts on the natural environment and on human health. Nowadays, it is a fact that human activities caused global warming. Year by year, the warming effects became more evident and sensitive.
The aim of this study is:
To highlight the frequency of heat wave phenomenon as one of the extreme weather phenomena that "has not spared" the Albanian territory.
To analyze the type and behavior of the heat phenomenon recorded in Albania, especially during the summer 2019.
To estimate the Thom's Thermal Discomfort Index (DI) for the Western Lowlands during the period of June – August, 2019.
This study was realized based on the classical methods, on a case study and it analyzes the air temperature and relative humidity values during the summer of 2019 over the Western Lowlands of Albania. The DI was calculated from Thom's formula. The data for the calculation have been taken from the readings of the relative humidity and air temperature in the summer months of 2019. The obtained results have an important scientific value, a didactic and managerial importance also during the heat wave situations. The results can assist the operating actors dealing with the study of the extreme weather situations and the geospatial distribution of this phenomenon. These results serve also as an important tool to the decision-makers, especially the authorities acting with the civil emergencies during heat waves events and many other extreme weather phenomena.

Keywords: heat waves, Western Lowland, Thom's Thermal Discomfort Index, emergency management, climate change.

1. Introduction, study area

The area included in the study represents the territory of the western Lowlands, presenting the western part of Albania with a wide outlet to the Adriatic Sea in the west and extends to the foot of the mountains of the mountainous provinces. It has a north-south extension of about 200km and east-west 50 km. The territory is flat with some hilly waves. The relief differs in general, for consistency of the morphology of the relief with the structure and regular intersection of anticline hills with syncline fields (Qiriazi, 2019). The plains are flat and low at sea level: most of them stretch up to 20 m height; only at the eastern ends, this height reaches 50-150 m. There are sectors below sea level: Tërbuf, Divjakë, Talë, Velipojë etc. (QSGJ, 1991). While the hilly part is encountered from sea level up to 932 m (Kerrabe) and 1198 (Mallakaster). The altitudes are at average 400-500 m above sea level. This natural landscape has enabled easier penetration of coastal winds to the interior of the territory. While the mountainous areas on the eastern borders have protected this area from the penetrations of cold climate from the east. There are some changes in the north-south extension at the local

level. The average annual temperature fluctuates from 15 ºC to 16 ºC, while during the summer 24ºC and 25ºC (in July). We emphasize these values, as they include the time span of the study. While the amount of precipitation fluctuates from 1000 mm around Myzeqe to 2000 mm in the northern part of the western Lowlands (Hydrometeorological Institute, 1980). According to Koppen's climate classification with additional modifications by Geiger and Pohl (1953), the territory of Albania belongs to the category Csa (C - moist climates with mild winters, s - dry summers, a - summers long and hot with classification criteria: warmest month > 22ºC with more than 4 months > 10ºC (Holden, 2012). This territory is considered the most populated in Albania, including the biggest residential centers and several metropolitan cities. This region is the main economic center of the country, satisfying the needs for all its sectors, such as agricultural economy, etc. The high concentration of the country's population in this region is accompanied by the increase of urban areas, highlighting the climate modification of urban areas known as the urban heat island. This is so called as the urban area is an “island” of warmer air within the surrounding cooler rural aria. The urban heat island may be disappeared depending on wind speeds and the size of the urban area (Holden, 2012, 173). The total population reaches over 2 million inhabitants, i.e. more than half of the entire population of Albania, while the population density per unit area is 300-400 inhabitants / km2. For the highest population density, the centers of cities such as Tirana (502-682 inhabitants / km2), Durres (517-680 inhabitants / km2), Elbasan (206-236 inhabitants / km2), Fieri (195-317 inhabitants / km2) are distinguished.), Lezhe (208-129 inhabitants / km2), Shkodra (230-155 inhabitants / km2), Vlora (170-315 inhabitants / km2) etc. (Porta vendore.al, 2022). So it can be seen that the Western Lowlands and its population mostly reflect the consequences of climate change of some species such as: inland flood and heat waves.

