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EDITORS

Debasis Bhattacharya
Visva-Bharati University, Santiniketan, India

Carlo Bianca
Laboratorie de Physique Statistique, Paris, France

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STUDY CORONAL INDEX WITH SSN AND COSMIC RAY INTENSITY DURING SC 20 TO SC 24

ASHOK KUMAR JYOTI, DR. MEERA GUPTA AND DR. JAGJEET KAUR SALUJA

ABSTRACT

Earth's magnetic field is widely affected by the various phenomenon occur on Earth's mental and core region (Earthquake, Tsunami, Volcanos eruptions etc.), fall of celestial body Asteroids, Meteorites and also due to Sun's magnetic field and various phenomena occurs in the Sun i.e., CMEs, SWP ejections, SPEs, Solar radio bursts, Sunspot, Solar flare and solar radio Flux emission, change the Earth-Sun climate effectively. During investigation it is observed that Sunspot number SSN Total (SIDC-SILSO) and Coronal Index (Slovakia) are highly positive correlated [C(t) ≈ 0.913] during the period April 1954 to December 2008. High degree of anti or negative correlation [C(t) ≈ -0.831] (CRI Oulu – CI), [C(t) ≈ -0.822] (CRI Moscow – CI) and [C(t) ≈ -0.825] (for CRI Rome – CI) observed during the same time interval.

Keywords- Coronal mass ejections, Coronal index, Sunspot number, Solar cycle, Sun-Earth climate, Radio blackouts, solar activity indices

1. INTRODUCTION

Universe is very large (diameter about $28x10^9$ Parsec) having several billions of galaxies (about 10^{11}) and several thousands of Quasars are there. Entire Universe is made up of matter and (baryonic matter, dark matter and light nuclei) energy. Matter exists in various forms, in the Universe. We find matter in very tiny nuclear particles, in atoms, in molecules in nebulae, in celestial bodies i.e., asteroids, satellites, meteorites, meteors, comets, planets, stars, galaxies (gaseous, dust and stars), quasars also. Energies exists in various forms, such as electromagnetic waves (gamma rays, x-rays, ultraviolet rays, visible light, micro waves, radio waves etc.), cosmic rays, gravitational waves, sound waves, electrical energy, magnetic energy etc. Large celestial body in the entire Universe is attracted through invisible huge supernatural gravitational attraction force. Maximum value of Coronal Index is observed in the year February 1957, and the value is 20.79. Minimum Coronal Index observed in the year February 1987 and the value is 1.46. Both researchers [1] observed that planetary indices (magnetic field intensity B, SWV, and tilt angle) increases with cosmic ray intensity, decrease at a faster rate during the A<0 epoch as compared to A>0. Researchers [2] studied long term correlative analysis between CRI with CMEs during SC 23 and 24 during 1997 to 2010, determined inverse correlation coefficient of -0.83, and for same SC they find out a negative correlation coefficient of -0.7 between CRI and SFI number. It is found that Sun Spot Number and Tilt Angle shows strong positive correlation with each other and these parameters show reverse correlation with Cosmic ray intensity [8]. In positive polarity of SC, negative correlation coefficient of -0.863 seen for CRI-SSN with time-lag of 5 month and negative correlation coefficient of -0.762 with time-lag of 10 month seen for CRI-TA [7,9,10]. During investigation they find that more than 90% large geomagnetic storms were associated with coronal mass ejections which strongly supports to produce supersonic interplanetary shocks waves in solar wind streams [4]. Researcher group [3] also trying to study the behaviour and correlation of cosmic ray intensity with solar, interplanetary and geomagnetic disturbances. Rathore et al. analyzed and noticed statistically that 55% solar storms have occurred during solar max and 45% have occurred during min phase of SA [5]. Gupta et al. examined and find out CC between various SA Indices and CRI during SC 21,22,23 and 24 from 1976-2014 [11]. During research study [6] suggested SFI as important parameter for solar-terrestrial analysis and for long term STR study CI is best parameter for solar cycle 20-24. Ahmad et al. [12] studied Geo-effectiveness of solar and IP features in the period SC 23 and 24. Khan et al. [13] examined and analysed the solar cycle distribution of GM storms during solar cycle 21 to 24. Gupta et al. [14] analysed correlative study of CRI with SSN and GSF during 1954 to 2021.

2. METHODS OF ANALYSIS AND DATA DETECTION TECHNIQUES -

The ground based neutron monitors world-wide network provides very stable and variable records of intensity of CR particles of different energy (rigidity) for more than 60 years of period. Thus, the monthly means of cosmic ray neutron monitor count rates as CRI (Oulu, Moscow & Rome) data have been used. Solar parameters such as monthly means of International Sunspot numbers SSN Total (SIDC-SILSO), Coronal index CI of green line XIV 5303 Å data has been used for study. 30 Month running average (smoothed) data of various solar parameters with CRI have been used for correlative study. Data have been normalized by using the formula (X/Xavg) *100. A detailed correlative study has been performed between CRI with coronal index and SSN. Our investigation focused on solar heliospheric and cosmological variable and interrelationship between them. In this paper we have focused our study on cosmic ray modulation and their correlative association with Coronal index. Most of the data have been taken from the website of NOAA. Worldwide cosmic ray neutron monitor stations, pressure corrected data taken from Oulu (low cut off rigidity Rc ≈ 0.81 GV), Moscow (middle cut off rigidity Rc ≈ 2.43 GV) and Rome (high cutoff rigidity Rc ≈ 6.27GV) have been used for correlation study and for graphical analysis.

3. OBSERVATIONAL RESULTS AND DISCUSSIONS-

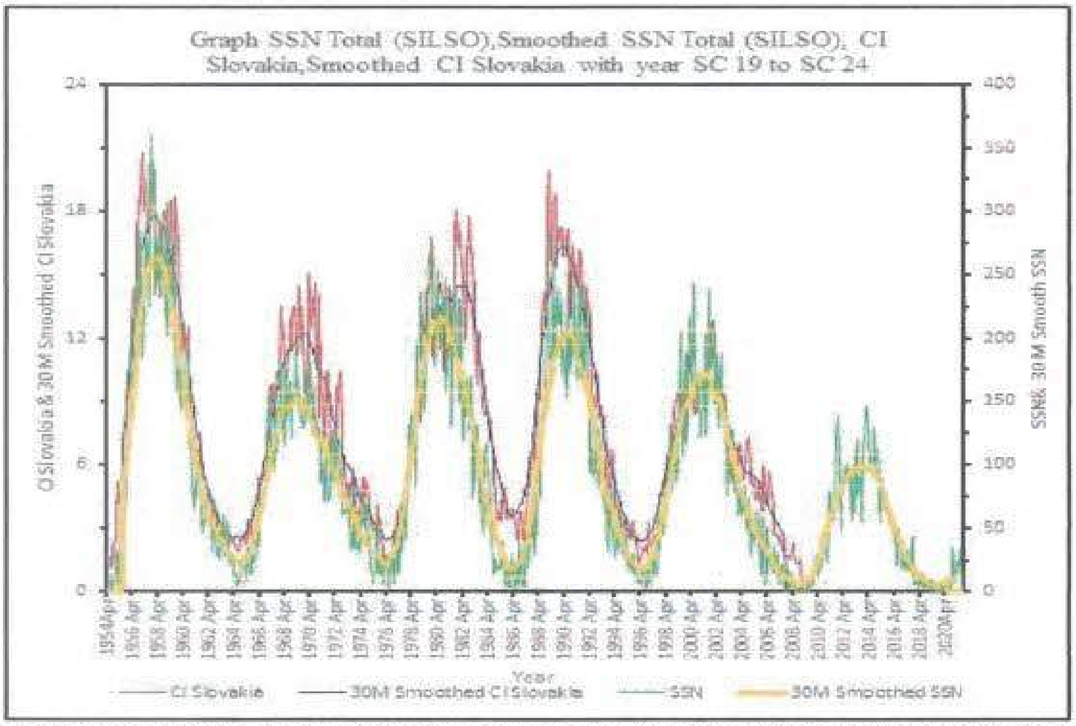

Fig.1 Correlation between Sunspot numbers and Coronal Index from SC 19 to SC 24 (April 1954 to July 2021).

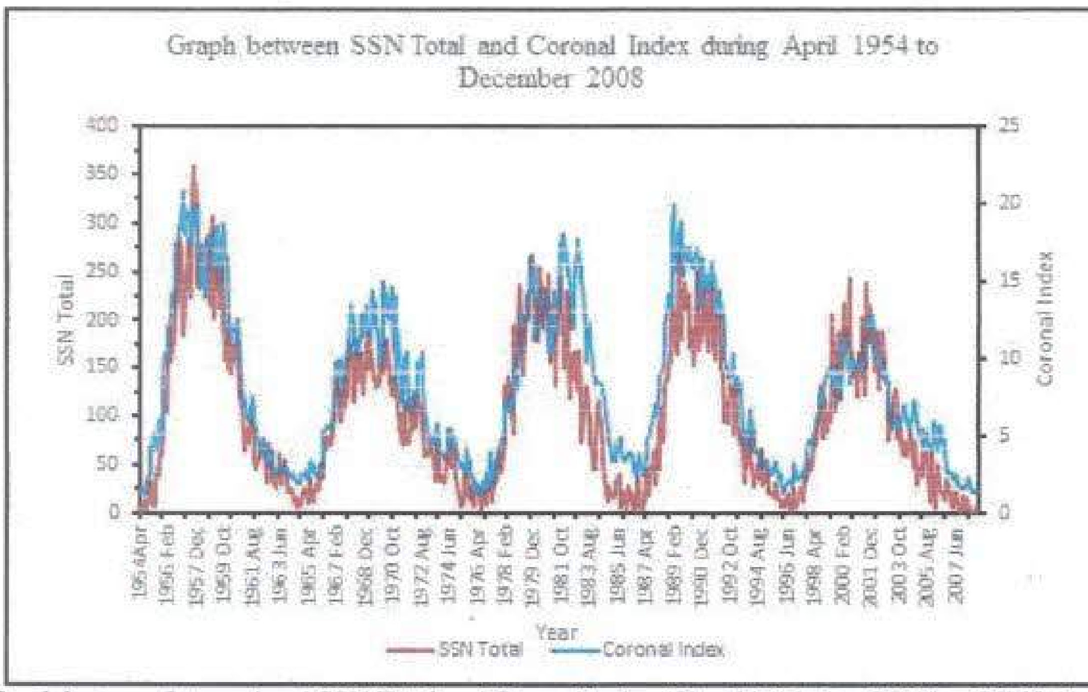

Fig.2 Graph between International SSN Total and Coronal Index (Slovakia) during SC 19 to SC 23 (April 1954 to December 2008).

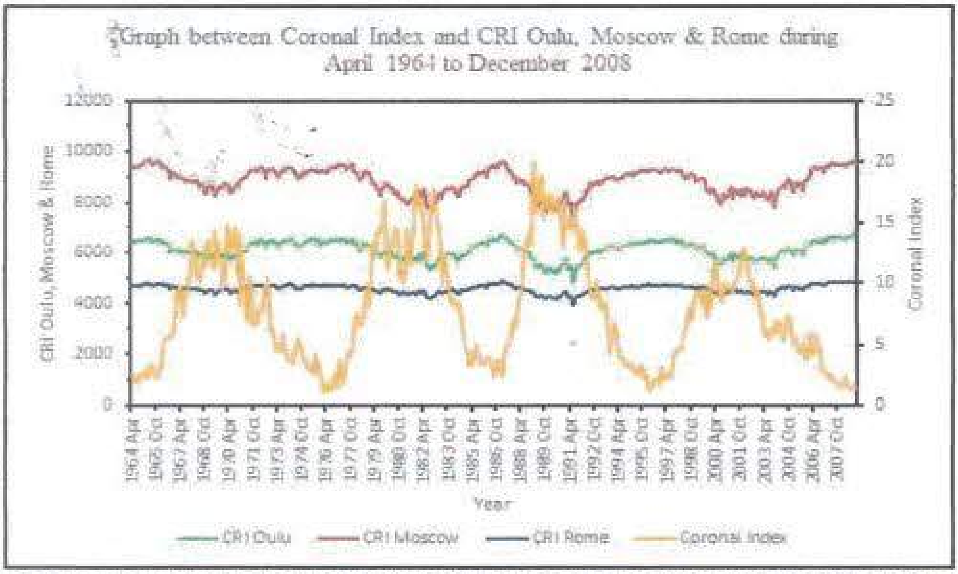

Fig.3 Graph between Coronal Index Vs CRI Oulu, Moscow & Rome during April 1964 to December 2008.

Cross correlation between SSN Total (SIDC-SILSO) and CI is observed very high, positive and correlation coefficient is found to be CC ≈ 0.913 during whole investigation period, SC 19 to ascending phase of the SC 23. Maximum CI (Slovakia) observed in the year February 1957 and the value is 20.79. Minimum Coronal index monthly average observed 1.46, in the year February 1987.

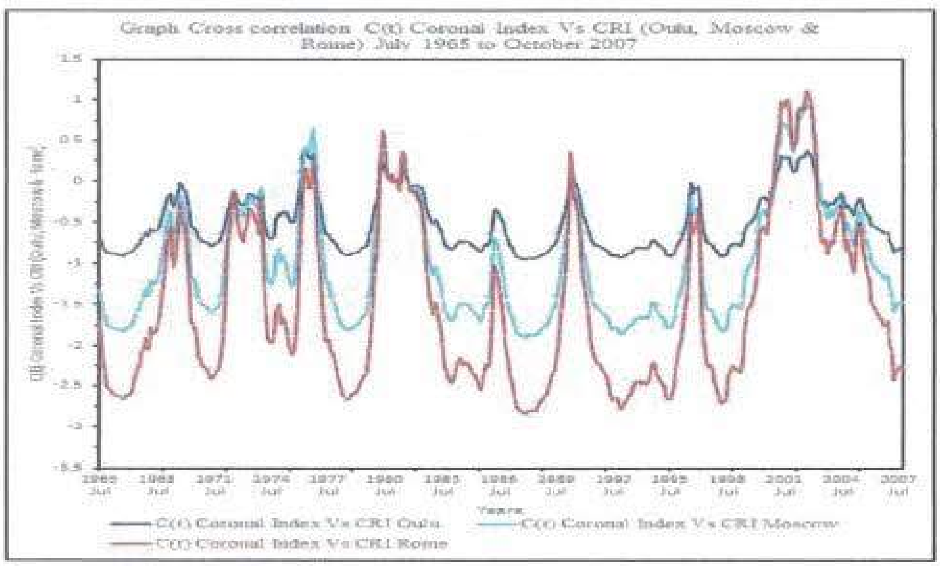

Fig.4 shows cross correlation coefficient between Coronal Index and Cosmic ray intensity of Oulu, Moscow and Rome neutron monitor series from July 1965 to October 2007.

Table-1 Cycle-wise Correlation Coefficient C(t) between Coronal Index (Slovakia) and CRI for different neutron monitor stations (Oulu, Moscow & Rome) for different phases of solar cycles 19 to 24.

Period	SC/ Phase	Correlation coefficient C(t), CRI Vs Coronal Index		
		Oulu	Moscow	Rome
SC-19(April 1954 –October 1964)	SC19	-0.408	-0.918	-0.923
	ASC	NA	-0.867	NA
	DESC	-0.408	-0.917	-0.910
SC-20 (October 1964 –March 1976)	SC20	-0.853	-0.843	-0.827
	ASC	-0.921	-0.932	-0.889
	DESC	-0.826	-0.793	-0.791
SC-21 (March 1976 -September 1986)	SC21	-0.811	-0.831	-0.812
	ASC	-0.903	-0.893	-0.889
	DESC	-0.774	-0.814	-0.762

SC-22 (September 1986-August 1996)	SC22	-0.909	-0.914	-0.876
	ASC	-0.941	-0.941	-0.929
	DESC	-0.947	-0.944	-0.906
SC-23(August 1996-December 2008)	SC23	-0.790	-0.769	-0.800
	ASC	-0.829	-0.829	-0.797
	DESC	-0.816	-0.770	-0.819
SC-24 (December 2008-December 2019)	SC24	NA	NA	NA
	ASC	NA	NA	NA
	DESC	NA	NA	NA
C(t) during SC 19 to SC 24 (Period April 1954 to April 2018)	C(t)	-0.831	-0.822	-0.825

During SC 19 ascending phase correlation is high [C(t) ≈ -0.918] (for CRI Moscow – CI) and [C(t) ≈ -0.923] (for CRI Rome – CI). During SC 20 ascending phase correlation is high [C(t) ≈ -0.921] (for CRI Oulu – CI), [C(t) ≈ -0.932] (for CRI Moscow – CI) and [C(t) ≈ -0.889] (for CRI Rome – CI). Same way during SC 22 ascending phase correlation is high [C(t) ≈ -0.941] (for CRI Oulu – CI), [C(t) ≈ -0.941] (for CRI Moscow – CI) and [C(t) ≈ -0.929] (for CRI Rome – CI). During investigation Maximum anti-correlation coefficient observed [C(t) ≈ -0.9951] (for CRI Oulu – CI), [C(t) ≈ -0.9477] (for CRI Moscow – CI) and [C(t) ≈ -0.9522] (for CRI Rome – CI) and corresponding Time-lag is 1 month for all the stations observed in the SC 22, Period from September 1986 to August1996 for CRI -CI. During SC19 to SC 24, the average Time-lag observed corresponding to maximum correlation is 0 to 8 month for CRI-CI.

The correlation coefficient between CRI (Oulu, Moscow &Rome) and Coronal index with time-lag has also been calculated for the SC 19 to SC 24 using the method of "Minimizing correlation coefficient method". Here we have selected both the series cosmic ray intensity and Coronal index for the same period with 0 time -lag and then shifted one series by a step of one months and calculated the cross correlation coefficient C(t) between both the series. Similarly, the other series has also been shifted by one months and the value of cross correlation coefficient C(t) is calculated. As much, the time (number of shifted months) is obtained, when the anti-correlation (negative) coefficient value is maximum. This is the time-lag between both the series CRI and Coronal index. Moreover, probable error (P.E.) for each value of correlation coefficients has been calculated by the formula: $P.E. = 0.6745(1-r^2)/\sqrt{N}$.

Table-2 Cycle-wise Maximum correlation coefficient between CRI (Oulu, Moscow & Rome) and Coronal Index (CI) Slovakia for solar cycles 19 to 24 with Probable error and Time-Lag.

Solar Cycles (SC)	Correlation coefficient C(t) &Probable Error			Time-Lag		
	Oulu	Moscow	Rome	Oulu	Moscow	Rome
SC19	NA	-0.9392± 0.00971	-0.9039± 0.01444	NA	8 Month	1 Month
SC20	-0.9072± 0.01039	-0.9234± 0.00836	-0.8407± 0.01665	0 Month	0 Month	4 Month
SC21	-0.8995± 0.01156	-0.9149± 0.00987	-0.8568± 0.016105	0 Month	0 Month	1 Month
SC22	-0.9951± 0.00536	-0.9477± 0.00622	-0.9522± 0.00569	1 Month	1 Month	1 Month
SC23	-0.9158± 0.00943	-0.9128± 0.00927	-0.8971± 0.01085	1 Month	0 Month	1 Month
SC24	NA	NA	NA	NA	NA	NA

Table-3 Cycle-wise Correlation Coefficient C (t) between Coronal Index (Slovakia) and CRI for different neutron monitor stations (Oulu, Moscow & Rome) for different phases of solar cycles 19 to 24.

Period	SC/ Phase	Correlation coefficient C(t), CRI Vs Coronal Index		
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SC-21 (March 1976 -September 1986)	SC21	-0.811	-0.831	-0.812
	ASC	-0.903	-0.893	-0.889
	DESC	-0.774	-0.814	-0.762
SC-22 (September 1986-August 1996)	SC22	-0.909	-0.914	-0.876
	ASC	-0.941	-0.941	-0.929
	DESC	-0.947	-0.944	-0.906
SC-23(August 1996-December 2008)	SC23	-0.790	-0.769	-0.800
	ASC	-0.829	-0.829	-0.797
	DESC	-0.816	-0.770	-0.819
SC-24 (December 2008-December 2019)	SC24	NA	NA	NA
	ASC	NA	NA	NA
	DESC	NA	NA	NA
C(t) during SC 19 to SC 24 (Period April 1954 to April 2018)	C(t)	-0.831	-0.822	-0.825

Table -4 Cycle-wise Correlation Coefficient C(t) between Coronal Index and SSN Total (SIDC-SILSO) for different phases of the SC20 to SC24.

Solar cycle (SC)	SC/Phase	Correlation Coefficient C(t), SSN Total Vs Coronal Index
SC 19 (April1954-October 1964)	SC19	0.954
	ASC	0.957
	DESC	0.950
SC-20 (October 1964 –March 1976)	SC20	0.921
	ASC	0.955
	DESC	0.912
SC-21(March 1976 -September 1986))	SC21	0.845
	ASC	0.958
	DESC	0.831
SC-22 (September 1986-August 1996)	SC22	0.951
	ASC	0.953
	DESC	0.958
SC-23 (August 1996-December 2008)	SC23	0.907
	ASC	0.888
	DESC	0.909
SC-24(December 2008-December 2019)	SC24	NA
	ASC	NA
	DESC	NA
(SC 20 to SC 24 Ascending Phase) (January 1966 to December 2014)	C(t)	0.913

4. CONCLUSIONS

There is a strong inverse correlation found between cosmic ray intensity with Coronal index. Cosmic rays being minimum during period of high solar activity and maximum during period of low solar activity. The correlation was generally stronger on a cycle by cycle basis. It has been found that solar activity indices CI shows anti-phase with Cosmic Ray Intensity (CRI). It is found that solar activity indices show decreasing trend with CRI and also shows negative correlation. During the period April 1954 to December 2008 the average time-lag observed between cosmic ray intensity and CI is estimated to be approximately 0 to 8 month for Oulu, Moscow & Rome NM stations. It is found that the Coronal index and CRI are highly anti-correlated (~ -0.8407 to -0.9951) with cosmic ray intensity for all these three stations. When correlation coefficient between CRI and CI for different solar cycles (19 to 24 is considered with time -lag, it is found that the time-lag is larger for odd solar cycles and it is smaller for even solar cycles for all the three stations (Oulu, Moscow & Rome), which supports the odd-even hypothesis of cosmic ray modulations. Coronal mass ejections related solar activity parameter i.e., Coronal Index (CI) has been found comparatively to be more effective in causing cosmic ray modulation.

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AUTHOR DETAILS:

ASHOK KUMAR JYOTI[1], DR. MEERA GUPTA[2] AND DR. JAGJEET KAUR SALUJA[3]
[1]Assistant Professor, Physics, Govt. B. P. Deo PG College Kanker, CG
[2]Professor, Physics, Govt. Dr. V.V. Patankar Girls PG College Durg, CG

[3]Professor, Physics, Govt. VYT PG College Durg, CG

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AN INTRUSION DETECTION SYSTEM TO DETECT AND MITIGATING ATTACKS USING HIDDEN MARKOV MODEL (HMM) ENERGY MONITORING TECHNIQUE

D. SUDHA AND DR. A. KATHIRVEL

ABSTRACT

The operational state transition model is used in the IEEE 802.15.4 mobile adhoc network (MANET) literature to anticipate energy usage. In some circumstances, if the residual energy calculation is not dependent on a node's operational statuses, the exact quantity of energy exhausted by each node may not be revealed. To address these challenges, we propose in this study to use an energy monitoring technique to create an intrusion detection system that can identify and neutralise attacks. By monitoring the node's energy, the malicious attacks are disclosed in this technique. Using a Hidden Markov Model, the monitoring nodes forecast energy (HMM). Attacks are reduced by establishing an attack-free route between the source and the destination. We demonstrate that the proposed method is effective by using simulation data.

1.1 INTRODUCTION

The IEEE 802.15.4 Mobile Adhoc Networks (MANETs) are a collection of wireless nodes that work together to monitor a variety of environmental conditions (for example, forest fires, air pollutant concentrations, and object movement) without the need for any underlying infrastructure. Mobile adhoc networks are widely used to suit unique application needs due to their inexpensive production costs and quick deployment. Intrusion detection is one of MANET's applications that has grown in prominence due to its unique implementation, such as mobile nodes deployed in an ad hoc manner to monitor any military scenario (Raza et al 2015). MANETs are networks of small, low-cost, low-energy, multipurpose sensors that are installed in close proximity to track an object, monitor a phenomenon, or regulate a process. The Internet of Things (IoT) is a new concept that seems to represent the future of MANET. She assumes that all human beings will be equipped with sensors that connect to form networks that make life much easier. Internet of Things (IoT) wireless nodes dynamically connect to the Internet and use the Internet infrastructure to collaborate and complete tasks (Murad et al. 2013).

1.2 Various Types of Attacks

MANET applications are more vulnerable to security attacks. Such as,

1.2.1 Eavesdropping or Passive Information Gathering

MANET applications use insecure radio channels as communication media. If the information is sent in clear text, nearby enemies can passively interfere with communication between the two legitimate nodes. Opponents can intercept the conversation and use it to later launch more advanced attacks on the MANET.

1.2.2 Node Malfunctioning

Real sensor nodes can behave inefficiently in the network. A malfunction of a wireless node can reject high-speed data packets or reject packet forwarding requests (if it is acting as a relay device). These nodes can have a significant impact on the overall performance of your network and should be identified immediately.

1.2.3 Denial of Service (Dos)

Denial of service (DoS) attacks can take many forms. Such attacks can be used to temporarily reduce network capacity to provide services, or to interrupt or disrupt network communication. Different types of DoS include black holes, resource exhaustion, sinkholes, wormholes, flooding, guided routing loops, and more.

1.2.4 Node Subversion

If a trespasser captures a genuine node, it may reveal all encryption information, secret keys, and algorithm to the trespasser. The attacker can then simply access the secure communication of the MANET under assault. The adversary can utilise the true node as an attacker in order to perform an insider assault. At this point, such a node may be effectively permitted, and the attack may go undetected by the MANET. This assault could result in a high level of security breach and serious consequences.

