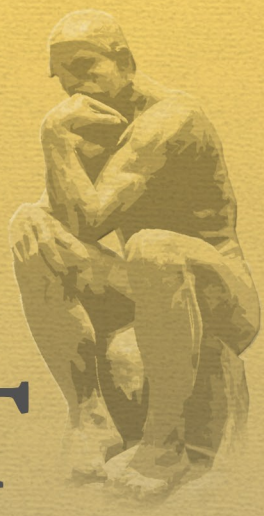
ISSN: 2250-0650



TRANSIENT

A Journal of Natural Sciences and Allied Subjects
(a peer reviewed Journal)

VOLUME VIII
2019-20

Don Bosco College
Tura, Meghalaya
India

TRANSIENT

A Journal of Natural Sciences and Allied Subjects

(a peer reviewed journal)
VOLUME VIII
2019-20

ISSN —2250-0650

DON BOSCO COLLEGE, TURA
Meghalaya, India

TRANSIENT

A Journal of Natural Sciences and Allied Subjects

(a peer reviewed journal)

VOLUME VIII — 2019-20

Advisory Board Members

Journal Officials/Office Bearers

Editorial Board/Committee Members

Contributors

A. Khardewsaw
Department of Physics,
North-Eastern Hill University,
Shillong, Meghalaya, India,

A. Pyngrope
Department of Physics,
North-Eastern Hill University,
Shillong, Meghalaya, India,

A. Saxena
Department of Physics,
North-Eastern Hill University,
Shillong, Meghalaya, India,

A. Shankar
Condensed Matter Theory Research Lab, Department of Physics,
Kurseong College, Darjeeling,
West Bengal, India,

A. Vishwa
Department of Environmental Studies,
North-Eastern Hill University,
Shillong, Meghalaya, India,

Aksana Neah Ch. Marak
Department of Environment,
Don Bosco College, Tura, Meghalaya, India,

Bhogtoram Mawroh
Research and Knowledge Management,
NESFAS, Shillong,

Bikash Koli Saha
Department of Mathematics,
The Assam Royal Global University,
Guwahati, Assam, India,

D. Maibam

Contents

STRATEGY ARTICLE

Solid State Nuclear Track Detectors — an exciting field of inquiry

Swarnali Ghosh

Department of Chemistry, Sankardev College, Shillong, Meghalaya, India

E-mail: swarnalighosh@yahoo.co.in

ABSTRACT

The scientific field of Solid State Nuclear Track Detectors is still an exciting field of inquiry after more than six decades of existence. Primarily a method for the detection and identification of nuclear particulate radiation, this technique has found numerous applications in varied field of science and technology. In the present paper, I discuss the main principles of one of its many applications that was developed by me along with my co-workers viz. the measurement of nuclear target thicknesses. I also review the current status and a few open questions that still haunt this field that possibly might be exciting and challenging for young researchers to investigate.

Keywords: SSNTD, nuclear tracks, calibration, target thickness

INTRODUCTION

The field of Solid State Nuclear Track Detectors (SSNTD) also known as nuclear track technology/methodology or on rare occasions as Trackology had a rather unpromising start in 1958 when the first reported instance of etched tracks by D. A. Young [1, 2] went unnoticed. 1959 saw a rediscovery by Silk and Barnes [3] and a consequent followed up by the American trio — Fleischer, Price and Walker. Their work in this field has led to a burgeoning of applications ranging from "Nuclear Physics to Biology, from the depths of the earth to the distant space, from the small to the large and from the ancient to the recent" [4].

The track technique is based on the principle that the passage of a positively charged particle through most bulk matter produces an *almost*-permanent damage (called the latent nuclear track) in the material which can then be measured by various means. Materials which keep the record of the passage of the nuclear radiation are called SSNTD. The process governing the damage creation is different for inorganic (glasses and crystals) and organic (plastic) matter. In inorganic matter, passage of particulate nuclear radiation or a fast moving heavy ion knocks out the orbital electrons of the atoms lying in and around its trajectory. This forms positive ions which repel one another thereby creating a narrow cylindrical zone (30-100 Å in diameter) under high strain. In metals due to the free electrons, recombination takes place before the repulsion can create the tracks and hence they are not good candidates for SSNTD.

In organic polymers the charged particle breaks the long molecular chains by ionization and excitation. The damaged regions form the latent tracks. The latex track diameter being of the order of nanometre can only be viewed by high-powered electron-microscopes and as such are of limited applicability.

There are several processes available for developing and permanently fixing the latent tracks,

the most common being the method of chemical etching. The process of etching can be crudely thought of as dipping the track-carrying SSNTD in a chemically corrosive liquid (called etchant). Subjecting an SSNTD to etching predominantly corrodes the region of the latent track thereby fixing it permanently in the form of a hole; the process of corrosion or etching can be carried on long enough enlarging the holes to sizes that can be observed under ordinary light microscopes; latent tracks which have been thus processed are called etched tracks. The size of the etched tracks is a controlled mainly by three factors: the nature of the etchant, the nature of the SSNTD and the nature of the track-forming projectile and the unravelling of the character of the relationship between these three factors is the principal aim of Trackology.

In the current article, I will elaborate on an application of the SSNTD technique viz. its use in measurement of small thicknesses developed by me along with my co-authors. Thereafter, I will also review and discuss in brief the status of this field after six decades of research.

AN APPLICATION OF SSNTD: MEASUREMENT OF TARGET THICKNESS

This method was first discussed in my thesis followed by publication in an article in the journal Radiation Measurements [5, 6].

Target thickness measurements are of utmost importance both directly and indirectly, to determine the cross-section of nuclear reactions, the thickness of backings and windows or the energy lost during passage through degrader foils. Different methods [7] have been used for the determination of target thickness such as comparison with a known cross-section, especially with Rutherford scattering, energy-loss of charged particles in the target, evaporation monitor system especially crystal oscillator, weighing etc. Nearly all these methods suffer from one drawback or the other — like reproducibility of the known cross-section, coefficient of condensation, change of densities in thin films or of chemical structures, destruction of targets during measurements, the necessity of calibrations and of dual measurements. A high flux of α-particles can also change the target properties by radiation damage and thermal heating.

In the light of these drawbacks it becomes necessary to evolve a technique which is accurate and also non-destructive [8]. These were some motivations for developing the nuclear track technique for the measurement of target thickness using a heavy ion beam. The target thickness is evaluated from the initial and transmitted energy of the heavy ions and from the range–energy plots and is discussed in the following subsections with the help of data used in my thesis [5].

The Methodology

The method basically involves two preparatory/experimental steps followed by the necessary calculation:

Step 1. The Energy-Track Length calibration of the detector

The first basic requirement for target thickness measurement by the nuclear track technique is a calibration curve for the heavy ion energy in a sensitive track detector. A well collimated and low flux beam of any heavy Ion can be used for this purpose. Basically the detector is irradiated with the given heavy ion of different known energies (E) and the corresponding maximum etchable track length (E) are experimentally determined. Then a curve-fitting procedure is applied to the experimental data, which gives a mathematical functional form of the relationship between E and L $\big($cf. equation $(1)\big)$; a one dimensional third order polynomial seems to produce the best fit to all the experimental points, but any order polynomial can be used. The energy of heavy ions may be determined by using the following equation:

$$E(\mathrm{MeV/u}) = \sum_{n=0}^{3} a_n L^n \ \mu m \qquad (1)$$

where, n is the order of the polynomial and the coefficients are represented by a_n.

A typical energy-track length calibration curve along with the experimental points (of 16.34 MeV/u ^{238}U in ZnP-glass SSNTD) is shown in figure (1).

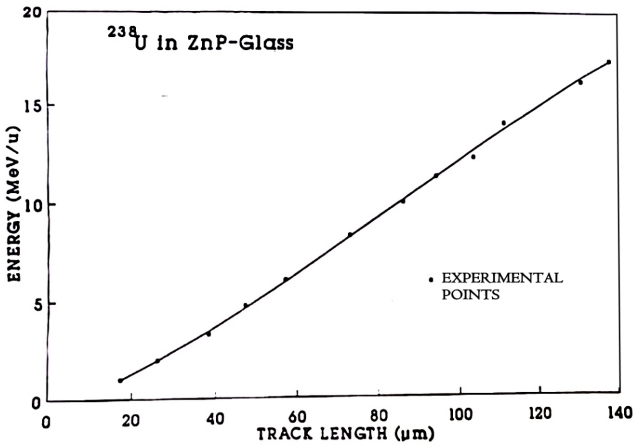


Fig. 1. Typical Energy-Track Length calibration curve [5, 6].

Step 2. The Range-Energy calibration of target element

The other factor that is essential for the application of this method is calibration of range of the heavy ion (R) in the target material in terms of projectile energy E. Herein too, curve fitting of experimental data gives a mathematical functional form of the relationship between R and E $\big($cf. equation (2)$\big)$; again a third order polynomial was used to fit the range-energy data. This polynomial relationship may be expressed as:

$$R(\mu\text{m}) = \sum_{m=0}^{3} b_m E^m \ (\text{MeV/u}) \qquad (2)$$

where, b_m represents a set of polynomial coefficients.

A typical range-energy calibration curve along with the experimental points (of 16.34 MeV/u ^{238}U in aluminium target) is shown in figure (2).

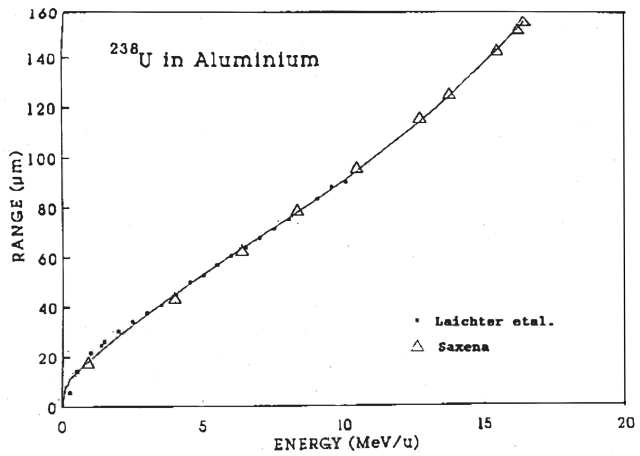


Fig. 2. Typical Range-Energy calibration curve.jpg [5, 6].

Experimentation details

The actual experiment is carried out as follows: Stacks containing different numbers of the target film are prepared (either in the form of staircase arrangement for a single exposure or by exposing the different stacks at different times; for stack information please see figure 1 in the article by R. Mishra et al. [9]). First the detector is exposed without any target material present and then with the different stacks. The track lengths associated with each stack arrangement are measured. By the use of the calibration curve given by equation (1) the track lengths L are converted into the transmitted energy E_x of the heavy ion. If the initial energy of a heavy ion (without target) be E_i then the range $\big(R(E_i)\big)$ corresponding to the initial energy E_i and the range $\big(R(E_x)\big)$ corresponding to the transmitted energy E_x can be obtained from the calibration given by equation (2). The target thickness may then be obtained using the equation:

$$X = R(E_i) - R(E_x) \qquad (3)$$

One requirement of the method is that the heavy ion beam should have sufficient energy to penetrate clean through the target stack, emerge on the other side and then strike the SSNTD with sufficient energy to produce visible nuclear tracks. The different sized stacks of the target are taken to have a better average value of the result viz. its thickness.

For the specific example used, the uncertainty in thickness determination by track method was found to be ± 1.8 μm [5].

CURRENT SCENARIO: NEW LOOK AT OLD QUESTIONS

It is beyond the scope of this limited review article to survey the vast areas of applications of SSNTD (I believe, it will require at least a few monographs for such a monumental task) but the following paragraphs may provide an initial impetus for a deeper literature survey.

Trackology has adapted itself to many diverse fields and has also opened up new fields on its own. In Nuclear Sciences, these detectors have proved ideal for fission studies [10, 11] and nuclear reactions [12, 13], With the help of these detectors intensive searches were made for superheavy elements and magnetic monopoles [14]. Fission track

dating [4] has been successfully applied to dating of geological, archaeological and cosmological samples. In the field of medicine it has been used in filtering cancer cells from normal blood cells [15] and in radiation dosimetry [16]. It has been used for uranium exploration [4] as well as earthquake prediction by radon/ thoron detection method [17, 18].

The current research in SSNTD can be broadly categorized into two groups:

Group 1: Deepening the understanding of the basic physics and chemistry of SSNTD.

Group 2: Widening the scope of the applications of SSNTD.

There are many challenges facing the first group mentioned above, most importantly a complete understanding of the SSNTD (at the molecular and atomic level) is far from complete primarily due to variety of materials that can be used as detectors and this makes a simple universal theory almost untenable. The "*Lack of theoretical understanding*" mentioned by Durrani in 2008 [19] is still valid today after more than a decade. But, researchers have also struggled with finding common threads that can serve to distinguish materials suitable as detectors from the rest; the thermal conductivity of materials and their resistivity [4, 20] were the earliest criteria that were explored but with unsatisfactory outcomes [21]. Slowly it became apparent that the nature of the ion cannot be ignored when trying to classify SSNTD and the focus shifted to the size (Z), energy and velocity of incoming ions and the damage caused to the detector material.
Various models that either described the nature of the damage or some criteria usually in the form of threshold value of known physical quantities (like stopping power, restricted energy loss etc.) were prescribed, principal among which were the ion-explosion spike model, reduced electronic energy loss and the thermal spike model [4, 22] and a kind of mixture of two — the compound spike [23]. It appears that none of the models have been completely vindicated in supersession of other models; even clear demarcation of the applicability of the various models appears to be unresolved.
For organic polymers or plastics, the only model proposed was the polymer-chain breaking mechanism, which remains unchallenged despite the sketchy chemistry used for its justification [4, 24, 25].

A deeper understanding of the chemistry of the etching process is also an area that has received meagre attention, the article by Gorbunov et al. [26] are among the handful of articles that try to shed some light into the fundamental chemistry of etching, most of the published analysis is based on empirical rather than purely theoretical considerations [27–29].

There are other areas in Trackology that are also under ongoing inquiry like the geometry of tracks [30–32], which area has particularly benefited from computer modelling [33, 34]. New methods like the use of confocal Raman spectroscopic system by Cerda et al. [35] for the study of of the morphology of nuclear tracks shows that new methods can be applied to old problems to gain new insights.

Regarding the research into the second group with respect to SSNTD viz. its applications, new areas have opened up such as their use in biosensors for the measurement and quantification of biological signals [36]; radiotherapy [37] etc. Fusion research has also seen some application of SSNTD [38].

The measurement of environmental radioactivity has been one of the important areas of application of nuclear tracks and continues to hold a pride of place, in particular, due to its robustness to environmental degradation, and a simple and economical setup [39, 40].
CR-39 and LR-115 are two polymeric SSNTD that are popular as can be observed by a survey of the particular SSNTD used in the cited articles in the current work. Their sensitivity and ready availability appears to be the prime driving factors, apart from the fact that a vast trove of literature exists dealing with the characterization of these detectors.

The title of this section, despite its tackiness does outline a fundamental fact of scientific research that when the frontiers of science are expanded, topics that were thought to be old, irrelevant or unchallenging, can present new insights and applications.

REFERENCES

[1] D. A. Young, "Etching of Radiation Damage in Lithium Fluoride," *Nature*, vol. 182, no. 4632, 1958. DOI: 10.1038/182375a0.

[2] R. Spohr, *Ion Tracks and Microtechnology*, K. Bethge, Ed. Wiesbaden: Vieweg+Teubner Verlag, 1990. DOI: 10 . 1007 / 978 - 3 - 322 - 83103-3.

