International Journal of Current Research in Multidisciplinary (IJCRM) *ISSN: 2456-0979*
Vol. 4, No. 9, (November'19), pp. 10-18

FLASH FLOODS IN HIMALAYA WITH SPECIAL REFERENCE TO MORI TEHSIL OF UTTARAKHAND, INDIA

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ABSTRACT

Hydro meteorological disasters on 18th August, 2019 in the catchment of Khaneda Gad, a tributary of Pabbar River caused devastation in Mori tehsil of Uttarkashi district. Heavy and concentrated rainfall in the upper reaches of the catchment of Khaneda Gad resulted in flash floods and debris flows in the downstream areas. These incidences killed 18 people while 3 went missing and 74 animals were lost. Besides, these inflicted heavy loss of property, infrastructure and livelihoods at various villages. The losses in the event were aggravated due to high relief of the area and unscientific habitation pattern in close vicinity of the streams. Apple crop cultivation is the main livelihood option for the inhabitant of the area. This also badly affected in these incidences. The purpose of this paper is to highlights the causes of disasters and its effects on inhabitants of affected areas. As also suggestions for future disaster risk reduction and sustainable development within the above said region.

KEYWORDS: *Heavy localised precipitation, flash floods, causes, damages, sustainable development, Uttarkashi*

INTRODUCTION

Located in Himalayan region the state of Uttarakhand is vulnerable to a number of natural hazards that include earthquake, landslide, flood, flash flood, avalanche and drought. Other disasters, heavy localised precipitation and associated flash floods are among the most devastating disasters in the Himalayan mountainous belt. Sudden increasing runoffs through the streams during monsoon season create flash floods situation which affect habitations and infrastructure downstream.

In the last decade, it is frequently occurred in the Himalayan state of Uttarakhand that caused heavy loss of human life, property and infrastructure. Some major extreme events in the same durations are: (i) August, 2009 Lah- Jhekla tragedy in Pithoragarh [1]; (ii) In the year 2012 particularly heavy rainfall was received between 4 and 6 August, 2012 in Asiganga valley in Uttarkashi and 13 and 16 September at Okhimath in Rudraprayag [2, 3]; (iii) Heavy rains and associated deluge on 16/17 June 2013 in the catchments of the Mandakini valley in Rudraprayag [4]; (iv) On July, 2016 debris flow occurred after heavy rainfall in Didihat, Bastari and Naulra in Pithoragarh [5]; (v) Localised heavy rains in the early hours of 14 August, 2017 in the catchment of the tributaries of Kali river, particularly Simkhola Gad and Malpa Gad [6]. These hydrometerological disasters claimed many human lives, property, infrastructure and livelihoods. These are often attributed to climate change. Additionally, unscientific habitation pattern in close vicinity of local streams, over transported sediments/fan deposits and colluvium has often resulted in devastation in the area. The area also falls in Zones IV and V of Seismic Zonation Map of India [7] and had suffered an earthquake on 1991 [8].

Despite industrialisation, growth, development and urbanisation overwhelmingly large proportion of the population of India (68.8 percent) resides in rural areas and with 28.4 percent of the population

and 71.4 percent of the workforce engaged in agricultural sector livelihood of large proportion of the people is still dependent on agriculture [9].

Situation is no different in the provinces and despite growth of secondary and tertiary sectors after the formation of Himalayan province of Uttarakhand in India in the year 2000, agriculture is major economic activity for overwhelmingly large population. 70,36,954 of the 1,00,86,292 persons of the province (69.8 percent) reside in rural areas and with 15,80,423 persons being cultivators and 4,03,301 engaged as agricultural labourers 19.7 percent of the population or 50.8 percent of the workforce of the province is engaged in agriculture sector [9].

Heavy localized precipitation and associated floods of 18 August, 2019 in Mori tehsil of Uttarkashi district that caused loss of 21 human lives and 74 animals lost. Besides floods, local and concentration rainfall in the area induced slope instability and triggered mass movement in the area. The water laden down slope moving mass was observed to have overrun the houses and cultivated lands at various places. 2 motor bridges on Arakot-Chiva-Balcha and Tikochi-Kunal-Duchanu roads are damaged along with 2 pedestrian bridges on Arakot-Chiwan track and near Dikochi damaged. Around 10 roads were disrupted in the affected area. Households of 2,021 of 15 villages was affected in these incidences. These include Chiwan, Gokul, Jhotadi, Balawat, Moldi, Arakot, Jagta, Dhara, Dagali, Duchanu, Monda, Tikochi, Kalich, Makuri and Barnali villages are adversely affected. Details of the same is given in Table 1.