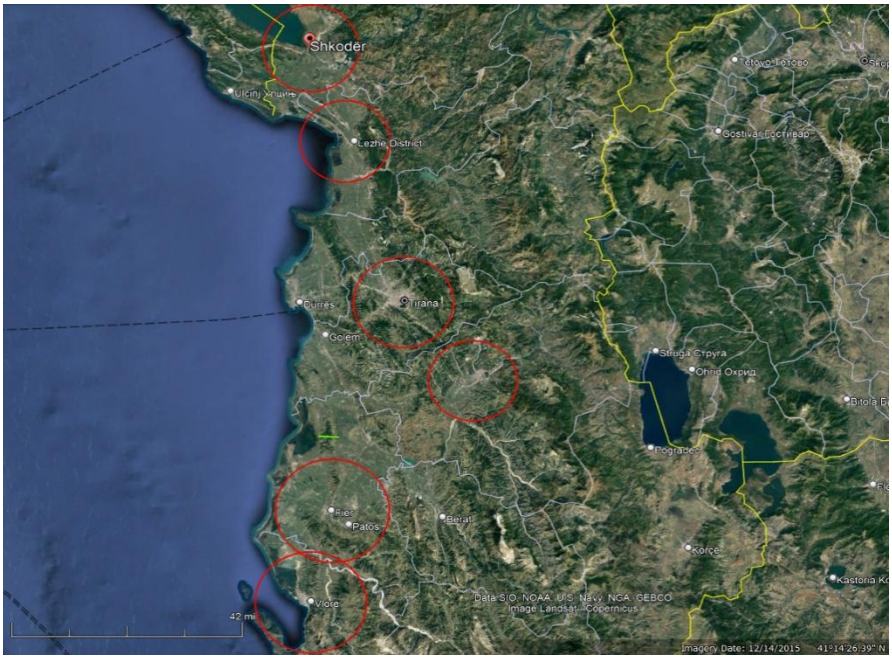


Fig 1. Study areas in Western Albania. Source: Google Earth Pro

Christopherson and Birkeland, (2015) states that studies of past climates, show that present temperatures are higher than at any time during the past 125,000 years. Global temperatures rose an average of 0.17ºC per decade since 1970, and this rate is accelerating. Heat waves are also on the increase. Heat waves are presented during the warmer months and most severe in urban areas. The frequency, intensity and the duration of the high temperatures and the increase of the frequency of heat waves bring challenges to people and their activities.

By definition, a heat wave is a prolonged period of abnormally high temperatures, usually, but not always, in association with humid weather (Christopherson & Birkeland, 2015). In the case of heat waves, the overall definition remains very broad in describing a period of consecutive days where conditions are excessively hotter than normal (Perkins & Alexander, 2013). Hess (2017) considers them the deadliest natural disasters on Earth. Definitions may vary according to why people are concerned about heat waves. For example, many organizations are monitoring global changes in climatic extremes, including heat waves, and they require a common definition. It is proposed that the Heat Wave Duration Index (HWDI) should be adopted for this purpose (Frich et al., 2002, p. 195). The HWDI, measured in days, is defined as:

Maximum period > 5 consecutive days with T_{max} >5°C above the 1961–1990 daily T_{max} normal (Zuo et al., 2015)

Radinović and Mladjen Ćurić (2012) pointed out that the HWDI should "be based on climatic features that permit the comparison of results across climatic zones". Between 1989 and 2006, earthquakes and floods accounted for 17% and 31% of all disasters in Albania, respectively. Globally, Albania ranks 41st for landslide risk, 43rd for earthquakes and 58th for droughts.

Their effects impact the death number in people suffering from heat-related illness or weather- related deaths, elder people and those who work outside. This heat discomfort for humans is the most presented during high air temperatures, high humidity and low winds. The level of the humidity in the air has impact to our ability to cool through evaporation from skin. During the heatwaves, a lot of wildfires occur, risking the land cover, agriculture and forests. There are significant implications associated with heat waves such as extra power consumption, community health, water consumption and quality, and additional costs within the natural and built environments (Zuo J, et al, 2015). Health impacts associated with heatwaves range from sunburn, heat stress and heat exhaustion to kidney failure and heart attacks (Thomas, et al., 2012). According to the Fifth Assessment Report of the Intergovernmental Panel on Climate change, heat waves will last longer, occur more frequently and cover a larger geographic area in the future. Heat-related deaths may triple by 2050s.