1.2.5 Message Corruption

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EDITORS

Debasis Bhattacharya
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Carlo Bianca
Laboratorie de Physique Statistique, Paris, France

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STUDY OF SOLAR FLARE INDEX WITH SSN AND COSMIC RAY INTENSITY VARIATIONS DURING SC 20 TO SC 24

ASHOK KUMAR JYOTI, DR. MEERA GUPTA AND DR. JAGJEET KAUR SALUJA

ABSTRACT

Cosmic rays originates from farthest (remote) galaxies (Galactic centre) as well as from substantial Super novae explosions, reached to the Earth's surface from all directions, detected from ground based NM stations detector, located in numerous cut-off rigidity (energy spectrum). Universe dynamically changing (fluctuating) continuously due to various astronomical phenomenon supernova bursts, gamma ray blasts, quasars, pulsars, blazars (active galactic nucleus AGN) and cosmic microwave background (CMB) [radiations in Big-Bang cosmology, is EM rays, remnants from early stage of the universe (relic radiation)]. Earth's surface temperature along with average land ocean temperature is gradually increasing (global warming) day by day. The Sun provides life to the Earth. Various phenomenon i.e., CMEs, Solar wind plasma emissions, Solar proton events. Solar radio blackouts, Sunspot creation, Solar flare and Solar Flux emission change the Sun -Earth climate (weather pattern) widely. It is observed that Sunspot number and Solar Flare Index are highly positive correlated [C(t) ≈ 0.818] during the period January 1966 to December 2014. High degree of anti-correlation (negative correlation) [C(t) ≈ -0.684] (CRI Oulu – SFI), [C(t) ≈ -0.693] (CRI Moscow – SFI) and [C(t) ≈ -0.710] (CRI Rome – SFI) observed during same period.

Keywords: Sunspot number (SSN), Solar Flare index, Cosmic ray intensity, Solar cycle, Neutron monitor, Coronal mass ejection, Grouped Solar flare

1. INTRODUCTION

Universe is very large (diameter about $28x10^9$ Parsec) having several billions of galaxies (about 10^{11}) and several thousands of Quasars are there. Entire Universe is made up of matter and energy (baryonic matter, dark matter and light nuclei). Matter exists in various forms, in the Universe. Earth's magnetic field changes due to different phenomenon occur on Earth's mental and core region (Earthquake, Tsunami, Volcano, fall of any celestial body like meteorites) and different phenomena occurs in the Sun. Sun -Earth interrelationship change the Earth's climate globally. Who and which major factor is responsible for this serious global supernatural climatic problem? Researchers group [1] studied correlation between CRI-SSN, CRI-TA for negative and positive polarity and find out the nature and polarisation of cosmic ray for recent solar cycle 21 and 22. During study by [3] galactic cosmic ray intensity is found to be different in both odd SC (21,23) and even SC (22, 24). During the minimum solar activity cycle 23, GCR intensity is found to be a record high value. In their observation [8] analysed that odd solar activity cycle has longer amplitude in comparison to the even solar activity cycle, and also the photosphere and chromosphere occurring phenomena SSN-SF is highly correlated. During study [6] suggested SFI as important parameter for solar-terrestrial analysis and for long term STR study CI is best parameter for solar cycle 20-24. During a brief study [7] conclude that the variation of cosmic ray intensity during odd and even solar cycles give us information about the mechanism behind the ascending and descending phase of solar cycles 21,22,23 and 24. Researchers [2] studied and found that GCRs are highly spirited nuclei of extra solar origin. Several SFs occur and CMEs are discharged from the sun later and travel in the IP space are important examination of evolution and effects of disturbances in the heliosphere and magnetosphere [4]. Period 1976 to 2015 (SC 21 to 24) Gupta and his collaborates [5] used low (Oulu), middle (Kiel) and High (Huancayo) cut off rigidity neutron monitor stations monthly mean of CRI data and established relationship of CRI with SSN and TA. Researchers group [9] studied Geo-effectiveness of solar and interplanetary features during SC 23 and 24. Group of investigators [10] examined Solar cycle distribution of geomagnetic storms during solar cycle 21 to 24. During study [11] analysed correlative study of cosmic ray intensity with sunspot number and grouped solar flare during 1954 to 2021.

2. METHODS OF ANALYSIS AND DATA DETECTION TECHNIQUES

For correlative statistical graphical analysis, we have taken data from NGDC (NOAA), OMNIWEB, WDC and SGD. The ground based world-wide neutron monitors network provides very stable and variable records of counts of Cosmic Ray intensity for different cut-off rigidity [Oulu (low Rc) and Moscow (middle Rc) NM data available from 1957, Rome (high Rc) NM data available from 1964]. Monthly means of cosmic ray neutron monitor count rates as CRI (Oulu, Moscow & Rome) data has been used. Cross correlation study being done by using 30-month average of SSN, SFI and pressure corrected cosmic ray intensity data. Solar parameters such as monthly means of International SSN Total taken from SIDC-SILSO. Solar flare index (SFI) data has also been used. 30 Month running average (smoothed) SFI data with CRI have been used for correlative study. Data have been normalized by using the formula (X/Xavg)*100. Our investigation focused on solar heliospheric and cosmological variable and their interrelationship. In this paper we have focused our study on cosmic ray modulation and their correlative association with Solar Flare index. Most of the data have been taken from the website of NOAA. For long term examination, monthly mean solar flare index data from january1966 to December 2014 is used. Worldwide cosmic ray neutron monitor stations, pressure corrected data taken from Oulu (low cut off rigidity, 0.81 GV, Lat. 65.05 ^{0} N, Longitude 25.47 ^{0} E and Alt. 15m), Moscow (middle cut off rigidity, 2.43 GV, 55.47 ^{0}N 37.32^0 E data from NM 12IGY, 18NM64 and from24NM64, http: //cro. izmiran.ru/scripts/nm64queryD.dll/mosc) and Rome (high cutoff rigidity,6.27GV, data from 20NM64, through website cro.izmiran.ru/rome/main.htm, Italy) have been used for correlation study and for graphical analysis.

3. OBSERVATIONAL RESULTS AND DISCUSSIONS

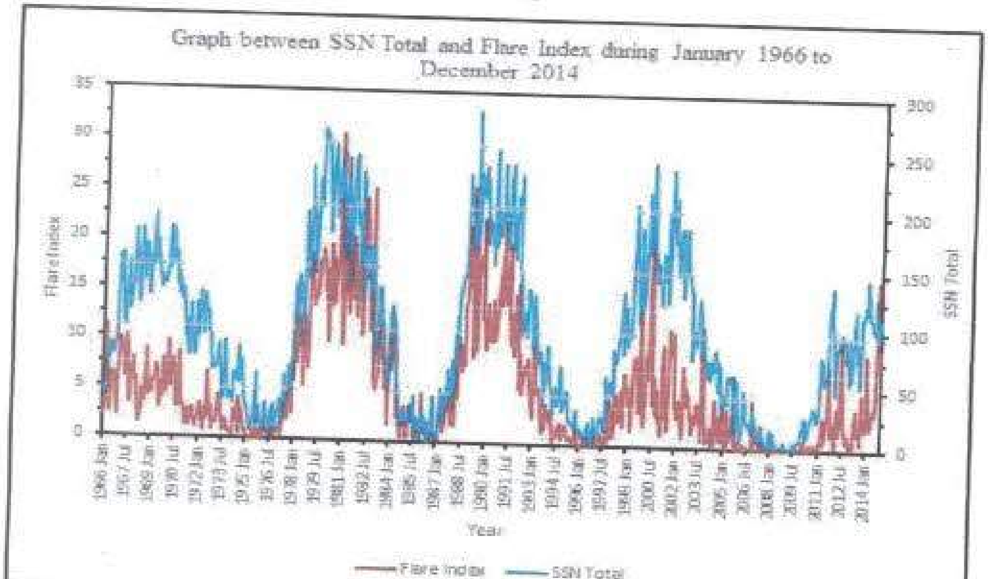

Fig.1 shows the graph between International SSN Total (SILSO) and Solar Flare Index during January 1966 to December 2014.

The Cross correlation between SSN Total (SIDC-SILSO) and Solar Flare index is found to be C(t) ≈ 0.818, high positive correlation observed during SC 20 to SC 24. Maximum value of Solar Flare Index is observed in the year November 1980, and the value is 30.73. Minimum Solar Flare Index observed in the year October 1996 and the value is 0.

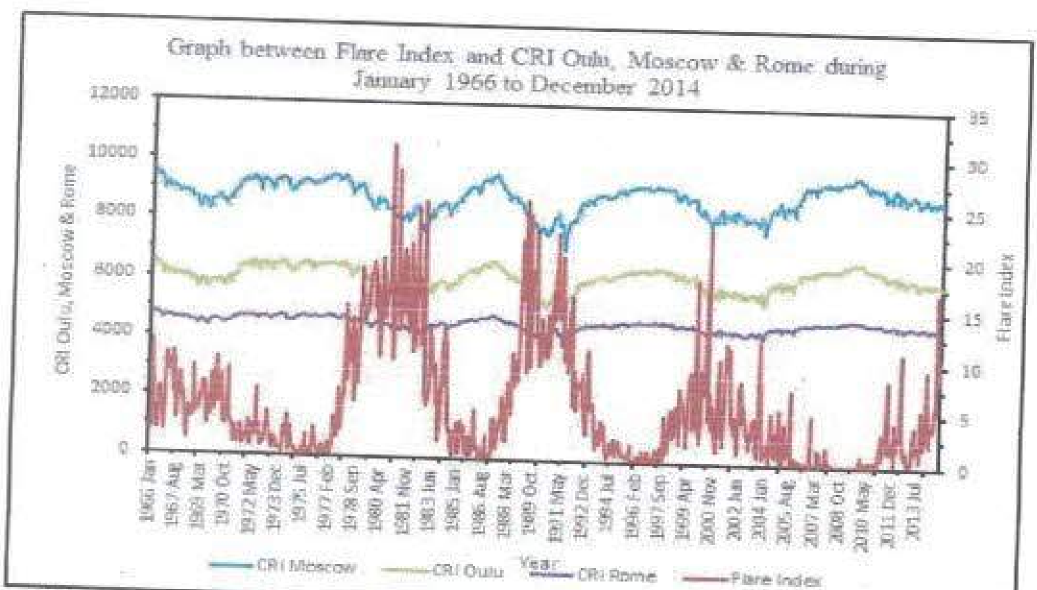

Fig. 2: Graph between Flare Index Vs CRI Oulu, Moscow & Rome during January 1966 to December 2014.

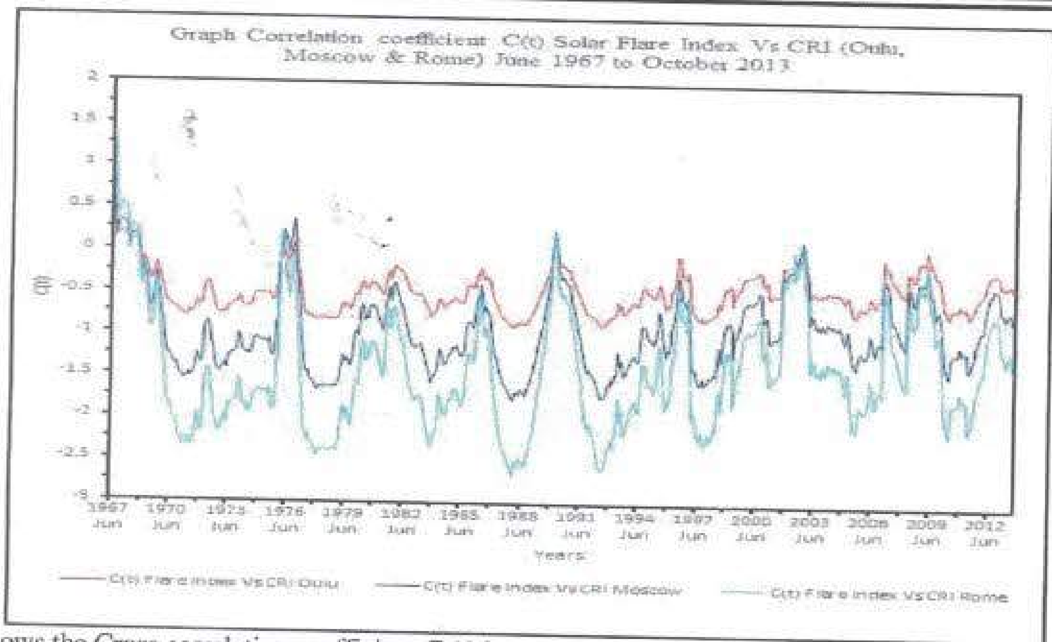

Fig.3: shows the Cross correlation coefficient C (t) between Solar Flare index and Cosmic ray intensity (Oulu, Moscow & Rome) neutron monitor count rates with years during June 1967 to October 2013.

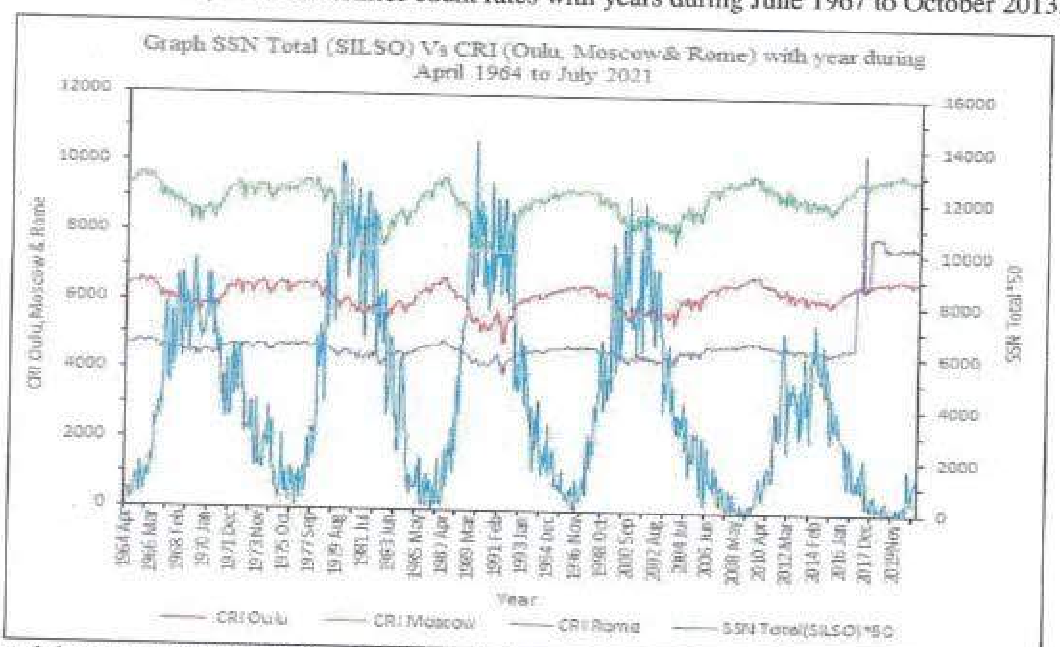

Fig.4: Graph between SSN Total*50 and CRI (Oulu, Moscow & Rome) during SC 20 to SC 24 (Period April 1964 to July 2021).

Table -1: Cycle-wise Correlation Coefficient C (t) between CRI (Oulu, Moscow & Rome) and SFI for different phases of the SC20 to SC24.

Solar Cycle(SC)	Correlation Coefficient C(t), CRI Vs SFI			
	SC/Phase	Oulu	Moscow	Rome
SC-19(April 1954 –October 1964)	SC19	NA	NA	NA
	ASC	NA	NA	NA
	DESC	NA	NA	NA
SC-20 (October 1964 –March 1976)	SC20	-0.636	-0.544	-0.527
	ASC	NA	NA	NA
	DESC	-0.810	-0.793	-0.796
SC-21 (March 1976 -September 1986)	SC21	-0.676	-0.701	-0.721
	ASC	-0.867	-0.849	-0.853
	DESC	-0.689	-0.744	-0.724

SC-22 (September 1986-August 1996)	SC22	-0.846	-0.846	-0.823
	ASC	-0.891	-0.882	-0.892
	DESC	-0.891	-0.884	-0.864
SC-23 (August 1996-December 2008)	SC23	-0.572	-0.566	-0.615
	ASC	-0.610	-0.630	-0.633
	DESC	-0.650	-0.606	-0.675
SC-24(December 2008-December 2019)	SC24	-0.598	-0.595	-0.674
	ASC	-0.597	-0.590	-0.639
	DESC	NA	NA	-0.528
Over all C(t) (SC 20 to SC 24 Ascending Phase) (January 1966 to December 2014)		-0.684	-0.693	-0.710

During SC 21 ascending phase correlation is high [C(t) ≈ -0.867] (CRI Oulu – SFI), [C(t) ≈ -0.849] (CRI Moscow – SFI) and [C(t) ≈ -0.853] (CRI Rome – SFI). Same way during SC 22 ascending phase correlation is high [C(t) ≈ -0.891] (CRI Oulu – SFI), [C(t) ≈ -0.882] CRI Moscow – SFI) and [C(t) ≈ -0.892] (CRI Rome – SFI). For other solar cycle correlation between CRI-SFI is found to be weak. During investigation Maximum anti-correlation coefficient observed [C(t) ≈ -0.8996] (CRI Oulu – SFI), [C(t) ≈ -0.8832] (CRI Moscow – SFI) and [C(t) ≈ -0.8867] (CRI Rome – SFI) and Time-lag is 0 month for all the stations observed in the year September 1986 to October 1996 (SC22) for CRI -SFI. For whole investigation period (SC20 to SC 24) average Time-lag observed corresponding to maximum correlation is 0 to 14 month for CRI-SFI.

Table-2: Cycle-wise Maximum correlation coefficient between CRI (Oulu, Moscow & Rome) and Solar Flare Index for SC 19 to SC 24 with Probable error and Time-Lag.

Solar Cycle (SC)	Correlation coefficient C(t) & Probable Error			Time-Lag		
	Oulu	Moscow	Rome	Oulu	Moscow	Rome
SC20 (1964.8-1976.5)(Oct 1964-June 1976)	-0.7753± 0.02553	-0.7756± 0.02574	-0.8328± 0.01979	0 Month	0 Month	5 Month
SC21 (1976.5-1986.7)(June1976-Sep 1986)	-0.8269± 0.01915	-0.8358± 0.01825	-0.7845± 0.02329	8 Month	8 Month	8 Month
SC22 (1986.7-1996.9)(Sep1986-Oct 1996)	-0.8996± 0.01163	-0.8832± 0.01343	-0.8867± 0.01305	0 Month	0 Month	0 Month
SC23 (1996.9-2008.9)(Oct 1996-Dec 2008)	-0.7949± 0.02047	-0.7839± 0.02143	-0.7527± 0.0241	6 Month	14 Month	3 Month
SC24 (2008.9-2019.9)(Dec2008-Dec 2019)	-0.7196± 0.02855	-0.7234± 0.04185	-0.7279± 0.04127	0 Month	0 Month	13 Month

During investigation Maximum anti-correlation coefficient observed [C(t) ≈ -0.8996] (for CRI Oulu – SFI), [C(t) ≈ -0.8832] (for CRI Moscow – SFI) and [C(t) ≈ -0.8867] (for CRI Rome – SFI) and Time-lag is 0 month for all the stations observed in the year September 1986 to October 1996 (SC22) for CRI -SFI. For whole investigation period (SC20 to SC 24) average Time-lag observed corresponding to maximum correlation is 0 to 14 month for CRI-SFI.

Table -3: Cycle-wise Correlation Coefficient C (t) between Solar Flare Index and SSN Total for different phases of the SC20 to SC24.

Solar cycle (SC)	SC/Phase	Correlation Coefficient C(t), SFI Vs SSN Total
SC-20 (October 1964 –March 1976)	SC20	0.676
	ASC	NA
	DESC	0.837
SC-21(March 1976 -September 1986)	SC21	0.904
	ASC	0.948
	DESC	0.890
SC-22 (September 1986-August 1996)	SC22	0.924
	ASC	0.923

	DESC	0.937
SC-23(August 1996-December 2008)	SC23	0.770
	ASC	0.778
	DESC	0.717
SC-24 (December 2008-December 2019)	SC24	0.611
	ASC	0.686
	DESC	NA
(SC 20 to SC 24 Ascending Phase) (January 1966 to December 2014)	C(t)	0.818

Table-4: Cycle-wise Correlation Coefficient C(t) between SSN Total (SIDC -SILSO) and CRI (Oulu, Moscow & Rome) for SC 19-24 with Ascending and Descending phase.

Solar Cycle (SC)	Solar Cycle/Phase	Correlation coefficient C(t), CRI Vs SSN Total		
		Oulu	Moscow	Rome
SC19 (April 1954 –October 1964)	SC19	-0.656	-0.916	-0.915
	ASC	NA	NA	-0.453
	DESC	-0.656	-0.914	-0.910
SC20 (October 1964 –March 1976)	SC20	-0.836	-0.812	-0.799
	ASC	-0.884	-0.899	-0.847
	DESC	-0.811	-0.771	-0.781
SC21(March 1976 -September 1986)	SC21	-0.599	-0.631	-0.628
	ASC	-0.864	-0.855	-0.844
	DESC	-0.620	-0.685	-0.630
SC22(September 1986-August 1996)	SC22	-0.912	-0.914	-0.884
	ASC	-0.930	-0.925	-0.920
	DESC	-0.929	-0.927	-0.894
SC23(August 1996-December 2008)	SC23	-0.789	-0.772	-0.821
	ASC	-0.840	-0.854	-0.829
	DESC	-0.839	-0.788	-0.863
SC24(December 2008-December 2019)	SC24	-0.861	-0.862	-0.590
	ASC	-0.857	-0.821	-0.849
	DESC	-0.918	-0.920	-0.790
C(t) during SC 19 to 24 (April 1954 to December 2019)	C(t)	-0.806	-0.805	-0.430

4. CONCLUSIONS

There is a strong inverse correlation between cosmic ray intensity and Solar Flare index during SC 20 to SC 24 for Oulu, Moscow & Rome. Cosmic rays being minimum during period of high solar activity and maximum during period of low solar activity. The correlation was generally stronger on a cycle by cycle basis. It has been found that solar activity indices SFI shows anti-phase with Cosmic Ray Intensity (CRI). During the period January 1966 to December 2014, it is found that the Solar flare index are highly anti-correlated (~ -0.684 to -0.710) with cosmic ray intensity for all these three stations. When correlation coefficient between CRI and Solar Flare index for different SC 20 to SC 24 is considered with time -lag, it is found that the time-lag is larger for odd solar cycles and it is smaller for even solar cycles for all the three NM stations (Oulu, Moscow & Rome), which supports the odd-even hypothesis of cosmic ray modulations. Solar Flare index shows negative (anti) correlation with CRI for all the three NM stations Oulu, Moscow and Rome period. During investigation Maximum anti-correlation coefficient observed [$C(t) \approx -0.8996$] (for CRI Oulu – SFI), [$C(t) \approx -0.8832$] (for CRI Moscow – SFI) and [$C(t) \approx -0.8867$] (for CRI Rome – SFI) and Time-lag is 0 month for all the stations observed in the year September 1986 to October 1996 (SC22) for CRI -SFI.

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AUTHOR DETAILS:

ASHOK KUMAR JYOTI[1], DR. MEERA GUPTA[2] AND DR. JAGJEET KAUR SALUJA[3]
[1]Assistant Professor, Physics, Govt. B. P. Deo PG College Kanker, CG
[2]Professor, Physics, Govt. Dr. V.V. Patanker Girls PG College Durg, CG
[3]Professor, Physics, Govt. VYT PG College Durg, CG

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डॉ. ऋचा ठाकुर
प्राध्यापक, नृत्य, शासकीय डॉ. वा.वा. पाटणकर कन्या स्नातकोत्तर महाविद्यालय, दुर्ग
richa.jyotindra@gmail.com

शबीना बेगम
शोधार्थी, इतिहास, पं. रविशंकर शुक्ल विश्वविद्यालय, रायपुर छत्तीसगढ़ shibu.2013@gmail.com

संगीत की तीनों विधाओं (गायन,वादन तथा नृत्य) में ताल का अत्यधिक महत्व है। ताल संगीत का व्याकरण तथा उसकी आत्मा है। ताल को क्रियात्मक रूप में प्रदर्शित करने के लिए वाद्यों की आवश्यकता होती है। जब ताल को किसी वाद्य पर प्रदर्शित किया जाता है, तभी ताल का सही रूप निखर कर सामने आता है। संभवतः यही कारण है कि संगीत के क्षेत्र में वाद्यों का अत्यधिक महत्व है।

लोक वाद्य

भारतीय संस्कृति के प्रारंभिक चरण से ही मानव अभिव्यक्ति का एक सशक्त माध्यम संगीत रहा है। संगीत के अंतर्गत नृत्य, गायन व वाद्य तीनों प्रमुख रूप से सम्मिलित है। प्राचीन काल में मनुष्य अपने खुशी, उत्संाह आदि को प्रदर्शित करने के लिए इन्हीं का सहारा लेता था। इनमें वाद्यों का प्रमुख स्थान है। संगीत और नृत्य की शोभा इन वाद्य यंत्रों के प्रयोग से बढ़ जाती है।

भारत में संगीत का स्वरूप हमें प्रागैतिहासिक काल से शैलचित्रों के माध्यम से दिखाई देता है जिसमें मनुष्यों को नृत्य करते हुए प्रदर्शित किया गया है। वाद्य यंत्रों का प्रयोग हमें वैदिक काल से देखने को मिलता है। ऋग्वेद, यजुर्वेद, सामवेद तथा अथर्ववेद में दुदुभि, वाण, नाड़ी, वेणु, कर्करि, गर्गर, अघाटि, वीणा, तूणव आदि प्रमुख वाद्य यंत्रों का उल्लेख स्पष्ट रूप से दिखाई देता है। रामायण-महाभारत बौद्धकाल में भी संगीत तथा वाद्यों का प्रयोग निरंतर चलता रहा मौर्य काल से लेकर पूर्व मध्यकाल तक की विभिन्न नए वाद्यों का उल्लेख मिलता है जैसे- ढोल, वंशी डफ आदि। इसी प्रकार मध्यकाल में सितार तथा तबला जैसे नए वाद्यों का प्रचार-प्रसार हुआ तथा आधुनिक काल में पश्चिम देशों के परिणाम स्वरूप गिटार, वायलीन, पियानो आदि विभिन्न वाद्य यंत्र आज हमारे संगीत का हिस्सा बन चुके है। किन्तु इन सबसे अलग हमारे लोक संस्कृति तथा लोकवाद्य है। प्राचीन काल से ही क्षेत्र विशेष की एक विशेष संस्कृति रही है जिन्हें लोक संस्कृति के नाम से जाना जाता है इनमें छ.ग. क्षेत्र भी एक विशिष्ट स्थान रखता है। लोक जीनव में प्रचलित विभिन्न कहानियों जनुश्रति आदि को लोकनृत्य, संगीत व नाट्य के द्वारा दिखाया जाता है तथा इनके लिए प्रमुख वाद्य यंत्रों को सहारा लिया जाता है। इन क्षेत्रीय लोक वाद्य यंत्रों की अपनी एक अलग विशेषता होती है।

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Major Tribal Festival of Central India – "GIRDA"

(With Special Reference to Saila and Reena Dance)

Prof. Dr. Richa Thakur- Govt Dr.WW Patankar Girls' PG College,Durg (CG)
richa.jyotindra@gmail.com

Dr. Shabeena Begam- Govt Dr.WW Patankar Girls' PG College,Durg (CG)
shibu.2103@gmail.com

The history of human race is very old, whose development has started from thousands of years ago and has reached the modern era through various stages. Even in this era, some human groups are adopting their own culture and religion, living a simple and simple life and using natural products. These human groups lead their lives in the midst of nature away from the luxuries of the modern age. This type of human group resides in different regions of India such as forest regions, plateau regions, far east hills, mountainous regions and dense forests etc. These human groups are known as tribal societies. The word "Janjati" is the Hindi version of the English word "Tribe" which refers to such a human group who, while living a simple life, have preserved their separate folk culture. The members of these tribal societies are addressed by various names such as primitive caste, tribe, forest caste, tribal, forest dweller etc.