Table 1. Details of the households of 2,021 of 15 villages in Mori Tehsil of Uttarakashi district

Sl. No.	**Affected villages**	**Households**
1	Chiwan	262
2	Dagali	120
3	Jhotadi	168
4	Dhara	120
5	Duchanu	119
6	Gokul	182
7	Kiranu/moldi	147
8	Monda	108
9	Makuri	104
10	Arakot	186
11	Kalich	106
12	Balawat	164
13	Barnali	35
14	Jagta	140
15	Tikochi	60
	Total	**2,021**

Apart from the loss of human lives, the affected population often suffers loss of their agricultural lands. The main land use practice in the study area is terrace farming and cultivation of apple crop. A large amount of apples have been exported from the area. Apple crop cultivation is the main livelihood option for the local people which was also badly affected in these incidences. This adversely affects the economy and quality of life of the affected population. The main objective of this present study is to assess the causes and consequences of the disasters and suggestions for future safe developmental planning in the area. This study is based on field work undertaken in the area aftermath of the disaster.

CHANGE IN RAINFALL AND CLIMATE

Change in rainfall pattern has been experienced during previous some years. Though according to Indian Meteorological Department (IMD) data there is not much change recorded in the average rainfall in Uttarakhand but change in rainfall intensity and duration cannot be ruled out. Description of average monthly rainfall (mm) in 15th June to 20th August 2019 in Uttarakhand is given in Table 2.

Table 2. District wise average monthly rainfall (in mm) from 15th June to 20th August 2019 in Uttarakhand.

2019	**June**		**July**		**August (upto20th)**		**Average Rainfall (01 Jun to 20 Aug)**	
District	**ACK**	**NOR**	**ACK**	**NOR**	**ACK**	**NOR**	**ACK**	**NOR**
Almora	77	152.3	179.4	273.3	190.9	189.9	149.1	205.2
Bageshwar	84	152.3	246.2	273.3	427.7	189.9	252.6	205.2
Chamoli	50.3	100.5	209.1	268.4	338.2	203.2	199.2	190.7
Champawat	98.4	213.7	267.5	473.2	346.7	266.6	237.5	317.8
Dehradun	89.8	180.8	336.3	554.8	286	385.4	237.4	373.7
Pauri Garhwal	23.1	161.1	202.6	419.8	267.9	312.9	164.5	297.9
Tehri	67.2	135.6	192.3	344.9	220	255.3	159.8	245.3
Haridwar	21.1	118.2	262.9	331.6	233.8	253.1	172.6	234.3
Nainital	134.4	230.7	498	491.9	271.9	291.5	301.4	338.0
Pithoragarh	133.7	258.6	423	539.5	356.6	338.3	304.4	378.8
Rudraprayag	101.8	208.1	351.2	521.5	448.6	389.8	300.5	373.1
Udham Singh Nagar	136	150.5	328.3	378.5	216.1	222.9	226.8	250.6
Uttarkashi	84.6	206.7	243.2	415.6	248.6	273.5	192.1	298.6
Average	**84.7**	**174.5**	**287.7**	**406.6**	**296.4**	**274.8**	**222.9**	**285.3**
ACK – Actual, NOR – Normal								

Although the rainfall recorded is much less but due to absence of localized precipitation data of extreme event, it is not clear that how much rainfall took place in the area around Arakot while the area faced large scale devastation. It has been observed that the frequency and recurrence of heavy localized precipitation events has increased over the period of time.

MATERIALS AND METHODS

The disastrous region is located in the mountainous terrain and enjoys good road connectivity and can be approached from Dehradun by Vikasnagar – Chakrauta – Tiuni motor roads and falls in Survey of India toposheet number 53 E/16. Tiuni town is situated at a distance of 158 kilometers from Dehradun via National Highway (NH -707). Arakot is situated on the banks of the Pabbar River and at a distance of around 24 kilometers upstream to Tiuni town. The most devastated area can be approached by the link road bifurcating from the Arakot along the Khaneda Gad catchment. Survey of India toposheet number 53E/16 on the scale of 1:50,000 have been used to prepare the location map of the area (Figure 1).