[3] E. C. H. Silk and R. S. Barnes, "Examination of fission fragment tracks with an electron microscope," *Philosophical Magazine*, vol. 4, no. 44, 1959. DOI: 10 . 1080 / 14786435908238273.

[4] R. L. Fleischer, P. B. Price, and R. M. Walker, *Nuclear tracks in solids: principles and applications*. Berkeley: University of California Press, 1975.

[5] S. Ghosh, "New Dimensions of Nuclear Track Technique," Ph.D. dissertation, NEHU, 1991.

[6] K. K. Dwivedi, S. Ghosh, and J. Raju, "A track technique for the measurement of target thickness using heavy ions," *Radiation Measurements*, vol. 24, no. 2, 1995. DOI: 10. 1016/1350-4487(94)00087-H.

[7] S. Kato, "Methods of target-thickness measurements," *Nuclear Instruments and Methods*, vol. 75, no. 2, 1969. DOI: 10.1016/0029-554X(69)90612-0.

[8] X. Guoji, Z. Yuhua, Z. Shengnan, and X. Yongchang, "Determination of thicknesses and impurities of targets by measuring backscattered particles from 2 MeV 4He+-bombardment," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 236, no. 3, 1985. DOI: 10.1016/0168-9002(85)90971-4.

[9] R. Mishra, S. P. Tripathy, A. Kulshreshtha, A. Srivastava, K. K. Dwivedi, and D. K. Avasthi, "Ranges and energy-loss measurement of 1.0–4.7 MeV/u ^{28}Si ions in makrofol-G using PADC as detector," *Radiation Effects and Defects in Solids*, vol. 147, no. 4, 1999. DOI: 10 . 1080 / 10420159908226995.

[10] R. L. Fleischer, P. B. Price, R. M. Walker, and E. L. Hubbard, "Ternary Fission of Heavy Compound Nuclei in Thorite Track Detectors," *Physical Review*, vol. 143, no. 3, 1966. DOI: 10.1103/PhysRev.143.943.

[11] D. S. Burnett, R. C. Gatti, F. Plasil, P. B. Price, W. J. Swiatecki, and S. G. Thompson, "Fission Barrier of Thallium-201," *Physical Review*, vol. 134, no. 5B, 1964. DOI: 10.1103/PhysRev.134.B952.

[12] E. U. Khan, "Study of the heavy ion reaction ^{238}U + ^{nat}U at the beam energies of 9.0 MeV/N and 16.7 MeV/N using mica as a solid state nuclear track detector," Ph.D thesis, Phillips University, Marburg, FRG, 1985.

[13] P. A. Gottschalk, P. Vater, H. J. Becker, R. Brandt, G. Grawert, G. Fiedler, R. Haag, and T. Rautenberg, "Direct Evidence for Multiple Sequential Fission in the Interaction of Pb 208 and U 238 with Uranium," *Physical Review Letters*, vol. 42, no. 6, 1979. DOI: 10. 1103/PhysRevLett.42.359.

[14] P. B. Price and R. L. Fleischer, "Are fission tracks in meteorites from super-heavy elements?" *Physics Letters B*, vol. 30, no. 4, 1969. DOI: 10.1016/0370-2693(69)90430-4.

[15] S. H. Seal, "A sieve for the isolation of cancer cells and other large cells from the blood," *Cancer*, vol. 17, no. 5, 1964. DOI: 10 . 1002 / 1097 - 0142(196405) 17 : 5<637 :: AID - CNCR2820170512>3.0.CO;2-I.

[16] R. L. Fleischer, H. W. Alter, S. C. Furman, P. B. Price, and R. M. Walker, "Particle Track Etching: Diverse technological uses range from virus identification to uranium exploration," *Science*, vol. 178, no. 4058, 1972. DOI: 10.1126/science.178.4058.255.

[17] C. Y. King, "Episodic radon changes in subsurface soil gas along active faults and possible relation to earthquakes," *Journal of Geophysical Research*, vol. 85, no. B6, 1980. DOI: 10.1029/JB085iB06p03065.

[18] C. Y. King, "Gas geochemistry applied to earthquake prediction: An overview," *Journal of Geophysical Research: Solid Earth*, vol. 91, no. B12, 1986. DOI: 10 . 1029 / JB091iB12p12269.

[19] S. A. Durrani, "Nuclear tracks today: Strengths, weaknesses, challenges," *Radiation Measurements*, vol. 43, 2008. DOI: 10 . 1016/j.radmeas.2008.03.044.

[20] A. Sigrist and R. Balzer, "Investigations on the formation of tracks in crystals," in *Solid State Nuclear Track Detectors*, F. Granzer, H. Paretzke, and E. Schopper, Eds., Pergamon, 1978. DOI: https://doi.org/10.1016/B978-1-4832-8338-8.50035-2.

[21] A. Barbu, A. Dunlop, D. Lesueur, and R. S. Averback, "Latent tracks do exist in metallic materials," *Europhysics Letters (EPL)*, vol. 15, no. 1, 1991. DOI: 10.1209/0295-5075/15/1/007.

[22] C. Dufour and M. Toulemonde, "Models for the description of track formation," 2016. DOI: 10.1007/978-3-319-33561-2_2.

[23] L. T. Chadderton, "Nuclear tracks in solids: Registration physics and the compound spike," *Radiation Measurements*, vol. 36, no. 1-6, 2003. DOI: 10.1016/s1350-4487(03)00094-5.

[24] W. Enge, "On the question of nuclear track formation in plastic material," *Radiation Measurements*, vol. 25, no. 1-4, 1995. DOI: 10.1016/1350-4487(95)00024-9.

[25] S.-L. Guo, B.-L. Chen, and S. A. Durrani, "Solid-state nuclear track detectors," 2020. DOI: 10.1016/b978-0-12-814397-1.00003-0.

[26] S. A. Gorbunov, R. A. Rymzhanov, and A. E. Volkov, "Dependence of track etching kinetics on chemical reactivity around the ion path," *Scientific Reports*, vol. 9, no. 1, 2019. DOI: 10.1038/s41598-019-51748-y.

[27] M. A. Al-Jubbori, "A parameterization of the chemistry-normality dependence of bulk etch rate in a CR-39 detector," *Applied Radiation and Isotopes*, vol. 118, 2016. DOI: 10.1016/j.apradiso.2016.09.022.

[28] E. M. Awad, S. Hassan, E. Bebers, and Y. S. Rammah, "Bulk etch rate for PADC CR-39 at extended concentration range of NaOH mixed with ethanol and etchant viscosity study," *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, vol. 464, 2020. DOI: 10.1016/j.nimb.2019.12.003.

[29] L. M. Muhamad and Y. Y. Qassem, "Finding bulk etch rate VB using the maximum value of the Lmax effect using practical diameters calculated from the falling alpha particles on the CR-39 nuclear track detector," *IOP Conference Series: Materials Science and Engineering*, vol. 928, 2020. DOI: 10.1088/1757-899x/928/7/072112.

[30] G. Somogyi, "Development of etched nuclear tracks," *Nuclear Instruments and Methods*, vol. 173, no. 1, 1980. DOI: 10.1016/0029-554x(80)90565-0.

[31] D. Nikezic and K. N. Yu, "Formation and growth of tracks in nuclear track materials," *Materials Science and Engineering: R: Reports*, vol. 46, no. 3-5, 2004. DOI: 10.1016/j.mser.2004.07.003.

[32] A. Cannavò, V. Lavrentiev, I. Lavrentieva, L. Torrisi, P. Horàk, G. Ceccio, and J. Vacìk, "Characterization of ion tracks in CR39 polymer exposed to 241Am α-particles," *Radiation Effects and Defects in Solids*, vol. 173, no. 9-10, 2018. DOI: 10 . 1080 / 10420150 . 2018.1528606.

[33] K. Muraleedhara Varier, V. Sankar, and M. P. Gangadathan, "TrackEtching — a java based code for etched track profile calculations in SSNTDs," *Computer Physics Communications*, vol. 218, 2017. DOI: 10 . 1016 / j.cpc.2017.04.013.

[34] Y. Pan and L. Qiu, "A mathematical morphology algorithm for detection and counting of nuclear tracks," *Journal of Physics: Conference Series*, vol. 1650, 2020. DOI: 10 . 1088/1742-6596/1650/3/032146.

[35] M. C. Z., J. A. Azamar-Barrios, C. Vazquez-Lopez, R. Fragoso-Soriano, B. E. Zendejas-Leal, J. Rurik-Farias, J. I. Golzarri, and G. Espinosa, "Nuclear tracks morphology study using Raman methodology," *Journal of Nuclear Physics, Material Sciences, Radiation and Applications*, vol. 4, no. 1, 2016. DOI: 10.15415/jnp.2016.41023.

[36] D. Fink, G. M. Hernández, H. G. Arellano, J. Vacík, V. Havranek, V. Hnatowicz, A. Kiv, and L. Alfonta, "Nuclear track-based biosensing: An overview," *Radiation Effects and Defects in Solids*, vol. 171, no. 1-2, 2016. DOI: 10.1080/10420150.2016.1160905.

[37] A. P. Bonifaz, O. B. Moliné, J. O. Schneider, B. L. R. L. Rosa, J. R. Hancco, V. G. Rojas, D. P. Fernández, P. P. Anaya, and M. E. L. Herrera, "Simple and low cost alternative method for detecting photoneutrons produced in some radiotherapy treatments using SSNTDs," *Applied Radiation and Isotopes*, vol. 161, 2020. DOI: 10 . 1016 / j . apradiso.2020.109169.

[38] M. Milanese, F. Castillo, M. Moroso, M. BarBaglIa, J. Golzarri, H. Martínez, and G. Espinosa, "Study of neutron from a dense plasma focus paco instrument by means of nuclear tracks detectors," *Journal of Nuclear Physics, Material Sciences, Radiation and Applications*, vol. 4, no. 1, 2016.

[39] S. A. Durrani and R. Ilic, *Radon Measurements By Etched Track Detectors-Applications In Radiation Protection, Earth Sciences*. World Scientific, 1997.

[40] V. Zorri, R. Remetti, M. Capogni, G. Cotellessa, and R. Falcone, "Feasibility study on the application of solid state tracks detectors for fast surveys of residual alpha contamination in decommissioning activities," *Radiation Measurements*, vol. 107, 2017. DOI: 10.1016/j.radmeas.2017.09.004.

Parthenium menance in North East India and its management through plant biocontrol agent

N. Irabanta Singh*[1], Y. Nganthoi Devi[2], and Sushilkumar[3]

[1]*Department of Life Sciences, Manipur University, Imphal, Manipur, India*

[2]*Centre of Advanced Study in Life Sciences, Manipur University, Imphal, Manipur, India*

[3]*Directorate of Weed Science Research, Jabalpur, Madhya Pradesh, India*

**E-mail:* irabanta.singh@gmail.com

ABSTRACT

Parthenium hysterophorus L. has been known to cause a number of environmental and agricultural problems such as loss of crop productivity, fodder scarcity, biodiversity depletion and health problems for livestock. In North East India also, it is found growing gregariously in wastelands, national and state highways, railway tracts including road dividends and also spreading like a wild fire. *P. hysterophorus* infestation in national and state highways of North East States were studied by using quadrat method with a case study for mapping *P. hysterophorus* growing sites in Manipur valley using GPS data. Allelopathic effect of Parthenium on the germination and productivity of economically important crops viz., *Brassica capitata* L., *Brassica caulorapa* Pasq., *Zea mays* L. and *Oryza sativa* L. were studied in pot condition. Management of Parthenium by broadcasting *Cassia tora* L. seed at the rate of 1000/m^2 before monsoon on the pre-identified Parthenium infested sites were performed for two consecutive year. *P. hysterophorus* has infested all North East states except Mizoram with mean frequency of 22.25%. Soil amended with dried shoot of Parthenium markedly reduced the germination of *B. capitata*, *B. caulorapa*, *Z. mays* and *O. sativa* with maximum inhibition in *B. caulorapa* (54.91%) followed by *B. capitata* (50.01%), *Z. mays* (49.96%) and *O. sativa* (41.82%). The productivity of the test crops were affected drastically with the increase concentration of dry shoot of Parthenium amended soil over the control. *C. tora* reduced the Parthenium population (28% to 30%) and dry matter (57 to 62%) during 2016 to 2017 respectively. Reduction in productivity of the agronomic and vegetables crops may be due to release of allelochemicals from the Parthenium in the rhizophere. *C. tora* can be recommended as one of the plant bioagent for the management of Parthenium in North East India.

Keywords: Parthenium, allelopathic effect, *Brassica capitata, Brassica caulorapa, Zea mays, Oryza sativa, Cassia tora.*

INTRODUCTION

Congress grass (*Parthenium hysterophorus L.*) has been rapidly spreading globally and continually affecting our health, livestock, flora and environment. Parthenium is known to cause a number of environmental and agricultural problems such

*Former Professor (Higher Academic Grade)

as loss of crop productivity, fodder scarcity, biodiversity depletion and health problems for livestock (Evans et al., 1997; Kohli & Rani, 1994). In North East India also, it is found growing gregariously in wastelands, national and state highways and railway tracts including road dividends and is spreading like a wild fire. Although a number of studies on Parthenium have been done in other parts of India, so far few works have been made on Parthenium in North East India. So, the objective of the present studies is to make a survey of Parthenium infested region, its effect on economically important crops and management of Parthenium using *Cassia tora* in North East India.

MATERIALS AND METHODS

Field survey of the areas infested with *Parthenium hysterophorus* L. in North East India

Systematic surveys were made on selected National highways, state highways and along the railways tracks of North Eastern States during April 2016- August, 2018 in order to record the distribution and invasion of Parthenium. 50 locations were randomly sampled each using 1×1 m^2 quadrat method from both side of the road. The greater the length of the survey sites, the greater is the distance between the quadrats. Absolute Density m^{-2} and frequency of the Parthenium weed and other weed species were recorded by using quadrat as described by Hussain et al., (2004) on the following parameters:

1. Absolute Density (AD) m^{-2}

$$\text{Absolute Density} = \frac{\text{Total no. of individuals of a species in all quadrat}}{\text{Total no. of quadrates}}$$

2. Frequency (%)

$$\text{Frequency (\%)} = \frac{\text{Number of quadrat in which species occur}}{\text{Total no. of quadrates}} \times 100$$

Case study for mapping the distribution of Parthenium

For mapping the distribution of Parthenium weed in selected highways (NH-39, NH-150, NH-53 & SH-Mayai lambi) of Imphal valley, Manipur, location of the Parthenium growing sites were collected with the help of GPS device. The locations were taken twice along the selected highways during July – August, 2016 and July -August, 2017. The latitudinal and longitudinal data of Parthenium growing point from GPS device was transferred to computer system in Microsoft Excel using Mapsource software and converted to decimal degree. The mapping of Parthenium growing site was done using Mapinfo professional software.

$$\text{Decimal degree} = Degree + \frac{Minute}{60} + \frac{Second}{3600}$$

Effect of Parthenium dry shoot on the germination and productivity of certain economically important crops

Whole plants of mature Parthenium were chopped into small portion (1-2 cm) and air dried for one week. Dried Parthenium shoot was weighed out separately in the quantity of 50, 100, 150, 200, 300 and 400 g respectively. The above noted quantities were mixed thoroughly with 10 kg soil separately and sufficient quantity of water was added to all the plastic bags containing soil and was kept for one week in the glass house to develop any possible microbial activity. Soil without any treatment was taken as control. Sufficient quantity of the healthy seeds of *Brassica capitata* L. (cabbage), *Brassica caulorapa* Pasq. (knolkhol), *Zea mays* L. (maize) and *Oryza sativa* L. (rice) were surface sterilized with 3% sodium hypochlorite solution and then thoroughly washed several times with water. 20 healthy seeds of each test plant samples were sown in each plastic bag at 0.5 cm (field sowing density) below the soil surface to all the treated (50, 100, 150, 200, 300 and 400g.) and control plastic bags. Three replication of each treatment was made and kept in randomized block design. After 30 days, 7(seven) healthy plants from each plastic bag were harvested and shoot length, root length and dry weight were measured to assess the growth of the plants. The plants were thinned down and only one (1) healthy plant was kept in each bag to check the productivity of the selected plants.