Scheduled Tribes account for a total of 8.2% of India's population in various states/union territories of India, except Jammu and Kashmir. In the states having more number of Scheduled Tribes, Madhya Pradesh and Chhattisgarh is important. In Madhya Pradesh 20.27% of the total population of the state belongs to Scheduled Tribes. In Chhattisgarh 31.8% of the total population of the state is from these tribes. Groups of different types of tribes are found in the entire part. They can be classified on various grounds. In particular, they can be seen by classifying them on the basis of geographical, cultural, ethnic, language and economic. Basically, these tribes are in constant struggle with nature to maintain their existence. It is highly dependent on natural resources to meet the basic needs. That is why they are grateful to nature. Even in the expression of their feelings, the words towards nature are visible. Their medium of expression is mainly dance and song. Taking inspiration from the dance forms of many beautiful arts of nature, they gave birth to folk dances. Folk dance is the product of nature.

The daily activities oz tribes are embodied in their folk dances. They dance on all occasions like marriage, festival, celebration, death, harvesting, hunting etc. Although it is difficult to establish their types, yet they can be divided into three types.

(1) Ritual folk dance

(2) Folk dance related to festival

(3) Practical folk dance

Basically Indian folk dance, irrespective of the region, this interrelationship is visible in them.

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Reshma Lakesh
Department of Home Science, Govt. Dr.W.W. Patankar Girls P.G, College, Durg, Chhattisgarh, India

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Research paper **UGC CARE Listed (Group -I) Journal**

INTERNET ADDICTION AMONG ADOLESCENTS AS IMPACT OF TECHNOLOGY

Tabssum
Department of Home Science
Research Scholar
Govt. Dr. W. W. Patankar Girls'
P. G. College Durg (C.G.)
Durg, Chhatisgarh, India
tabssumalidurg@gmail.com

Dr. Reshma Lakesh
Department of Home Science
Assistant. Professor
Govt. Dr. W. W. Patankar Girls'
P. G. College Durg (C.G.)
Durg, Chhatisgarh, India
Drreshmalakesh30@gmail.com

Abstract- ***Internet has emerged as a necessary part of our life. Adolescent have become entirely dependent on the internet to search for information, social website, recreation, online purchasing and online gaming. Educational institutions around the world are making use of the internet to upgrade teaching and studying indoors or outside the classroom using the internet. As India is overrunning towards digitalization and along with showing technological advancement and usefulness. It has also presented some deplorable outcome for the adolescents. The present research work is to find out the impact of technology advancement focusing the internet usage, with reference to positive and negative effect. The researcher has attempted to recognize the several factors having influence on youth's internet addiction level and also analysis the effects. To overcome all these negative effects of internet and technology, the parents needs to monitor their children on regular basis.***

Key words- ***Internet, Internet addiction, Adolescents, Technological advancement, Digitalization.***

I. INTRODUCTION

Internet has emerged as a necessary part of our life. Through internet and social media website any social networking sites have become a handy way to communicate and made feasible to chat with peoples who reside far away.

Adolescent have become entirely dependent on the internet to search for information, social website, recreation, online purchasing and online gaming. Educational institutions around the world are making use of the internet to upgrade teaching and studying indoors or outside the classroom using the internet. If the internet is used wisely then it proves to be very useful for the students such as research instruments, seeking information, improve their interpersonal skills, interchange experience and understanding with worldwide students and others practice even as the internet has many benefits and proves to make higher efficiency, it can also be harmful for students if they become addicted to it. Therefore the objective of this study is to analyse the level of internet addiction among adolescent students.

Now a days, adolescents are rely upon social networking sites like Google, yahoo, Gmail, you-tube, face book, whatsApp, hike, twitter, tik-tok, omeglee, instagram, gaming apps etc.

Studies show that teenager population is a high risk group for internet dependency [1], one of the reasons for this could also be the lack of supervision and guidance while using internet [2]. Internet addiction may also refer as lack of ability to control the will of using internet. It can be described as preoccupation with internet, high use of internet, when they go offline feel restlessness and depressed [3].

The impact of the internet on particular's social participation and health shows that excessive use of internet make you less in touch with family and friends, this will reduce the social circles [4]. Working on internet can decrease social interconnection and communication. Moreover, it denotes that the socially remoted adolescents are more probable to use the internet [5, 6]. Quick and smooth access to the required information also decrease the creativity of the adolescents and oppression using the web facility is the worst effect of the internet. The research carried out by Stanford university on internet utilization showed that 12.4% of students stayed online longer than expected. It is observed that intemperate electronic media usage at night interrupt the sleep which grows the depression [7]

A. INTERNET

The internet sometimes called "the net", is a worldwide system of computer network. A network of networks in which users at any one computer can, If they have authority, get data from other computer system. (And infrequently chat directly to other computer users) it was conceived by the advanced research projects agency (ARPA) of the U.S. government in 1969 and was first known as the APRA Net. The authentic purpose was to create a network that would permit users of a research computer at one universities to "talk to" research computer at other universities.

Now a days the internet is a popular communication and self-sufficient means to hundreds of millions of people worldwide. It is utilized by numerous people as the major source of information utilization, creation and development of its personal social ecosystem via social networking sites and content sharing.

B. ADOLESCENT

Adolescent is the transitional period from childhood to mature adulthood. This is the stage between ages 13 to 19 years. Adolescent is a period between immaturities to maturity. According to WHO, (2017) Adolescent is the phase of life between childhood and adulthood, from ages between 10 to 19. It is a unique stage of development and a vital stage for laying the foundation of wellbeing. Adolescent experience physical, cognitive and psychological growth. According to Hurlock (1990) adolescence begins at the age of 13 and ends at the age of 21.

C. INTERNET ADDICTION

The thought of internet addiction was first used by Young in 1996 he describe internet addiction as an impulse control disorder that does not involve the use of an intoxicating drugs however alike to pathological gambling [8], Internet addiction is also recognized as internet compulsivity, internet dependency, pathological internet use, problematic internet use is a psychological disorder that causes humans to dwell so much time on a smart phone or computer system to the extent that it affects their health, work & social relationship [9].

Internet addiction is described as any web based compulsive behavior which intervence with normal daily lives and cause intense stress an family, friends, relationship and work environment. It is a compulsive conduct that completely dominates the internet addict's life. Internet dependent people make the internet priority more important then family, friends, relationship and work. The internet take place the organizing precept of addicts lives [10].

According to Young et.al. (2000) internet dependence is wide term covering a variety of behavioral problem[11]. There are 5 sub-type of internet addiction are-

1) **Cybersex addiction:-** This sub type of addiction is the most common type of internet dependency. It includes the uncontrolled use of online pornographic material, chartroom, adult websites and obsession with these. Services can be unsafe.
2) **Net compulsion**:- Many adolescent are addicted to this subtype of internet addiction. Net compulsion problem interactive activities like online gaming, stock trading, gambling or use of online auction and compulsive online purchasing. These habits can have an unsafe impact on one's financial stability and problem at work.
3) **Cyber relationship addiction:-** This sub-type of internet addiction refers to social networking websites, chartrooms, and messaging to the extent that virtual

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friends become more important than real world relationship.

4) **Compulsive information seeking:-** **C**ompulsive information seeking is a rising problem both in one's personal life and work place. People may also spend endless hours to search and accumulate a data for the web and get out of manage from browsing through websites. when someone is addicted they might also withdraw from the real world and relationship and work productivity.
5) **Internet gaming addiction :-** This type of addiction can involve all types of offline/online gaming such as video games and computer games. Adolescents are attracted to the graphic, dynamic of the characters and content of games.

D. IMPORTANCE OF INTERNET

The internet is worldwide networking system that uses most of the devices these days and has become a necessary part of daily life. It is one of the significant creation and gives instant access to an interminable supply of information and entertainment.

Some specific examples of importance of the Internet in daily life are-

1. **Search and Research**
Internet contains interminable knowledge and information that you get answer of any question you may have. It is playing a important role in the field of Search and Research. Before the invention of internet, it was difficult to get information about anything. People had to read hundreds of books and journals for reference to get require information. However internet made it easy and anyone can get the desired information at some easy steps or click only. Usage of internet in the field of research have given incredible benefits for the researchers.

2. **Social networking & communication**
Social networking sites have made communication very easy. In the past, it used to take days or months to receive someone's letter, social networking sites have connected people all over the world. Social networking is an necessary part of the internet. With the help of internet, people can send an e-mail or message to anyone across worldwide within a second only.

3. **E - Commerce, Banking and Bills**
Internet is not only limited to ordering goods but also it gives you facilities of online transaction view the balance, through E-Banking, Bill payment and send money. Online shopping is a great advantage of the internet, it gives people the facility to find products of their interest and buy them without going to store. It is also provide facility to customer to compare prices of two or more companies, and even see other customer's review about the particular products.

4. **Entertainment**
Today, internet is the most powerful medium of entertainment. There are many options in the internet in which people can watch movies, playing games, listening music etc. through the internet people can also share contents like videos, pictures, songs online with others. Also, nowadays people attracted towards live TV or sports on smart phone.

5. **Work From Home and Access to a Global Workforce**
The internet is the best place to work with people from worldwide. Many online services help you work from home or globally and with instant communication with the help of internet many people have ability to work from home or have a virtual office. Work from home can save money and time.

6. **Real Time Updates**
Now a days, people do not have to wait for a day to get news and knowing what is happening around the world. People get information instantly through internet. Many information websites gives instant or real time updates on various categories

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like history, News, Sports, Politics, Marketing, Technology etc. e-news papers and e-magazines are updating people and reduce paper usage.

E. SOCIAL IMPACT OF THE INTERNET

The social impact of internet are both positive and negative. On one side where people isolate, separate, alienation and social withdrawal seems, on the other side internet has positive effect on communication, sociability and intensive of relationship. Whether the impact of internet are both god or bad, internet has changed the way of social communication and associated people worldwide.

II. REVIEW OF LITERATURE

Abonmai et. al. studied the level of internet addiction among adolescent students, revealed that below 50% of students are mild internet addicted and their discussion declare that internet dependency is a very common problem in young population caused by lack of knowledge and awareness[12].

Goswami & Singh conclude that, over use of the internet turn into one of the major challenges of the modern world and causes physical and psychological problems [13].

Kowalski and Limber examined that, relationship between children and adolescents experiences with cyberbullying, psychological health, physical health, and academic performance. Sample of study was nine hundred thirty-one students in grades 6 through 12 completed an anonymous survey examining their experiences with cyberbullying and traditional bullying. Also included were measures of anxiety, depression, self-esteem, physical well-being, school attendance, and academic performance. Results of study indicated that, those in the bully/victim groups (and particularly the cyber bully/victim group) had the most negative scores on most measures of psychological health, physical health, and academic performance[14].

Vandana, Balvinder and Singh concluded that most of the adolescents use internet for chatting, watching videos, listening music, downloading data and they found that more than 50% of the Adolescents were above average internet users[15].

Yadav, et.al. studied the internet dependency in Indian school students. The results showed addiction by time spent online & usage of social networking website, gaming app and chat rooms [16].

Yen et al. investigated that, differences in the diversity of family factors between adolescents with and without Internet addiction and substance use experience. Sample of study was 3662 students (2328 boys and 1334 girls) from seven junior high schools, six senior high schools, and four vocational high schools in southern Taiwan. The results of study indicated that, adolescent Internet addiction and substance use experience shared similar family factors, which indicate that Internet addiction and substance use should be considered in the group of behavioral problem syndromes [17].

A. RESEARCH GAP

As India is moving towards digital conversion and it has become the rapid economy of the world. Beside with the going on digital platform, there are negative effects of usage of the technology and internet which human deliberately neglect. Without reason using the internet for long time expresses that people are getting dependent on digital device and tried to measure the internet addiction level of people, specially outside India, but a few studies have emphasized on measuring adolescent's addiction level and recognize the numerous factors having impact on it.

B. RELEVANCE OF THE STUDY

The present research work is to find out the impact of technology advancement focusing the internet usage, with reference to positive and negative effect. The study is important to get an attention of individual , a group and the government on the negative effects of the technology which the people generally neglect. Everyone is trying to get digitalize and the government is also focusing on it. Digital literacy is not only regarding the knowledge of digital devices, but also not getting addicted of technology. The problem of technology and internet addiction should be focused in the initial stage of one getting digital literacy either by any of the family member or institution.

III. METHODOLOGY

A. Research design

A descriptive/cross-sectional research design carried out to assess the level of internet addiction among adolescent.

B. Sample of the study

In this research work 100 adolescent, studying in higher secondary & college first year of age range 15 to 19 years from Durg District (C.G.) were included. The simple random sampling technique was used.

C. Measures

The level of internet addiction was assessed by internet addiction test (Young 1998). It has 20 items. Each item is rated on a 5-point scale ranging from 0 to 5. That measures normal level, mild level, moderate level and severe level of internet dependence. The maximum score is 100 points and the minimum score is 20. The higher the score is, the higher is the severity of addiction.

IV. RESULTS

Statistical analyses procedure

All 100 cases were included for data analyses and calculation. Multiple regression models were used to examine the predicting effect of different predictor on criterion. SPSS version 22.0 was used for prediction analyses. Variable entered methods-Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

Table-1

Stepwise multiple regression models for the predicting effect of different demographical factors on internet addiction

Predicators	**B**	**Std. Error**	**β**
(Constant)	41.462	33.773	
Sex (1=Male, 2=Female)	-4.426	3.043	-.141
Class (1=11th, 2=12th, 3=1st Year)	-4.680	2.608	-.280
Age	.510	2.131	.040
Online use in years	2.273	1.110	.211*
Screen time in a day	3.018	.858	.362**
R			**.483****
R^2			**.233****
$F_{(5, 94)}$			**5.718****

$p<0.01$, *$p<0.05$

Table-1 indicated that, all predictors explained 23.30% of the total variance (R^2= .233; $F_{(5, 94)}$ = 5.718; p<0.01). Further, online use in years was positively associated with internet addiction (.211, p<0.01). This indicated that, those participants higher levels of online use in years were reported high internet addiction. Furthermore, screen time in a day was positively associated with internet addiction (.362, p<0.01). This indicated that, those participants higher levels of screen time in a day were reported high internet addiction.

V. CONCLUSION

The main reason of being dependent on internet and technology are sense of satisfaction and belief of feeling happy over social networking sites [18]. To overcome all these negative effects of internet and technology, the parents need to monitor their children on regular basis, when they use internet although it is little difficult for the parents to monitor the child all the time because digitalization in schools, college has made children to use technology for not only doing the online uploaded homework but also for tracking the progress in class and for taking help of internet to prepare project or assignments [19]. The adolescents have good excuse for using internet and technology. So, digitalization or technological advancement has high impact on the internet addiction level of adolescents.

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डॉ. ऋचा ठाकुर

प्राध्यापक, नृत्य विभाग, शास.डॉ. वा. वा. पाटणकर कन्या स्नातकोत्तर, महाविद्यालय, दुर्ग

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डॉ. ऋचा ठाकुर
प्राध्यापक, नृत्य विभाग, शास.डॉ. वा. वा. पाटणकर कन्या स्नातकोत्तर, महाविद्यालय, दुर्ग
Email: richa.jyotindra@gmail.com

डॉ. के. माधवी
असिस्टेन्ट प्रोफेसर–भरतनाट्यम्, नृत्य एवं नाट्य विभाग, वनस्थली विद्यापीठ (राजस्थान)
Email: madhavinatyam@gmail.com

नाट्य एक व्यापक शब्द है। नाटक इसका एक प्रकार मात्र है। लोकनाट्य 'नाट्य' को इसी व्यापकता में लेते हैं। इसके अंतर्गत उनके वैविध्य एवं प्रयोगशीलता का सहज समावेश है। लोकनाट्य ही नहीं अपितु समस्त लोककला रूपों का अस्तित्व नाट्यशास्त्र से पूर्व भी रहा होगा, ऐसा अनुमान किया जा सकता है। यही नहीं, नाट्यशास्त्र के व्यापक नाट्यानुशासन के बाद भी संस्कृत नाटककारों ने अपनी मौलिकता और प्रभाव के लिए नाट्यशास्त्रीय नियमों का अतिक्रमण किया है उसकी क्षमता और कल्पनाशीलता उन्हें लोकनाट्य से ही प्राप्त हुई होगी। इस प्रकार मानव संस्कृति और समाज के विकासक्रम में लोकविधाओं के नैरन्तर्य ने ही शास्त्रों या अन्य व्यवस्थित कला विधाओं को निर्माण और विकास का आधार दिया है।[1]

लोक नाट्य की परिभाषा–

लोकनाट्य की सर्वमान्यपूर्व निर्धारित परिभाषा न होने के कारण हमें उसके निर्धारण के लिए निम्नांकित तीन स्रोतों का अध्ययन अप्रेक्षित प्रतीत होता है–

1. कोषगत व्याख्याएं
2. विद्वानों के मत
3. लोकधारणाएँ

1. कोषगत व्याख्या–

लोकनाट्य, लोक तथा नाट्य, इन दो शब्दों से बना है। सामान्यतः लोक के तीन अर्थ लिये जाते है–

अ) सभ्यता के प्रभाव के कारण बहुत कम प्रभावित हुआ हो और जिनकी वृत्तियां मौलिक रूप से आदिम और अपरिमार्जित हो।

ब) वह जो गाँवों में निवास करता हो जिस पर बांहरी आधुनिक सभ्यता का प्रभाव नहीं के बराबर हुआ हो।

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This is to certify that the article entitled

ADOPTION OF ARTIFICIAL INTELLIGENCE (AI) IN INSURANCE SECTOR

Authored By

Dr. K.L. Rathi
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Adoption of Artificial Intelligence (AI) in Insurance Sector

Neha Yadav[1]

Dr. K.L. Rathi[2]

Dr. Ravish Kumar Soni[3]

[1] Research Scholar Kalyan P.G. College Sector-7 Bhilai, Durg

[2] Assistant Professor, Govt. Dr. W. W. Patankar Girl P.G. College, Durg

[3] Assistant Professor, Kalyan P.G. College Sector-7 Bhilai, Durg

Abstract

AI which stands for artificial intelligence refers to systems or machines that mimic human intelligence to perform tasks and can iteratively improve themselves based on the information they collect. We want to explore the scope and market penetration of AI in insurance services to overcome ongoing problems for better customer satisfaction in insurance industry.AI can help insurers to assess risk, detect fraud and reduce human error in the application process.AI will reshape claims, distributions, underwriting and pricing. AI by its advanced algorithms can handle initial claims routing and can increase efficiency and accuracy. AI algorithms can learn and improve themselves independently based on past experiences thereby it will result in a more dynamic approach rather than static. Its biggest benefit for insurance sector is potential cost saving.

Keywords: - Artificial Intelligence, Insurance sector

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A brief Study on International Trade in Agricultural Products with Special reference to Indian Economy

Neha Yadav
Research Scholar, Kalyan P.G.College, Sec-7, Bhilai
Dr. K.L. Rathi
Assistant Professor, Govt. WW Patankar Girls PG College, Durg
Dr. Ravish Kumar Soni
Assistant Professor, Kalyan P.G.College, Sec-7, Bhilai

Abstract :- For any country's economy agriculture is a very special sector, so its foreign trade is also very important as other economic sectors. Meaning of Agricultural trade is buying and selling of products that have been produced through the forestry and farming industries. It can give the consumers greater access to a variety of agricultural products, and that too at affordable prices.Agriculture is an important sector for both the developing as well as developed countries, the largest part of agricultural trade is done within the nearby regions.In the world trade the most important trade products are cereals, meat, fruits, and vegetables. European Union and the United States are the largest trading partners all over the world. The European Union exports mainly consumer-oriented, processed products such as wine, whisky and cheese, while US exports are mainly focused on bulk products and animal feed.

In this study the recent international trade in agricultural and food products (agri-food goods) was analyzed. International trade can help to stimulate a wide group of industries which is linked to agriculture, such as transportation, processing, and farm input suppliers. Most of the future growth in food demand is expected to occur in developing countries like India.Agricultural trade is the solution to possible food production shortages occurred due to climatic or other reasons. Ultimately, it contributes to the prosperity of farmers, industries and consumers.

Keywords :- Agriculture, International trade, Agro Product, Import, Export.

Introduction :- Agriculture is one of the most important economic sectors all over the world. Agricultural exports have several economic benefits. It helps to stimulate a wide group of industries which is linked to agriculture, such as transportation, food processing industries, and farm input suppliers. Most of the future growth in agriculture is expected to occur in developing countries. However, there are some circumstances which causes increase in international trade of agricultural goods, such as

- Increased trade liberalization
- Population growth
- Urbanization
- Changing diets

But at the same time countries have to face several challenges as well like

- Climate change
- Deteriorating soil conditions
- Biological diversity loss

Ultimately Agriculture is a specific economic sector in both the developing and developed countries as well. It requires a special treatment and in some cases also requires government involvement. While international trade in non-food products mainly carried upward with gradual liberalization and lowering tariffs (which is the result of several rounds of international trade negotiations), it was not the case in the trade of agricultural products. Unequal position of agriculture compared to other economic sectors leads to the need for protectionism.

Main special characteristics of agricultural production are :-

- Seasonal character;
- Very slow turnover of capital;

IMPACT OF EMPLOYABILITUY SKILLS FOR CAREER ENHANCEMENT

Shikha Markam[1]

[1]Department of Home Science, Research Scholar, Govt. Dr. W.W. Patankar Girls', P.G. College, Durg (C.G.), Durg, Chhatisgarh, India, markamsphm@gmail.com

Dr. Reshma Lakesh[2]

Department of Home Science, Assistant Professor, Govt. Dr. W.W. Patankar Girls', P.G. College, Durg (C.G.), Durg, Chhatisgarh, India, drreshmalakesh30@gmail.com

ABSTRACT-

The present research article deals with the bundle of skill, abilities and knowledge areas that are most likely to be important in the future employability and also the skill investments that will have the greatest impact on occupational demand and information for educators and government can use for strategic and policy making purposes. This effort is made to highlight the importance of employability skills requirements.

Key words- Employability, skills, occupational demand, career enhancement, policy making.

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I. INTRODUCTION

The illiterate of 21st century will not be those who cannot read and write, but those who cannot learn, unlearn and relearn. - Alvin Toffler.

It is predicted that the future work force will be demanding developments. In the current era of technological change and globalization many employability skills are a must required. One of the biggest problem worldwide is unemployment and the main reason is that gap between skills required by the job providers and job seekers.

Career decision making is now seen as part of process of developing career which includes career enhancement. A career mature person is more capable of making an appropriate and realistic career choice and decision. Career mature individual have the ability to identify specific occupational preference and important activities in order to achieve their goals.

The construct of career maturity consists of a readiness, attitude and competency to cope effectively with the career development task. The assumption can be made that a career mature person is more capable of making an appropriate and realistic career choice and decision. Career mature individuals have the ability to identify specific occupational preferences and to implement activities in order to achieve their goals.

For career enhancement every individual needs abilities to analyse information and integrate diverse sources of knowledge for problem solving by observation, inference, communication, language, presentation skills and interpret it effectively from well reasoned conclusion and solution, testing them against relevant criteria and standards.[1]

CAREER ENHANCEMENT

Career enhancement, for most people is a lifelong process of engaging the work world through choosing among employment opportunities made available to them. Each individual undertaking the process is influenced by many factors, including the context in which they live, their personal aptitude and educational attainment [2].

A career can be defined as the employment you prepare during the first quarter of your life engage in during the best years of your life and reap the rewards from when you are least able to enjoy them. Behind the cynicism of this observation lies an important truth choosing a life's vocation is not a decision to be taken lightly. To justify the effort you will invest in your career, it should be stimulating, rewarding and productive.

Career enhancement plan is very tedious and challenging. Effective communication and interpersonal skills are crucial to increase employment opportunities and to complete successfully in career. The real key to the effectiveness of professionals is their ability to put their domain knowledge into effective practice. In this context soft skills and communication have a crucial role to play. Thus, soft skills and effective communication training provide a unique opportunity to all students to develop their personality and upgrade their communication and presentation skills.

II. GENERAL REVIEW, ANALYSIS AND DISCUSSION

It is need of hour to investigate the feature or causes of unemployment, the skills embedded by higher education institutions which provide a semi-skilled and skilled work force to compete in the global work market [3].

The skill gaps between employers and employees is a big concern raised worldwide [4, 5 & 6]. So according to ILO 2014 and Statistical Malasian Department of statistic (2014), the issue of employment needs to be addressed seriously [7].

As per Trilling and Fadel the 21st century skills are set of skills required by students in the area of learning, work, life and career [8].

According to World B Group, around 50% of employers could not find right skilled job seekers [9]. So lack of expertise is also one of the biggest reason of unemployment as found by R. Franita [10].

Khatiwada and veloso said that 62% of new jobs in India are classified as high skilled [11]. While Frey and Osbornee Found risk of automation higher in low-usage and low-skills jobs and so adequate preparation and future work force is essential [12].

Suddenly need to develop their potential to have employability skills. Employability is a skill that one should have to continue their career in life and to face global competition and future world work, they need to renew their employability skills [13].