Thom's Thermal Discomfort Index (DI) is used to assess the outdoor thermal discomfort. This index estimates if people suffer or no from discomfort due to high air temperature and high relative humidity on human thermal comfort. Normal values of physiological temperature for a neutral thermal sensation in different regions (Ghani S., et. al, 2017): for the coasts of the eastern Mediterranean are in the range 20-25°C, for Hungary are 18-23°C, for Bangladesh are 28.5-32°C (RH over 70%), for India are 29.23°C. Human beings have two basic elements that regulate his comfort: the body and the surrounding environment. When one element changes, the other should be adapted to maintain the thermal equilibrium. Some limited studies have shown that people begin to feel discomfort when the DI indicator is greater than 24. The human perception of thermal comfort is influenced by many factors, so its objective estimation still remains a science challenge.

Increasing the episodes with the heat waves make people feel more discomfort.

Law no. 45/2019, ON CIVIL PROTECTION1 Article 3 point 9, qualifies them as "a natural disaster". "Natural disasters" are disasters caused by extreme natural phenomena, related to earthquakes, floods, extreme and prolonged temperatures, architectural landslides, avalanches, strong winds on land and sea, massive forest fires, massive infective diseases and other phenomena that affect human life, living things, production, natural heritage and the environment ".

Managerial aspects related to heat waves are related to action plan in institutional, medical and cultural point of view, where each country acts to mitigate and adapt to its population.

Study aims to answer the research questions on frequency of heat waves in summer 2019, if episodes remain in the same rate as previous; how the heat discomfort index and the geographical distribution of their values in Western Lowland are expressed.