Management of Parthenium by *Cassia tora* L. in natural field condition as plant biocontrol agent

About 300 kg of *C. tora* L. seeds were bought from the local people and healthy seeds of *Cassia tora* were broadcasted at the rate of 1000/m^2 before monsoon on the pre-identified Parthenium infested sites. The impact of *Cassia tora* on growth and development of *P. hysterophorus* was moni-

tored at four different selected sites for two consecutive years 2016 and 2017 during the monsoon as well as during the post monsoon periods. Five replicates were maintained for each experimental site with the plot size of 1×1 m^2. Germination, survival of the plant and growth performance of Parthenium in terms of biomass production per plant was monitored under natural field condition.

Table 1. Density m^{-2} of *Parthenium hysterophorus* L. and other weed species in different states of North East India (mean value of each state).

Weed species	Assam	Manipur	Meghalaya	Nagaland	Tripura	Sikkim	Mizoram	Arunachal Pradesh
Parthenium hysterophorus	28.4	25.6	8.21	17.23	14.1	8.3	0	9.2
Urena lobota	0.46	0.36	0.4	0.34	0.22	0.18	0.12	0.16
Chenopodium album	0.16	0.18	0	0.08	0.1	0.08	0.06	0.12
Alternanthera philoxeroides	0.36	0.62	0.5	0.64	0.4	0.26	0.36	0.22
Cynodon dactylon	32.64	34.4	30.84	29	33.4	31.54	40.67	38.9
Casssia sericea	1.76	1	0.36	0.76	0.97	0	0	0
Rumex maritimus	0.56	0.62	0	0.46	0.34	0	0.06	0
Ageratum conyzoides	1.02	0.98	1.22	1.32	1.16	1.02	1	1.28
Polygonum orientale	1.02	1.84	0.28	0.84	0.22	0.18	0.26	0.16
Riccinus cumminis	0.12	0.18	0.08	0.1	0.16	0.06	0.08	0.02
Mimosa pudica	0.22	0.18	0.16	0.12	0.12	0.16	0.08	0.26
Xanthium strumarium	1.62	1.82	0.64	0.98	1.02	0.62	0.4	0.36
Amaranthus spinosus	1.72	2.04	0.44	0.92	1.28	0.98	0.24	0.12
Chromolaena adorata	1.16	0.62	0.51	0.72	0.69	0.22	0.26	0.18
Cassia tora	10.58	15.02	3.95	4.55	5.38	1.8	1.22	1.62
Lantana camara	1.08	0.68	0.6	0.52	0.57	0.41	0.32	0.24
Ipomoea carnea	2.24	1.64	0.28	1.28	1.36	0.22	0.32	0.26
Mirabilis jalapa	0.12	0.34	0	0	0.1	0.18	0.12	0.18

Table 2. Frequency (%) of *Parthenium hysterophorus* L. and other weed species in different states of North East India.

Weed species	Assam	Manipur	Meghalaya	Nagaland	Tripura	Sikkim	Mizoram	Arunachal Pradesh
Parthenium hysterophorus	46	42	8	30	14	8	0	10
Urena lobota	28	20	12	16	19	4	10	14
Chenopodium album	14	18	0	16	14	2	6	4
Alternanthera philoxeroides	20	12	12	10	8	2	2	6
Cynodon dactylon	90	82	86	92	86	94	82	94
Casssia sericea	24	20	8	12	16	0	0	0
Rumex maritimus	28	24	0	24	22	0	10	16
Ageratum conyzoides	36	20	12	10	21	6	4	2
Polygonum orientale	10	12	8	8	4	2	4	6
Riccinus cumminis	4	6	2	6	4	4	2	2
Mimosa pudica	18	20	8	12	14	6	8	4
Xanthium strumarium	10	18	14	12	6	8	4	6
Amaranthus spinosus	28	16	12	10	14	4	6	4
Chromolaena adorata	16	20	14	8	11.	18	14	10
Cassia tora	24	28	20	22	27	14	18	20
Lantana camara	20	12	2	12	11	8	4	2
Ipomoea carnea	32	20	8	12	16	2	6	6
Mirabilis jalapa	10	18	0	0	6	12	8	4

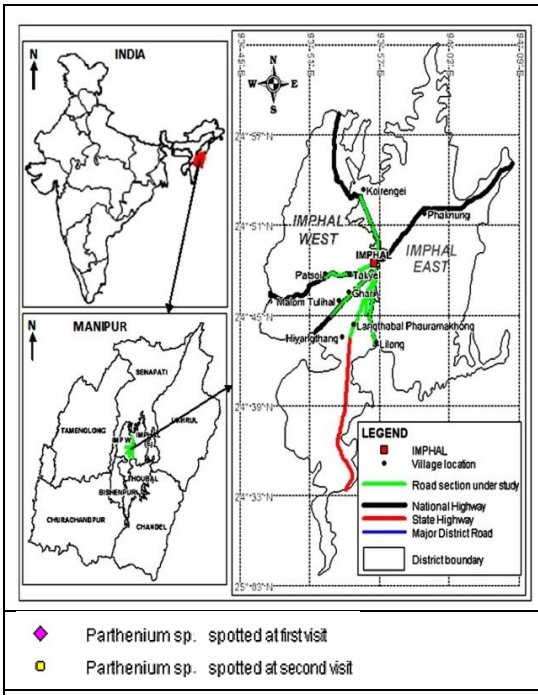


Figure 1. Map of India showing Manipur state and the study sites.

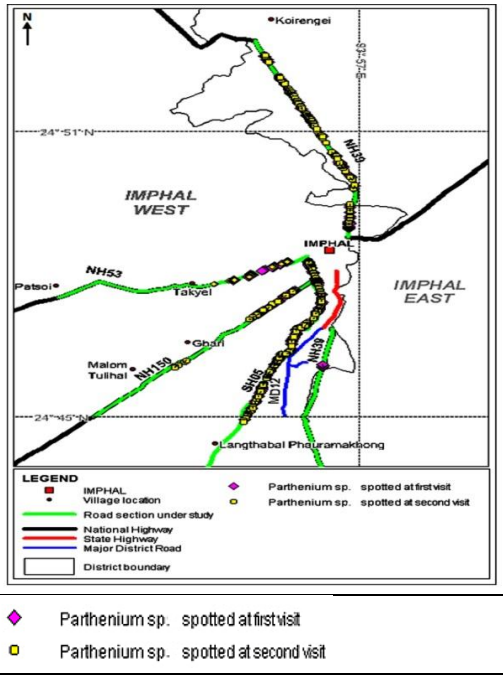


Figure 2. Enlarged map of National Highways and State highway of Manipur showing Parthenium infested regions during the two different survey period (i.e July- August, 2016 and July- August, 2017).

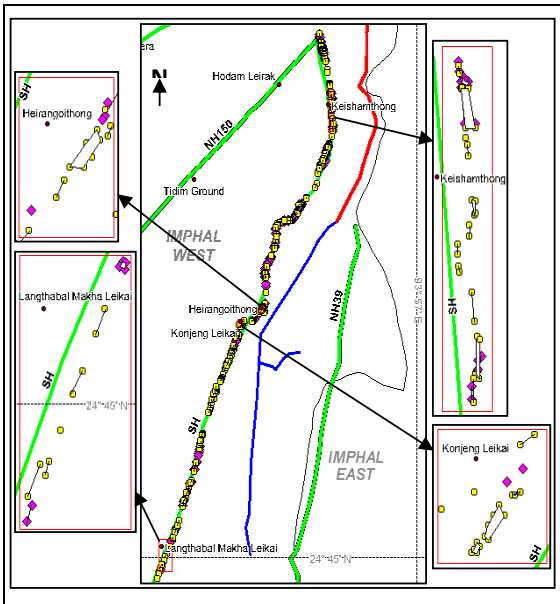


Figure 3. Enlarged map of SH- Mayai Lambi showing spread of Parthenium infestation during the two different survey period (i.e July- August, 2012 and July – August, 2013).

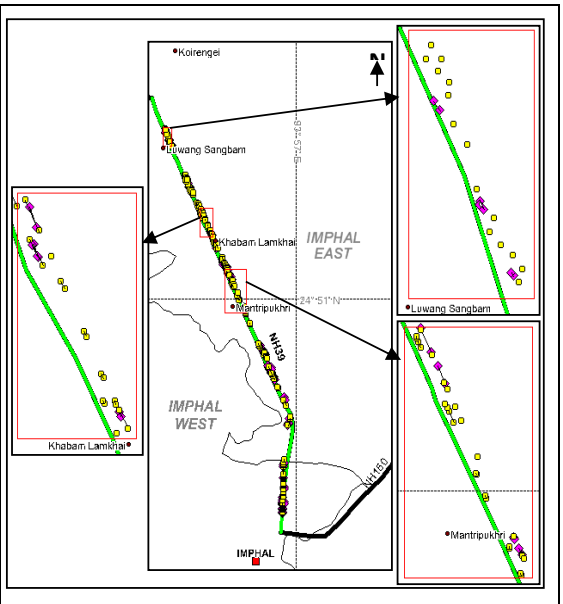


Figure 4. Enlarged map of NH-39 showing spread of Parthenium infestation during the two different survey period (i.e July- August, 2012 and July – August, 2013).

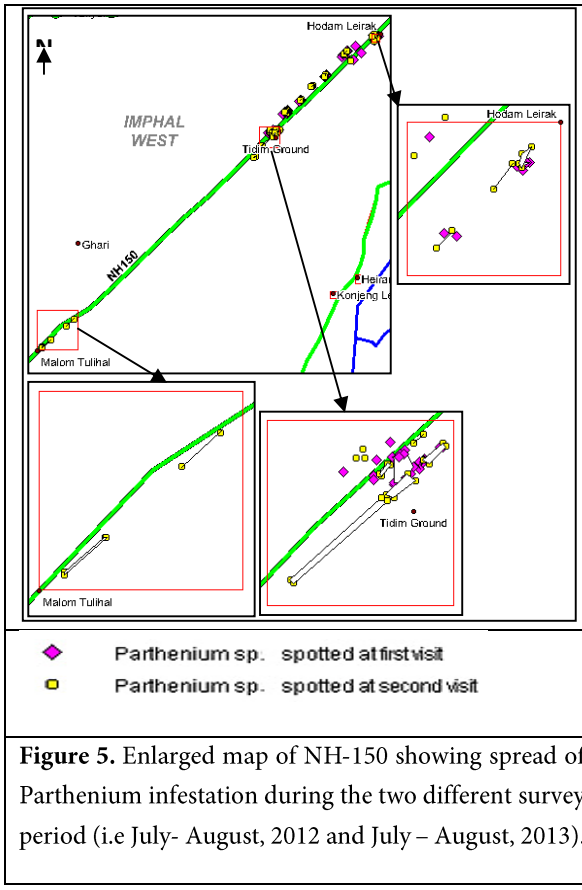


Figure 5. Enlarged map of NH-150 showing spread of Parthenium infestation during the two different survey period (i.e July- August, 2012 and July – August, 2013).

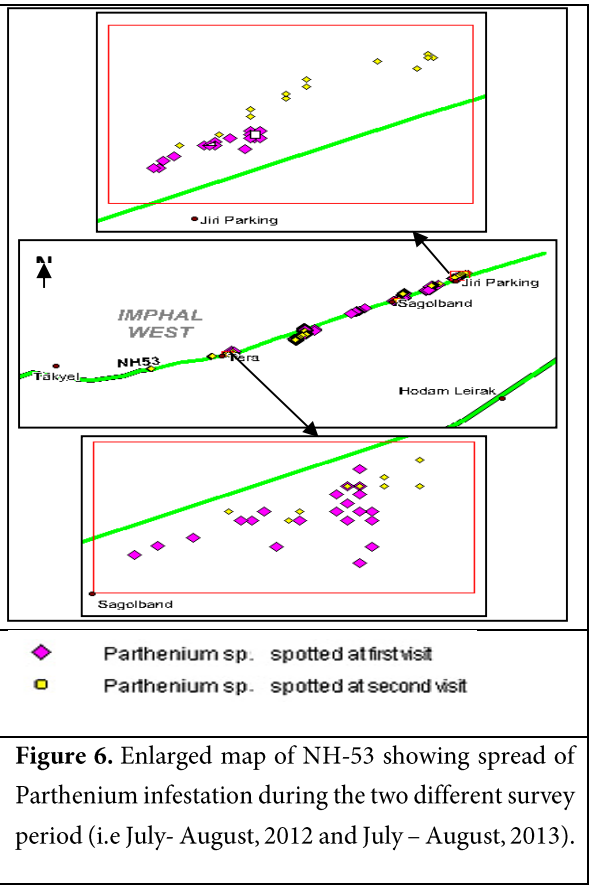


Figure 6. Enlarged map of NH-53 showing spread of Parthenium infestation during the two different survey period (i.e July- August, 2012 and July – August, 2013).

RESULTS AND DISCUSSION

Field survey of the areas infested with *Parthenium hysterophorus* L. in North East India Density m^{-2}

The survey data revealed that among the states of North East India, the highest density of various weed species i.e 88.12 m^{-2} was recorded in Manipur, closely followed by 85.24 m^{-2}, 61.59 m^{-2} and 59.86 m^{-2} at Assam, Tripura and Nagaland respectively (Table 1). The highest infestation of *Parthenium hysterophorus* was recorded at Assam (28.4 m^{-2}) followed by Manipur (25.6 m^{-2}), Nagaland (17.23 m^{-2}), Tripura (14.1m^{-2}), Arunachal Pradesh (9.2 m^{-2}), Sikkim (8.3 m^{-2}), and Meghalaya (8.21 m^{-2}) respectively.

Frequency (%)

A core infestation of Parthenium weed is present in the whole North East states except Mizoram having mean frequency of 22.57% (Table 2). The highest frequency (46%) of *Parthenium hysterophorus* was observed in Assam, while the minimum frequency of (8%) of Parthenium weed was observed in Meghalaya and Sikkim. Among all the weeds, *Cynodon dactylon* was recorded to be the highest mean frequency with 88.25% followed by Parthenium (22.57%) and *Cassia tora* (21.63%).

The survey revealed that the obnoxious weed (Parthenium) has infested all the main national highways, state highways and railway tracts of Assam. Medium infestation of Parthenium was found in Manipur national and state highways barring a few spots where it was severe. In states like Sikkim, Tripura and Meghalaya, mild infestation was found at a few places. In Nagaland, severe infestation was found in Dimapur. In Arunachal Pradesh, severe infestation was found on border while inside of Arunachal Pradesh, infestation was negligible. In Mizoram, till now Parthenium was not seen in all the surveyed sites. It is expected to continue its dissemination because of the negligence not only by the people but also by the agricultural department or government to control it. Parthenium is well established in North East India due to its adaptability to varying conditions and lack of natural enemies, Parthenium weed will replace the precious native flora and will pose strong threats to the biodiversity if it is not controlled as

soon as possible. In our survey among the North-Eastern states except Mizoram, the spreading level is high in Assam and Manipur, medium in Nagaland, and low in Arunachal Pradesh, Meghalaya, Tripura and Sikkim. For Mizoram State, Parthenium is yet to be discovered because in our survey sites, we fail to notice it. The domination and rapid spread of *P. hysterophorus* along the highways could be attributed to its invasive capacity, allelopathic properties, high growth rate, short growth cycle and large number of seed production (Evans et al., 1997; Oudhia, 1998).