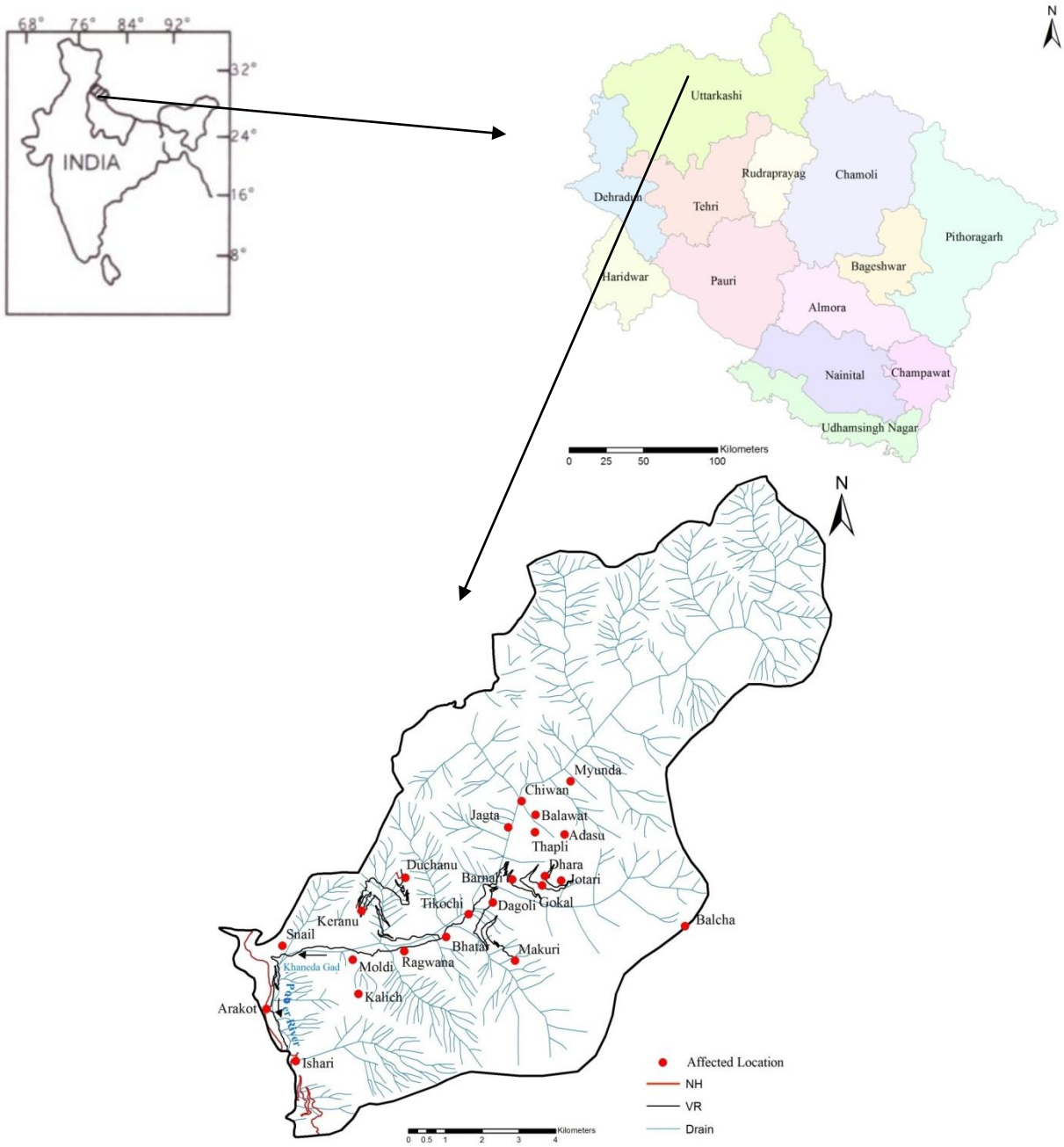

Figure 1: Location map of the devastated area

GEOLOGY AND GEOMORPHOLOGY

Geologically, the area is occupied by rocks belonging to Kulu Group and undifferentiated Jaunsar Group. The Kulu Group of rocks exposed in the area and Thrusted by Kulu Thrust over the Jaunsar Group. The Kulu Group is made up dominantly of streaky and bended gneiss, and schist and quartzite. The foliation planes were observed to dip towards NW at angles 50º. The undifferentiated Jaunsar Group is the youngest rock Group in the area exposed along Pabber valley. It comprises greywacke, shale, phyllite, quartzite and dolomite. The bedding planes were observed to dip towards E-SE at angles 45º.