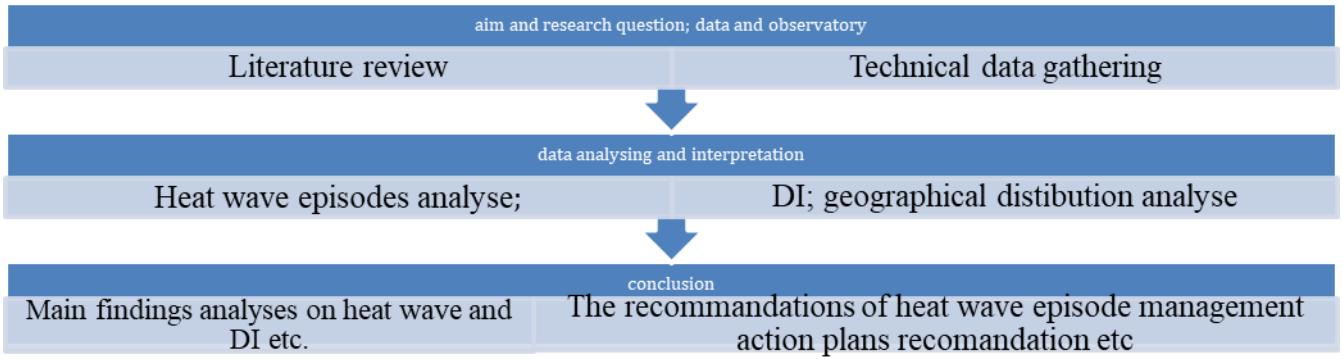
2. Methodology

The territory under the study includes the Western Lowlands where the data are obtained from meteorological automatic stations of Shkodra, Lezhë, Tirana, Fier and Vlorë. The five stations are located in the urban areas. The Western Lowlands region represents the area with the largest population in our country (2/3 of the population are settled in this region, approximately 2 million inhabitants).
Math and statistical calculation were done by Microsoft Excel based on gathered data of mean air temperature and average relative humidity (%) for June - August 2019 and during heat wave episodes. This data are provided by Meteoalb Ltd, a company for consulting and services on hydrometeorology and environment. The type of instruments EE08 Series: High-Precision Miniature Humidity / Temperature Transmitter (THIES CLIMA Germany), the sensor of temperature - Pt 1000 (DIN A) and the relative humidity sensor HC101.
The definition of the heat wave phenomenon for the Albanian territory is based on: a) the threshold estimation value of the daily maximum air temperatures and b) the time duration of the heat wave phenomenon (Fritch, P. 2002). The estimated threshold value satisfies the condition of at least five consecutive days with daily maximum temperatures of at least 5°C above the annual maximum air temperature of 30.2°C (in normal climate). The estimated air temperature threshold for the Western Lowlands counts on 35.2°C.
The DI indicator determines the thermal comfort or discomfort of the population, depending on certain environmental conditions such as 1) air temperature and 2) relative humidity. The DI calculations include values of air temperature and relative humidity that were taken from daily measurements during the interval of 08:00 - 16:00 from the station instruments, for the period May – September 2019. Their average monthly values were calculated and in a second step, calculation of the thermal discomfort indicator was done for the five stations taken in the study (Shkodër, Lezhë, Tirana, Fier and Vlorë).
The used formula is as follow (Thom, 1959, Yousif, & Tahir, 2013):

$$DI = T-(0.55-0.0055LR) (T-14.5)$$

Where DI – Discomfort Index; T = mean monthly temperature in (°C); RH = mean monthly relative humidity of air (%)
The same assessments were made for the days which belong to the heat wave episodes.

Scheme 1. The simplified methodological scheme of research



3. Results and discussion

The threshold value of the daily maximum air temperature at which the areas of the Albanian Western Lowlands are considered in the conditions of the heat wave is estimated at 35.2°C. Beside the "threshold value" of 35.2°C, in the Western Lowlands areas of Albania should at least be recorded, 5 consecutive days with daily maximum air temperatures above 35.2°C.
During the period of 2013 – 2019, in the Albanian Lowlands areas, it resulted a number of 121 days with daily

maximum air temperatures above 35.2°C but not all those days meet the second criterion of lifetime of the phenomenon. During the total of 121 days with maximum air temperatures above 35.2°C, only 59 days meet the criterion of at least 5 consecutive days that exceed the estimated threshold value.

Table 1. Data of episodes and heat wave day number 2015 -2019

Year	No. of day (T≥35.2°C)	Total day (heat waves)	Episodes/year
2015	30	16 days (6; 10 days)	2
2016	10	0 days	0
2017	29	18 days (6; 12 days)	2
2018	19	12 days (5; 7 days)	2
2019	33	13 days (5; 8 days)	2

Table 1 states that during 2015-2019 have happened 8 episodes in 5 years; ≈ 1.6 episodes per year; 121 days with heat waves criteria;

Table 2. Data of episodes and heat wave day number 1980-2014

Month	Number of episodes	Heat wave day number (day)
May	6	49
June	12	126
July	6	52
August	13	129
Total	37 episodes/35 years	356

Table 2 indicates that for period of time 1980-2014 have happened 37 episodes in 35 years; ≈ *1.1 episodes per year*; 356 days with heat waves; 68% of episodes occur between June and July; some episodes happened and before the summer.

The years with the highest number of heat wave days result 2015 and 2019, with 57% of the total number of the heat-wave days.

The years with the longest heat waves episodes result 2015 and 2018, with a maximum of lifetime of respectively 10 and 12 days with daily maximum air temperatures above the threshold.

During the period of 2015 – 2019, the Albanian Western Lowlands areas have averagely been hit around 1.6 times /year by the heat wave phenomenon with time-duration of 5 – 12 days.

The daily maximum air temperatures recorded during the heat waves events belong to the interval of values of (35.3°C - 42 °C).

The heat wave frequency for the Albanian Western Lowlands areas has increased from 1.1 events / year for the period of 1980 – 2014, up to 1.6 events / year for the period of 2015 – 2019.

Referring to table 1, it is noticed that 2019 recorded 2 episodes of heat waves, one of 5 days lifetime and the second of 8 days lifetime. Based on the monthly average air temperature values and the relative humidity as well, the Thom's Thermal Discomfort Index (DI) (Thom, 1959), was estimated for the months of June, July and August and also for the two episodes of the first and second heat wave. Results and findings are reflected in the Tables 3 and 4 with the corresponding Fig ures.