Case study result

In case study site map (Fig. 1) the latitudinal and longitudinal location of Parthenium infested sites were located and in the map of Parthenium infested sites along the selected highways, Parthenium was spotted highest in the State highway (Mayai lambi) followed by NH-39, NH-150 and NH-53 (Fig. 2).

The gap between the two Parthenium spotted sites during the first survey was found with the presence of Parthenium in the second time survey. In the survey site of Mayai lambi state highway four areas were spotted out namely Keishamthong, Heirangoithong, Konjeng leikai and Langthabal makha leikai where Parthenium was found spreading and growing luxuriantly, which was absent during first survey (Fig. 3.). Along the NH-39, Luwang sangbam, Khabam Leikai and Mantripukhri were the areas where Parthenium was spotted and found to be growing in monocultural strand during the second time survey (Fig. 4). Similar, observations were found in Hodam leirak machin and near Tiddim ground along NH-150 (Fig. 5) but in NH-53, Jiri Parking and Tera bazar were the areas where Parthenium was spotted in large number during the first visit of survey compared to the second time survey which may be due to the construction along the roadside (Fig. 6). Almost all the selected NHs and state highway of the Imphal valley had a heavy infestation of Parthenium weed except NH-53. In the roadsides, one can easily observe dominance of Parthenium weed over other weeds. Parthenium weed rapidly invades new surroundings often replace the indigenous species and pose a serious threat to biodiversity., Among the survey sites, in State highway (i.e Mayai Lambi) Parthenium was found to be heavily infested and spreading faster than the other sites which may be attributed to beside spreading of seeds by wind, it might be spread by water run-off of the river as Nambul river is flowing along the side of Mayai Lambi state highway. The seeds are easily spread by vehicles, machinery and animals and in pasture seed, stock feed and water current and to a lesser extent by the wind. Small size and light weight of its seeds greatly help in its easy dissemination by wind or water current over the large areas and also to long distances (Kohli & Rani, 1994; Narwal, 2012).

Effect of Parthenium dry shoot amendment to soil on germination and productivity of the test crop plants

Effect of Parthenium dry shoot on germination of *Brassica capitata*, *Brassica caulorapa*, *Zea mays* and *Oryza sativa* are shown in the Table 3. Dried shoot of *Parthenium hysterophorus* amended soil markedly reduced the germination of *B. capitata*, *B. caulorapa*, *Z. mays* and O. sativa with the increase in the amount of Parthenium dry shoot. The highest seed germination inhibition was observed in 400g amended sample, which showed maximum inhibition of 54.91% in *B. caulorapa* followed by *B. capitata* (50.01%), *Z. mays* (49.96%) and *O. sativa* (41.82%).

The different types of allelochemicals released from the decaying Parthenium dry biomass might have caused the retardation in seed germination percentage and speed of germination index by acting negatively on the process. The adverse impact of allelochemicals on seed germination is concentration dependent. Jabeen and Ahmed (2009) reported that the dry powder of *Asphodelus tenuifolius, Euphorbia hirta* and *Fumaria indica* also exhibited negative allelopathic effect on the seed germination and speed of germination index of maize. Parthenium dry biomass was found inhibitory effects on seed germination of rice (Biswas, 2010; Oudhia & Tripathi, 2000) (Oudhia and Tripathi, 2000; Biswas et al., 2010). The plant species differed in their response to the rate of Parthenium residue in the soil.

Table 3. Effect of dry shoot of *Parthenium hysterophorus* L. amendment to soil on the germination of selected agronomically important crop plants (Values are mean of three replicates).

Concentration	*Zea mays* L.	*Brassica capitata* L.	*Oryza sativa* L.	*Brassica caulorapa* Pasq.
Control	88.33	86.67	91.67	85
50g/10 kg soil	74.4	71.67	80	66.67
100g/10 kg soil	68.3	63.33	76.67	56.67
150g/10 kg soil	56.67	55	65	51.33
200g/10 kg soil	51.33	50	58.33	46.67
300g/10 kg soil	49.3	45	55	41.67
400g/10 kg soil	44.2	43.33	53.33	38.33

Table 4. Allelopathic effect of different concentration of dry shoot *Parthenium hysterophorus* L. amended soil on certain growth parameters of *Brassica capitata* L. (Values are mean of three replicates).

	Parameters				
	Whole cabbage weight (g)	**Cabbage head weight (g)**	**Equatorial diameter (cm)**	**Polar diameter of head (cm)**	**No. of non wrapper leaves**
CONTROL (T1)	1383.67 ± 24.13	1062.33 ± 45.39	34.87 ± 1.40	21.77 ± 1.29	11.67 ± 0.58
50g/10kg soil (T2)	1127.33 ± 9.07	826.67 ± 8.62	31.60 ± 1.20	18.00 ± 0.26	10.33 ± 0.58
100g/10kg soil (T3)	961.00 ± 9.17	746.00 ± 8.00	26.17 ± 1.01	16.70 ± 0.36	8.33 ± 0.58
150g/10kg soil (T4)	740.67 ± 8.08	530.67 ± 7.51	23.20 ± 0.66	15.40 ± 0.40	7.67 ± 0.58
200g/10kg soil (T5)	603.67 ± 8.62	386.00 ± 12.00	20.73 ± 0.35	13.90 ± 0.30	6.67 ± 0.58
300g/10kg soil (T6)	500.00 ± 14.11	313.33 ± 9.07	19.40 ± 0.30	13.03 ± 0.25	10.67 ± 0.15
400g/10kg soil (T7)	409.00 ± 13.23	290.67 ± 8.74	18.17 ± 0.25	11.70 ± 0.66	11.33 ± 0.58
SEm (±)	**10.42**	**15.34**	**0.49**	**0.49**	**0.49**
CD(0.05)	**21.79**	**32.07**	**1.02**	**1.03**	**1.02**

*Mean ± S.E, Significant at p=0.05

Allelopathic effect of Parthenium dry shoot on the productivity of *Brassica capitata*

The result revealed that all the parameters which attribute to productivity of the test crop plants were drastically affected with the increase in concentration of the dry shoot of Parthenium incorporated to soil over control.

The whole cabbage plant weight and the cabbage head weight was found to have significantly reduced as the concentration of dry Parthenium shoot increased (Table 4). The whole plant weight was found to have reduced to 18.53%, 30.55%, 46.47%, 56.37%, 63.86% at 50g, 100g, 150g, 200g, 300g and 400g respectively in Parthenium amended soil samples. However, reduction percentage of cabbage head weight was 22.18%, 29.78%, 50.05%, 63.66%, 70.51% and 72.64% at 50g, 100g, 150g, 200g, 300g and 400g respectively as compared to control.

Allelopathic effect of Parthenium dry shoot on productivity of *Brassica caulorapa* Pasq. (Knol khol)

The whole plant weight and the tuber weight were found to have reduced in all the treatments as compared to control. At low concentration (T2), the whole plant weight and the tuber weight was reduced to 15.59% and 11.96% over the control. But at higher concentration T7 (400g), it was observed that the reduction percentage in whole plant weight and tuber weight were 74.87% and 80.91% respectively as compared to control (Fig. 7).

The equatorial diameter of *B. caulorapa* tuber was found to have reduced with the increased in dry shoot concentration. The maximum diameter was recorded in control (T1) with a value of 11.77 cm and maximum inhibition was observed in T7 (400g) of dry biomass incorporated in soil with a value of 5.30 cm (Table 5).

Table 5. Allelopathic effect of different concentration of dry shoot of *Parthenium hysterophorus* L. amendment to soil on certain growth parameters of *Brassica caulorapa* Pasq. (Values are mean of three replicates).

	Parameters				
	Whole plant weight (g)	**Body weight (g)**	**Equatorial diameter (cm)**	**Polar diameter (cm)**	**No. of leaves**
CONTROL (T1)	269.33 ± 5.03	225.33 ± 4.16	11.77 ± 0.35	12.13 ± 0.40	18.67 ± 0.58
50g/10kg soil (T2)	227.33 ± 6.43	198.37 ± 16.25	9.88 ± 0.46	10.47 ± 0.57	16.67 ± 1.15
100g/10kg soil (T3)	165.00 ± 21.79	124.67 ± 4.73	9.10 ± 0.10	10.00 ± 0.10	16.33 ± 0.58
150g/10kg soil (T4)	125.33 ± 2.52	87.67 ± 11.24	8.02 ± 0.44	8.70 ± 0.30	13.67 ± 1.15
200g/10kg soil (T5)	115.33 ± 5.51	73.33 ± 5.03	7.02 ± 0.06	7.63 ± 0.51	13.33 ± 0.58
300g/10kg soil (T6)	84.00 ± 4.00	53.33 ± 4.16	6.52 ± 0.08	7.13 ± 0.12	12.33 ± 0.58
400g/10kg soil (T7)	67.67 ± 4.04	43.00 ± 4.58	5.30 ± 0.58	5.93 ± 0.45	10.67 ± 0.58
SEm (±)	**7.77**	**5.69**	**0.22**	**0.31**	**0.56**
CD(0.05)	**16.23**	**11.9**	**0.46**	**0.66**	**1.18**

*Mean ± S.E, Significant at p=0.05

Table 6. Allelopathic effect of different concentration of dry shoot of *Parthenium hysterophorus* L. amendment to soil on certain growth parameters of *Zea mays* L. (Values are mean of three replicates).

	Parameters				
	Corn Length (cm)	**Corn Weight (g)**	**Plant Height (cm)**	**Dry Plant Biomass (g)**	**Grain Weight/ Corn (g)**
CONTROL (T1)	17.77 ± 0.81	141.53 ± 1.80	198.33 5.13	177.67 ± 6.11	95.10 ± 2.61
50g/10kg soil (T2)	14.77 ± 0.72	124.20 ± 1.25	159.67 ± 5.69	158.33 ± 7.02	72.53 ± 2.30
100g/10kg soil (T3)	12.47 ± 0.35	108.23 ± 4.48	147.33 ± 2.52	143.33 ± 2.52	64.23 ± 2.24
150g/10kg soil (T4)	12.13 ± 0.50	94.60 ± 3.70	139.00 ± 3.00	136.33 ± 2.52	55.10 ± 2.10
200g/10kg soil (T5)	11.50 ± 0.53	84.57 ± 2.65	137.33 ± 2.52	129.00 ± 2.00	49.40 ± 1.91
300g/10kg soil (T6)	11.17 ± 0.40	73.03 ± 2.47	133.67 ± 2.08	122.67 ± 2.52	38.03 ± 2.17
400g/10kg soil (T7)	10.30 ± 0.56	64.23 ± 3.27	131.33 ± 2.52	112.67 ± 3.52	22.27 ± 2.46
SEm (±)	**0.44**	**2.59**	**2.03**	**2.42**	**1.66**
CD(0.05)	**0.91**	**5.40**	**4.25**	**5.06**	**3.47**

*Mean ± S.E, Significant at p=0.05

The data on the number of leaves on each treatment revealed that the dry shoot of parthenium also affected significantly on the number of leaves. The number of leaf decreased as the concentration of dry biomass of Parthenium increased. The lower concentration of dry biomass did not have much effect on the number of leave as compared to control but in higher concentration (T7), it was reduced by 42.85%. The number of leaf might have relation with the size and weight of the tuber as the leaf is the site for photosynthesis. Photosynthesis is a process of manufacturing food which is deposited in tuber. As the number of leaf decreased the size and weight of the tuber also decreases accordingly.

Allelopathic effect of Parthenium dry shoot on the productivity of *Zea mays* L. (Maize)

The result revealed that dry shoot of Parthenium incorporated in soil affected the plant height, plant dry biomass, corn length, corn weight and grain weight per corn of *Z. mays* (Table 6). At lower concentration T2 and T3, it did not have much ef-

fect on the plant height but as the concentration increased (T4 –T7) it was reduced by 29.91% to 33.78% as compared to control (Fig. 8). The corn length of maize plant grown in Parthenium dry shoot amended soil was also found to have been affected. The highest corn length was observed in control (T1) with a value of 15.97 cm but at higher concentration (T7), it was reduced by 35.50%.

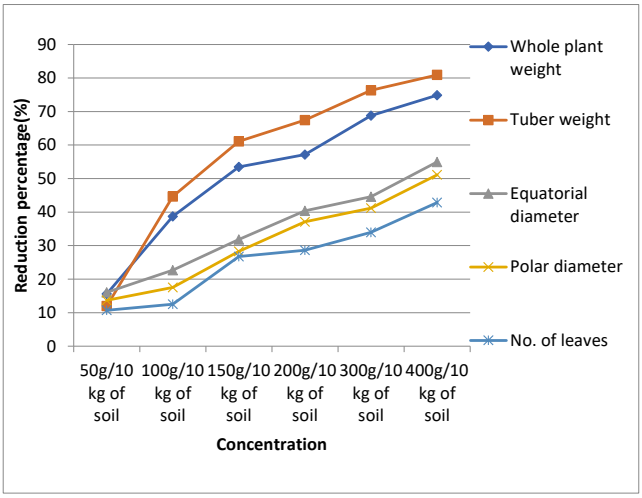


Figure 7. Allelopathic effect (%) of dry shoot of *Parthenium hysterophorus* L. amendment to soil on different growth parameters of *Brassica caulorapa*.

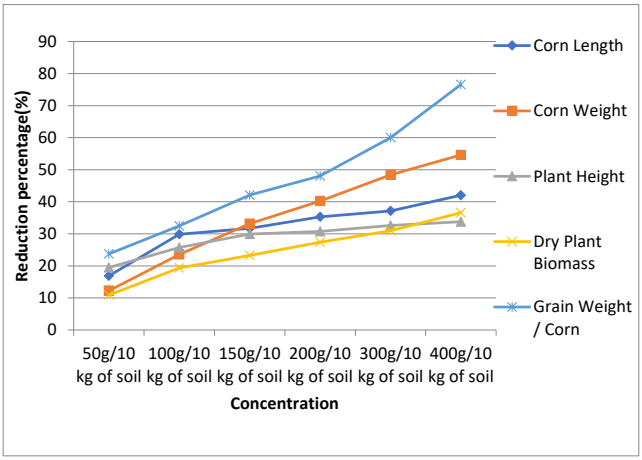


Figure 8. Allelopathic effect (%) of dry shoot of *Parthenium hysterophorus* L. amendment to soil on different growth parameters of *Zea mays* L.

The result showed that the corn length of the maize was also Parthenium dry shoot concentration dependent. As the concentration of the dry shoot of Parthenium amendment to soil increased, the reduction in corn length was also found to have increased.

Similar affect were also observed with the grain weight per corn. The grain weights per corn were found to have reduced in all the treatments over the control. The maximum grain weight per corn was obtained in control with 95.10g and lowest in T7 with a value of 22.27g. These results suggest that corn weight and grain weight per corn decreased significantly (p=0.05) as parthenium dry shoot amendment to soil increased.