Geomorphologically, the area is drained by ENE-WSW and S-SSE flowing Pabbar River which is an important tributary of Tons river. It is fed by Khaneda Gad in the Uttarakhand which is meeting in the area around Arakot. It is 5th order stream originating from an approximate elevation of 3912 m above mean sea level. Mostly the drainage system of the area is of dendritic type. The Khaneda valley exhibits characteristically distinct rugged mountainous topography of the both Lesser and Higher Himalayan terrains. The imprints of geological structures and lithology are observed in the area in the form of strike ridges and deeply incised valleys. The area is observed to be dissected by several ridges and the ground elevations vary from about 1150 to 3230 meters above mean sea level. In the Khaneda valley most motor roads were disrupted by landslides and flash floods and the area was largely approached on foot. During field investigations accumulation of huge amount of boulders and debris at Tikochi and bank erosion by Khaneda Gad at Mauldi was observed.

ON 18TH AUGUST, 2019 DISASTROUS MORI TEHSIL

According to eyewitness accounts cloudburst incidence took place around Arakot along with Khaneda Gad valley after heavy rainfall in the morning hours (around 0445 hr) in which Arakot, Mauldi, Makuri, Tikochi-Nagwara, Snail, Duchanu etc. villages were severely affected and devastated. Heavy rainfall/Cloudburst like incidences took place in two phases, in first phase at 4.45 AM on 18th August, 2019 Khaneda Gad valley devastated by heavy downpour and associated flash floods afterwards in second phase on the same day at 6.00 AM extreme weather events occurred at Arakot and Snail area. Unprecedented damage and destruction occurred in the Khaneda Gad valley. It has been observed during field investigation that Khaneda Gad a tributary of Pabbar River has changed its course and shifted at several locations, due to heavy discharge. These caused loss of human life, property and infrastructure in the area. High sediments leaden discharge through steep gradient streams in the area around Arakot washed away road which lead to Himachal Pradesh and damaged many structures which was exist its flanks (Figure 2a).

Continuous localised precipitation in the catchment of Khaneda valley caused spate in its course that has considerably changed the original topography of the area. Major destruction and damages have been occurred in Tikochi village (Figures 2b and 2c). Besides, Chiwan, Gokul, Jhotadi, Balawat, Moldi, Jagta, Dhara, Dagali, Duchanu, Monda, Kalich, Makuri and Barnali villages are adversely affected. The landslides and toe erosion by the streams caused breaching of the road and overran the vehicles in the area (Figures 2d and 2e).

Human losses in disaster induced by heavy rainfall on 18th August 2019 in Mori Tehsil are (i) 1 missing and 6 dead in Arakot village; (ii) 1 missing and 5 dead in Makuri village; (iii) 1 missing and 3 dead in Snail village; (iv) 1 dead at Nagwara near Tikochi village; and (v) 1 missing and 3 dead in Sanol village.

One helicopter of Heritage Aviation crashed in the affected area while engaged in relief and rescue operations (Figure 2f). 3 persons onboard the ill fated chopper including Pilot and Co-Pilot died in the incidence. Detail of the losses is given in Table 3.

Table 3. Losses incurred in the disaster of 18th August, 2019 (Data source: State Emergency Operations Centre)

Sl. No.	Causes of losses	Human loss			Animal loss	
		Dead	Missing	Injured	Dead	Missing
1	Heavy rainfall and cloudburst	15	3	12	74	3
2	Helicopter crashed during search & rescue operations	3	0	0	0	0
3	Emergency lending due to Helicopter breakdown on hours of search & rescue operations	0	0	2	0	0
	Total	**18**	**3**	**14**	**74**	**3**

Despite road blockade on all sides teams of Police, State disaster response force (SDRF), Disaster Mitigation and Management Centre (DMMC), Health, and administration have managed to reach the affect area and have established the base at Arakot. The relief camp was established in the same area for the affected people. Total of 410 affected people were sheltered in these. Out of total, 174 people sheltered in Forest Guest House and 201 people sheltered in Primary School while remaining 35 people sheltered in Government Intermediate College.