Sam Pitroda, head knowledge commission (2006) revealed many students graduating from different institutions and universities are not employability skills therefore it is necessary that higher education needs to be integrated with the finishing school concept of importing employable skills [14].

The Collins English Dictionary defines the term “Soft Skills” as desirable qualities for certain forms of jobs that do not depend on acquired knowledge, which include common sense, the ability to deal with people and a positive flexible attitude. A study by Harvard University noted that 80% of achievements in career is determined by soft skills and only 20% by hard skills.

According to experts soft skills training should began for person when they are students, to perform efficiently in their academic environment as well as their feature work place. While studies by Stanford Research institute and the Carnegie Mellon Foundation among Fortune 500 CEO’s established 75% of long term job success resulted from soft skills and only 25% from technical skills. So, soft skills are as important as cognitive skills [15].

Most young adult who encounter difficulties in making a career decision try to cope with these difficulties in one way or another. Some individual are likely to feel paralyzed or anxious and may use ineffective coping strategies, such as escape-avoidance behaviors [16, 17], where as other are more likely to use problem-focused coping activities, such as planning, taking direct action or seeking help, indeed, coping strategies have been studied extensively in various contexts and much is known about coping method that are seen as more or less useful [18, 19, 20] .

Living in the 21st century urges people to have current skills, especially higher education students who think that ideally, they will be employed upon graduation. If so, students should take the initiative to enhance and learn skills needed to be employed. Life and career skills comprise of knowledge needed to expand opportunities in gaining employment. Life and career skills consist of what most employers consider as employability skills but from a broader perspective. These skills cater for more than employability skills, they include soft skills, technical skills and academic skills to survive. The new learning paradigm is the formulation of essential skills with the direct aim of teaching students to learn and work well with skills [3].

To meet the workforce demands of Industry 4.0, strengthening learning in existing and new education systems will be crucial. This would entail adopting pedagogical approaches or innovative modes of delivery that enhance how learners learn rather than what they learn, to encourage inquiry and creativity Adopting new approaches may also require educating teachers in using technology and reorienting their primary role as facilitators rather than lecturers[21].

The perception to obtain a suitable job after graduation is only possible, if during learning they are nurtured with different skills are categorized in following domains:

Traditional Core Skills as reading, writing and arithmetic and basic literacy and numeracy.

Learning and Innovation Skills Flexibility, adaptability, initiative, teamwork and leadership.

Digital Literacy Skills Technological proficiency, digital fluency, computing media and information literacy.

Career and Life Skills Flexibility, adaptability, initiative, teamwork and leadership [3].

Technical skill or hard skills are capability which can be learned are easier to measure, which is use of software and this qualification are supposed to be connected to cognitive intelligence and related to the ability to perform particular task [22].

The technical skills include the ability to apply the knowledge and skills of that particular discipline to technical activities, the ability to identify and solve technical problems, the ability to conduct experiments/tests and to analysis results and the ability to identify and use of technical literature [23].

But a additional set of qualification is also required named sift skills. Martin R et al. (2005) and this are a collection of interpersonal and social qualification that allow the individual to function well in society for achievement of their objectives, Redish EF et al (2008). This soft skills are effective written and oral communication, efficient team work, engagement in self directed learning, commitment to continuous improvement and addressing professional and ethical responsibilities [23].

III. CONCLUSION

It is clear that rapid technological advancement have new implication for workforce development, like demand for specialized skills leading to shrinking shelf life of skills and adapting successfully to technological advancements which will require unlearn old technologies and practices and relearning new ones.

Therefore, in order to meet changing demands and maximize the full potential that technology offers, cultivating learn-ability is required and for continuous learning to happen, existing education systems alone is not sufficient, but the creation of learning society is necessary.

Shahin Majid, concluded that there is a need to create awareness about importance of communication skills for career enhancement among students [24].

The punch line is that the academic institutions should accept this change and modify the learning outcomes to include developing and enhancing the soft skills and it depends on how well one interacts with other influences the success of his/her career.

If you want a job, have technical skills. If you want a career, have people skills.

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DR. RESHMA LAKESH,
Assistant Professor, Department of Home Science, Govt. Dr. W.W. Patankar Girls' P.G. College, Durg (C.G.)

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Editor

SIGNIFICANCE OF HINDI LANGUAGE AND INTERNET USAGE AMONG ADOLESCENCE

TABSSUM, Research Scholar, Department of Home Science, Govt. Dr. W.W. Patankar Girls' P.G. College, Durg (C.G.) :tabssumalidurg@gmail.com
DR. RESHMA LAKESH, Assistant Professor, Department of Home Science, Govt. Dr. W.W. Patankar Girls' P.G. College, Durg (C.G.) :drreshmalakesh30@gmail.com

Abstract
This research article, deals with the fact that, this is a time of concern to look forward and make sincere efforts to popularise Hindi, not only in the country, but also around the world. The present national education policy has stressed the importance of mother tongue- Hindi and has suggested various steps for this with the increasing use of internet specially after COVID-19, where students have gone through a big change in the present education system, which has moved to online. Since maximum number of students belong to a group who are not English speaking. Thus, it has become essential to make Hindi language web information to a satisfactory level. The presence of Hindi on the world wide web is still limited and tentative because of attitudinal and technical factors. Besides the other technical setbacks, the Hindi language search engines face many problems. This article deals with the performance of internet usage supporting Hindi language, specially amongst adolescence.

Keywords: *Popularise, Internet usage, Education system, Search engine, Hindi language, Adolescence.*

1. Introduction

The present research article deals with the fact, this is a time of concern to look forward and make sincere efforts to popularize Hindi, not only in the country, but also around the world with the increasingly use of internet specially after COVID-19, where students have gone through a big change in the present education system, which has moved to online. Since maximum number of students belong to a group who are not English speaking. With the web content being written in different languages, English is on the top position, while Hindi on the fifth. [1]
Hindi language information retrieval on the web is still in its nascent stage. The number of users who want the information in Hindi language is increasing. This leads to the demand of the Hindi information retrieval on the web.Hindi is spoken about 30% of people of the country, [2] and is also a major language of many newspapers, magazines, radio and television and media and so it is essential to develop powerful tools for Hindi language information retrieval.[3].
Languagesare a medium of communication and Hindi is that language which connect the whole country. As per data available nearly half a billion people worldwide speak this wonderful language. Hindi also has a good presence on the internet these days and even Google recognizes Hindi as the primary Indian language. Hindi is not only a language but it is our cultural heritage. Our young citizens are the carriers of the culture could vanish. It is important for the younger generation to understand that to know your language is the key way to keep and preserve our culture. [4]
The present national education policy has stressed the importance of mother-tongue-Hindi and has suggested various steps for this with the increasingly use of internet specially by the adolescence of age group (13-17 years) at higher secondary level.

2. Hindi Language and Internet Searching

The spread of Internet in India is today constrained by the fact that mostly the English knowing have been benefited by Internet which is a disappointing situation as the real benefit of internet does not reach to the common man having less/no knowledge of English language. [5]
A recent survey by a Delhi based research organization – Juxt Consult - says that 44 % of existing Internet users in India prefer Hindi to English, if made available.Similarly, 25% existing Internet

users prefer other regional languages. Many big companies like Google, Yahoo and Sify are also taking big steps in Hindi and other regional languages. Despite the latent demand among Internet users for Hindi, if there is very dismal use of Hindi, it is due to certain constraints. These include technological, attitudinal and economic factors. The most important hardware used for internet surfing is the keyboard. Various Hindi keyboards are available in different varieties. Most of the keyboards are phonetically different. However, a detailed analysis of whether these are truly optimal or better arrangements exist, has not been done. Most of this research has been in two broad directions: *Normal Keyboards Ambiguous Keyboards* [6].

Another constraint in spread of Hindi over the WEB is that of limited content. Where there are more than 20 billion pages on web in English, this number is not more than 10 million in Hindi. This poverty of content is partly due to technological factors and partly due to attitudinal. It is a big dilemma that on the one hand the number of Hindi readers and number of Hindi-speaking people using mobile and computers is so large, and on the other hand the websites are very limited in their content and number [7]. This dilemma should be overcome as soon as possible.

3. Search Engines Supporting Hindi Language

Now a day's various search engines support information retrieval in different languages. Google, yahoo, Bing, AltaVista are popular worldwide for searching the web. Recently Hindi search engines like Guruji and Raftaar from India have emerged out for information retrieval in Hindi Language. These Indian search engines are new as compared to international search engines listed above.[5]

4. Factors Affecting

Factors which affect searching Hindi information on web are.

- Morphological Factors: Morphology is the branch of linguistics that studies patterns of word formation within and across languages, and attempts to formulate rules that model the knowledge of the speakers of those languages. [8]
- Phonetic nature of Hindi Language: Many different languages are spoken in India, each language being the mother tongue of tens of millions of people. While the languages and scripts are distinct from each other, the grammar and the alphabet are similar to a large extent. One common feature is that all the Indian languages are phonetic in nature. [9]
- Words Synonyms: India has rich diversity in languages, culture, customs and religions. But, the language structure and variation in dialects is making hindrances in the advantages of Information retrieval revolution in India. For example: we know God is named as "Bhagwan" in Hindi but we can also call "Bhagwan"as "Prabhu" "Ishwar" or "Devta" and more. It is difficult to decide that which one is to choose?
- Ambiguous Words: Many words are polysemous in nature. Finding the correct sense of the words in a given context is an intricate task. One word has more than one meaning and meaning of word is depends on context of sentence. Example - Kar(Tax) having synonymsByaj, Sud, Tax in one context and in another contextKar- Hand or arms and to doin another context.

5. Conclusions

In this research article we discussed the issues and problems which a user may face while finding Hindi information on web and also importance of promotion of Hindi Language and find out the causes and solutions. It is also necessary to make Indian young generation feel proud of mother tongue.

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शास्त्रीय नृत्य भरतनाट्यम - विकास से नवाचार तक

डॉ ऋचा ठाकुर
प्राध्यापक (नृत्य), शास डॉ वा वा पाटणकर कन्या स्नातकोत्तर महाविद्यालय, दुर्ग (छग)
richa.jyotindra@gmail.com

नृत्य मानवीय अभिव्यक्तियों को रसमय प्रदर्शन है1 भारत में प्रचलित 64 कलाओं में से एक कला नृत्य है। संगीत की लय और ताल अनुसार, नृत्य लयबद्ध तरीके से शरीर की गतिविधि है। नृत्य एक विचार या भावना व्यक्त करने का एक तरीका है। भारत, विविधताओं का देश है, जहाँ कला कई रूपों में मौजूद है। भारत में प्राचीन काल से कई कलायें विकसित हुई, नृत्य भी उनमें से एक है। भारत में प्राचीन काल से नृत्य परंपरा को जाना जाता रहा है। मोहन जोदड़ो की खुदाई में मिली नर्तकी की मूर्ति से पता चलता है कि उस काल में भी नृत्य को समझा या जाना गया होगा। हम यूनेस्को की विश्वधरोहर स्थल " भीमबेटका' की गुफा में भी नृत्य की आकृतियाँ देख सकते है। वेद, पुराण, महाभारत और रामायण में भी नृत्य परंपरा का उल्लेख मिलता है। उस समय, भगवान की भक्ति को प्रदर्शित करने के लिये नृत्य किया जाता था। परिवर्तन संसार का नियम है और प्रयोग मनुष्य की स्वभावगत विशेषता मनुष्य की प्रयोगशीलता जितनी उसके जीवन से जुड़ी है उतनी ही उसके क्रियाकलापों से भी जुड़ी है। शास्त्रीय नृत्य कलाओं में मनुष्य की प्रयोगशीलता स्पष्ट रूप से दर्शित होती है । भरतनाट्यम शास्त्रीय नृत्य शैली भारत की प्राचीन नृत्य शैली है जो पूर्णरूप से शास्त्र सम्मत है। माना जाता है कि शास्त्रीय नृत्य शैलियों परंपरा में बँधी होती है अतः उनमें किसी भी प्रकार का परिवर्तन एवं प्रयोग नही किया जा सकता। किंतु यदि ऐसा होता तो जो कला प्राचीन काल में मंदिरों में धार्मिक रीति की तरह प्रस्तुत की जाती थी वर्तमान काल में वह कला प्रेक्षागृहों में मनोरंजन हेतु कैसे प्रस्तुत होने लगी ?

इस प्रश्न का उत्तर यह है कि परंपरा कोई गतिहीन तालाब नही अपितु सदैव प्रवाहित होने वाली नदी की तरह है जिसमें जो जल कल था वो आज नही होगा और जो जल आज है वह कल नही होगा। नदी में बहने वाला जल तो वही रहता है किंतु फिर भी रूपरेखा अथवा ढाँचे में परिवर्तन हो जाता है। कहने का अर्थ है मूल वही रहता है किंतु स्वरूप परिवर्तित हो जाता है परंपरा परिवर्तन के साथ विकसित होती है। परिवर्तन समय के साथ होते है और परिवर्तित परिस्थितियों के द्वारा निश्चित होते है। और यही परिवर्तित परिस्थितियाँ मनुष्य को प्रयोगशील बनाती है। इसलिये भरतनाट्यम नृत्य के कई विविध रूप तथा विभिन्न क्षेत्रों में उसके विविध प्रयोग वर्तमान में देखने को मिल रहे है।

भरतनाट्यम के इतिहास का जब अध्ययन करते है तो ज्ञात होता है कि मंदिर की देवदासी परंपरा से वर्तमान भरतनाट्यम के स्वरूप में बहुत बदलाव आये है । रूक्मिणी जी के इस क्षेत्र में कदम रखते ही प्रयोगों के नवीन युग का आरंभ हुआ। जिसका विकास स्वतंत्रता प्राप्ति के बाद और तीव्रता से हुआ। जिसके परिणामस्वरूप वर्तमान में नवीन विषय, नवीन रचनायें, नवीन नृत्य संरचनायें, नवीन प्रदर्शन आदि के द्वारा यह नृत्य नई सौंदर्यात्मक दृष्टि के साथ दिखायी दे रहा है। शास्त्रीय नियमों का पालन करते हुये इस नृत्य में विभिन्न प्रयोग हो रहे है जिसके कारण इस नृत्य में पर्याप्त विविधता देखी जा सकती है।

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Chemical fractionation of particulate-bound metal(loid)s to evaluate their bioavailability, sources and associated cancer risk in India

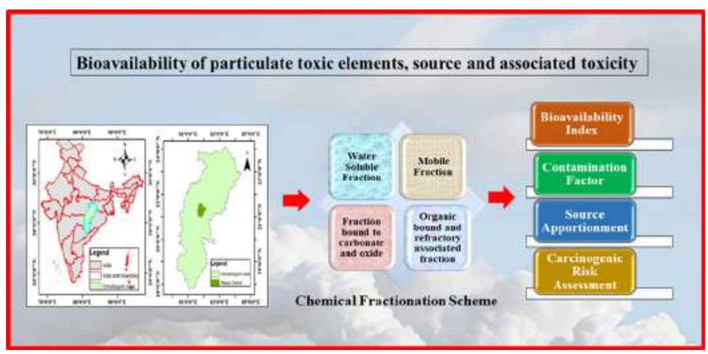
Archi Mishra [a], Shamsh Pervez [a,*], Madhuri Verma [a], Carla Candeias [b], Yasmeen Fatima Pervez [c], Princy Dugga [a], Sushant Ranjan Verma [a], Indrapal Karbhal [a], Kallol K. Ghosh [a], Manas Kanti Deb [a], Manmohan L. Satnami [a], Kamlesh Shrivas [a], Aishwaryashri Tamrakar [a]

[a] School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur 492010, Chhattisgarh, India
[b] GeoBioTec Research Centre, Department of Geosciences, University of Aveiro, 3810-193 Aveiro, Portugal
[c] Government Dr. Waman Wasudev Patankar Girls PG College, Durg, Chhattisgarh, India

HIGHLIGHTS

- Chemical fractionation of 11 metal(loid)s in Indian ambient fine and coarse particulates
- $PM_{2.5}$ metal(loid)s bioavailable fractions are 2.4-fold higher than those for coarse mode.
- Mn has shown highest bioavailable fraction in both fine and coarse particulate mode.
- Source apportionment of fine and coarse particulate metal(loid)s bioavailable fractions
- Bioavailable index, contamination factors and Carcinogenic risks were estimated.

GRAPHICAL ABSTRACT



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ABSTRACT

Eleven potentially toxic metal(loid)s (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn), proven source markers of mineral based coal-fired industrial emissions and vehicular exhausts, were analysed using the four steps sequential extraction method to evaluate metal(loid)s concentration, in total and fractions of bioavailable and non-bioavailable for fine ($PM_{2.5}$) and coarse ($PM_{10-2.5}$) particulate modes. A total of 26-day-wise samples with three replications (total number of samples = 78) were collected in January–December 2019 for each PM_{10} and $PM_{2.5}$ at an urban-residential site in India. In both the coarse and fine particulate modes, Pb and Cr have respectively shown the highest and lowest total concentrations of the measured metal(loid)s, indicating the presence of coal-fired power plants and heavy vehicular activities near to study area. In addition, Mn has shown highest bioavailable fraction for both coarse and fine particulate modes. More than 50 % of metal(loid)s concentration, in total to a bioavailable fraction (BAF) were observed in case of As, Cd, Cr, Co, Mn, Ni, and Pb of $PM_{2.5}$. Mn and Zn have shown similar behaviour in the case of coarse particulate mode. Source apportionment of metal(loid)s bioavailable fractions using positive matrix factorization (PMF 5.0) has found three significant sources: crustal and natural dust (30.04 and 39 %), road traffic (49.57 and 20 %), and industrial emission (20.39 and 41 %) for coarse and fine particulate mode, respectively. Cancer risk through the inhalation pathway was high in total concentration but lower in BAF concentration in both age groups (children and adults).

* Corresponding author.
E-mail address: shamshpervez@gmail.com (S. Pervez).

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1. Introduction

Particulate pollution has attracted worldwide attention as it continues to rise due to an expanding fleet of automobiles, urbanisation, and industrialization. The World Health Organization (WHO, 2016) has reported about 4.2 million premature deaths ascribed annually to fine particulate matter ($\leq PM_{2.5}$) (particles having a diameter of <2.5 μm). According to GBD 2015 Risk Factors Collaborators (2017), exposure to outdoor $PM_{2.5}$ is the 5th leading risk factor worldwide and India's third-leading risk factor. Several elements known for their potential toxicity have been measured in terms of total concentration accumulated in air particulate matter, and associated health hazards. (Kastury et al., 2017; Bano et al., 2018; Pervez et al., 2020; Li et al., 2019; Pervez et al., 2020; Javed and Guo, 2021; Rahman et al., 2021; Gregoris et al., 2021; Rai et al., 2021; Manojkumar et al., 2022). The International Agency for Research on Cancer (IARC) reported that PM is primarily associated with cancer incidence, especially lung cancer (IARC, 2013). Recent studies also highlighted that PMs are correlated with COVID-19, being responsible for an increase in the disease transmission of COVID-19 worldwide (Comunian et al., 2020; Zhou et al., 2020; Chakrabarty et al., 2021). Chakrabarty et al. (2021) established a link between PM long-term exposure and COVID-19 spread in the US. They found that a 1.0 $\mu g{\cdot}m^{-3}$ PM increment in long-term exposure is associated with a 0.25 increase in R_0 (the basic reproduction ratio).

However, the bioavailable and environmentally mobile fractions of PM potentially toxic element's total concentration, are reported to be the only fractions that are known to have the potential to enter human target organs and cause deleterious effects (Anake et al., 2017; Juda-Rezler et al., 2021). The chemistry involved in the emissions, resulting from combustion processes of industrial and domestic heating activities, and vehicular engines, is greatly affected by the processing temperature, combustion efficiency, quality and handling of input fuels/materials, and influence the physical (morphology and solubility) and chemical (chemical bonding) properties of the particles and associated chemical species (Li et al., 2015). Most elemental species associate themselves with the emitted particulate matter based on different physical (morphology and solubility) and chemical (chemical bonding) properties; they produce different fractions: soluble, oxides/reducible, and organic/silicate bound elemental components. These chemically differentiated forms of metal(loid)s found in solid phase matrices are known to be quantified using sequential extraction methods (Chester et al., 1989; Li et al., 2015; Gope et al., 2017; Wang et al., 2021; Mishra et al., 2021). These methods assess the reactivity of metals under diverse physicochemical atmospheric conditions and their relative bonding strength in distinct solid substrates. The sequential extraction method comprises a sequence of chemical extractions using several reagents on the same sample to determine specific fractions of components (Sah et al., 2019; Vollprecht et al., 2020). It is presumed that free metal ions exist in the water-soluble fraction of elements in PM, and soluble organic compounds form a complex bond with metal ions. The most rapidly soluble metal species (sulphates, nitrates, chloride, etc.) can also influence the release of exchangeable metal species by increasing ionic strength (Świetlik and Trojanowska, 2022). Water soluble and exchangeable fractions are considered "bioavailable" or "mobile", being more accessible to the environment and, therefore, hazard to humans (Mbengue et al., 2014; li et al., 2015; Jan et al., 2018).

These potentially toxic elements can influence human health through inhalation, dermal contact, and/or ingestion of ambient particulate matter and thereby being responsible for inducing deleterious health impacts. For instance, Arsenic (As) exposure can be linked to low birth weight and infant mortality, and Chromium (especially Cr(VI)) may lead to lung cancer in mice via inhalation route (ATSDR, 2000; Briffa et al., 2020). An assessment of the health risks associated with total metal(loid)s and bioavailable fraction concentration can outline the negative consequences that a population may face. Heavy industries are considered the significant anthropogenic trace metal sources (As, Hg, Fe, etc.) in urban areas of developing and developed countries. High-temperature processing industries, vehicular activities, and road dust are significant sources of emission of potentially toxic elements in the atmosphere. Also, mineral-based coal-fired industries are responsible for the harmful elements input into the air (Pervez et al., 2020).

This study was conducted to address the research objectives: 1) identification of a receptor site for monitoring the ambient particulate matter a representative receptor site for all types of particulate emission sources (anthropogenic and natural) and free from any dominating local source of ambient particulate matter; 2) Longitudinal sampling of ambient PM was selected to achieve more reliable data of bioavailable fractions and associated source impacts; 3) evaluation of variation in metal(loid)s bioavailability between coarse ($PM_{10-2.5}$) and fine ($PM_{2.5}$) mode of ambient particulate matter; 4) health risk assessment to understand the more reliable adverse health impacts from particulate toxic loads. Considering the research questions and deliverables (scientific objectives, experimental design, and findings), results will be beneficial for many urban-industrial locations globally, to identify and improve air pollution health-related mitigation measures.

2. Methodology

2.1. Sampling site and sampling method

Ambient PM_{10} and $PM_{2.5}$ sampling was carried out in the urban-residential area of Raipur district, Chhattisgarh. It is located southeast of the central peninsular plateau of India (Fig. 1). Raipur is 244 to 409 m above sea level and extends from latitude 21° 23″ to longitude 81° 65″. Raipur has a maximum temperature of 44.3 °C, and a minimum of 12.5 °C and is distributed over about 2892 km^2. Two National Highways (NH-53 and NH-30) pass through the city (MSME, Raipur (C.G.), 2022), with an urban population of 1,276,652 (Census, 2011). The dominating industrial activities in and around Raipur are non-ferrous and steel casting, wire manufacturing, ferro-alloys, foundries, glass, brick factories, pulverization, engineering works, and chemicals. The study area is surrounded by coal-fired thermal power plants and heavy vehicular activities.

PM_{10} and $PM_{2.5}$ was carried out on the roof of a building situated in Kabir Nagar, Raipur, from January to December 2019 (January to May, November, and December) (Fig. 1). Sampling was not done during rainy seasons for the safety purpose of equipment. Air samples were collected on quartz fibre filters (47 mm diameter, Whatman Catalog No. 1851–047) for 24 h by a fine particulate sampler (APM 550, Envirotech) at 16.6 L/min flow rate. Three sets of parallel samples were obtained by operating three PM samplers biweekly. A total of 78 samples (3 replications in each of the 26 sampling events) were collected for each PM_{10} and $PM_{2.5}$. On each sampling day, field blank samples were collected for a minimum duration of 15 min (Pervez et al., 2019). Collected samples were put in polyethylene bags, brought to the laboratory, and stored in a refrigerator (~4 °C). Before and after sampling, the filters were weighted by a single pan top loading digital balance *(Denver, Model TB-2150)* with a precision value of ±10 μg (Watson et al., 2017). Prior to weighting, all filters were prebaked, followed by conditioning in a desiccator at 250 °C and 40 % relative humidity for 48 h. Mass concentrations and chemical components of $PM_{10-2.5}$ were obtained by subtracting $PM_{2.5}$ from PM_{10} concentration (Bano et al., 2018) and considered coarse particles.

2.2. Extraction method

2.2.1. Sequential extraction of metal(loid)s

The sequential extraction method (Richter et al., 2007) was used for the fractionation of metal(loid)s into four fractions: water-soluble (F1), loosely held and exchangeable mobile (F2), carbonate and oxide bound fraction (F3), and refractory fraction (F4). Fractions, reagents and conditions in the sequential extraction procedure are given in Table 1.