Allelopathic effect of Parthenium dry shoot on the productivity of *Oryza sativa* L. (Rice)

Parthenium dry shoot amendment to soil had a negative allelopathic effect on all measurable parameters (i.e plant height, total tiller per plant, effective tiller per plant, panicle length, fill grain per panicle and grain weigh per 100 grain) which is attributed to the productivity of *O. sativa* (Table 7).

Rice plant height was found to have affected significantly (p=0.05) by the different amount of Parthenium dry shoot amendment to soil. The percent reduction in plant height over control was 13.58%, 18.81%, 33.7%, 59.89%, 68.30% and 78% at T2, T3, T4, T5, T6 and T7 respectively (Fig. 9).

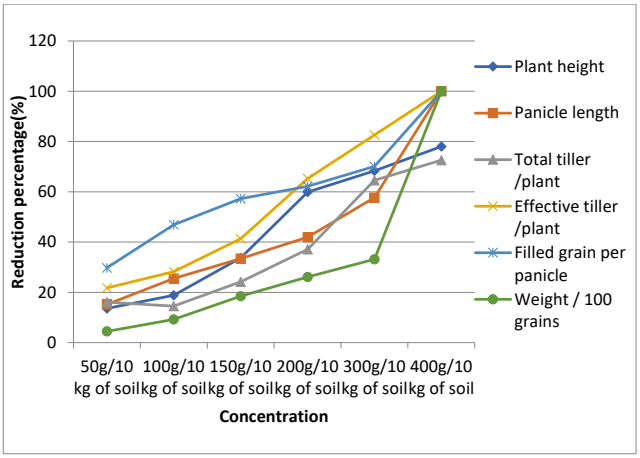


Figure 9. Allelopathic effect (%) of dry shoot of *Parthenium hysterophorus* L. amendment to soil on different growth parameters of *Oryza sativa* L.

The reduction percentage of tiller per plant was 16.13%, 20.16%, 24.19%, 37.1%, 64.52% and 72.58% at T2, T3, T4, T5, T6 and T7 respectively as compared to control. None of the tillers of rice plant samples were effective in T7 (400g) sample.

The residue of Parthenium also affected the panicle length of rice. The panicle length were reduced by 15.18%, 25.47%, 33.4%, 41.92%, 57.69% and 100% at T2, T3, T4, T5, T6 and T7 respectively as compared to control. The reduction percent-

Table 7. Allelopathic effect of increased concentration of dry shoot of *Parthenium hysterophorus* L. amendment to soil on certain growth parameters of *Oryza sativa* L. (Values are mean of three replicates).

	Parameters					
	Plant height (cm)	**Panicle length (cm)**	**Total tiller/ plant**	**Effective tiller/ plant**	**Filled grain per panicle**	**Weight/ 100 grains (g)**
CONTROL (T1)	66.12 ± 5.21	20.42 ± 1.48	12.4 ± 1.14	9.2 ± 0.84	149.2 ± 8.87	3.14 ± 0.07
50g/10kg soil (T2)	57.14 ± 1.32	17.32 ± 0.72	10.4 ± 0.89	7.2 ± 0.84	104.8 ±10.99	3.00 ± 0.09
100g/10kg soil (T3)	53.68 ± 1.20	15.22 ± 0.51	10.6 ± 0.89	6.6 ± 0.55	79.2 ± 7.01	2.85 ± 0.06
150g/10kg soil (T4)	43.84 ± 3.19	13.6 ± 0.37	9.4 ± 0.55	5.4 ± 0.55	63.8 ± 4.32	2.56 ± 0.14
200g/10kg soil (T5)	26.52 ± 1.86	11.86 ± 0.45	7.8 ± 0.84	3.2 ± 0.84	56.4 ± 4.04	2.32 ± 0.09
300g/10kg soil (T6)	20.96 ± 1.55	8.64 ± 0.70	4.4 ± 1.34	1.6 ± 0.55	44.6 ± 7.54	2.10 ± 0.12
400g/10kg soil (T7)	14.54 ± 1.16	0	3.4 ± 0.55	0	0	0
SEm (±)	**1.55**	**0.48**	**0.62**	**0.42**	**4.70**	**0.05**
CD(0.05)	**3.16**	**0.98**	**1.27**	**0.86**	**9.59**	**0.11**

*Mean ± S.E, Significant at p=0.05

Table 8. Effect of *Cassia tora* on growth of *Parthenium hysterophorus* L. in natural condition

Experimental Site	**Plant height (cm)**		**Plant population/m^2**		**Dry weight/plant (g)**	
	2016	2017	2016	2017	2016	2017
Hiyangthang	94.8	43.3	15.0	7.5	26.1	15.6
Langthabal	92.4	40.6	12.3	6.7	24.3	14.5
Manitripukhri	76.2	29.7	10.3	6.1	17.6	10.12
Tera	87.6	36.8	11.3	6.4	23.7	14.7
Control	108.2	106.8	24.6	29.2	32.5	32.1

age of filled grain to the total number of grain per panicle in different concentration of Parthenium dry shoot treatment was 29.62%, 46.92%, 57.24%, 62.2% and 70.11%, at T2, T3, T4, T5 and T6 respectively.

The present study indicates that dry shoot of *P. hysterophorus* when mixed with soil adversely affected the productivity of certain agronomic crops and vegetable crops. The reduction in weight of edible part of the vegetable crops, grain weight per corn and affective tiller per rice plant and rice grain weight per 100 grains in all the treatment was up to 90.81%, 76.58%, 100% and 33.12% respectively as compared to their control and this signifies the negative allelopathic effect of Parthenium dry shoot in the crops grown in amended soil. The reduction in the productivity of all the tested plants may be caused by the phytotoxic chemical released from the decaying parthenium dry shoot in the soil. It has also been well documented that *P. hysterophorus* contain phytotoxic phenolics and flavonoids and these allelochemicals in soil either released by leaching or decomposition may directly or indirectly affect plant growth by altering the physico-chemical properties of soil (Prati & Bossdorf, 2004) (Prati and Bosdorf, 2004). Among the test species the order of susceptibility to dry shoot of Partheniumat high concentration was *O. sativa>B. caulorapa>B.capitata>Zea mays*. The chemical exudates from Parthenium dry shoot are supposed to play a major role in the allelopathic mode of action. There could be marked differences among the species in their susceptibility towards the effect of allelochemicals (An et al., 2001) (An et al., 2001). The present finding is also agreement with the above statement.

Management of Parthenium by *Cassia tora* in natural field condition

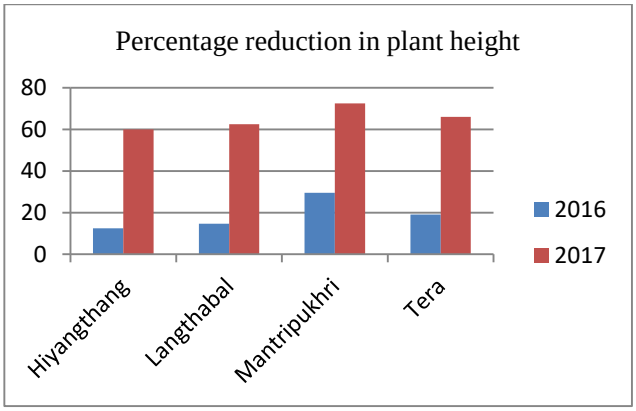


Figure 10. Effect of *Cassia tora* on percentage reduction on growth of *Parthenium hysterophorus* L parameters of *Oryza sativa* L.

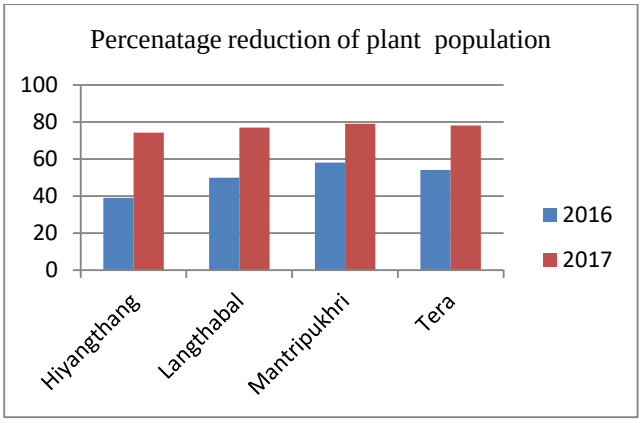


Figure 11. Effect of *Cassia tora* on percentage reduction of population of *Parthenium hysterophorus* L.

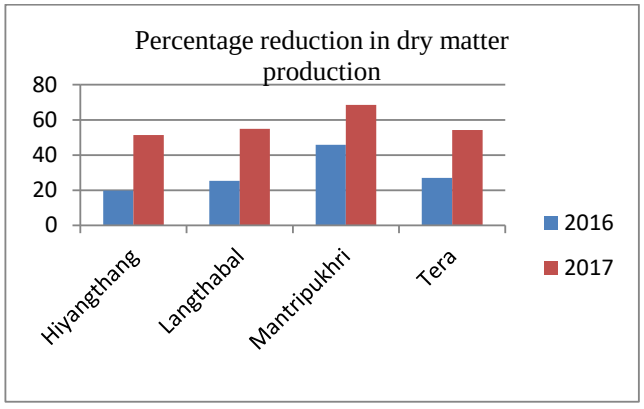


Figure 12. Effect of *Cassia tora* on percentage reduction on dry matter production of *Parthenium hysterophorus*.

Field experiment results indicate that the growth of *Cassia tora* severely inhibited the growth and development of *Parthenium hysterophorus* as indicated in the given table 8. The result revealed that there was an average height reduction by over 38% to 43% from the year 2016 to 2017 (Fig. 10). The data further revealed that population and dry matter production of *P. hysterophorus* by *C. tora* was significantly reduced from 2016 to 2017. It was observed that parthenium population was reduced by 28% to 30% (Fig. 11). Similarly, *C. tora* had strongly inhibited the dry matter production in Parthenium also. It was observed that there was percentage reduction of dry matter in Parthenium by over 57 to 62% from 2016 to 2017 (Fig. 12).

From the study it was observed that seedling of *Cassia tora* were found to be larger than Parthenium due to which *C. tora* grew faster and had taken over the Parthenium.Due to faster growth of *Cassia tora* in its early stage, Parthenium population got suppressed. Later on, the whole area was covered by *Cassia tora* in each plot and Parthenium was not able to compete with them. These resulted in the reduction of Parthenium plant height, its number of branches and flowers per plant.

Even though Parthenium is known for its allelopathic nature on the other weeds or plants, *Cassia tora* can suppress the growth of Parthenium to a greater extent. The reason may be due to their larger leaf size in early seedling stage than Parthenium, which overtakes Parthenium and keeps them under control. The plants in early phenological stages exhibit higher metabolic activities resulting in biosynthesis and accumulation of potential allelochemicals and releases them into the soil as root exudates.

Researchers from different places of India have also demonstrated the use of competitive plant species to suppress the growth of Parthenium. It has been reported that Parthenium intensity was reduced by 95% when *Cassia tora* was broadcasted before monsoon in the Parthenium infested areas (Tiwari et al., 1997). In Madhya Pradesh, heavily infested Parthenium sites were replaced at many places by deliberate broadcasting of the seeds of *C. tora* during March- April (Sushilkumar & Varshney, 2007) (Sushilkumar and Varshney, 2007). *Cassia tora* have low seed productivity and

spreading ability than Parthenium and can adapt to wide range of climatic conditions of India. Besides these, the seeds of *C. tora* are heavy in weight so there are the least chances of its spreading from the infested sites to crop fields.

CONCLUSION

Parthenium has infested all the states of North East India except Mizoram. The infestation level is high in Assam and Manipur, medium in Nagaland and Tripura; low in Arunachal Pradesh, Meghalaya, and Sikkim. Parthenium in the form of residue can affect the germination and productivity of certain agronomic crops (*Zea mays* L. and *Oryza sativa* L.) and vegetables crops (*Brassica capitata* and *B. caulorapa*). *Cassia tora* seed when broadcasted in previously Parthenium infested regions before the onset of monsoon suppressed the growth and density of Parthenium at large extent. During field survey in NE India, we came across massive growth of *C. tora* on road medians, on either side of the National Highways resulting natural suppression of Parthenium. Hence, *Cassia tora* can be recommended as one of the plant bioagent for the management of Parthenium in North East India.

ACKNOWLEDGEMENT

We thank DBT, GOI for funding Twinning R & D programme on "Biological control based integrated Parthenium management for saving environment, health and biodiversity in NE India" during the period the present work was performed.

REFERENCES

An, M., Pratley, J. E., & Haig, T. (2001). Phytotoxicity of Vulpia residues: IV. dynamics of allelochemicals during decomposition of Vulpia residues and their corresponding phytotoxicity. *Journal of Chemical Ecology*, *27*(2). https : / / doi . org / 10 . 1023 / a : 1005692724885

Biswas, O. (2010). *Allelopathic effects of plant debris of Parthenium weed on seed germination, growth and development of field crops* (Master's thesis). Department of Agronomy, BAU, Mymensingh.

Evans, H. C. et al. (1997). Parthenium hysterophorus. a review of its weed status and the possibilities for biological control. *Biocontrol News and Information*, *18*.

Jabeen, N., & Ahmed, M. (2009). Possible allelopathic effects of three different weeds on germination and growth of maize (zea mays) cultivars. *Pak. J. Bot*, *41*(4).

Kohli, R. K., & Rani, D. (1994). Parthenium hysterophorus - a review. *Research Bulletin of the Panjab University, Science*, *44*(1/4).

Kohli, R., & Rani, D. (1994). Exhibition of allelopathy by Parthenium hysterophorus L. in agro ecosystems. *Tropical Ecology*, *35*(2).

Narwal, S. S. (2012). *Allelopathy in crop production*. Scientific publishers.

Oudhia, P. (1998). Parthenium: A curse for the biodiversity of Chhattisgarh plain. *Abstract. National Research Seminar on Bio-chemical Changes. An Impact on Environment, RD Govt. PG College, Mandlaa (MP)*, *26*.

Oudhia, P., & Tripathi, R. S. (2000). Allelopathic effects of an obnoxious weed Parthenium hysterophorus L. on germination and seedling vigour of rice var. Mahamaya. *Research on Crops*, *1*(1).

Prati, D., & Bossdorf, O. (2004). Allelopathic inhibition of germination by Alliaria petiolata (Brassicaceae). *American Journal of Botany*, *91*(2). https://doi.org/10.3732/ajb.91.2.285

Sushilkumar, & Varshney, J. (2007). Gajarghas ka jaivik niyantrana: Vartman stathi avamn sambhavnam [Hindi) [Biological control of Parthenium: Present and future].

Tiwari, J. P., Kurchania, S. P., Bhalla, C. S., & Paradjar, N. R. (1997). Studies on allelopathic effects of Cassia tora and Parthenium hysterophorus L. *Proceeding of First International Conference on Parthenium*.

RESEARCH ARTICLE

Effect of magnetic degrees of freedom on the ground state configuration of Ni_2ScGe Heusler Alloy

M. Ram[*1,2], N. Limbu[1,2], A. Saxena[2], and A. Shankar[1]

[1]*Condensed Matter Theory Research Lab, Department of Physics, Kurseong College, Darjeeling, West Bengal, India*

[2]*Department of Physics, North-Eastern Hill University, Shillong, Meghalaya, India*

[*]*E-mail:* mahesh.ram933@gmail.com

ABSTRACT

A large number of first principles studies are going on in Heusler alloys. The determination of the exact ground state configuration is an important aspect. One of the important factors to consider while optimizing the ground state is the magnetic degrees of freedom. Thus, many initial magnetic configuration like the ferromagnetic and ferrimagnetic ordering of magnetic moments of the atoms were taken while optimizing the volume of Ni_2ScGe and its effect on the magnetic state was examined.