Figure 2: On 18th August, 2019 hydro-meteorological disaster induced losses; (a) high velocity discharge through local streams damaged road and other structures in Arakot; (b) damaged shops due to debris flows in Tikochi village; (c) damage to bridge and washed away Allopathic Hospital due to flash floods at Tikochi village; (d) road leading to Arakot-Chiwan blocked due to landslide; (e) vehicles washed away due to breaching of road and debris flows; (f) crashed helicopter of Heritage Aviation in the affected area

CAUSES OF DEVASTATION IN THE AREA

Heavy localised precipitation/ cloudburst like incidences took places in Mori tehsil resulted heavy discharge in streams causes toe erosion, landslide, debris flow incidences at a number of places. Habitations located along the close vicinity of the river and tributaries are severely damaged while settlements vulnerable for the landslide due to slope made up of overburden / loose materials as well as old landslide mass have been badly affected and damaged. These inflicted heavy loss of human lives, property, infrastructure and livelihoods.

Mostly tributaries and seasonal streams have been observed to be overwhelmed by debris flows and heavy discharge of water during these incidences and flash floods occur in downstream areas, as was noticed in Arakot, Snail, Nagwara and Tikochi areas. Some major causative factors for the mass instability are as follows:

- Heavy localised precipitation in a short period of time and change in climate
- High dissected hills and steep valley slopes
- Agricultural practices over fan deposits, old landslide mass and colluvium
- Fragile and weak rocks due to major Thrust/Fault
- High relief which promoted fast and high surface runoff
- Unscientific habitation pattern in close vicinity of the local streams, over transported materials/fan deposits
- The area falls in physiographic region between 1200 to 3500 meters altitude zone
- Overburden slopes undercut by both seasonal streams and perennial streams
- Excessive rainfall increases pore water pressure that resulted mass wastage, landslides and debris flows

RESULTS AND DISCUSSION

Heavy downpour and associated flash floods is not an uncommon in Uttarakhand Himalaya and it has become quite frequent in last decade due to change in weather regime. This is attributed to change in climate. A disaster struck on 18th August, 2019 in the area around Arakot after localised heavy precipitation in Mori tehsil of Uttarkashi district. This heavy precipitation resulted into the swelling of Khaneda Gad, a tributary of Pabbar River. The water filled up streams that overflowed, particularly

during the early morning on 18th August, 2019, killing about 18 persons while 3 went missing and 74 animals were lost. Thus, the furious Khaneda Gad and local streams destroyed the property, infrastructure and cultivation lands that came in its way. The landslides and toe erosion by the streams caused breaching of the roads in the area around Arakot and catchment of Khaneda valley region at various places and bridges of Arakot-Chiwan-Balcha and Tikochi-Kunal-Duchanu roads were damaged.

The present study area is occupied by rocks of Lesser Himalaya and Higher Himalaya. It mainly consists of gneiss, schist and quartzite. Geologically, the rocks in this area are found highly deformed, degraded and dissected by structural discontinuities. Geo-tectonically, the area is traversed by several faults and thrusts, which are considered to be geodynamically active.

Geomorphology of the area indicates that the surface slopes consist mostly of fluvial and colluvium which are mostly unconsolidated and loose in nature. Due to morphological setting of the devastated areas, the streams have high sinuosity and hence, high level of erosive capacity, especially when these are loaded with sediments. Thus, the terrain conditions combined with weather conditions and unscientific habitation pattern made a favorable environment for such a disastrous process to take place in the same region.

Unscientific habitation pattern in close vicinity of the streams are therefore required to be identified and marked safe or unsafe by respected agency and accordingly all anthropogenic interventions in these areas have to be banned. In case people are already residing in such areas provision has to be made for their timely relocation. This provision in the long run would encourage people to settle down at safer places due to enhanced awareness in this regard.

CONCLUSIONS

Located in the adverse physiographic region and socio-economic conditions, Mori tehsil of Uttarkashi district is vulnerable to heavy localised precipitation and associated flash floods. On 18th August, 2019 heavy localised precipitation cause devastating flash floods in the catchment of Khaneda Gad in Mori tehsil. As many as 18 persons were died while 3 persons went missing and 74 animals were lost in these incidences. Apart from the loss of human lives, the affected population often suffers loss of their dwellings, animal stock, cultivation lands and business. This adversely affects the economy and quality of life of the affected population.