The extraction procedure was conducted with a microwave–assisted reaction system (MARS 6, CEM Corporation, Matthews, NC). Reduced treatment time, lower reagent and sample usage, higher reproducibility and improved operator safety are the benefits of microwave (MW) method over traditional hot-plate heating methods and ultrasonic extraction (Karthikeyan et al., 2006; Castillo et al., 2011; Relić et al., 2013). For the

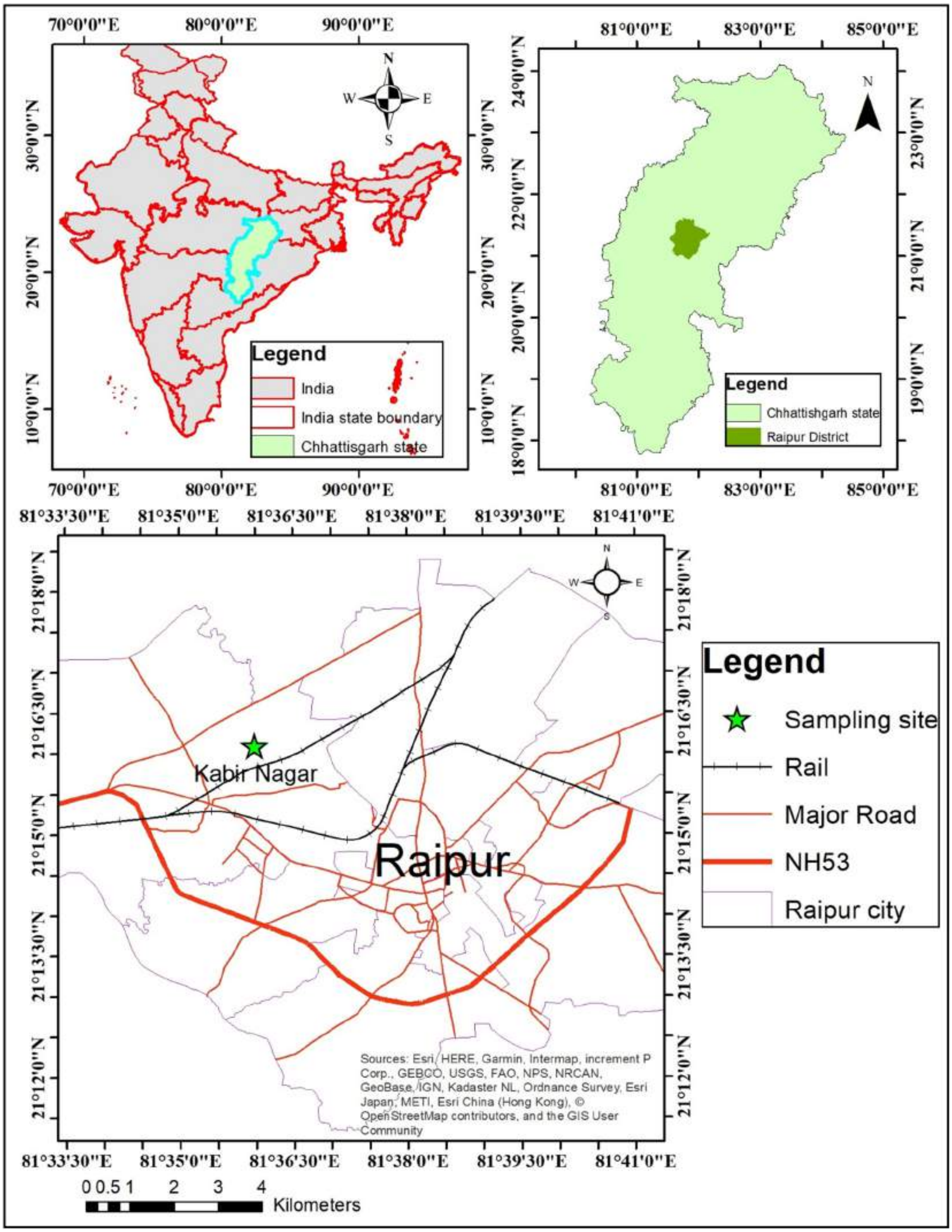

Fig. 1. Map of Raipur city showing the land-use pattern and the Kabir Nagar sampling site.

analysis of samples, quartz filters were cut into 1/4th part and digested sequentially, which was then analysed by furnace atomic absorption spectroscopy (FAAS) (USEPA, 1999). Microwave extractions were performed using microwave energy of 500 W, a pressure of 800 psi and a temperature of 170 °C for 10 min (Karthikeyan et al., 2006; Celo et al., 2010; MARS Protocol, 2020).

2.3. Quality assurance and quality control (QA and QC)

Before and after sampling, each filter was weighted three times and an average value of the three measurements was used as the final weight. After weighting, samples were individually kept in filter cassettes followed by an airtight polyethylene zip lock bag for refrigerated storage (~4 °C). Analytical solutions were prepared in deionized-double distilled water (DDW) for chemical analysis. To minimize potential contamination, filter assemblies and glassware were acid washed and dried in an oven. The Atomic Absorption Spectroscopy (AAS) equipment was calibrated for elemental analysis using a series of five standards for each species. Linear regression calibration curves were taken when correlation coefficient value (R^2) > 0.95. Laboratorial filter blanks were used to assess background levels. For quality control (QC), one standard was analysed for each set of ten samples to assure the 80–98 % recovery range. Each sample was analysed three times to ensure precisions inside the range of ±10 %.

Table 1
Fractions, used reagents and conditions in the four steps sequential extraction procedure.

Stages	Fractions	Procedures
F1	Water soluble	One quarter of the filters were cut into small pieces and placed in digestion micro vessels. The extraction was carried out using 25 mL deionized water for 1 min. Supernatant was filtered out from the residues into a Teflon beaker. Supernatant was preserved with drops of nitric acid pH < 2 at 4 °C. The residue was dried on a water bath and weighed before starting the following step.
F2	Loosely held & exchangeable (Environmentally mobile)	Residues from F1 were again subjected to microwave extraction process for 10 min with 25 mL of 1 mol L^{-1} NH_4OAc (ammonium acetate) at pH 7. The supernatant phase was filtered out and preserved with drops of nitric acid pH < 2 at 4 °C for analysis. The residues were dried.
F3	Fraction bound to carbonate and oxide	Residues from F2 were extracted for 10 min with 25 mL of 1 mol/L hydroxylamine hydrochloride—25 % *v*/v acetic acid and, after leaching, the suspensions were separated. The supernatant liquid was filtered out from the residues and stored for analysis.
F4	Organic bound and refractory associated fraction	Residues from F3 were extracted for 25 min with 10 mL of HNO_3 + 2 mL of HF, 1 mL of H_{2O2}. Then evaporated to dryness and diluted to 25 mL with deionized water.

2.4. Statistical analysis

Gravimetric mass of PM_{10} and $PM_{2.5}$ was calculated using the average of three replicate measurements on a weighting table for each filter. Data is presented as the calculated mean values of the longitudinal measurements of mass and metal(loid)s concentrations, indicating ± standard deviation (SD) and coefficient of variation (CV%). The coefficient of variation was calculated to determine the variation in percentage metal(loid)s concentrations, in total, of each fraction along with the bioavailable fraction. Statistical box plot was drawn to address mean, median, and distribution of the 25th to the 75th percentile of $PM_{2.5}$ and PM_{10} longitudinal measurements, using OriginPro 2016. Measurement data of mass and metal(loid)s concentrations for individual sampling events is presented in supplementary material (Tables S3 and S4). Results were considered significant when $p < 0.05$, on applying the analysis of variance (ANOVA) test.

2.5. Assessment of metal(loid)s contamination

The assessment of metal contamination in PM, measures the degree of contamination in the environment to its retention time. It is given through individual contamination factor (ICF) and global contamination factor (GCF) (Li et al., 2015; Jan et al., 2018). ICF is classified in four groups based on its contamination level viz., ICF < 1 (low contamination); 1 < ICF < 3 (moderate contamination); 3 < ICF < 6 (considerable contamination); and ICF >6 (very high contamination). It is a single-element index, calculated as follows (Eq. 1):

$$\mathrm{ICF} = \mathrm{C(mobile)}/\mathrm{C(immobile)} = \mathrm{C(F1+F2+F3)}/\mathrm{CF4} \tag{1}$$

where C (immobile) represents the refractory metal(loid)s concentration (F4) (usually unavailable for human body), C (mobile) is the concentration of metal(loid)s in the first three fractions (F1, F2 and F3), which become available (on changing the pH) to humans. Global contamination factor (GCF) was evaluated by adding the ICFs of all the metal(loid)s in a sample.

(Eq. 2):

$$\mathrm{GCF} = \Sigma\mathrm{ICF} \tag{2}$$

2.6. Source apportionment (PMF model 5.0)

Positive matrix factorization is an analytical tool that splits input sample data matrices into factor contributions (G) and factor profiles (F) (Norris et al., 2014; Dugga et al., 2020). It is the foremost advanced method for analysing factors and is more capable of handling error estimations in real-world data than other receptor models (e.g., principal component analysis, factor analysis). Through the matrix algorithm of concentration and uncertainty for data sets, PMF profiles and factor contributions were obtained by minimizing object function (Q) in Eq. (3) (Dugga et al., 2020).

$$Q = \Sigma_{i=1}^{n}\Sigma_{j=1}^{m}\left[\frac{x_{ij}\Sigma_{k=1}^{p}g_{ik}f_{kj}}{u_{ij}}\right] \tag{3}$$

where u_{ij} represents the uncertainty estimation of the j^{th} size interval measured for the i^{th} sample. (Norris et al., 2014; Matawle et al., 2018). In the above equation, n shows the number of samples and m denotes the number of chemical elements. Matrix G, which contains the contributions of each source for each sample (g_{ik}), and Matrix F, which contains the concentration of each chemical element to each source (f_{kj}), are the final outputs. Result is determined by the number of factors (p), which are specified by the user (Betsou et al., 2021). The S/N ratio classification of species is "good" (>1), "weak" (0.5–1), and "bad" (<0.5). The most important and unique feature of PMF is that it can weight information of each data point without missing or excluding any species. The uncertainty can be modified to minimize the effect of the missing species or below the detection limit.

Eleven chemical elements (Al, As, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, and Zn) were selected to be analysed in the 78 samples, and were included in the source apportionment database. The correlation between each variable and their percentage contribution in the specific group were used to assess the possible pollution source for each factor (Matawle et al., 2018).

2.7. Health risks assessment

Human Health Risk was assessed for two age groups (children and adults) through three exposure pathways (ingestion, dermal contact and inhalation), considering the BAF fraction (F1 + F2) and total metal(loid)s concentrations (F1 + F2 + F3 + F4). According to the International Agency for Research on Cancer (IARC), air pollutants can be classified as carcinogenic and non-carcinogenic (IARC, 2013). In this study, carcinogenic risk was calculated for six cancer-causing metal(loid)s (As, Cd, Co, Cr (VI), Ni, and Pb) using the methodology given by the US EPA (2009) and the parameters from US EPA (2011).

$$\mathrm{CDI} = (\mathrm{C{*}IngR}) = \mathrm{BW{*}(EF{*}ED)} = \mathrm{AT{*}CF}$$

$$\mathrm{DAD} = (\mathrm{C{*}SA{*}AF{*}ABS})/\mathrm{BW{*}(EF{*}ED)}/\mathrm{AT{*}CF}$$

$$\mathrm{EC} = \mathrm{C{*}(ET{*}EF{*}ED)} = \mathrm{ATn}$$

where:CDI = Chemical daily intakeDAD = Dermal absorbed doseEC = Exposure concentrationIngR = Ingestion rate (according to US EPA model) BW = The average body weight (15 kg for children and 70 kg for adults) C = Concentration of metal(loid) (in mg/m^3) for EC and in mg/kg for DAD and CDIET = Exposure time in hours per day (24 h in the study) EF = Exposure frequency (350 days/year in this study)ED = Exposure duration (6 years for children and 24 years for adults)AT = Average time (for non-carcinogenic risks AT = ED × 365 days × 24 h/day, while for carcinogenic risks AT = 70 years × 365 days × 24 h/day)CF = conversion factor (106 kg/mg)SA = surface area of the skin (2800 cm^2 for children and 3300 cm^2 for adults) that contacts the airborne particulates

AF = skin adherence factor for the airborne particulates (0.2 mg/cm^2 for both adults and children)

ABS = dermal absorption factor (0.03 for As and 0.001 for Cd; 0.01 for other elements)

All parameters used in calculating CDI, DAD and EC were taken from reports published by the US EPA.

Carcinogenic risk characterization was conducted for three exposure pathways viz.; ingestion, dermal and inhalation as follows:

$$CR = CDI * SFo(Ingestion)$$

$$CR = DAD * (SFo/GIABS)(Dermal)$$

$$CR = IUR * EC(Inhalation)$$

where,SFo = oral slope factor (mg/kg/day).GIABS = gastrointestinal absorption factor.IUR = inhalation unit risk (mg/m^3).

The SFo, GIABS and IUR values were adopted from the US EPA (US EPA, 2011).

USEPA defined cancer risks as "the incremental probability of an individual to develop cancer over a lifetime as a result of exposure to a potential carcinogen" (USEPA, 1991).

The range of acceptable risk is 1×10^{-6}–1×10^{-4} indicating the maximum acceptable limit (1×10^{-4}) while, below the lower limit (1×10^{-6}) values represent no harmful risk.

3. Results and discussion

3.1. PM_{10} and PM $_{2.5}$ mass concentrations

A total of 26-day-wise samples with three replications (total number of samples = 78) were collected in January–December 2019 for each PM_{10} and $PM_{2.5}$ at an urban-residential site. The study area is surrounded by coal-fired thermal power plants, heavy vehicular activities, and industries such as non-ferrous and steel casting, wire manufacturing, ferroalloys, foundries, and brick factories. The annual average of PM_{10} and $PM_{2.5}$ concentration was 232.65 ± 79.38 μg·m^{-3} and 159.84 ± 73.32 μg·m^{-3}, respectively. For both PM_{10} and $PM_{2.5}$, the values were 11.63 and 16.00 times higher than the WHO air quality guidelines (WHO, 2006) and 3.87 and 4.00 times higher than the respective annual Indian National Ambient Air Quality Standard (NAAQS, 2009). The outcomes of the present study revealed that the level of PM_{10} and $PM_{2.5}$ is of significant concern because they exceeded the permissible limits. In this study, the average $PM_{2.5}$/PM_{10} mass concentration ratio varied from 0.41 to 0.95, with an average of 0.69, indicating that PM_{10} contains approximately 69 % of $PM_{2.5}$ particles. This result showed the dominance of $PM_{2.5}$ particles in the collected samples.

On applying an ANOVA test, variation in the mass concentrations of both $PM_{2.5}$ and PM_{10} was statistically significant ($p < 0.05$). Fig. 2 depicts monthly concentrations (μg·m^{-3}) of PM_{10} and $PM_{2.5}$ at the urban site. The study was separated into two climatic seasons to assess seasonal variation: winter (January, February, November, and December) and summer (March, April, and May). The higher concentrations were observed in winter, in both fractions. Wind speed, moderate relative humidity, and low temperature can be the reasons for poor dilution of particulate pollution during winter (Kulshrestha et al., 2009).

3.2. Metal(loid)s concentration, in total, associated to coarse ($PM_{10–2.5}$) and fine ($PM_{2.5}$) particulates

Tables 2 and 3 summarize present total metal(loid)s concentration and standard deviation (SD), concentrations of four fractions (F1 to F4), BI and ICF values in coarse and fine particles ($PM_{10–2.5}$ and $PM_{2.5}$, respectively) determined on the analysed samples. Metal(loid)s total concentration (sum of four fractions concentrations: F1, F2, F3 and F4), for both coarse and fine particles, were ranked Pb > Fe > Al > Zn > Mn > Cu > Ni > Co > Cd > As > Cr, and Pb > Fe > Zn > Mn > Al > Cu > Ni > Cd > Co > As > Cr, respectively. Among all elements, Pb showed the highest concentration in coarse and fine particles, followed by Fe, Al, and Zn in coarse, and Fe, Zn, and Mn in fine fractions, while Cr showed the lowest concentration in both PMs. The probable metal(loids) main sources were metallurgical, road traffic, construction, biomass burning, and steelworks. In addition to these,

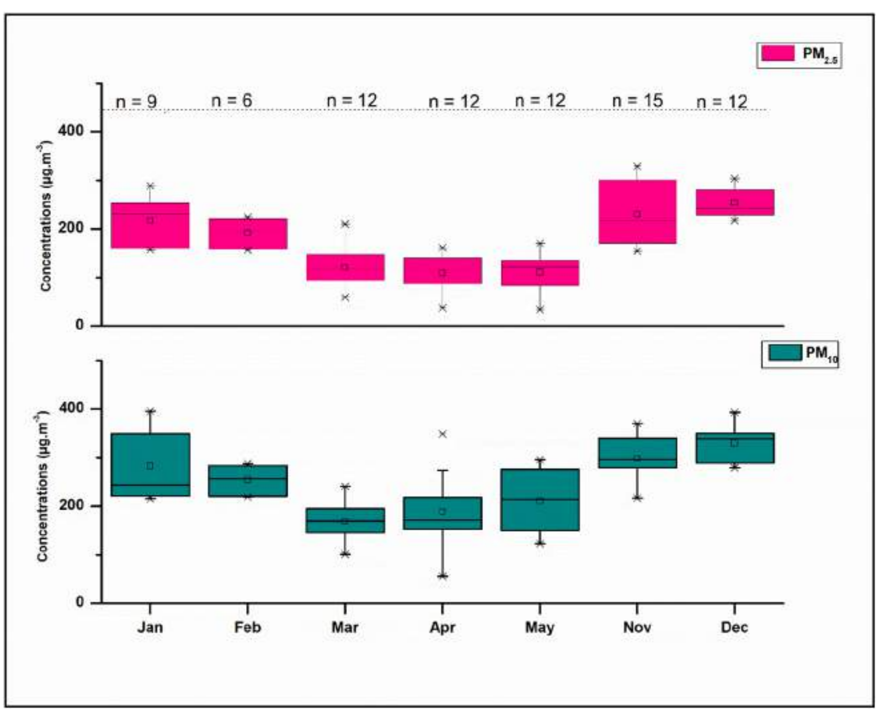

Fig. 2. Monthly averaged ambient $PM_{2.5}$ and PM_{10} concentrations in the study area (urban-residential site) during the sampling period of January–December 2019. A total of 78 measurements (03 replicate measurements in each of 26 sampling events during January–December 2019). Vertical elongated lines represent adjacent values (i.e., extreme values between the 25th and 75th percentiles of each group within a 1.5 interquartile range); horizontal black lines within each box represent median values; small black squares in the boxes show mean value; boxes represent the distribution of values for each category from the 25th to the 75th percentile; the boxes themselves span the values of each group's distribution from the 25th to the 75th percentile. n- denote number of sampling events in respective months.

Table 2

Chemically fractionated and total concentration (μg·m^{-3}) (mean ± SD) of metal(loid)s in ambient $PM_{10–2.5}$ (Coarse particulate) measured in an urban residential site during the period of January–December 2019 with sampling frequency of n = 78. Percentage of coefficient of variability across the measured metal(loid)s (CV_1) and across the longitudinal measurements of individual metal(loid)s (CV_2) for bioavailable fractions, in percentage (F1 + F2) is presented. Bioavailability index (BI) and individual contamination factor (ICF) of measured metal(loids) were also presented.

Fractions (coarse particle)	Al	As	Cd	Cr	Co	Cu	Fe	Mn	Ni	Pb	Zn	
Metal(loid)s in defined fractions and concentration, in total (μg·m^{-3})												
F1	0.016 ± 0.02	0.007 ± 0.01	0.008 ± 0.01	0.004 ± 0.00	0.007 ± 0.01	0.024 ± 0.02	0.082 ± 0.08	0.200 ± 0.155	0.012 ± 0.01	0.308 ± 0.30	0.242 ± 0.20	
F2	0.053 ± 0.05	0.003 ± 0.00	0.007 ± 0.01	0.004 ± 0.01	0.013 ± 0.01	0.017 ± 0.02	0.144 ± 0.08	0.011 ± 0.01	0.008 ± 0.01	0.432 ± 0.39	0.150 ± 0.11	
F3	0.142 ± 0.13	0.007 ± 0.00	0.012 ± 0.01	0.004 ± 0.00	0.016 ± 0.01	0.063 ± 0.09	0.292 ± 0.19	0.013 ± 0.01	0.048 ± 0.04	0.564 ± 0.79	0.116 ± 0.10	
F4	0.451 ± 0.33	0.013 ± 0.01	0.022 ± 0.02	0.007 ± 0.01	0.037 ± 0.03	0.049 ± 0.05	0.864 ± 0.84	0.038 ± 0.02	0.054 ± 0.04	0.856 ± 0.74	0.104 ± 0.08	
(F1 + F2 + F3 + F4)	0.662 ± 0.36	0.029 ± 0.02	0.049 ± 0.03	0.019 ± 0.01	0.073 ± 0.04	0.154 ± 0.15	1.383 ± 0.86	0.263 ± 0.17	0.122 ± 0.07	2.160 ± 1.50	0.611 ± 0.37	
Percentage contribution of metal(loids) concentration, in total to the defined fractions (%)												CV_1 (%) (BAF: F1 + F2)
F1	2.61 ± 2.49	21.63 ± 16.60	16.58 ± 15.30	20.76 ± 15.64	10.28 ± 9.33	17.39 ± 12.49	8.02 ± 9.12	68.69 ± 16.19	11.96 ± 9.43	14.84 ± 12.64	36.95 ± 17.11	51.30
F2	9.45 ± 8.96	11.50 ± 11.11	14.61 ± 14.37	23.07 ± 18.51	17.97 ± 14.64	12.47 ± 8.09	14.18 ± 10.62	5.77 ± 5.15	8.70 ± 6.44	21.63 ± 17.37	25.97 ± 15.04	
F3	23.92 ± 17.02	23.50 ± 14.41	27.73 ± 19.80	22.73 ± 17.87	23.36 ± 16.98	38.12 ± 18.15	26.56 ± 15.52	6.00 ± 3.97	36.91 ± 19.75	24.24 ± 19.46	18.73 ± 11.11	
F4	64.02 ± 19.81	43.37 ± 18.72	41.09 ± 23.81	33.44 ± 19.77	48.39 ± 24.62	32.02 ± 19.77	51.24 ± 18.69	19.54 ± 11.58	42.42 ± 22.21	39.29 ± 21.44	18.34 ± 13.42	
CV_2(%) (BAF: F1 + F2)	79.73	56.55	69.40	54.98	65.84	47.10	69.90	18.35	63.19	60.53	23.11	
Bioavailability index (%) and individual contamination factor values												
BI	10.40	34.29	30.69	27.40	44.29	27.16	16.40	80.35	16.50	34.27	64.13	
ICF	0.47	1.29	1.22	0.96	1.86	2.16	0.60	5.84	1.25	1.52	4.90	

Table 3

Chemically fractionated and total concentration (μg·m^{-3}) (mean ± SD) of metal(loid)s in ambient $PM_{2.5}$ (fine particulate) measured in an urban residential site during the period of January–December 2019 with sampling frequency of n = 78. Percentage of coefficient of variability across the measured metal(loid)s (CV_1) and across the longitudinal measurements of individual metal(loid)s (CV_2) for bioavailable fractions, in percentage (F1 + F2) is presented. Bioavailability index (BI) and individual contamination factor (ICF) of measured metal(loids) were also presented.

Fractions (fine particle)	Al	As	Cd	Cr	Co	Cu	Fe	Mn	Ni	Pb	Zn	
Metal(loid)s in defined fractions and concentration, in total (μg·m^{-3})												
F1	0.0657 ± 0.12	0.0272 ± 0.03	0.0328 ± 0.04	0.0097 ± 0.02	0.0250 ± 0.03	0.0727 ± 0.08	0.1106 ± 0.12	0.5641 ± 0.44	0.0963 ± 0.20	0.9671 ± 1.14	0.3397 ± 0.26	
F2	0.09 ± 0.25	0.01 ± 0.01	0.03 ± 0.04	0.01 ± 0.02	0.02 ± 0.03	0.08 ± 0.10	0.17 ± 0.18	0.05 ± 0.06	0.03 ± 0.10	1.17 ± 1.76	0.31 ± 0.22	
F3	0.22 ± 0.22	0.01 ± 0.01	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.01	0.13 ± 0.18	0.36 ± 0.44	0.03 ± 0.03	0.02 ± 0.04	0.95 ± 1.40	0.32 ± 0.31	
F4	0.32 ± 0.42	0.01 ± 0.01	0.03 ± 0.02	0.003 ± 0.00	0.02 ± 0.02	0.11 ± 0.12	0.66 ± 0.84	0.15 ± 0.05	0.02 ± 0.02	0.92 ± 1.40	0.32 ± 0.30	
(F1 + F2 + F3 + F4)	0.696 ± 0.66	0.055 ± 0.04	0.097 ± 0.09	0.031 ± 0.04	0.082 ± 0.07	0.394 ± 0.31	1.303 ± 1.24	0.791 ± 0.45	0.173 ± 0.28	4.006 ± 4.34	1.294 ± 0.80	
Percentage contribution of metal(loids) concentration, in total to the defined fractions (%)												CV_1 (%) (BAF: F1 + F2)
F1	7.84 ± 9.46	40.02 ± 24.87	28.65 ± 19.00	53.91 ± 20.37	26.68 ± 13.67	20.49 ± 18.18	11.32 ± 10.15	61.74 ± 21.77	46.65 ± 24.67	26.76 ± 21.28	26.29 ± 14.33	29.44
F2	14.41 ± 12.93	*19.11* ± 17.72	23.99 ± 18.80	13.25 ± 11.32	23.98 ± 14.64	18.76 ± 19.04	16.21 ± 15.78	6.45 ± 5.12	7.95 ± 11.05	27.21 ± 19.68	26.13 ± 14.63	
F3	35.00 ± 21.24	19.60 ± 16.18	16.06 ± 16.17	14.71 ± 9.72	21.41 ± 16.03	31.07 ± 23.06	27.06 ± 18.31	5.82 ± 4.94	20.37 ± 17.59	22.85 ± 20.11	23.03 ± 15.24	–
F4	42.75 ± 26.99	21.28 ± 20.13	31.29 ± 21.62	18.12 ± 16.88	27.93 ± 16.63	29.68 ± 23.92	45.42 ± 26.18	25.99 ± 17.50	25.02 ± 20.20	23.18 ± 20.08	24.56 ± 18.28	–
CV_2 (%) (BAF: F1 + F2)	87.43	42.68	49.31	31.11	44.47	71.97	79.56	30.69	44.39	52.87	35.35	
Bioavailability index (%) and individual contamination factor values												
BI	22.68	66.16	63.00	70.24	57.99	38.80	21.77	77.35	71.73	53.46	50.24	
ICF	1.17	4.66	2.86	5.29	3.16	2.60	0.98	4.42	6.17	3.32	2.99	

industrial activities on the outskirts of the city, particularly from the Urla and Siltara located at ~8 and 13 km from the study site, may also contribute to metal concentration. Pb is a carcinogenic element and interacts with various enzymes (Jaishankar et al., 2014). Many biological effects of Pb have been shown experimentally, including effects on the nervous system, immune system, cardiovascular system, endocrine system, reproductive organs, liver, and gastrointestinal tract (Jaishankar et al., 2014). Occurrence of higher Pb concentrations might be due to impact of emissions resulting from coal combustions in high temperature metallurgical industries, located around the sampling area (within a radius of ~10 km) and vehicular exhausts (Das et al., 2018; Zhang et al., 2020).