Keywords: Heusler alloys, density functional theory, magnetic configuration

INTRODUCTION

Heusler alloys (HAs) are ternary intermetallic alloys with general formula XYZ (so called half-HAs) and X_2YZ (so called full-HAs) where X and Y are transition elements and Z is a main group element [1]. It was discovered by Fritz Heusler in 1903 with an interesting fact that Cu_2MnAl showed a magnetic behaviour, even though the constituent elements were non-magnetic[2, 3]. The popularity of HA among researchers increased after the prediction of first half-metal (HM) alloy NiMnSb and PtMnSb by de Groot, in which the electronic structure shows continuous metallic type band for one spin-channel at the Fermi energy (E_F) level whereas a semiconducting gap for other spin channel at E_F [4]. HMs are finding tremendous position as candidate materials in spintronic application such as GMR and TMR and the preference of HAs over other HM alloys system like perovskites [5] and oxides [6] is because of the high Curie Temperature (T_C) [7] and similar crystal structure like that of mostly used binary semiconductors (GaAs). At present, several of tunable multifunctional properties like HM ferromagnets, HM compensated ferrimagnets, superconductors, thermoelectrics, perpendicular magnetic anisotropy, shape memory alloys, magnetocaloric effect to name a few have been reported in HAs [1].

Although a large number of experimental reports are there and studies are still going on HAs, theoretical studies and especially the trending density functional theory (DFT) helps a lot to predict the promising properties of these alloys. The valence electron count rule and Slater-Pauling rule can estimate the magnetic moment of HAs for a given structure. It is therefore very crucial to determine the correct structure and magnetic configuration (if it is magnetic) of the HAs. This paper thus tries to show the effect of different magnetic configuration on stabilizing the crystal structure by taking Ni_2ScGe as a sample material using DFT.

Table 1. Lattice constant, total energy, total and individual magnetic moment of Ni_2ScGe in $L2_1$ and XA type structures with different magnetic configuration.

Structure type	Magnetic configuration	Lattice constant (in a.u.)	Total energy (in Ry)	Magnetic moment (in μB)				
				Total	Ni1	Ni2	Sc	Ge
$L2_1$	NM	11.4250	-961.830018	-	-	-	-	-
	FM	11.4250	-961.830018	0.50	0.1924	0.1924	0.0303	0.0344
	FiM1	11.4233	-961.829763	0.02	0.0074	0.0059	0.0016	0.0014
	FiM2	11.4233	-961.829762	-0.01	-0.0060	-0.0050	-0.0013	-0.0012
	FiM3	11.4250	-961.830027	0.50	0.1929	0.1928	0.0299	0.0344
XA	NM	11.4852	-961.770385	-	-	-	-	-
	FM	11.4852	-961.770395	0.33	-0.0021	0.2398	0.0258	0.0202
	FiM1	11.4856	-961.770395	0.32	-0.0021	-0.2339	-0.0253	-0.0197
	FiM2	11.4856	-961.770395	0.32	-0.0021	0.2339	0.0253	0.0197
	FiM3	11.4856	-961.770395	0.33	-0.0018	0.2411	0.0257	0.0202

COMPUTATIONAL METHODOLOGY

We have used a plane wave pseudopotential (PW-PP) method using PWscf code based on spin-polarized DFT for calculation in present manuscript[8]. The exchange-correlation functional is approximated by using the Perdew-Burke-Ernzerhof scheme of generalized gradient approximation (PBE-GGA) [9] and the electron-ion interactions have been treated by using Vanderbilt ultrasoft potentials. The kinetic energy cut-off value of 50 Ry with charge-density cut-off of 500 Ry was used in the expansion of Kohn-Sham orbitals. Marzari-Vanderbilt scheme of smearing was used for fermionic occupation. Following the convention of Monkhorst and Pack, a grid of 12 X 12 X 12 automatically generated k-points, centred at Γ-point have been used for integration over the Brillouin zone.

RESULTS AND DISCUSSION

Full HAs in cubic phase crystallizes in the regular $L2_1$ type structure (225, Fm-3m) if the valence electron count (VEC) of X is greater than that of Y and where X occupies $4a$(0,0,0) and $4b$(0.5,0.5,0.5) positions, Y at $4c$(0.25,0.25,0.25) and Z at $4d$(0.75,0.75,0.75) [1]. However, if the valence electron count of Y is greater than that of X, than the X at $4b$ and Y at $4c$ interchange their positions to give an XA type structure (216, F-43m), which is so-called inverse HAs. For convenience, the X at $4a$ and at $4b$ ($4c$ in case of XA structure) will be termed as X1 and X2 respectively.

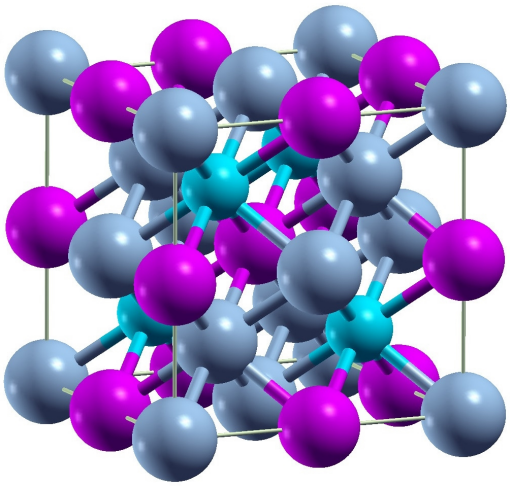


Fig. 1. Full inverse Heusler alloys (216, F-43m). Color scheme: Ni = grey, Sc = pink and Ge = blue.

The VEC most often predicts the correct structure but there has been reports of its violation, for instances for the same X and Y, Mn_2RhSi and Mn_2RhGe shows $L2_1$ type and XA type for Mn_2RhSn [10] and similar kind of structure anomalies has been reported by Galehgirain et al. in a series of HAs [11, 12]. Thus, it is important to check that which structure is favoured energetically. The task gets complicated by the induction of magnetic degrees of freedom. It was found that

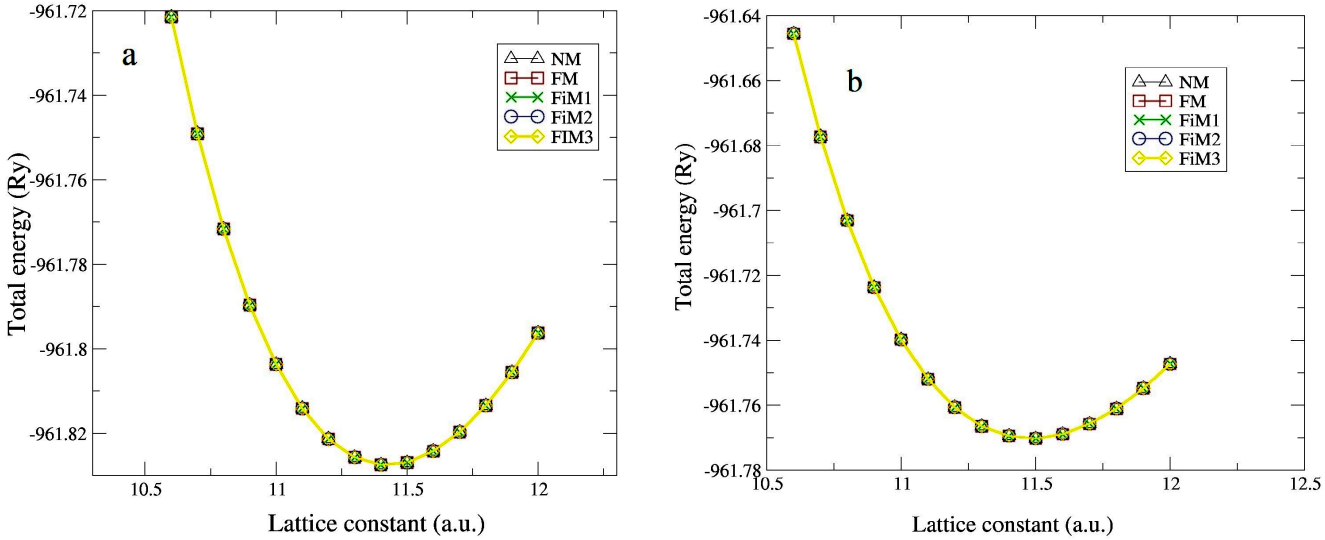


Fig. 2. Lattice constant, total energy, total and individual magnetic moment of Ni_2ScGe in $L2_1$ and XA type structures with different magnetic configuration.

the different initial magnetic configurations of the transition elements leads to a different state. Thus, for each type of crystal structure, following initial magnetic configuration were considered under the magnetic phase: (1) All the moments of transition elements were parallel (ferromagnetic: FM), (2) moments of X1 and Y are parallel and X2 antiparallel (Ferrimagnetic1: FiM1), (3) moments of X2 and Y are parallel and X1 antiparallel (Ferrimagnetic2: FiM2) and (4) moments of X1 and X2 are parallel and Y antiparallel (Ferrimagnetic3: FiM3).

The total energy as a function of the lattice constant for the two types of structures with non-magnetic and different magnetic configurations fitted to Murnaghan's equation of state shows that energetically it is the $L2_1$, which is favored over the XA structure (Figure 2). Although from the graph, the first impression is that there is no difference in the non-magnetic and different magnetic configurations and it appears that Ni_2ScGe crystallizes in non-magnetic state. However, the converged states for the non-magnetic and different initial magnetic configuration reveal a different picture, which is evident from table 1. The optimized lattice constants and total energy for $L2_1$ are slightly different but for different magnetic configuration in each case were almost the same. But the total and individual magnetic moment for different initial magnetic configuration was different in the $L2_1$ type structure and not much variation was observed in case of XA type structure.

CONCLUSION

The ground state configuration was optimized for Ni_2ScGe for $L2_1$ and XA type structures with different initial magnetic configuration. The volume optimization curve shows that energetically it is the $L2_1$ structure which is favoured over the XA type in accordance with VEC. Moreover, the volume optimization curves give the impression of no effect of different initial magnetic configuration for both the structure on the lattice constant and total ground state energies. However, a careful analysis of the converged state shows a significant variation in the total and individual magnetic moments i.e., the magnetic state. A similar variation is expected in the electronic structure and requires a thorough investigation.

REFERENCES

[1] T. Graf, C. Felser, and S. S. Parkin, "Simple rules for the understanding of Heusler compounds," *Progress in Solid State Chemistry*, vol. 39, no. 1, 2011. DOI: https://doi.org/10.1016/j.progsolidstchem.2011.02.001.

[2] F. Heusler, "Uber magnetische magan-legierungen," *Verh. d. DPG*, vol. 5, 1903.

[3] F. Heusler, W. Starck, and E. Haupt, "Uber die synthese ferromagnetischer manganlegierungen," *Verh. d. DPG*, vol. 5, 1903.

[4] R. A. de Groot, F. M. Mueller, P. G. van Engen, and K. H. J. Buschow, "New class of materials: Half-metallic ferromagnets," *Physical Review Letters*, vol. 50, no. 25, 1983. DOI: 10.1103/physrevlett.50.2024.

[5] Z. Ali, I. Ahmad, B. Khan, and I. Khan, "Robust half-metallicity and magnetic properties of cubic perovskite $CaFeO_3$," *Chinese Physics Letters*, vol. 30, no. 4, 2013. DOI: 10.1088/0256-307x/30/4/047504.

[6] J. Coey and C. Chien, "Half-metallic ferromagnetic oxides," *MRS Bulletin*, vol. 28, no. 10, 2003. DOI: 10.1557/mrs2003.212.

[7] H. X. Liu, Y. Honda, T. Taira, K. I. Matsuda, M. Arita, T. Uemura, and M. Yamamoto, "Giant tunneling magnetoresistance in epitaxial $Co_2MnSi/MgO/Co_2MnSi$ magnetic tunnel junctions by half-metallicity of Co_2MnSi and coherent tunneling," *Applied Physics Letters*, vol. 101, no. 13, 2012. DOI: 10.1063/1.4755773.

[8] P. Giannozzi, S. Baroni, N. Bonini, M. Calandra, R. Car, C. Cavazzoni, D. Ceresoli, G. L. Chiarotti, M. Cococcioni, I. Dabo, A. D. Corso, S. de Gironcoli, S. Fabris, G. Fratesi, R. Gebauer, U. Gerstmann, C. Gougoussis, A. Kokalj, M. Lazzeri, L. Martin-Samos, N. Marzari, F. Mauri, R. Mazzarello, S. Paolini, A. Pasquarello, L. Paulatto, C. Sbraccia, S. Scandolo, G. Sclauzero, A. P. Seitsonen, A. Smogunov, P. Umari, and R. M. Wentzcovitch, "QUANTUM ESPRESSO: A modular and open-source software project for quantum simulations of materials," *Journal of Physics: Condensed Matter*, vol. 21, no. 39, 2009. DOI: 10.1088/0953-8984/21/39/395502.

[9] J. P. Perdew, K. Burke, and Y. Wang, "Generalized gradient approximation for the exchange-correlation hole of a many-electron system," *Physical Review B*, vol. 54, no. 23, 1996. DOI: 10.1103/physrevb.54.16533.

[10] D. Bensaid, T. Hellal, M. Ameri, Y. Azzaz, B. Doumi, Y. Al-Douri, B. Abderrahim, and F. Benzoudji, "First-principle investigation of structural, electronic and magnetic properties in Mn_2RhZ ($Z = Si, Ge,$ and Sn) Heusler alloys," *Journal of Superconductivity and Novel Magnetism*, vol. 29, no. 7, 2016. DOI: 10.1007/s10948-016-3390-9.

[11] S. Galehgirian and F. Ahmadian, "First principles study on half-metallic properties of Heusler compounds Ti_2VZ ($Z = Al, Ga,$ and In)," *Solid State Communications*, vol. 202, 2015. DOI: 10.1016/j.ssc.2014.10.017.

[12] H. Luo, Y. Xin, B. Liu, F. Meng, H. Liu, E. Liu, and G. Wu, "Competition of $L2_1$ and XA structural ordering in Heusler alloys X_2CuAl ($X = Sc, Ti, V, Cr, Mn, Fe, Co, Ni$)," *Journal of Alloys and Compounds*, vol. 665, 2016. DOI: 10.1016/j.jallcom.2015.11.207.

RESEARCH ARTICLE

Spectroscopic study of Rhodamine B dye doped in silica glass prepared by Sol-Gel technique

Dipangkar Kalita[1,2]

[1]*Department of Physics, Mizoram University, Aizawl, Mizoram, India*

[2]*Department of Physics, North-Eastern Hill University, Shillong, Meghalaya, India*

E-mail: dipangkarnehu@gmail.com

ABSTRACT

Spectroscopic studies of Rhodamine B (RhB) dye-doped Silica glass were carried out. RhB dye-doped Silica glass sample is first prepared by Sol-gel technique and then characterization study is being carried out. Absorption edge and band gap for pure RhB dye and RhB doped Silica glass were calculated with the help of iHR 320 Spectrometer from the absorption spectra in the visible region. The emission spectral distribution of pure RhB dye and RhB dye-doped Silica glass has been recorded using 370 nm and 450 nm excitation source. The obtained results are discussed in details.