The area also fall in Zones IV and V of Seismic Zonation Map of India and had suffered an earthquake on 1991 which caused weakening of rock masses, landslides and damaged human settlements. High relief, fragile mountainous slope, overburden, heavy localised precipitation and change in climate are the responsible and controlling factors for the extreme weather events and associated flash floods in the area. Besides, unscientific habitation pattern in close proximity of streams, over transported sediments, colluvium are deduced to be the main causes of the devastation in the area. Recent anthropogenic activities like road cutting, extension of apple orchards instead of trees having deep roots and infrastructure development concentrated along valley side further aggravated the situation.

Although, the hydro-meteorological events cannot be restricted but loss of life and property can be reduced by taking certain precautionary measures. In such areas constructions should be carried out after through and detailed geological and geomorphological studies. The identified areas as a high risk require more detailed mapping.

In view of vulnerability to such hydro-meteorological events, network of weather observatory and early warning system must be installed widely in the same region. Meteorological parameters like the

wind velocity, volume of rainfall, percentage of relative humidity, flood levels etc. should be monitored regularly [10]. They are providing timely alerts to the community in any emergency situation. According to timely warning dissemination, inhabitants of the area will be shifted to safer places and we can be safe the invaluable life.

Acknowledgements

The Executive Director, Disaster Mitigation and Management Centre, Department of Disaster Management, Uttarakhand Secretariat, Dehradun, India is acknowledged for their suggestion, cooperation and valuable support. Colleagues at Disaster Mitigation and Management Centre and Uttarakhand Disaster Management Authority are thanked for cooperation and support.

REFERENCES

[1] R.A. Singh. La-Jhekla landslides, Pithoragarh district, Uttarakhand, India. Landslides and Environmental Degradation. Gynodaya Prakashan, Nainital, 2013, 141-149.

[2] Piyoosh Rautela and Sushil Khanduri, Investigations in the areas around Okhimath in Rudraprayag district on the aftermath of landslide incidences of September, 2012. Unpublished report of Disaster Mitigation and Management Centre, Department of Disaster Management, Government of Uttarakhand, 2012, 37.

[3] Piyoosh Rautela and Sushil Khanduri, Investigations in the Asi Ganga valley on the aftermath of flash flood/landslide incidences in August, 2012. Unpublished report of Disaster Mitigation and Management Centre, Department of Disaster Management, Government of Uttarakhand, 2012, 45.

[4] S. Khanduri, K.S. Sajwan, A. Rawat, C. Dhyani, and S. Kapoor. Disaster in Rudraprayag District of Uttarakhand Himalaya: A Special Emphasis on Geomorphic Changes and Slope Instability. Int. J. Geogr. Nat. Disast., 8(1), 2018, 1 – 9.

[5] Sushil Khanduri. Disaster hit Pithoragarh District of Uttarakhand Himalaya: Causes and implications. Int. J. Geogr. Nat. Disast., 7(3), 2017, 1 – 5.

[6] Sushil Khanduri, K.S. Sajwan and Ashish Rawat. Disastrous Events on Kelash-Mansarowar Route, Dharchula Tehsil in Pithoragarh District, Uttarakhand in India. J. Earth. Sci. Clim. Change, 9(4), 2018, 1 – 4.

[7] Indian Standard (IS): 1893 Part I. Criteria for earthquake resistant design of structures. Bureau of Indian Standards, New Delhi, India, 2002.

[8] P. Rautela, G.C. Joshi, B. Bhaisora, S. Khanduri, S. Gildiyal, C. Dhyani, and A. Rawat. Earthquake Risk Assessment around Naintal in Uttarakhand Himalaya, India, Int. J. Geogr. Nat. Disast., 9(1), 2019, 1 – 6.

[9] Census of India, "Population profiles: India, States and Union Territories", Office of the Registrar General, India, New Delhi, 2011.

[10] A.K.L. Asthana and Harshita Asthana. Geomorphic control of cloudbursts and flash floods in Himalaya with special reference to Kedarnath area of Uttarakhand, India. International Journal of Advancement in Earth and Environmental Sciences, 2(1), 2014, 16 – 24.