Table 3. Thom's Thermal Discomfort Index (DI) June-August 2019

Meteorological Station	DI_June	DI_July	DI_August
Elbasan	22.7	22.8	23.7
Fier	23.2	23.2	24.2
Lezhe	25.4	25.3	26.2
Shkoder	25.2	25.6	26.4
Tirane	24.0	24.1	25.0
Vlore	23.0	23.6	24.6

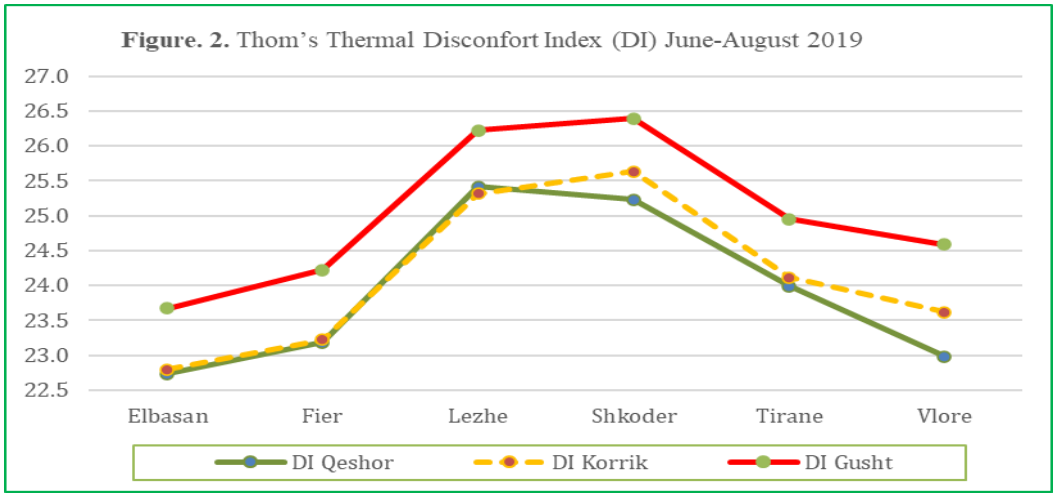


Table 4. Thom's Thermal Discomfort Index (DI) heat wave 1 and heat wave 2 (summer 2019)

Meteorological station	DI Heat wave 1	Tmax_24h Heat wave1	Day/Month/Year	DI Heat wave 2	Tmax_24h Heat wave 2	Day/Month/Year
Elbasan	24.05	38.5 °C	28-06-19	24.3	40.6 °C	24-08-19
Fier	24.43	38.2 °C	29-06-19	25.2	39.2 °C	24-08-19
Lezhe	26.59	36.4 °C	27-06-19	27.4	38.9 °C	23-08-19
Shkoder	26.02	37.2 °C	26-06-19	26.5	40.3 °C	23-08-19
Tirane	25.14	37.7 °C	27-06-19	25.5	39.1 °C	23-08-19
Vlore	23.82	36.6 °C	29-06-19	25.3	38.6 °C	26-08-19