Keywords: RhB dye, Silica glass, absorption edge, band gap energy

INTRODUCTION

Sol–gel process is a potential technique for preparing oxide gels, glasses, and ceramics under mild conditions (low temperature and pressure) [1, 2]. This technique utilizes the low temperature reactions like hydrolysis and condensation and has many advantages over the conventional quench technique because of lower temperature processing, excellent homogeneity at a molecular level, high compositional purity and the possibility of incorporating organic molecules at low temperature [3–5]. Being a low temperature synthesizer of glass, it enables doping of even organic molecules at high concentration in glasses [6]. The dopant molecules may be incorporated in the pores of these glasses.

Dye doped in silica glasses have gain much interest owing to their attractive optical and physical properties; and has extensive applications in Photonics, Solid state laser physics, molecular spectroscopy and laser amplification etc. [7–9]. Among the dye, RhB dye is one of the important cationic Xanthene dye and its wavelength is of the range 550-650 nm, and it is used as photosensitizer, a quantum counter and laser dye [10, 11]. The absorption spectra of RhB dye in solution and RhB dye doped in silica glass are dependent on the concentration and type of solvent used [12]. Inertness and transparency are the most important characteristics of silica glass [13].

In this paper, we have investigated the optical properties of pure RhB dye and dye doped in Silica glass. We also calculated the absorption edge and band gap of pure RhB dye and RhB dye doped in silica glass at 10^{-3} (mole/litre) RhB solution.

EXPERIMENTAL DETAILS

The dye-doped silica glass sample was prepared by a Sol-gel method that rely on the hydrolysis and condensation of tetraethyl orthosilicate (TEOS), in

Table 1. Absorption edge and band gap energy in pure RhB dye and doped RhB dye in Silica glass.

Compound	Absorption edge (nm)	Band gap energy (E_g; eV)
Pure RhB at concentration 10^{-3} (mole/liter)	607.78	2.04
RhB doped in silica glass at concentration 10^{-3} (mole/liter)	592.32	2.09

the presence of H_2O. The initial solution is typically composed of 2.2 ml of TEOS, 1 ml of deionized water (H_20) and 2 ml of ethanol (C_2H_5OH). A small amount of HNO_3 is also added to lower the PH value and increase the rate of hydrolysis. The ratio of TEOS to other constituents viz, H_2O, C_2H_5OH, and HNO_3 is 2.2: 1: 2 respectively. The Molar Concentration of 10^{-3} (mole/litre) RhB dye dissolved in 10 ml of ethanol and a small amount of dissolved RhB dye is added with the initial solution after stirring the mixture for few minutes. The mixture is stirred for 1 hour using a magnetic stirrer without heating to form a sol. The sol is then poured in a small plastic container and then sealed to prevent evaporation. The sol is left sealed at room temperature for a few days during which it forms a solid gel. Pin holes are then made in the cover of the plastic container to allow slow evaporation and then left for a period of two weeks. The gels are dried by slow heating to form a dense glass sample.

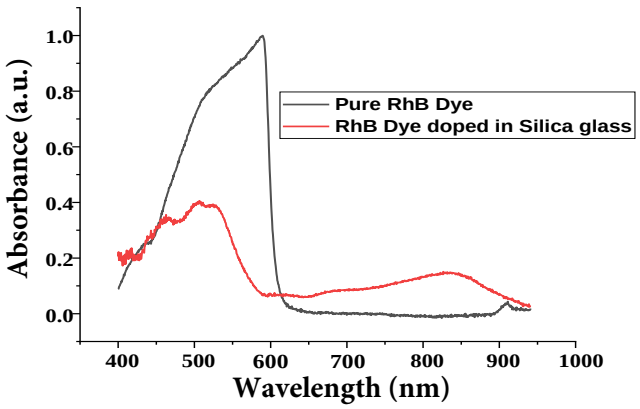


Fig. 1. Absorption spectrum of Pure RhB dye and RhB dye in Silica glass.

The Absorption and emission spectra were recorded using the iHR320 Imaging Spectrometer using Syner JY^{TM} software from Horiba. For emission spectra, we used the Excitation wavelength of 370 nm and 450 nm.

RESULTS AND DISCUSSION

The absorption spectrum of the prepared sample is shown in figure 1. The maximum peak for RhB doped in silica is about 506.35 nm but the maximum peak for pure RhB dye is at about 590 nm which is comparatively different from other observations [14], the reasons may be due to the type of filter machine used. Besides, solvent and pH value of the solution can be a contributing factor. The intensity for pure RhB is nearly at about 1 a.u., but the maximum intensity for RhB doped in silica glass is about 0.40 a.u. as shown in figure 1. Absorption edge and bandgap energy are calculated [15] as shown in table 1. The absorption spectra of pure RhB dye and RhB dye doped in silica glass showed the shifting in the absorbance edges. There was a possibility of cluster formation due to the presence of the aromatic group in the RhB dye.

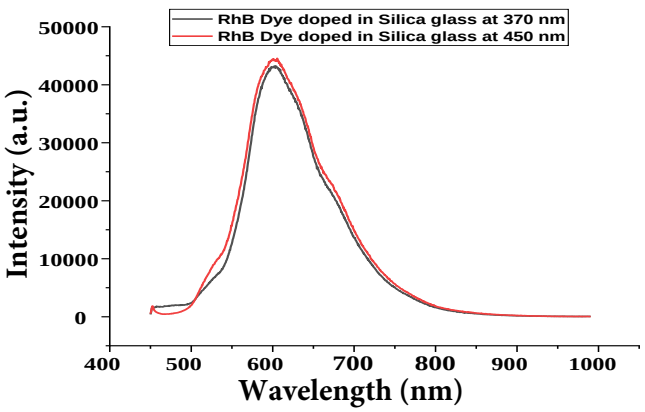


Fig. 2. Emission spectra of RhB dye in Silica glass at different wavelength.

But, in silica glass there are no aromatic group present; therefore, the dye doped in silica glass absorption edge is shifting from Visible towards UV side.

Table 2. Maximum intensity and FWHM in Pure RhB dye and RhB dye in Silica glass.

Sl. no.	Compound	Max. peak (nm)	Max. intensity (a.u.)	FWHM (nm)
1	Pure RhB at concentration 10^{-3} (mole/litre)	598.19	32983	56.94
2	RhB doped in silica glass at concentration 10^{-3}(mole/litre)	602.43	43232	110.65

Emission spectrum was recorded in the UV-visible region using 370 nm and 450 nm excitation respectively. Figure 2, shows that these two spectra have the same trend in different excitation wavelength of RhB dye doped in silica glass.

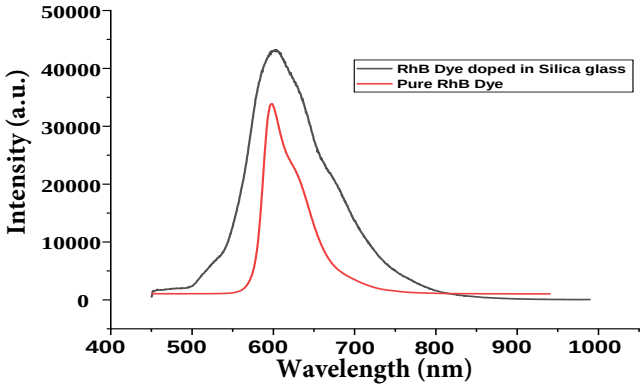


Fig. 3. Emission spectra of Pure RhB dye and RhB dye in Silica glass.

Therefore, we can use one of the excitation wavelength for further investigation. In figure 3, we plot the intensity versus wavelength of pure RhB dye and dye doped in silica glass which, shows that the shifting of peak from UV towards Visible side. This also suggest that the frequency shifting of RhB dye doped in silica glass is around 70.75 peta Hz. Full width half maxima (FWHM) is describing the transmission characteristics of an optical band-pass filter, describing the width of the spectrum at the wavelengths that the filter passes, in nanometres. From table 2, shows that the FWHM increases when RhB dye doped in silica glass.

CONCLUSION

To conclude, the absorption and emission spectra for RhB dye and RhB dye doped in silica glass have been investigated. Sol-gel technique has been employed to prepare RhB dye doped in silica glass. The absorption edge for pure RhB dye was 607.77 nm and the doped RhB dye was 592.32 nm. The optical band gap for pure RhB was 2.04 eV and doped RhB dye was 2.09 eV. The frequency shifting was around 70.75 peta Hz. These results offer a promising efficient solid-state dye laser action, which could replace liquid-dye laser systems in certain applications.

REFERENCES

[1] B. Dunn and J. I. Zink, "Probes of pore environment and molecule-matrix interactions in sol-gel materials," *Chemistry of Materials*, vol. 9, no. 11, 1997. DOI: 10 . 1021 / cm970270p.

[2] N. Negishi, M. Fujino, H. Yamashita, M. A. Fox, and M. Anpo, "Photophysical properties and photochemical stability of rhodamine B encapsulated in SiO_2 and Si-Ti binary oxide matrixes by the sol-gel method," *Langmuir*, vol. 10, no. 6, 1994. DOI: 10.1021/la00018a025.

[3] A. Fanai, U. Khan, and S. Rai, "Luminescence enhancement of Pr^{3+} doped sol-gel silica glass as a result of Al^{3+} co-doping," *Journal of Non-Crystalline Solids*, vol. 503-504, 2019. DOI: 10.1016/j.jnoncrysol.2018.09.027.

[4] S. Rai and A. L. Fanai, "Spectroscopic studies of Ho^{3+} doped $SiO_2 - TiO_2$ nanoparticle for photonic applications," *Sci. Vis*, vol. 14, no. 3, 2014.

[5] X. Fan, M. Wang, and G. Xiong, "Spectroscopic studies of rare earth ions in silica glasses prepared by the sol-gel process," *Materials Letters*, vol. 27, no. 4, 1996. DOI: 10.1016/0167-577x(95)00279-0.

[6] S. Hazarika and S. Rai, "Structural, optical and non-linear investigation of Eu^{3+} ions in sol–gel silicate glass," *Optical Materials*, vol. 27, no. 2, 2004. DOI: 10.1016/j.optmat.2004.02.025.

[7] G. M. Ziarani, R. Moradi, N. Lashgari, and H. G. Kruger, *Metal-free synthetic organic dyes*. Amsterdam, Natherlands: Elsevier, 2018.

[8] H. A. S. Al-Shamiri, Y. A. Badr, and M. T. H. A. Kana, "Optical, photo-physical properties and photostability of laser dyes impregnated in sol-gel matrix," 2011. DOI: 10.1109/siecpc.2011.5876987.

[9] H. A. S. Al-Shamiri and M. T. H. Abou Kana, "Laser performance and photostability of rhodamin B in solid host matrices," *Applied Physics B*, vol. 101, no. 1-2, 2010. DOI: 10.1007/s00340-010-4192-6.

[10] Y. Takahashi, T. Kitamura, M. Nogami, K. Uchida, and T. Yamanaka, "Luminescence of rhodamine dyes doped in amorphous silica glasses," *Journal of Luminescence*, vol. 60-61, 1994. DOI: 10 . 1016 / 0022 - 2313(94) 90189-9.

[11] G. A. Kumar and N. V. Unnikrishnan, "Energy transfer and optical gain studies of FDS: Rh B dye mixture investigated under cw laser excitation," *Journal of Photochemistry and Photobiology A: Chemistry*, vol. 144, no. 2-3, 2001. DOI: 10.1016/s1010-6030(01)00533-0.

[12] T. Fujii, H. Nishikiori, and T. Tamura, "Absorption spectra of rhodamine B dimers in dip-coated thin films prepared by the sol-gel method," *Chemical Physics Letters*, vol. 233, no. 4, 1995. DOI: https://doi.org/10.1016/0009-2614(94)01477-D.

[13] Y. Klichko, M. Liong, E. Choi, S. Angelos, A. E. Nel, J. F. Stoddart, F. Tamanoi, and J. I. Zink, "Mesostructured silica for optical functionality, nanomachines, and drug delivery," *Journal of the American Ceramic Society*, vol. 92, 2009. DOI: 10.1111/j.1551-2916.2008.02722.x.

[14] H. Tian, Y. Tang, and K. Chen, "Bichromophoric rhodamine dyes and their fluorescence properties," *Dyes and Pigments*, vol. 26, no. 3, 1994. DOI: 10 . 1016 / 0143 - 7208(94)80032-4.

[15] T. Nguyena and A. R. Hind, "The measurement of absorption edge and band gap properties of novel nanocomposite materials," *Varian Cary*, vol. 500, 2014.

RESEARCH ARTICLE

Solution of non-Newtonian Boundary Layer Flow in a Convergent Channel using Homotopy Perturbation Method

Kamal Debnath* and Bikash Koli Saha

Department of Mathematics, The Assam Royal Global University, Guwahati, Assam, India

**E-mail:* debnathtura@gmail.com

ABSTRACT

The two-dimensional boundary layer flow through a convergent channel of a non-Newtonian electrically conducting fluid characterized by Walters Liquid (Model B') in presence of transverse magnetic field has been investigated analytically using Homotopy perturbation method. Similarity solutions of the problem are obtained considering a special form of magnetic field. The velocity expression and skin friction coefficient at the wall have been attained and numerically worked out for different values of the flow parameters involved in the solution. The velocity and the skin friction coefficient have been presented graphically to observe the non-Newtonian effects for various values of the magnetic parameter across the boundary layer.

Keywords: Homotopy perturbation method, Hydromagnetic, Non-Newtonian fluid, Similarity solution, Skin-friction

INTRODUCTION

The study of hydromagnetic electrically conducting non-Newtonian fluid flow through a convergent channel possesses not only a theoretical appeal but also model of many biological and engineering problems such as plasma studies, industrial metal casting, nuclear reactors, blood flow problems, etc. The theory of such flow has many applications in aerospace, chemical, civil, environmental, mechanical and bio-mechanical engineering.

Jeffry [1] and Hemel [2] have carried out the mathematical formulations of incompressible viscous fluid flow through convergent or, divergent channel in 1915 and 1916, respectively. Srivastava [3] has extended Jeffery's work to an electrically conducting fluid in presence of transverse magnetic field. The numerical calculations of Jeffery-Hamel flows between non-parallel plane walls were performed by Millsaps and Pohlhausen [4]. The solution of two-dimensional incompressible laminar flow in a converging channel with impermeable wall has been presented by Rosenhead [5]. The slow laminar flow in a converging or diverging channel with suction at one wall and blowing at the other wall has been analyzed by Terril [6]. The two-dimensional laminar boundary layer flow of an incompressible, viscous, non-uniform stream past solid obstacles has been analysed first by Falkner and Skan [7]. Phukan [8] has investigated the convergent channel flow of a Newtonian electrically conducting fluid. Hydromagnetic laminar flow of a viscous fluid in a converging or diverging channel with suction at one wall and equal blowing at the other wall has been investigated by Mahapatra et al. [9]. The two-dimensional laminar MHD boundary layer flow past a wedge with slip velocity has been studied by Sanyal and Adhikari [10]. Alam

and Khan [11] has carried out the critical analysis of the MHD flow in convergent-divergent channels. Choudhury and Dey [12] has investigated the hydromagnetic convergent channel flow of a visco-elastic electrically conducting fluid with slip velocity. Hydromagnetic flow of an incompressible viscous fluid through convergent or divergent channel in presence of a high magnetic field has been investigated by Hosseini et al. [13]. The hydromagnetic effects on mixed convection flow through a diverging channel with circular obstacle has been investigated by Alam and Khan [14]. Khan et al. [15] and Hafeez et al. [16] studied the Jeffery-Hamel flow of second grade fluid and nanofluids through convergent and divergent channel respectively. The preliminary work in Homotopy perturbation method (HPM) was studied by He [17–19] and after that these investigations inspired a lot of researchers Ariel et al. [20], Belendez et al. [21], Ganji and Rajabi [22], Ganji and Siddiqui et al. [23] and many others to solve nonlinear equations with this method.