All metal(loid)s showed higher concentration in winter than summer in both PMs except Fe, which exhibited higher concentration in summer in the coarse fraction. The higher concentration of metal(loid)s during winter may be due to lower wind speed and thermal inversion, which leads to poor dispersion of particle-bound metals from the local sources during this season (Ravindra et al., 2008; Kulshrestha et al., 2009). Increased biomass emission and agricultural crop residue burning could also contribute to metal(loids) concentrations increase during winter (Sah et al., 2019). Wind speed and lower relative humidity, which favour dust resuspension in the atmosphere, can be linked to higher Fe concentration in summer (mainly from crustal sources) (Khillare and Sarkar, 2012).

3.3. Particulate-bound metal(loid)s concentration in defined fractions

The chemical fractionations of metal(loid)s showed more valuable and factual information about the potential toxicity, health risk, and sources of metal-bound particles. Results from the four-steps sequential extraction provided an insight into the variability of metals associated with the two particle sizes (Tables 2 and 3). The percentage distribution of metal(loid)s in different fractions is shown in Fig. 3 a and b, showing that Mn contributed to the highest water-soluble percentage (about 68.69 %-61.74 %) of the total, in both coarse and fine particles, respectively. Emissions from mineral-based coal-fired industries (steel processing and ferromanganese industries) were the primary source of higher levels of bioavailable fraction of Mn concentration, in total in both $PM_{2.5}$ and $PM_{10–2.5}$.

Most of the elements contributed in refractory associated fractions (F4) of coarse particles viz.: Al (64.02 %), Fe (51.24 %), Co (48.39 %), Cd (41.09 %), Ni (42.37 %), As (43.61 %), with the smallest percentage of all metals found in the water- soluble fraction (F1), except for Mn (68.69 %). In the fine PM, Mn (61.74 %), Cr (53.91 %), Ni (46.65 %), and As (40.02 %), shown higher percentages in F1. As, Cd, Cr, Co, Cu, Mn, Ni, Pb, and Zn were associated with F3 (>30 %), while, Al, Cd, Co, Cu, Pb, and Zn were distributed in F2 fine particles. Among the four fractions, the bioavailable fraction (F1 + F2) was the one representing the highest potential to cause adverse health effects, as it can easily be dissolved in liquids, being more bioavailable to the organism (Mbengue et al., 2014). However, metal(loid)s in F3, and F4, even being less mobile, may pose potential health and environmental risk (Jan et al., 2018). Based on fractionation results, metal(loid)s were categorized into three main fractions: 1) bioavailable (BAF)/mobile elements, easily accessible when interacting with human fluids (F1 + F2); 2) elements that mainly bound to carbonates and oxides (F3); and 3) the more immobile elements, mainly bound to silicates and organic matter (F4). Trend of BAF (F1 + F2) in both PM fractions (coarse and fine particles) were ranked Mn > Zn > Cr > As >Pb > Cd > Cu > Co > Fe > Ni > Al, and Cr > Mn > Ni > As > Cd > Co > Pb > Zn > Cu > Al > Fe, respectively. Most of the elements were emitted from industrial activities and can be attributed to the location of the sampling area, close to industrial areas (Agarwal et al., 2017; Panda et al., 2021). Metals bound to carbonate fraction (F3) can be easily mobilized and transformed into F1 or F2, under low pH conditions, suggesting a potential effect on human body due to its pH (Yuan et al., 2011). The elements contribution in F3 fraction, for both PMs (coarse and fine) was ranked Cu > Ni > Pb > Cd > As > Co > Al > Fe > Cr > Zn > Mn, and Cu > Al > Fe > Zn > Pb > Co > As > Ni > Cd > Cr > Mn, respectively. Results indicated that Cu, Ni, Pb, and Cd in coarse, and Cu, Al, Fe, and Zn in fine fractions were more susceptible to oxidizing conditions and may cause harmful environmental effects. The immobile fraction (F4) contains metals mainly in the form of silicates, cement, and passivated oxides that may hold metals within their crystal structure (Feng et al., 2009). Fe and Al were present in higher percentages in the immobile fraction in both PMs, as expected for crustal metals with refractory character and would be environmentally immobile. Sources, such as combustion, soil, mechanical wear, and resuspended road dust, can be attributed to Fe content (Yadav et al., 2018; Morantes et al., 2021).

In a similar fractionation study performed in Agra, India, Sah et al. (2019), reported that Cd (65.7 %) and Co (48.8 %) were mainly distributed in the soluble fraction (F1), while Ni (72.8 %), Cr (65.5 %) and Pb (50.9 %) were found in the residual fraction (F4), while, 44.5 % of As was found on the F2 and the smallest percentage of all metals distributed in the reducible fraction (F4), in $PM_{2.5}$ fraction. In Nanjing, China, Li et al. (2015) found that a higher percentage of Cd, Mn, Cu, and Zn was present in the soluble and exchangeable fraction (F1), whereas Mn highly contributed to the F2 fraction. However, a high percentage of Cu was associated with the F3 fraction, and Fe (45.5 %) was present in the residual fraction. In another study conducted in Guangzhou, Feng et al. (2009), reported that >40 % of Zn, Cd, and As, and > 30 % of Ni and Mn, were distributed in the F1 fraction. In contrast, >70 % Pb, ~40 % of Cd, Zn, and Cu, and 30 % of Mn and As, were distributed in the F2 fraction; while, ~40 % of Ni and > 30 % of Co, Mo, Cr, and Cu were associated with F3, and Cr (>50 %) was the dominant metal in the residual fraction (F4), in $PM_{2.5}$ fraction. Variations in results conducted in different areas might be due to different meteorological conditions and sources.

3.4. Toxicity levels

3.4.1. Bioavailable Index ($PM_{10–2.5}$ and $PM_{2.5}$)

Bound to carbonate and oxide (F3), as well as organic bound fractions (F4) are reported to be strongly associated with minerals solid structure, being immobile. Hence, F3 and F4 fractions are considered to represent low toxicity to human health. However, elements fractionated in the soluble fraction (F1) can be easily released into aqueous solutions and show an impact on human health (Feng et al., 2009). Similarly, elements in the exchangeable fraction (F2) are susceptible to pH variations and redox conditions. These elements are thermodynamically not stable and available under oxidation-reduction conditions (Sah et al., 2019). Hence, F1 and F2 fractions are considered as bioavailable fractions (BAF), since they can interact with human body fluids by inhalation or ingestion. The percentage of BAF in total elemental concentration is used as a bioavailability index (BI) to determine the bioavailability and toxicity level of metal(loid)s (Feng et al., 2009; Sun et al., 2014). Metal(loid)s can be classified with low bioavailability if BI <30 %, medium bioavailability when 30 % < BI < 50 %, and high bioavailability if BI >50 %. Metal(loid)s with higher BIs are considered physiologically more active and may pose a greater risk to humans. The calculated bioavailability indices for the 11 toxic elements analysed on fine and coarse PM fractions are shown in Fig. 4a. In coarse particles, Mn and Zn showed higher BI when compared to fine particles results, while in $PM_{2.5}$ As, Cd, Cr, Co, Mn, Ni, and Pb showed the highest bioavailability index. Whereas, As, Cd, Co and Pb exhibited medium bioavailability index, and Al, Cr, Cu, Co, Fe and Ni had low bioavailability index in coarse particles. In $PM_{2.5}$ Cu showed medium BI and metals such as Al, and Fe showed lower BI. The different BI of these metal(loid)s in both fractions could be attributed to their different chemical states. The chemical states of metals in PM are altered due to various source emissions or atmospheric processes (Jiang et al., 2014). Higher and middle BI value indicates that the metal may be completely available after interacting with human body fluids and can cause severe health risk to human health (Sah et al., 2019).

Jan et al. (2018) have done similar study and observed higher BI values of Cd (66 %), Pb (55 %) and Cr (38 %) in fine particles and higher BI values of Cd (83 %), Pb (59 %) and Cr (54 %) in course particle ($PM_{10–2.5}$. Similarly, Sah et al. (2019) have reported Cd (~85 %) and Co (~70 %) with highest bioavailability index. On the other hand, Varshney et al. (2016)

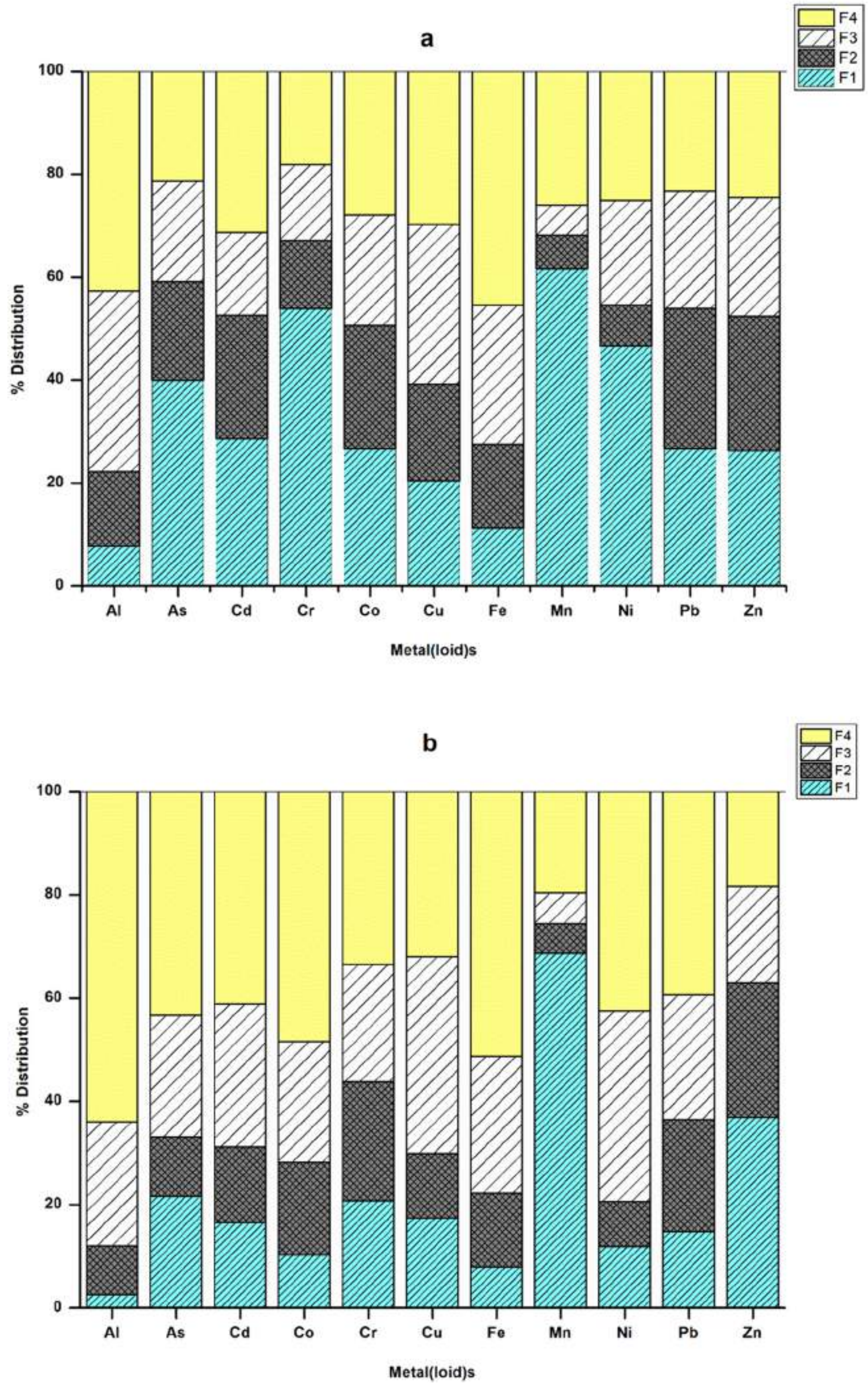

Fig. 3. Percentage distribution of metal(loids) concentration, in total to defined fractions; F1- Water soluble, F2-Exchangeable, F3- Carbonates, oxides bound, F4- Residual fractions (a) Fine Particulate mode ($PM_{2.5}$) (b) Coarse Particulate mode ($PM_{10-2.5}$). A total of 78 measurements (03 replicate measurements in each of 26 sampling events during January–December 2019.

found that Pb had high percentage of bioavailability index of 28 % and Cd (17 %) showed lower percentage of bioavailability index. This variation was related to different elemental chemical states, in different conditions.

3.4.2. Metal(loid)s contamination factor

Individual contamination factors (ICF) were determined by dividing the sum of the metal concentration in the mobile and carbonate bound fractions (F1 + F2 + F3) by the concentration in the refractory fraction (F4), being used to determine the element retention time in the environment (Moses and Orok, 2015; Sah et al., 2019). A higher contamination factor for an element indicates a lower retention time and higher environmental mobility. Thereby, are more accessible to the human body and can be responsible for inducing severe health effects. The calculated results for individual contamination factors (ICFs) by metal(loid)s are shown in Fig. 4b. ICF ranged 0.4–5.8, and 1.0–6.17, in coarse and fine particles, respectively. In coarse particles, only Mn (5.8) and Zn (5.0) showed considerable contamination levels, while Co (1.9), Cu (2.2), As (1.3), Cd (1.2), Pb (1.5) and Ni (1.2), showed moderate contamination. On the other hand, elements Al (0.5), Cr (1.0), and Fe (0.6) exhibited low contamination levels. In fine particles, only Ni (6.2) was found to be very highly contaminated, while metal(loid)s such as Cr (5.3), As (4.6), Mn (4.4), Co (3.1), and Pb (3.3) showed considerable contamination value. Zn (3.0), Cu (2.6), Cd

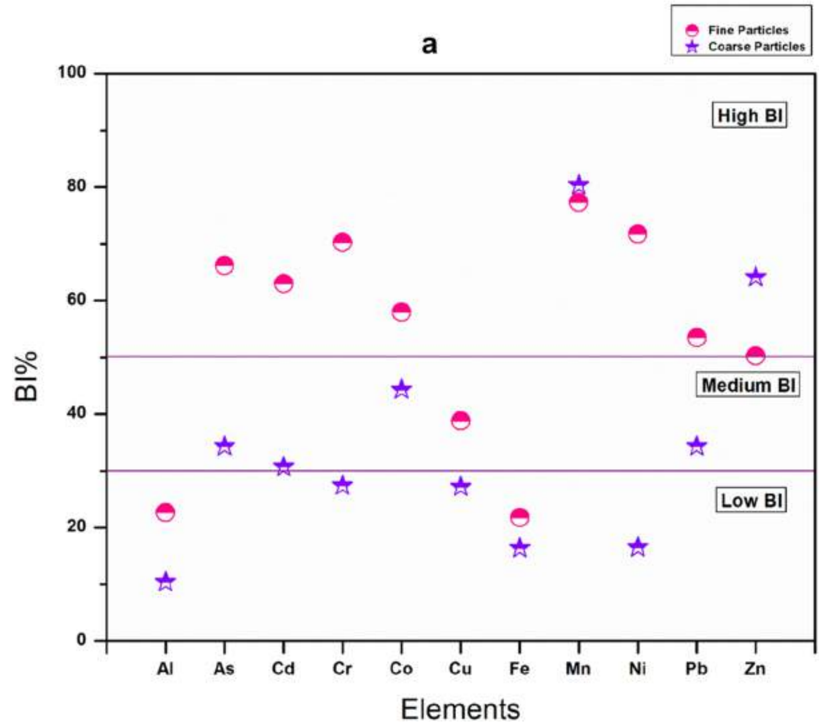

Fig. 4a. Bioavailability index (BI) of particle bound metal(loid)s in fine ($PM_{2.5}$) and coarse particles ($PM_{10-2.5}$). BI is calculated using the metal(loid)s concentrations of F1 and F2. The lines show low bioavailability when BI<30 %, medium bioavailability when 30 % < BI<50 %, and high bioavailability if the BI>50 %. A total of 78 measurements (03 replicate measurements in each of 26 sampling events during January–December 2019.

(2.8) and Al (1.2) were moderately contaminated, whereas Fe (1.0) had low contamination value. Calculated GCF value for coarse and fine particles was 22.1 and 37.6, respectively, which indicated that fine fraction is more contaminated with the considered elements, than coarse one. A study conducted in Agra (Jan et al., 2018), showed high contamination loading by Cd, considerable contamination loading by Pb, Cr, and Co in coarse particles. Fine particles the highest contamination was due to Pb, and considerable contamination for Cu, Cd, Co, was observed. Variability in the results might be attributed to different sampling conditions (seasons, time, and temperature), and sources around the study area. Li et al. (2015) reported Zn and As content with high CF values, while Cr and Fe with low CF values among all elements in $PM_{2.5.}$ In another study of fine particles, Cr, Ni and Pb had low contamination concentrations, As and Co had considerable contamination, while Cd (> 6) showed the highest

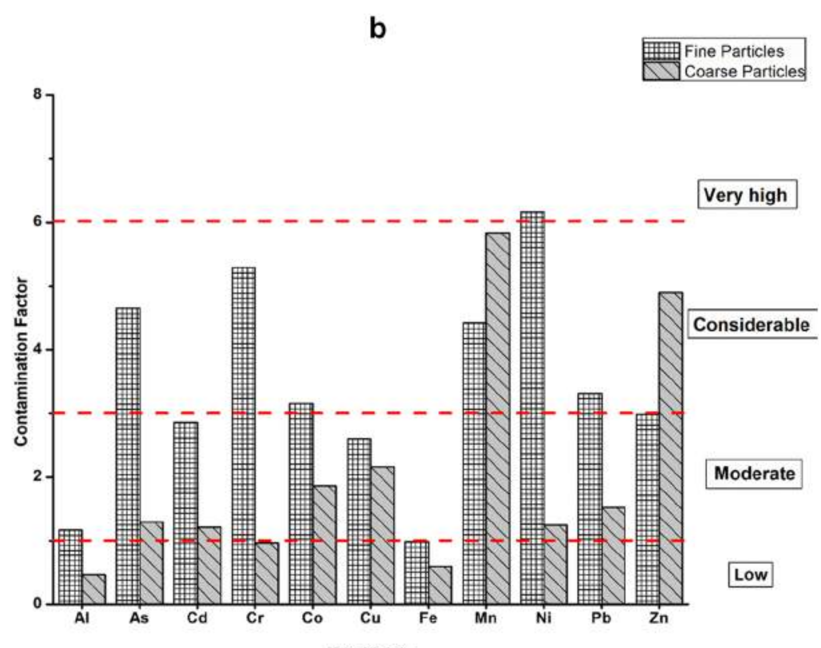

Fig. 4b. Individual contamination factor of particle bound metal(loid)s in fine ($PM_{2.5}$) and coarse particles ($PM_{10-2.5}$). The red dashed lines show contamination level viz., ICF < 1 (low contamination); 1 < ICF < 3 (moderate contamination); 3 < ICF <6 (considerable contamination); and ICF >6 (very high contamination). A total of 78 measurements (03 replicate measurements in each of 26 sampling events during January–December 2019.

contamination factor, indicating its greater mobility potential and lower retention time (Sah et al., 2019).

3.5. Source apportionment of metal(loid)s bioavailable fraction

Twenty random runs were used in PMF model 5.0 to determine the number of factors that could be considered, and the run with the lowest Q value was selected for three factors (Norris et al., 2014). The estimated Q value, agreed with its theoretical value, was applied to recognize the visible result. The number of factors increased with decreasing in estimated Q value. The concentration of loading species to a specific factor profile was used to compute the absolute number of source factors (Matawle et al., 2018). Highly contributed species were employed for specific factors as an indicator of the definite source type (Vossler et al., 2016).

Fig. S1 and S2 depict the PMF factor profile of BAF fraction as a concentration and percentage of each analysed element associated with coarse and fine particles, respectively. The percentage contributions of different sources in coarse and fine particles are displayed in Fig. 5. In coarse particles, factor 1 was dominated by Al and Fe, with moderate domination of Pb, Cu, and Ni. Resuspended road dust, combined with automotive emissions and crustal materials, can emit Fe and Al (Yadav et al., 2018). Ni and Cu are used in higher concentrations in cement and clayey materials (Kulshrestha et al., 2009; Rai and Gupta, 2020). Hence, this source factor probably was responsible for the crustal source. Factor 2 contributed 49.57 % in total, and was prominent by Cr, Co, Pb, and Zn, but also included Cd, Cu, Ni and Al. This source factor could be related to road dust. The use of Pb in gasoline was eliminated in 2000, in India, although, over the years, it was mixed with the road dust and it still persists from earlier vehicular exhaust emissions (Rai and Gupta, 2020). Previous studies reported Cu, and Zn as chemical tracers of particle brake wear, tire wear, and engine abrasion (Grigoratos and Martini, 2015; Adamiec et al., 2016). A 20.39 % of contribution was observed in factor 3 with high loading of As, Mn and Fe, and moderate loading of Cd, Cr, Cu and Zn. This factor possibly represented emissions from industrial activities. These metals may have their origin in steel industries and road dust resuspension (Srivastava and Jain, 2008; Jan et al., 2018). Cr is used in steel and cutting tools (Kulshrestha et al., 2009; Rai and Gupta, 2020), and Cd is emitted by burning of fossil fuels (Ghosh et al., 2014; Rai and Gupta, 2020). Cheng et al. (2021) reported that metal smelting, manufacturing, and coating production activities are responsible for the emission of Cu, and As to the atmosphere.

In fine particles, factor 1 with high contribution of Ni, Pb and Zn may be attributed to vehicular activities and contributed 20 % in total. Zn can be emitted from tire wear and it is a common component of fuel additives, engine oils, tires, and brake linings (Chakraborty and Gupta, 2010). Factor 2 with 39 %, contained anthropogenic elements As, Cd, Cu and Pb. This factor is likely related to crustal and natural dust (Pant and Harrison, 2013). Factor 3 (41 %) showed higher contribution of Al, As, Cr, Co, Fe, Mn and Ni, that can probably be assigned to industrial sources (Saradhi et al., 2008). Arsenic is widely used as a marker for coal and fuel combustion (Cai et al., 2021). Previous studies documented Cr as a tracer of industrial activities (e.g., metallurgy, electroplating, refractory, and foundry industries) (Morrison and Murphy, 2010; Mansha et al., 2012). Xu and Tao (2004) reported that Mn has a similar atomic radius and chemical morphology to Fe group elements, which indicate easy enrichment during iron ore formation. Several metal manufacturing plants near the sampling site could have influenced the air quality.

3.6. Health risk assessment of total concentration and bioavailable fraction

Health risk assessment through three exposure pathways (ingestion, dermal contact and inhalation) was calculated for total metal(loid)s concentration (F1 + F2 + F3 + F4), and bioavailable fraction (F1 + F2). Results of carcinogenic risk for six metal(loid)s (As, Cd, Co, Cr (VI), Ni and Pb) through each exposure pathway were depicted in Fig. 6 and Tables S1 and S2, for coarse and fine particulate fractions, respectively. Inhalation of both coarse and fine particles, was considered the leading exposure pathway, followed by ingestion and dermal exposure. In coarse particulate mode, cancer risk through inhalation exposure, in total metal(loid)s concentration, Cr (VI) was higher than the maximum acceptable limit (1×10^{-4}), for both children and adults. Higher risk was identified in adults when compared to children. Cancer risk value due to As, Cd, Co, Ni and Pb, to both age groups exceeded the minimum acceptable limit (1×10^{-6}), through the inhalation route. However, cancer risk via inhalation had shown different values for a bioavailable fraction (BAF). Carcinogenic risk of Cr (VI) in BAF fraction for children, was observed within the maximum acceptable limit (1×10^{-4}), and Ni was found to be below the minimum acceptable limit in the BAF fraction.

In the case of fine particulate mode, cancer risk of total concentration for Cr (VI) was observed to be higher than the maximum acceptable limit (1×10^{-4}) for both age groups; children and adult (1.52×10^{-4} and 6.02×10^{-4}, respectively). Considering the BAF concentration, the estimated cancer risk value was reduced (1×10^{-4} and 4.25×10^{-4}) for both the age groups, children and adults, respectively. Cancer risk value decreased when considering the BAF instead of total metals concentration. This study emphasises the importance of determining the metal(loid)s bioavailable fraction in risk assessment investigations.

4. Conclusions

This study examined the chemical fractionation of eleven potentially toxic metal(loid)s associated with coarse ($PM_{10–2.5}$) and fine ($PM_{2.5}$) particulate matter, in an area with significant pollution sources, including heavy vehicle activities, coal-fired industries, crustal origin and soil. PM_{10} and $PM_{2.5}$ levels were 3.87 and 4.00 times higher than the annual Indian National Ambient Air Quality Standard, and 11.63 and 16.00 times higher than WHO air quality limits, respectively. Concentration of both PMs fractions were higher in the winter, than in summer what might be attributed

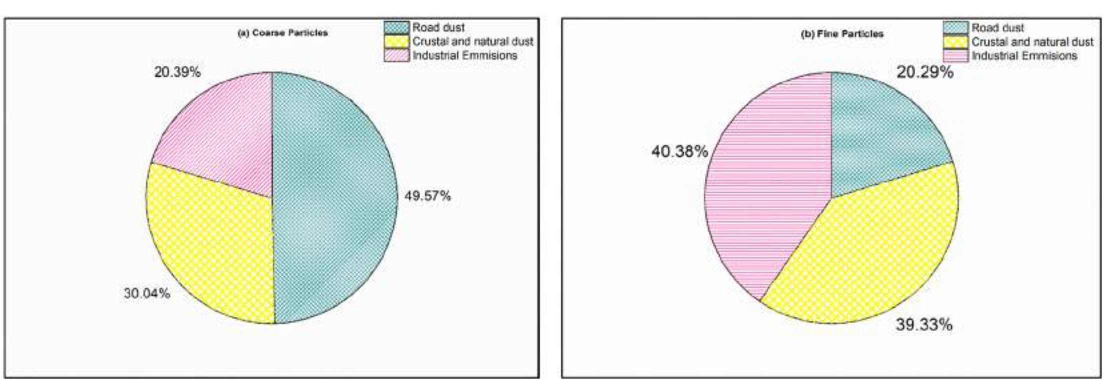

Fig. 5. Assessment of average contributions of sources associated with bioavailable fractions (Sum of water soluble and environmental mobile fractions: F1 + F2) for coarse particles ($PM_{10–2.5}$) (a) and fine particles ($PM_{2.5}$) (b) using EPA PMF 5.0 model.