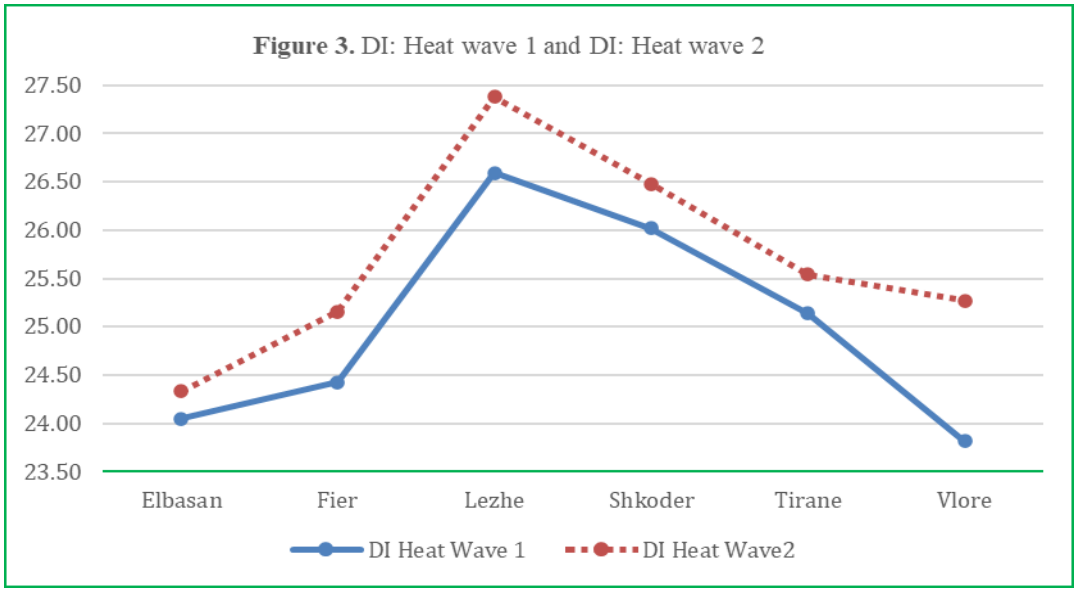


Table 5. Thom's discomfort states (Yousif and Tahir, 2013)

Condition	DI range
No discomfort	**< 21**
Under 50% of population feels discomfort	**21 - 24**
Over 50% of population feels discomfort	**25 - 27**
Most of population feels discomfort	**28 - 29**
Everyone feels stress	**30 - 32**
State of medical emergency	**> 32**

Referring to table 5 and the findings of the study presented in table 3, it is noticed that less than 50% of the population of the urban areas of Elbasan, Fier and Vlora feel discomfort generally during the summer months. While for the urban areas of Tirana, Shkodra and Lezha it is noticed that over 50% of the population feel discomfort. So high temperature values affect the comfort of the Western Lowland population. Furthermore, on days with heat wave episodes, the geospatial distribution of DI is observed within the range 24.05 - 27.4 indicating that more than 50% of the population feels discomfort. Vlora is an exception during the first episode with heat wave. The highest values are found in the urban area of Lezha and Shkodra.

Emphasizing that heat waves are known as a phenomenon with great health risk, it becomes necessary to manage such situations to minimize the effects and adapt to them. Management plans should include actions in health, infrastructure and institutional, cultural or awareness-raising aspects.

4. Conclusions

* Heat waves are qualified as "silent disaster" and belong to the group of natural hydro-meteorological disasters.
* Its frequency is on average with two episodes occurring during the summer months.
* There are variability in their duration and severity ranging from an average of 5-8 days
* They have an impact on population, fauna, agricultural systems, construction, and infrastructures. They require special attention as an influencer on the thermal comfort of different population groups. Heat waves at their extreme values cause physiological stress to death.
* Summer heat waves have caused discomfort for more than half of the population for Shkodra, Tirana, Fier, Vlora and in Lezha almost the entire population has felt discomfort (level 4 of the Thom's thermal Discomfort Index).
* Early warning systems make it possible to assist in managing situations with heat wave episodes by helping to reduce the risk of this natural disaster.
* It is suggested to conduct other studies in correlation with eco physiological studies, approaching with realistic theoretical results related to DI. Regarded to thermal comfort / discomfort some other studies can be done by calculation of Humidex, WBGT, MCV, Cooling-power index
* The geospatial study of this phenomenon creates faster managerial and operational opportunities for the most affected areas, highlighting the principle of subsidiarity, Article 7 of Law No. 45/2019, on civil protection.
* There are suggested the design of heat wave episode management action plans by adapting models of countries like Australia, India and especially Spain as a country part of the Mediterranean basin. They consists of: Australia: adaptation to reduce exposure; adaptation to increase adaptive ability, adaptation to reduce sensitivity, adaptation to respond to HV impact (during and after the episode). Spain: National plan is activated every summer since 2004 during the months of June – September. The risk factors associated with high temp in this plan are: personal, environmental, social and local. A daily map with the risk areas is realized; maximum and minimum daily temp are given for 4 consecutive days. Indian model: Creating a map of high risk communities; Creation of "Public places of refreshment"; Awareness and reporting on heat waves through various media; increased readiness in health centers (type of health concern, symptoms and ways of dealing with the injured). Defining and recommending a list of behaviors and actions of what to do and what not to do during atmospheric heat wave situations.

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