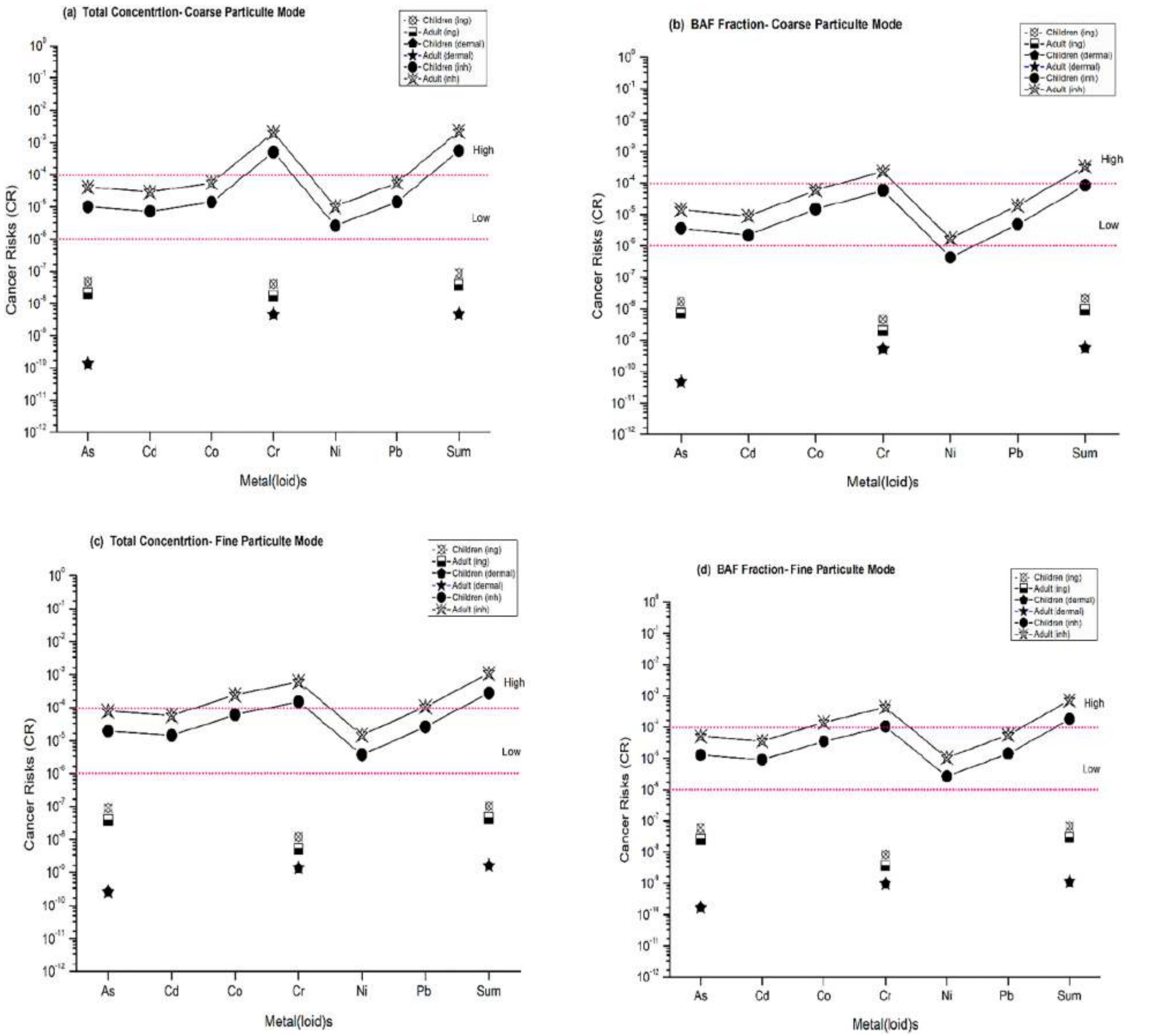

Fig. 6. Cancer risk (CR) for children and adults to metal(loid) through ingestion (ing), dermal and inhalation (inh) exposure pathways (a) total concentration of coarse particulate mode (b) BAF fraction of coarse particulate mode(c) total concentration of fine particulate mode and (d) BAF fraction of fine particulate mode. Total concentration = F1 + F2 + F3 + F4, BAF fraction = F1 + F2 (Bioavailable fraction).

to wind speed, moderate relative humidity, and low-temperature conditions in the study area. Results of the sequential extraction procedure showed that in coarse particles, most elements contributed to F3 and F4 fractions. At the same time, Mn was the dominant metal in the soluble fraction (F1). Mn, Cr, Ni, and As showed a higher percentage in soluble form in fine particles. PMF observations revealed that anthropogenic sources significantly impacted the airborne particles collected in Raipur city during sampling Sources, like coal-fired based industries, vehicular activity, waste incineration, soil, and road dust, are possible key contributors to PM-bound bioavailable toxic metal(loid)s. The individual contamination factor ranged from 0.4 to 5.8 and 1.0–6.17 in the case of $PM_{10-2.5}$ and $PM_{2.5}$, respectively. Coarse particles showed considerable contamination by Mn and Zn content, while fine particles contamination level presented high Ni content, and considerable Cr, As, Mn, Co, and Pb. As, Cd, Cr, Co, Mn, Ni, and Pb revealed the highest bioavailability index in the fine particles, whereas Mn and Zn showed higher BI in coarse particles. Metal(loid)s showed higher cancer risk when considering the total metal(loid)s concentration compared to BAF fraction through inhalation exposure pathways. In coarse mode, Ni showed cancer risk via inhalation above the minimum acceptable limit (1×10^{-6}) to both age groups (children and adults) in total concentration. BAF Ni fraction was below the minimum acceptable limit. Cr (VI), in total metal concentration, showed higher cancer risk in both fractions (coarse and fine mode) in children and adults. Cancer risk due to Cr (VI) in both fractions BAF was considerably reduced for children via inhalation exposure pathway and within the low-risk limit.

This study emphasized the need of examining the bioavailable fraction of potentially toxic metal(loid)s emitted from high-temperature processes involved with mineral processing coal-fired industries worldwide. This research also advances the knowledge on health risk calculations of bioavailable fraction metal(loid)s to understand the more reliable adverse health impacts. A more thorough study on uncertainties related to the extraction method, an entire comparison, and its attestation with in vivo and in vitro assays is necessary.

CRediT authorship contribution statement

Archi Mishra: Data curation, Formal analysis, Investigation, Writing-Original draft, Writing - review & editing Visualization.

Shamsh Pervez: Conceptualization, Data curation, Validation, Writing - original draft, Writing - review & editing, Visualization, Supervision.

Madhuri Verma: Validation, Visualization, Writing- Software, Reviewing and Editing.

Carla Candeias: Writing- Software, Validation, Reviewing and Editing.

Yasmeen Fatima Pervez: Writing- Software, Validation, Reviewing and Editing.

Princy Dugga: Validation, Reviewing and Editing.

Sushant Ranjan Verma: Reviewing and Editing.

Indrapal Karbhal: Validation, Reviewing and Editing.

Kallol K Ghosh: Reviewing and Editing.

Manas Kanti Deb: Validation, Reviewing and Editing.

Manmohan L Satnami: Validation, Reviewing and Editing.

Kamlesh Shrivas: Validation, Reviewing and Editing.

Aishwaryashri Tamrakar: Validation, Reviewing and Editing.

Data availability

No data was used for the research described in the article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2022.159516.

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Atmospheric Abundance of $PM_{2.5}$ Carbonaceous Matter and Their Potential Sources at Three High-Altitude Glacier Sites over the Indian Himalayan Range

Sushant Ranjan Verma, Shamsh Pervez,* Papiya Mandal, Judith C. Chow, John G. Watson, Syed Muzaffarali Andrabi, Madhuri Verma, Princy Dugga, Noor Afshan Khan, Yasmeen Fatima Pervez, Archi Mishra, Manas Kanti Deb, Indrapal Karbhal, Suresh Tiwari, Kallol K. Ghosh, Kamlesh Shrivas, and Manmohan Lal Satnami

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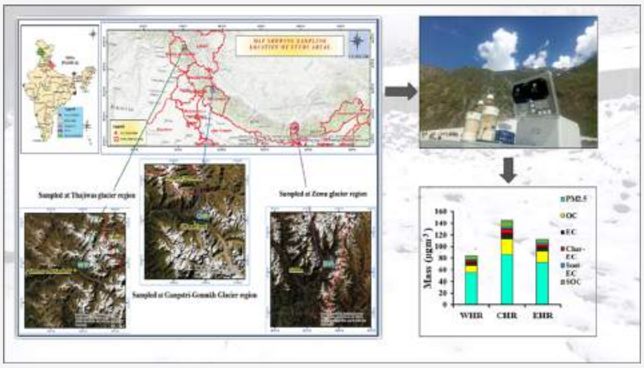

ABSTRACT: This study inspects the concentrations of fine particulate matter ($PM_{2.5}$) mass and carbonaceous species, including organic carbon (OC) and elemental carbon (EC), as well as their thermal fractions in the Indian Himalayan glacier region at the western Himalayan region (WHR; Thajiwas glacier, 2799 m asl), central Himalayan region (CHR; Gomukh glacier, 3415 m asl), and eastern Himalayan region (EHR; Zemu glacier, 2700 m asl) sites, throughout the summer and winter periods of 2019–2020. Ambient $PM_{2.5}$ samples were collected on quartz fiber filters using a low-volume sampler, followed by carbon (OC and EC) quantification using the IMPROVE_A thermal/optical reflectance methodology. Different seasonal variations in $PM_{2.5}$ and carbonaceous species levels were found at all three sites investigated. Averaged $PM_{2.5}$ mass ranged 55–87 $\mu g\ m^{-3}$ with a mean of 55.45 ± 16.30 $\mu g\ m^{-3}$ at WHR, 86.80 ± 35.73 $\mu g\ m^{-3}$ at CHR, and 72.61 ± 24.45 $\mu g\ m^{-3}$ at EHR. Among the eight carbon fractions, high-temperature OC4 (evolved at 580 °C in the helium atmosphere) was the most prevalent carbon fraction, followed by low-temperature OC2 (280 °C) and EC1 (580 °C at 2% oxygen and 98% helium). Char-EC representing incomplete combustion contributed to 56, 67, and 53% of total EC, whereas soot-EC contributed to 38, 26, and 43% of total EC in WHR, CHR, and EHR, respectively. The measured OC/EC ratios imply the presence of secondary organic carbon, whereas char-EC/soot-EC ratios suggested that biomass burning could be the predominant source of carbon at CHR, whereas coal combustion and vehicular emission might be dominant sources at WHR and EHR sites.

KEYWORDS: *$PM_{2.5}$, Himalayan glacier aerosol, carbonaceous matters, char-EC and soot-EC, secondary organic aerosol, biomass burning*

1. INTRODUCTION

Carbonaceous aerosols, including organic and elemental carbon, are important components of suspended particulate matter (PM), especially in the respirable fraction with aerodynamic diameters less than 2.5 μm($PM_{2.5}$).[1] These carbonaceous aerosols work as climate forcing[2] agents and contribute to glacier retreat via interactions with solar radiation in the atmosphere.[3,4] The Himalayan glacier contains the most extensive glacial area outside the polar regions and is also known as the "Third pole".[5] Severe glacier retreat in the Himalayan region has the potential to disrupt water availability to billions of residents living in the Indo-Gangetic plain.[5−11] Because of lower population density and minimal industrial activities, the Himalayan region is considered to be one of the most pristine region, alongside the Arctic and Antarctic.

However, the emergence of atmospheric brown clouds (ABCs) over south Asia raised environmental concerns.[12−14] Numerous studies have suggested that long-range transport of pollutants from the Indo-Gangetic plain to the Himalayan region during premonsoon is the vital factor.[15,16] In addition, local sources from low lands of the Himalayan region also contribute to air pollution.[17] Most of studies were conducted in the foothills[18−20] rather than high altitudes of the Himalayan region.[21−23] This study measures ambient $PM_{2.5}$ and carbonaceous matter (OC and EC) over three subregions of Himalayan glacier locations to evaluate associated spatiotem-

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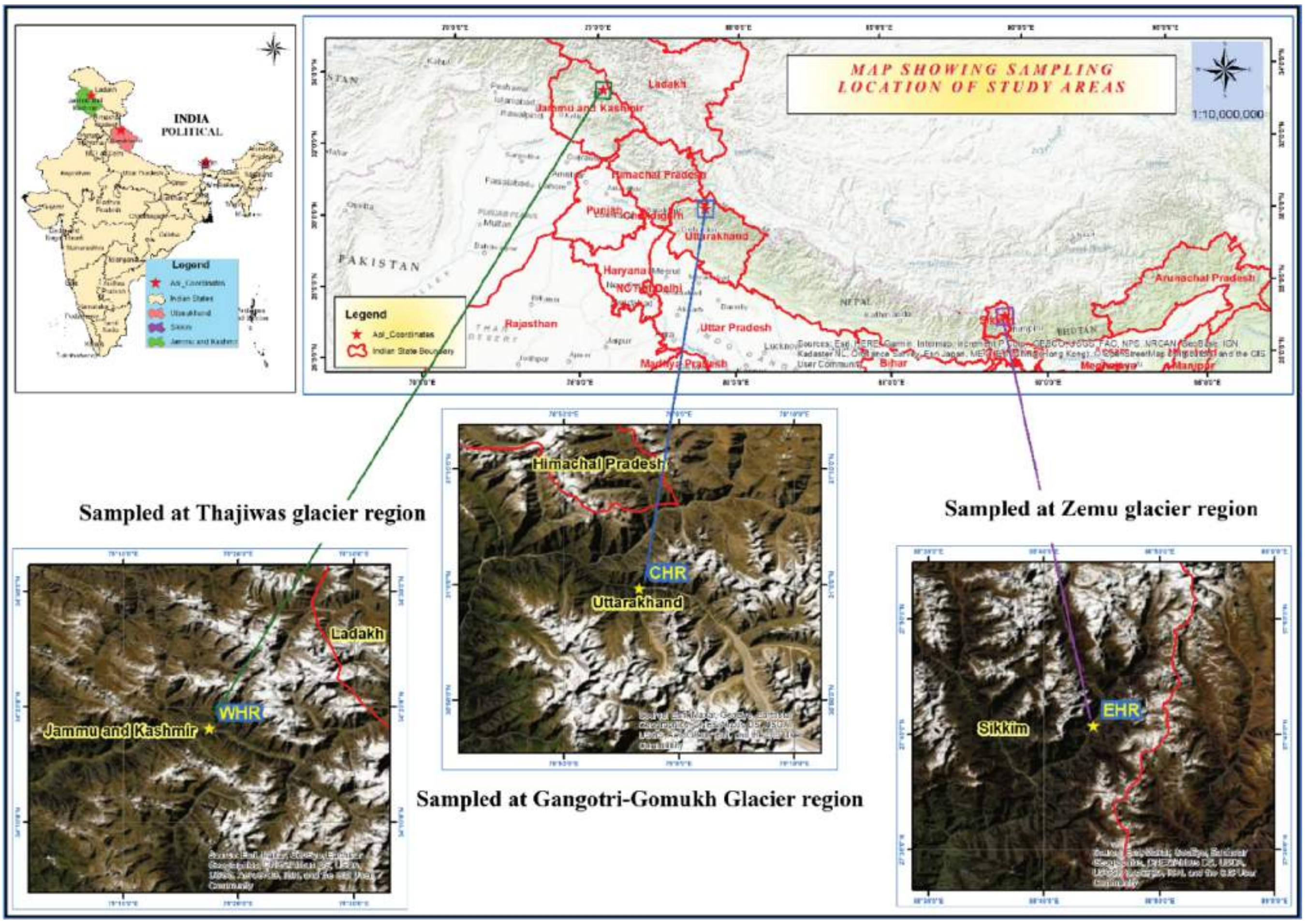

Figure 1. Map showing geographical location of the three sites in the Himalayan Glacier Region of India; from left to right: location of the Western Himalayan Region (WHR: Thajiwas glacier, 34°18′05.9″N 75°17′31.3″E, altitude, 2799 m asl), the Central Himalayan Region (CHR: Gangotri−Gomukh glacier, 30°59′36.2″N 78°56′27.5″E, altitude, 3415 m asl), the Eastern Himalayan Region (EHR: Zemu glacier region, 27°40′41.8″N 88°44′18.9″E, 2700 m asl).

poral variations and seasonal changes. The study's findings have important implications for appropriately assessing the effects of carbonaceous matter on glacial melting and water availability in high-altitude Himalayan glacier regions.

2. METHODOLOGY

2.1. Study Area. Details of geographical locations of the three high-altitude Himalayan glacier sites are depicted in Figure 1. The first site located at the western Himalayan region (WHR) in the mouth of Thajiwas glacier (34°18′05.9″N 75°17′31.3″E) at an altitude of 2799 m above the sea level (asl); the second site located at the central Himalayan glacier (CHR) near the Gomukh glacier (30°59′36.2″N 78°56′27.5″E) where holy Bhagirathi river originates and the famous Gangotri temple (one of the Chota Char-Dham) is situated at an altitude of 3415 m asl; and the third site is located at the eastern Himalayan region (EHR) in the foothills of the Zemu glacier (27°40′41.8″N 88°44′18.9″E) at an altitude of 2700 m asl. Simultaneous sampling was conducted every third day during the summer season of July−October 2019 and during the winter season of November 2019−March 2020.

All sampling sites were located outside of densely populated urban regions and fixed at snow-covered glaciers. Profuse ritual burning practices (oil and incense burning) and domestic heating activities (cooking and heating using solid fuels) have been noted in the vicinity of the CHR site (∼3−4 km away from the sampling site). Locations of highways passing from measurement sites are the Srinagar−Kargil highway (2 km away from WHR), Haridwar−Gangotri highway (3 km away from CHR), and Gangtok−Lachung highway (4 km away from EHR). In addition, open biomass and charcoal/coal burning for domestic heating purposes were also observed to affect the study region. Heavy-duty vehicles on the Srinagar−Kargil highway operated by Indian armed forces and Amaranath pilgrims near the WHR site along with motor vehicles of Indo-Tibetan police force near the EHR site were, also, found to affect the study region.

2.2. Sample Collection of $PM_{2.5}$. A pair of miniVol air samplers (version 4.2, AirMetrics Model Oregon, USA, equipped with $PM_{2.5}$ inlets) was installed at each site at the height of 2 m above the snow surface. The samplers were operated for 12 h (10 a.m.−10 p.m.) at a flow rate of 5 L·min^{-1} (calibrated using the laminar flow rate).[24,25] A total number of 60 sampling events, 20 in each of three sites (10 in each of summer and winter seasons), were performed. Each sampling event was carried out by operating three particulate samplers simultaneously. A total of 180 filter deposited $PM_{2.5}$ samples were collected from all three sites. Samples were collected on prebaked quartz fiber filters (QFFs) (47 mm diameter,

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Whatman, Catalog No. 1851-047) and Teflon membrane filters (Pall Corporation, Catalog No. R2PJ047). QFFs were prefired for four hours at 600 °C to remove carbon residues from the blank filters.[26−28] Each Teflon filter paper was weighed before and after sampling using a digital balance with a precision of ±10 μg (Denver, Model TB-2150).[29] Before each sampling event, a field blank was collected using the blank filter exposed in an air sampler with no flow rate. After collection, the samples were wrapped with aluminum foil, kept in air-tight container, and stored at −4 °C until chemical analysis.

2.3. Analytical Procedures To Quantify the Mass and Carbon Content of $PM_{2.5}$. *2.3.1. Gravimetric Analysis of $PM_{2.5}$.* $PM_{2.5}$ mass was calculated using the averages of three triplicate measurements from each membrane filter. Independent quality control tests were applied.

2.3.2. Chemical Analysis of OC and EC. The QFF samples were analyzed for thermally speciated carbon fractions using a Thermal/Optical Carbon Analyzer (DRI Model 2001; Atmoslytic Inc., USA). A 0.5 cm^2 punch from the filter was analyzed for eight carbon fractions following the IMPROVE_A (Interagency Monitoring of Protected Visual Environments) thermal/optical reflectance (TOR) protocol.[28,30] Differential volatilization of OC in four fractions occurs as a result of stepwise heating of the sample: OC1@140 °C, OC2@280 °C, OC3@480 °C, and OC4@580 °C in a pure helium environment (He), whereas three EC fractions volatilize at higher temperatures: EC1@580 °C, EC2@740 °C, and EC3@840 °C in a mixture of 98% He + 2% oxygen (O_2). The optical method is used to determine pyrolyzed organic carbon (OP) when the reflectance approaches its starting value quickly after the injection of mixed gas (at 580 °C). At low temperatures, fractions of OC evolved in the presence of pure He and catalyst manganese dioxide (MnO_2), whereas fractions of EC evolved in the presence of 98% He with 2% O_2 at high temperatures.[32] Char-EC is calculated by subtracting OP from EC1, while the sum of EC2 and EC3 is expressed as soot-EC.[26,31] To ensure accuracy, autocalibration was performed after every eight samples by using methane (CH_4) gas. The quality assurance/control procedure has been followed.[33]

2.3.3. Statistical Analysis. Microsoft Excel was used to generate annual and seasonal averages of $PM_{2.5}$ (e.g., coefficient of variance, OC to EC ratios, and percentage of secondary organic carbon (SOC) in total OC. Graphical plots were developed through Origin Pro 2016.

3. RESULTS AND DISCUSSION

3.1. $PM_{2.5}$ Mass Variability. As shown in Figure 2, average $PM_{2.5}$ mass concentrations at the WHR, CHR, and EHR sites were 55.45 ± 16.30 μg m^{-3} (ranged 16−86 μg m^{-3}) in WHR, 86.80 ± 35.73 μg m^{-3} (ranged 27−149 μg m^{-3}) in CHR, and 72.61 ± 24.45 μg m^{-3} (ranged: 24−112 μg m^{-3}) in EHR sites (Supplementary Tables S1, S3, and S5). $PM_{2.5}$ concentrations in the WHR, CHR, and EHR are 1.3, 2.1, and 1.8 times higher than those set by the National Ambient Air Quality Standards (NAAQs, 2009) of India (40 μg m^{-3}). Romshoo et al.[18] conducted a long-term study over the urban environment at WHR during 2013−2017 and reported a mean $PM_{2.5}$ concentration (87 ± 97 μg m^{-3}) which was 1.6 times higher than that reported in the present study. Sandeep et al.[17] reported annual averaged $PM_{2.5}$ concentrations (73.14 ± 20.76 μg m^{-3}) at Srinagar (a town in CHR), which is ∼16% lower than that reported in the present study. Furthermore, the present study reported 2−4 times higher $PM_{2.5}$ concentration in the EHR than those reported by Sharma et al.[23] and Arun et al.[21]

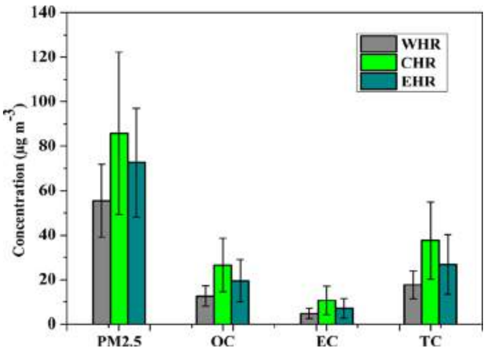

Figure 2. Mean concentration (μg m^{-3}) of $PM_{2.5}$, OC, EC, and TC measured at the WHR, CHR, and EHR of the Himalayan glacier region. Twenty measurements, 10 in each of two seasonal periods (summer and winter) were carried out.

Seasonal mean concentrations during summer and winter periods are 48.51 ± 13.79 and 63.39 ± 16.06 μg m^{-3} at the WHR and 73.77 ± 39.61 and 102.14 ± 28.99 μg m^{-3} at the CHR, whereas summer and winter season concentrations were 63.98 ± 26.57 and 82.41 ± 20.66 μg m^{-3} at the EHR. Highest seasonal average mass concentrations were found in the CHR with higher winter concentrations than nonwinter concentrations (Figure 3). The higher $PM_{2.5}$ concentrations during the winter months can be ascribed to the weather conditions, including stable atmosphere and cold temperature-induced air inversion, reduced wind flow, and trap pollutants near the surface.[23]

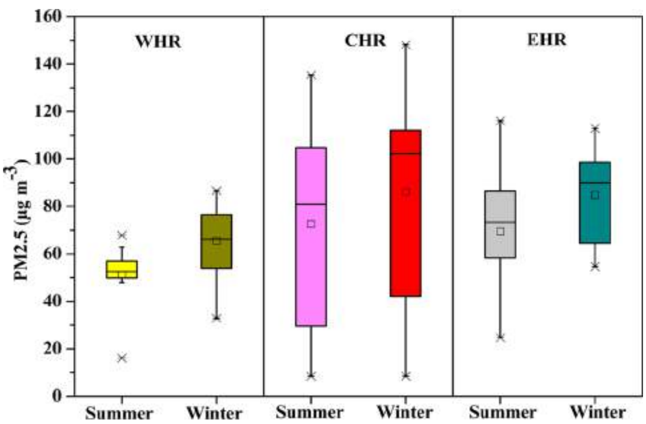

Figure 3. Box and whisker plot showing seasonal variations of $PM_{2.5}$ for the WHR, CHR, and EHR during the period of summer and wintertime over the Himalayan glacier region.

Backward air mass trajectories across the WHR, CHR, and EHR have been plotted to understand the wind pattern and long-range pollutant transport (Figure 4). One hundred and twenty hours back-trajectory graphs at three heights (500, 1000, and 1500 m above the ground level) were generated by the HYSPLIT model (http://ready.arl.noaa.gov/HYSPLIT.php). During summer, trajectories show that the WHR is influenced by the northern part of India, while for the CHR site, the wind patterns show that Indian summer monsoon plays a vital role, entering from Arabian sea, carrying pollutants to the receptor site. The EHR site also exhibited similar wind

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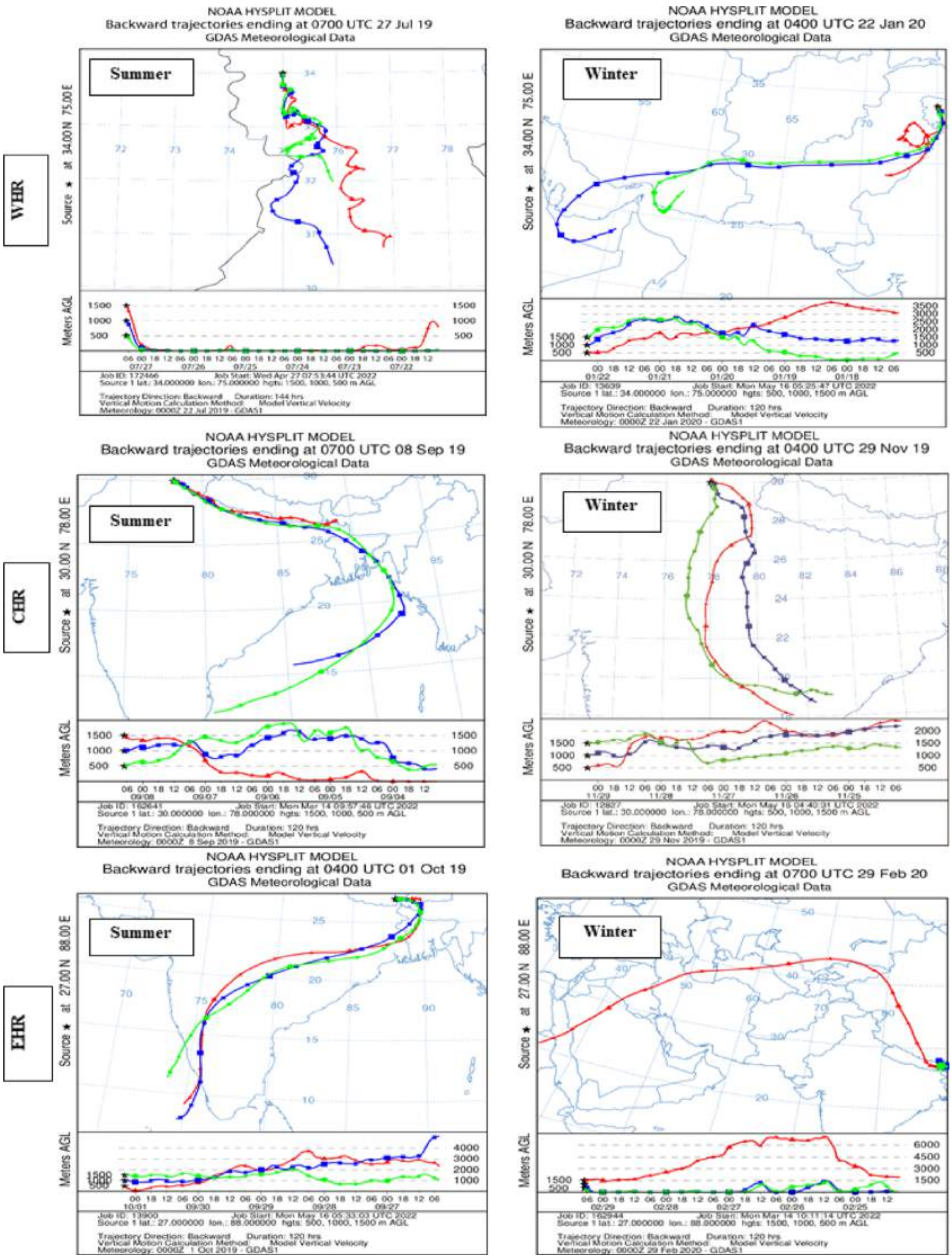

Figure 4. Representative air mass trajectories (backward) over three sampling sites (WHR, CHR and EHR) during summer and winter months. HYSPLIT model (http://ready.arl.noaa.gov/HYSPLIT.php) was used to construct 120 h air mass back trajectory plots at three distinct heights (500, 1000, and 1500 m above the ground level).

as those of the CHR during summer monsoon. In winter months, the WHR and EHR are influenced by long-range transport from far west and local sources, while the CHR is dominated by the central part of India.

3.2. $PM_{2.5}$ Carbon Variability. Average of OC and EC concentrations along with thermal carbon fractions are summarized in Tables S1–S6. As shown in Figure 2 the highest OC and EC concentrations were found in the CHR, followed by the EHR and WHR, respectively. The observed OC concentrations were 12.62 ± 4.53 μg m^{-3} (ranged: 3–23 μg m^{-3}) at the WHR, 27.31 ± 6.53 μg m^{-3} (ranged 10–43 μg m^{-3}) at the CHR, and 19.51 ± 9.54 μg m^{-3} (ranged 9–36 μg m^{-3}) at the EHR. The corresponding EC concentrations were 4.80 ± 2.34 μg m^{-3} (ranged 3–10 μg m^{-3}) at the WHR, 10.07 ± 5.59 μg m^{-3} (ranged 4–25 μg m^{-3}) at the CHR, and 7.13 ± 4.53 μg m^{-3} (ranged 3–20 μg m^{-3}) at the EHR.

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Figure 5 shows the seasonal variations of carbon thermal fractions with higher winter concentrations than summer. The

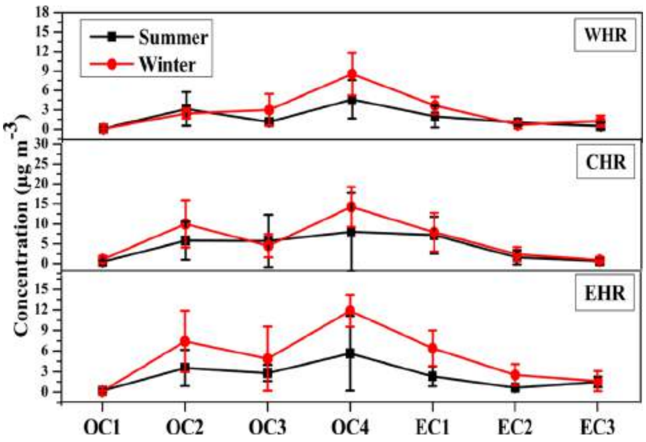

Figure 5. Seasonal variations of temperature-resolved thermal fractions of OC (OC1–OC4) and EC (EC1–EC3) at the WHR, CHR, and EHR during the period summer and winter in the Himalayan glacier region.

observed OC and EC concentrations throughout the summer period were WHR: 10.20 ± 3.37 and 3.87 ± 2.11 $\mu g\ m^{-3}$, CHR: 22.69 ± 12.47 and 9.93 ± 5.85 $\mu g\ m^{-3}$, and EHR: 14.57 ± 6.20 and 4.74 ± 1.94 $\mu g\ m^{-3}$, and during winter months, WHR: 15.61 ± 4.12 and 5.95 ± 2.29 $\mu g\ m^{-3}$, CHR: 31.14 ± 9.82 and 10.80 ± 5.66 $\mu g\ m^{-3}$, and EHR: 26.13 ± 8.63 and 10.71 ± 4.22 $\mu g\ m^{-3}$, respectively. Average percentage contribution of OC to $PM_{2.5}$ ranged 23–31% (23% at the WHR, 31% at the CHR, and 27% at the EHR, while contribution of EC to $PM_{2.5}$ ranged 8–12% (9% at the WHR, 12% at the CHR, and 10% at the EHR). The coefficient of variation (CVs) revealed that the EC concentration showed higher variability throughout the sampling period, with 48.75% at the WHR, 55.51% at the CHR, and 63.54% at the EHR, with less variability in the corresponding OC concentration 35.89% at the WHR, 23.91% at the CHR, and 48.89% at the EHR. These CVs were comparable to those observed in New Delhi, India.[34] The relationship between OC and EC were also established using scatter plots (Figure 6), where significantly lower correlations were observed for the WHR (R^2 = 0.29), similar to those observed over high-altitude central Tibetan plateau, suggesting that OC and EC may be originated from different sources.[35] However, an average correlation (R^2 = 0.76) and (R^2 = 0.59) found in the EHR and CHR indicates common pollution sources.

As shown in Table 1, the high mean OC/EC ratios of 2.79, 3.15, and 2.91 at the WHR, CHR, and EHR suggested contribution from vehicular emission and incomplete combustion. These OC/EC ratios showed similar seasonal variations, with slightly higher values in winter (2.66–3.38) than in summer (2.81–3.17). Carbonaceous aerosols from combustion sources are known to be higher in OC than in EC, resulting in much greater OC/EC ratios. OC/EC ratios were used to differentiate the emission sources. Lower values of OC/EC ratios (≤2) characterize vehicle and industrial emissions, whereas higher OC/EC (>2) ratios indicate the presence of secondary organic aerosol.[36]

The amount of carbon in each of the eight carbon components is used to profile the sources[30,37] of carbonaceous aerosols (i.e., OC1–OC4 and EC1–EC3) which are presented in Tables S2, S4, and S6. As depicted in Figure 7, the mean concentrations of thermally speciated carbon fraction revealed that high-temperature OC4 (580 °C in He) is the dominant fraction followed by EC1 and low-temperature OC2 (280 °C). Higher contents of OC4 (580 °C in 2% oxygen and 90% He) and EC1 reflect abundance of combustion emissions.[38] The highest OC4 (10.08 ± 7.89 $\mu g\ m^{-3}$), OC2 (7.57 ± 5.16 $\mu g\ m^{-3}$), and EC1 (6.97 ± 4.33 $\mu g\ m^{-3}$) were found for the CHR region, which was ~2–3 times higher than the other two sites, indicative of semivolatile organic compounds from solid fuel or ritual burning practices and vehicular emissions. High-temperature EC3 (840 °C) was also elevated (0.26–9.1 $\mu g\ m^{-3}$) over the Himalayan glacier region, which pointed to the use of heavy-duty diesel fuels and combustion of fossil fuels.[39,40]

In addition to OC and EC, total carbon (TC), total carbonaceous aerosol (TCA), and secondary organic aerosol (SOA) are also summarized in Tables S1, S3, and S5. The TC is the summation of OC and EC (TC = OC + EC), while TCA is estimated by multiplying OC with a factor of 1.8 and then adding EC (TCA = OC × 1.8 + EC). Overall, TCA contributes 51, 69, and 59% to $PM_{2.5}$ mass at the WHR, CHR, and EHR, respectively. Higher TCA% in the Himalayan glacier region is 7–25% higher than those high-altitude Garhwal Himalayas reported by Sandeep et al.[17] with TCA accounting for an average of 43% of $PM_{2.5}$ mass in 2017. During winter months at CHR, TCA accounts for 67.11 ± 21.73 $\mu g\ m^{-3}$ similar to those during winter months reported by Kumar et al.[22] at Pantnagar (CHR). This revealed that higher concentrations of CHR could be attributable to

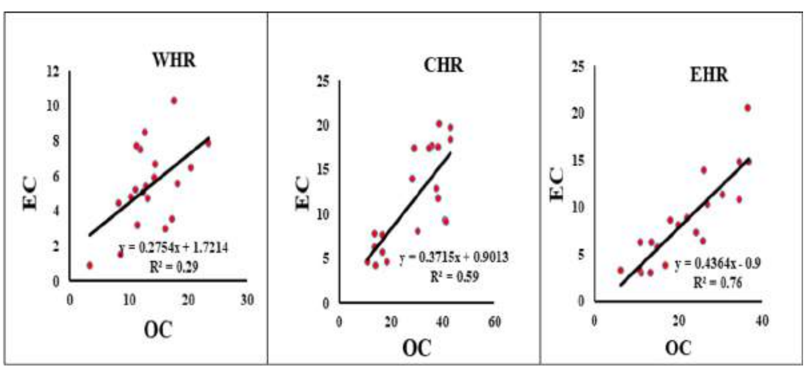

Figure 6. Scatter plot between OC and EC using measurements carried out during the entire study period for (A) WHR, (B) CHR and(C) EHR sampling sites to predict the similarity/dissimilarity in the sources of OC and EC.

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Table 1. Statistical Summary of the Mass Concentration ($\mu g\ m^{-3}$) of the Measured Species ($PM_{2.5}$, OC, TC, TCA, SOC, Char-EC, and Soot-EC), along with the OC/EC Ratio and the Char/Soot Ratio at WHR, CHR, and EHR Sites

location	season	$PM_{2.5}$	OC	EC	TC	SOC	TCA	char-EC	soot-EC	OC/EC	char-EC/soot-EC
WHR	summer	48.51 ± 13.79	10.20 ± 3.37	3.87 ± 2.11	14.23 ± 5.20	5.43 ± 2.08	22.41 ± 7.84	1.98 ± 1.68	1.60 ± 0.66	2.85 ± 1.39	1.32 ± 0.93
	winter	63.39 ± 16.06	15.61 ± 4.12	5.95 ± 2.29	21.96 ± 4.93	7.42 ± 4.64	34.51 ± 8.00	3.67 ± 1.35	2.15 ± 1.19	2.74 ± 1.45	1.92 ± 1.92
	average mean ± SD	**55.45 ± 16.30**	**12.62 ± 4.53**	**4.80 ± 2.34**	**17.68 ± 6.11**	**6.35 ± 3.81**	**27.81 ± 9.61**	**2.69 ± 1.59**	**1.86 ± 1.01**	**2.79 ± 1.38**	**1.59 ± 1.16**
CHR	summer	73.77 ± 39.61	22.69 ± 12.47	9.93 ± 5.85	32.81 ± 17.96	9.71 ± 6.61	50.99 ± 27.87	7.21 ± 4.64	2.47 ± 1.42	2.81 ± 1.00	4.47 ± 5.93
	winter	102.14 ± 28.99	31.14 ± 9.82	10.80 ± 5.56	42.23 ± 14.12	16.42 ± 7.60	70.13 ± 22.98	7.16 ± 4.20	3.27 ± 1.71	3.38 ± 1.79	3.13 ± 5.81
	average mean ± SD	**86.80 ± 35.73**	**27.31 ± 6.53**	**10.07 ± 5.59**	**36.56 ± 16.33**	**12.60 ± 7.88**	**57.54 ± 25.52**	**6.76 ± 4.33**	**2.66 ± 2.08**	**3.15 ± 1.48**	**3.79 ± 5.93**
EHR	summer	63.98 ± 26.57	14.57 ± 6.20	4.74 ± 1.94	19.46 ± 7.76	6.00 ± 4.36	31.13 ± 12.68	2.32 ± 1.45	2.29 ± 0.88	3.17 ± 0.84	1.10 ± 0.52
	winter	82.41 ± 20.66	26.13 ± 8.63	10.71 ± 4.22	37.17 ± 11.59	6.45 ± 7.29	58.12 ± 18.30	6.32 ± 2.33	4.24 ± 2.28	2.66 ± 1.50	1.91 ± 0.95
	average mean ± SD	**72.61 ± 24.45**	**19.51 ± 9.54**	**7.13 ± 4.53**	**26.89 ± 13.40**	**6.22 ± 5.92**	**42.53 ± 20.93**	**3.83 ± 2.80**	**3.12 ± 2.04**	**2.91 ± 1.50**	**1.45 ± 0.88**

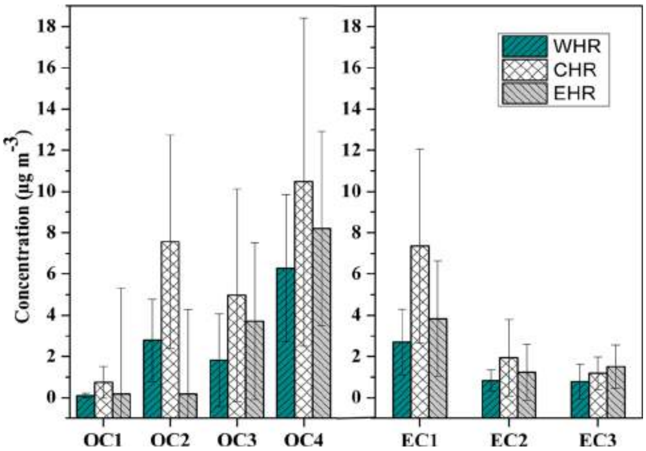

Figure 7. Mean concentrations ($\mu g\ m^{-3}$) of temperature-resolved fractions of OC (OC1–OC4) and EC (EC1–EC3) at the WHR, CHR, and EHR during the period of summer and winter in the Himalayan region.

industrial activities and seasonal agricultural waste burning. However, the estimated TCA% at the WHR and EHR were significantly higher than that reported in previous studies. Kaushal et al.[41] observed lower TCA (29%) PM_{10} ratio at Dharamshala (WHR), whereas Sharma et al.[23] reported lower TCA (22%) to total $PM_{2.5}$ ratio at Darjeeling than the present study.

3.3. Estimation of Secondary Organic Aerosol. SOC was estimated using the EC-Tracer method.[41−43] This technique assumes that the minimum OC/EC ratio only indicates OC contribution from the primary emission source.[44,45] As a result, the minimum OC/EC ratio can be utilized to calculate primary OC (POC).

$$POC = EC \times (OC/EC)_{min} \quad (1)$$

$$SOC = OC - POC \quad (2)$$

SOC can be formed primarily by photochemistry or aqueous phase reactions of volatile organic compounds (VOCs). As shown in Tables S1, S3, and S5, the average percentage of SOC in OC was ∼50% (ranging 19−80%) at the WHR, 43% at the CHR (ranging 6−61%), and ∼31% at the EHR (ranging 13−66%). Moreover, the estimated percentage of SOC−OC was 41% in all the three studied sites, which is quite comparable with the earlier reported study of the Himalayan region.[21,23] The SOC/OC ratio was the highest at the WHR (0.51) followed by the CHR (0.48) and the EHR (0.32).

3.4. Char-EC and Soot-EC. On the basis of physicochemical and optical properties, EC can be classified into two classes: char-EC and soot-EC. In general, char-EC is created as a result of incomplete combustion or heating of carbonaceous matter with restricted access to air, whereas soot-EC is formed as a result of gas-particle re-condensation during a high-temperature burning process.[46−48]

As shown in Table 2, averaged char-EC of 2.69 ± 1.59 $\mu g\ m^{-3}$ at the WHR, 6.76 ± 4.33 $\mu g\ m^{-3}$ at the CHR, and 3.83 ± 2.80 $\mu g\ m^{-3}$ at the EHR are comparable to 4.05 and 5 $\mu g\ m^{-3}$ reported in earlier studies of central and western Himalaya.[22,49] Average soot-EC 1.86 ± 1.01 $\mu g\ m^{-3}$ at the WHR, 2.66 ± 2. 08 $\mu g\ m^{-3}$ at the CHR, and 3.12 ± 2.04 $\mu g\ m^{-3}$ at the EHR were 4−10 times higher than those reported in previous studies.[22,41,49] Elevated char-EC and soot-EC levels during winter (Table 1) can be attributed to variations in fuel

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Table 2. Comparison of the Present Study with Earlier Reported Values of Particulate Matter, OC, EC, Char-EC, and Soot-EC and the Ratio of OC/EC and Char/Soot at Different High-Altitude Himalayan Regions

site location	study period	altitude (m a.s.l.)	particle size	μg m^{-3}					OC/EC	char/soot	sources prediction based on OC/EC and char/soot	references
				mass	OC	EC	char-EC	soot-EC				
Qomolangma	2009–2010	4276	TSP		1.43	0.25			6.69		biomass burning	Cong et al.[51]
Lhasa	2013–2014	3656	$PM_{2.5}$	26.68	3.27	2.24			1.46			Li et al.[50]
Kangra	2012–2013	733	PM_{10}	76.60	13.50	5.10	5.00	0.19	2.65	26.31		Kumar and Attri et al.[49]
Dharamshala	2015–2015	1457	$PM_{2.5}$	39.00	5.00	2.50	2.10	0.40	2.00	5.25	biomass and coal burning	Kaushal et al.[41]
Srinagar	2017–2017	560	TSP	76.08	15.28	5.21			2.94			Sandeep et al.[17]
Lachung	2019–2020	2700	PM_{10}	17.25	4.75	0.93			5.14			Arun et al.[21]
Bhimtal	2018	1413	TSP	99.35	15.75	4.50	4.05	0.45	3.50	9	biomass burning	Kumar et al.[22]
Darjeeling	2018–2019	2042	$PM_{2.5}$	37.00	3.46	1.93			1.79			Sharma et al.[23]
Thajiwas glacier region (WHR)	2019–2020	2799	$PM_{2.5}$	55.45	12.62	4.80	2.69	1.86	2.79	1.59	vehicular and coal burning	present study
Gangotri–Gomukh glacier region (CHR)	2019	3415	$PM_{2.5}$	86.80	27.31	10.07	6.76	2.66	3.15	3.79	biomass burning and vehicular emmisions	present study
Zemu glacier region (EHR)	2019–2020	2700	$PM_{2.5}$	72.61	19.51	7.13	3.83	3.12	2.91	1.45	vehicular and coal burning	present study

combustion and meteorological conditions. Averaged char-EC/soot-EC ratios were similar at the WHR (1.59 ± 1.16) and EHR (1.45 ± 0.88) but higher at the CHR (3.79 ± 5.93), attributing to biomass burning.[22]

4. CONCLUSIONS

Carbonaceous aerosol is regarded as a key contributor to atmospheric chemistry and local/regional air quality. This study shows preliminary observations in the western, central, and eastern Himalayan glacier regions (WHR, CHR, and EHR) which cover the comparative assessment of eight carbon fractions in $PM_{2.5}$, along with source attribution using char-EC/soot-EC ratios. Average $PM_{2.5}$, OC, EC, and TCA concentrations were 55.45 ± 16.30 μg m^{-3}, 12.62 ± 4.53, 4.80 ± 2.34, and 27.81 ± 9.61 μg m^{-3} at the WHR; 86.80 ± 35.73, 27.31 ± 6.53, 10.07 ± 5.59, and 57.54 ± 25.52 μg m^{-3} at the CHR and 72.61 ± 24.45, 19.51 ± 9.54, 7.13 ± 4.53, and 42.53 ± 20.93 μg m^{-3} at the EHR. Higher $PM_{2.5}$ mass and carbon fraction at CHR could relate to biomass burning emissions from domestic heating activities and wildfires, as well as low temperatures and steady atmospheric conditions. It is also evident from 7 day air mass back trajectories that during the summer season, the CHR and EHR, which have a substantial impact from the Indian summer monsoon, play an important part in higher aerosol mass loading in such a high-altitude Himalayan region. It is also evident from 7 day air mass back trajectories that during the summer season, the CHR and EHR, which have a substantial impact from the Indian summer monsoon, play an important part in higher aerosol mass loading in such a high-altitude Himalayan region. The percentage contributions of OC, EC, and TCA to $PM_{2.5}$ mass are 23, 9, and 51% at the WHR, 31, 12, and 69% at the CHR, and 27, 10, and 59% at the EHR, respectively. Among the eight carbon fractions, higher temperature OC4 is the most abundant species followed by OC2 and EC1 indicative of abundant biomass combustion. Char-EC and soot-EC contribute 56 and 38% of EC at the WHR, 67 and 26% of EC at the CHR, and 53 and 43% of EC at the EHR, respectively. The average OC/EC and char/soot ratios are found to be 2.79 and 1.59 at the WHR, 3.15 and 3.79 at the CHR, and 2.91 and 1.45 at the EHR that are mostly impacted by vehicle exhaust. The higher char/soot ratio and OC2 at the CHR reveals the additional impact from biomass burning and ritual burning emissions. The correlation between OC and EC indicates that OC and EC may arise from similar sources at the CHR and EHR, whereas sources of OC and EC may differ at the WHR. This work provides an overview of carbonaceous aerosols, their generation methods, and source attributions. To better understand the source/receptor connections, future studies will require a larger sample effort as well as air quality modeling of different size fractions of aerosols. The findings of this study can be used in estimating aerosol radiative forcing and short-term climate effects of organic species and their light absorption tendency toward short-wave electromagnetic radiation.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsearthspacechem.2c00216.

Detailed database of individual measurements of ambient $PM_{2.5}$, OC, and EC; temperature-resolved thermal fractions of OC and EC; TC, TCA, and SOC concentrations (μg m^{-3}) and OC/EC ratios for summer and winter seasons for all three monitoring sites (Tables S1–S6) (PDF)

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AUTHOR INFORMATION

Corresponding Author

Shamsh Pervez – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India;* orcid.org/0000-0001-8334-9387; Phone: +91-9753413202; Email: shamshpervez@gmail.com

Authors

Sushant Ranjan Verma – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India*

Papiya Mandal – *National Environmental Engineering Research Institute, Nagpur, Maharashtra 440020, India*

Judith C. Chow – *Division of Atmospheric Sciences, Desert Research Institute, Reno 89512, United States; Institute of Earth and Environment, Chinese Academy of Science, Xian 710061, China*

John G. Watson – *Division of Atmospheric Sciences, Desert Research Institute, Reno 89512, United States; Institute of Earth and Environment, Chinese Academy of Science, Xian 710061, China;* orcid.org/0000-0002-1752-6899

Syed Muzaffarali Andrabi – *Kashmir University, Srinagar 190006, India*

Madhuri Verma – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India*

Princy Dugga – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India*

Noor Afshan Khan – *National Environmental Engineering Research Institute, Nagpur, Maharashtra 440020, India*

Yasmeen Fatima Pervez – *Government Dr. Waman Wasudev Patankar Girls PG College, Durg, Chhattisgarh 491001, India*

Archi Mishra – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India*

Manas Kanti Deb – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India*

Indrapal Karbhal – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India*

Suresh Tiwari – *Indian Institute of Tropical Meteorology, Pune, Maharashtra 411008, India*

Kallol K. Ghosh – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India;* orcid.org/0000-0002-5805-0305

Kamlesh Shrivas – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India;* orcid.org/0000-0003-3035-3168

Manmohan Lal Satnami – *School of Studies in Chemistry, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh 492010, India;* orcid.org/0000-0001-7045-8971

Complete contact information is available at: https://pubs.acs.org/10.1021/acsearthspacechem.2c00216

Author Contributions

Sushant Ranjan Verma contributed to field work analysis, visualization, data curation, and writing original draft preparation. Shamsh Pervez involved in conceptualization, formal analysis, visualization, and writing review and editing. Papiya Mandal performed validation and review. Judith C. Chow contributed to data validation, review, and language editing. John G. Watson contributed to review and editing. Syed Muzaffarali Andrabi, Madhuri Verma, Princy dugga, Noor Afshan Khan, Yasmeen Fatima Pervez, Archi Mishra, Manas Kanti Deb, Indrapal Karbhal, Suresh Tiwari, Kallol K. Ghosh, Kamlesh Shrivas, and Manmohan Lal Satnami contributed to review and editing.

Notes

The authors declare no competing financial interest.

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