The aim of the present work is to investigate the two-dimensional boundary layer flow of non-Newtonian electrically conducting fluid through a convergent channel characterized by Walters liquid (Model B') [24, 25] in presence of transverse magnetic field using Homotopy Perturbation method. The non-Newtonian effects across the boundary layer on the dimensionless velocity component and skin friction coefficient have been shown graphically with the combination of magnetic and other flow parameters involved in the solution.

MATHEMATICAL FORMULATION

The basic equations for steady two-dimensional boundary layer flow of Walters liquid (Model B') in the presence of transverse magnetic field $B(x)$ are given by

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}=U\frac{\partial U}{\partial x}+v\frac{\partial^2 u}{\partial y^2}-\frac{k_0}{\rho}\left[u\frac{\partial^3 u}{\partial x\,\partial y^2}+v\frac{\partial^3 y}{\partial y^3}-\frac{\partial u}{\partial y}\frac{\partial^2 u}{\partial x\partial y}-\frac{\partial v}{\partial y}\frac{\partial^2 u}{\partial y^2}\right]+\sigma B^2(x)\frac{(U-u)}{\rho} \tag{2}$$

subject to the boundary conditions

$$\begin{aligned} y=\ 0\ :&\quad u=0,\ v=0\\ y\to\infty\ :&\quad u=U(x)\end{aligned}$$

where x-axis coincides with the wall of the convergent channel and y-axis is perpendicular to it. $U(x)$ is the main stream velocity, u and v are the flow velocities in the direction of x and y respectively, ρ is the fluid density, is the kinematic viscosity, σ is the electrical conductivity of the fluid and k_0 is the visco-elastic parameter.

It is assumed that the induced magnetic field is negligible compared to imposed one, the electric field is zero and the electric field due to polarization of charges is also negligible. The velocity of the potential flow along the wall of a convergent channel is given by Schlichting [26] :

$$U(x)=-\frac{u_1}{x} \tag{3}$$

with $u_1>0$ represents two-dimensional motion in a convergent channel with wall (sink) and it leads to similarity solution.

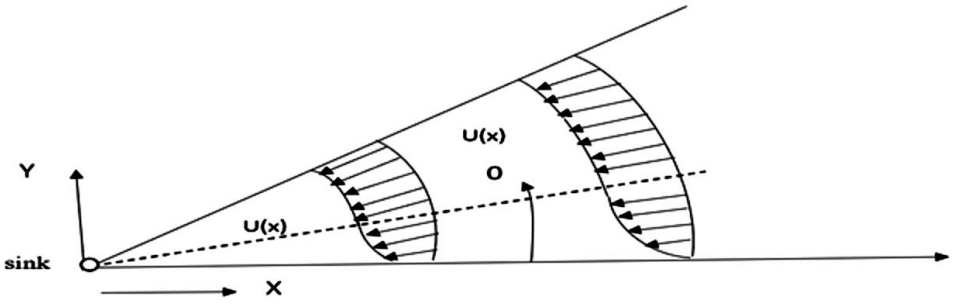


Fig. 1. Physical sketch of the flow in a convergent channel.

To obtain similarity solutions we introduce the following change of variables:

$$\eta(x,y) = y\sqrt{-\frac{U(x)}{xv}} = y\sqrt{\frac{u_1}{x^2 v}} = \frac{y}{x}\sqrt{\frac{u_1}{v}} \quad (4)$$

and the stream function

$$\psi(x,y) = -\sqrt{vu_1}\, F(\eta) \quad (5)$$

Then, we obtain the velocity components as

$$u = \frac{\partial \psi}{\partial x} = U(x)F'(\eta) \quad (6)$$

$$v = -\frac{\partial \psi}{\partial x} = -\frac{\eta}{x}\sqrt{u_1 v}\, F'(\eta) \quad (7)$$

The equation of continuity (1) is identically satisfied for the velocity components. Similarity solution exists if the magnetic field $B(x)$ has the special form Chiam [27]

$$B(x) = \frac{B_0}{x} \quad (8)$$

Using the equations (3) to (8), the equation (2) takes the form as follows:

$$\begin{aligned} F''' - F'^2 - k_1\left[4F'F''' - 2F''^2\right] \\ +M(1-F') + 1 = 0 \end{aligned} \quad (9)$$

where prime indicated the differentiation with respect to η. k_1 and M denote the modified non-Newtonian parameter and magnetic parameter respectively.

The corresponding boundary conditions are

$$F'(0) = 0,\ F'(\infty) = 1 \quad \& \ F''(\infty) = 0 \quad (10)$$

METHOD OF SOLUTION

To get the self-similar form of the governing equation, we consider

$$z = \sqrt{M}\,\eta \quad \& \quad f(z) = \sqrt{M}\, F(\eta) \quad (11)$$

Then,

$$\begin{aligned} f'(z) = F'(\eta),\ f''(z) = \frac{1}{\sqrt{M}}F''(\eta), \\ f'''(z) = \frac{1}{M}F'''(\eta) \end{aligned} \quad (12)$$

Using the equations (12) in the equation (9), we get the following differential equation

$$\begin{aligned} f''' - k_1\left[4f'f''' - 2f''^2\right] + (1-f') \\ = \varepsilon\left(f'^2 - 1\right) \end{aligned} \quad (13)$$

The modified boundary conditions are

$$f'(0) = 0,\ f'(\infty) = 1 \quad \& \ f''(\infty) = 0 \quad (14)$$

Using Homotopy perturbation method, equation (13) is constructed as follows:

$$\begin{aligned} (1-p)(f''' - f') + p\left[(f''' - f')\right. \\ \left. -k_1\left(4f'f''' - 2f''^2\right) - \varepsilon f'^2 + \lambda\right] \end{aligned} \quad (15)$$

where $p \in [0,1]$ is the impeding parameter and $\lambda = 1 + \varepsilon$.

We consider $f = f_0 + pf_1 + p^2 f_2 + \cdots$, and thus equation (15) becomes,

$$\begin{aligned} (1-p)\left[\left(f_0''' + pf_1''' + p^2 f_2''' + \cdots\right)\right. \\ \left. -\left(f_0' + pf_1' + p^2 f_2' + \cdots\right)\right] \\ +p\left[\left(f_0''' + pf_1''' + p^2 f_2''' + \cdots\right)\right. \\ \left. -\left(f_0' + pf_1' + p^2 f_2' + \cdots\right)\right] \\ -k_1\left\{4\left(f_0' + pf_1' + p^2 f_2' + \cdots\right)\right. \\ \left(f_0''' + pf_1''' + p^2 f_2''' + \cdots\right) \\ \left. -2\left(f_0'' + pf_1'' + p^2 f_2'' + \cdots\right)^2\right\} \\ \left. -\varepsilon\left(f_0' + pf_1' + p^2 f_2' + \cdots\right)^2 + \lambda\right] = 0 \end{aligned} \quad (16)$$

Terms independent of p gives,

$$f_0''' - f_0' = 0 \quad (17)$$

The boundary conditions are,

$$f_0'(0) = 0,\ \ f_0'(\infty) = 1,\ \ f_0''(\infty) = 0 \quad (18)$$

Term containing only p gives,

$$f_1''' - f_1' - 4k_1 f_0' f_0''' - 2f_0'' - \varepsilon f_0'^2 + \lambda = 0 \quad (19)$$

The boundary conditions are,

$$f_1'(0) = 0,\ \ f_1'(\infty) = 1,\ \ f_1''(\infty) = 0 \quad (20)$$

Terms containing only p^2 gives,

$$\begin{aligned} f_2''' - f_2' - 4k_1(f_0' f_1''' + f_1' f_0''') - 4f_0'' f_1'' \\ -2\varepsilon f_0' f_1' = 0 \end{aligned} \quad (21)$$

The boundary conditions are,

$$f_2'(0) = 0, \quad f_2'(\infty) = 1, \quad f_2''(\infty) = 0 \tag{22}$$

Terms containing only p^3 gives,

$$\begin{aligned} f_3''' - f_3' - 4k_1(f_0'f_2''' + f_1'f_1''' + f_2'f_0''') \\ -2\left(f_0''^2 + 2f_2''f_0''\right) \\ -\varepsilon\left(f_1'^2 + 2f_2'f_0'\right) = 0 \end{aligned} \tag{23}$$

The boundary conditions are,

$$f_3'(0) = 0, \quad f_3'(\infty) = 1, \quad f_3''(\infty) = 0 \tag{24}$$

Solving equations (17), (19), (21) and (23) with the help of boundary condition, we get (18), (20), (22) and (24)

$$\begin{aligned} f(z) = \lambda\left(z + e^{-z} - 1\right) + p^3\left(D + Ee^{-z}\right. \\ \left. + Fe^{-2z} + Gze^{-z} + Hz\right) \cdots \end{aligned} \tag{25}$$

Differentiating equation with respect to z, we obtain

$$\begin{aligned} f'(z) = \lambda\left(1 - e^{-z}\right) + p^3\left(-Ee^{-z}\right. \\ \left. -2Fe^{-2z} + G\left(e^{-z} - ze^{-z}\right) + H\right) \cdots \end{aligned} \tag{26}$$

From equation (26) we can easily find the dimensionless velocity $F'(\eta)$ across the boundary layer. The constants of the solution of the differential equations are not presented here for the sake of brevity.

RESULT AND DISCUSSION

The skin friction coefficient at the wall of the convergent channel is given by

$$\tau = f''(0) - k_1\left(\frac{3}{v}\right)f'(0)f_1''(0) \tag{27}$$

where,

$$\begin{aligned} f'(0) &= -p^3(E + 2F - G - H) \\ f''(0) &= \lambda + p^3(E + 4F - 2G) \end{aligned} \tag{28}$$

The effects of visco-elastic parameter on the two-dimensional laminar MHD boundary layer flow through a convergent channel is discussed analytically in this study. The solution of this problem is obtained analytically using Homotopy perturbation method. The numerical computations for the velocity and skin friction at the wall have been carried out for various values of flow parameters using Matlab software. The non-Newtonian effect is exhibited through the non-dimensional parameter k_1. All the corresponding results for Newtonian fluid are obtained by setting $k_1 = 0$.

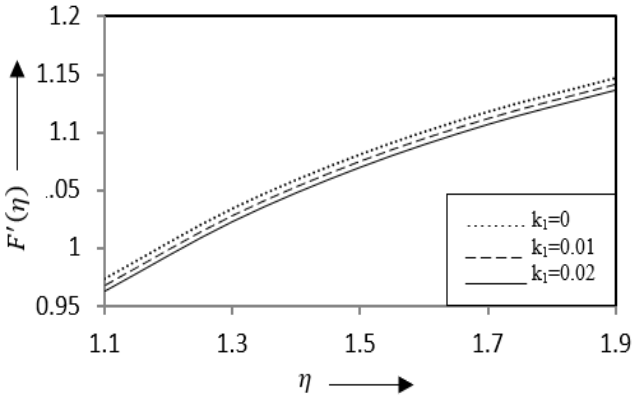


Fig. 2. Velocity distribution against η for $M = 8$.

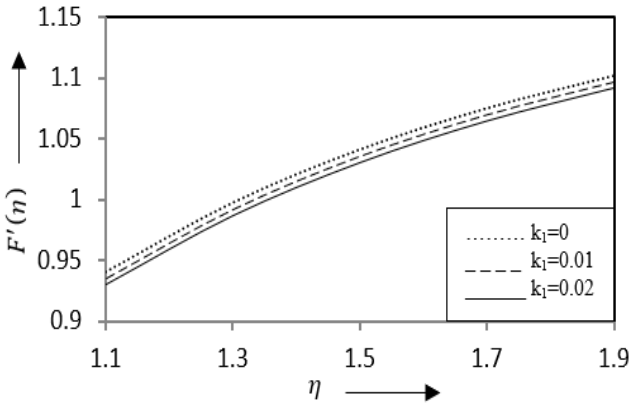


Fig. 3. Velocity distribution against η for $M = 10$.

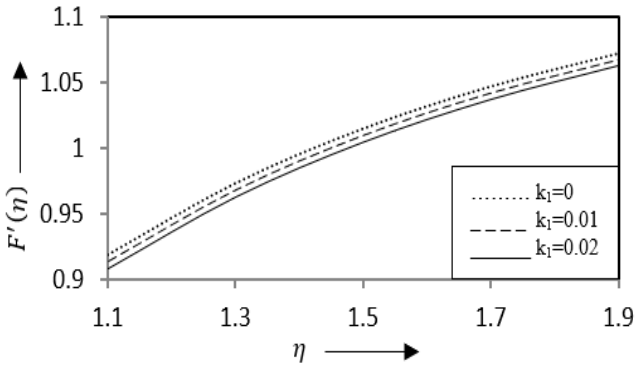


Fig. 4. Velocity distribution against η for $M = 12$.

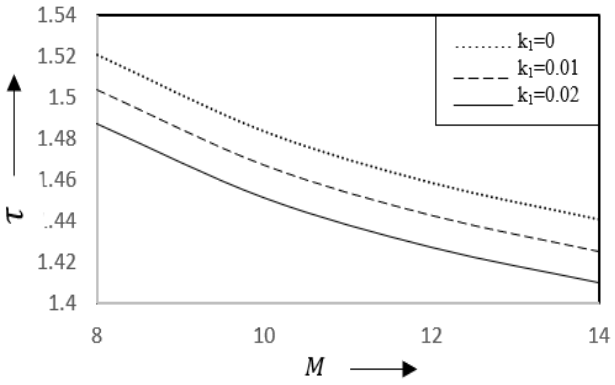


Fig. 5. Skin friction coefficient for different values of k_1.

Figures 2 to 4 depict the variations of dimensionless velocity $F'(\eta)$ against the variable η across the boundary layer for different values of visco-elastic and magnetic parameters. It has been observed that the velocity increases in both Newtonian and non-Newtonian cases with increasing values of η. It indicates that the thickness of boundary layer, developed near the convergent channel decreases with the parameter η. But the velocity diminishes with the increasing values of the visco-elastic parameter in comparison with the Newtonian fluid for some fixed values of magnetic parameter. Further, it is noticed from the figures 2 to 4 that $F'(\eta)$ decreases with the increasing values of magnetic parameter. It shows that the boundary layer thickness enhances with the growth of magnetic parameter.

Figure 5 reveals the dimensionless shearing stress at the wall of the convergent channel against the magnetic parameter M for various values of visco-elastic and other flow parameters. It demonstrates that the shearing stress reduces with the increasing values of visco-elastic parameter in both Newtonian and non-Newtonian cases. It is also observed that the shearing stress initially increases with magnetic parameter M, but ultimately it diminishes with the increasing values of M. This is compatible with the fact that the growth of magnetic parameter, the boundary layer thickness decreases.

CONCLUSION

In this paper, the homotopy perturbation method is implemented to find the solution of highly nonlinear differential equations. This method has advantage over the regular perturbation method as noticed from the above mentioned reference papers. It is observed that the flow field is highly affected by the visco-elastic and magnetic parameter. The study reveals that the boundary layer flow is possible for the case of non-Newtonian fluid characterized by Walters Liquid (Model B'). Numerical methods can also be employed to find the solution of the same problem to compare the results obtained by analytical method. A future study investigating the flow simulation of the problem would be very interesting. So, in future the work can be extended in many ways.

REFERENCES

[1] G. B. Jeffery, "The two-dimensional steady motion of a viscous fluid," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, vol. 29, no. 172, 1915. DOI: 10.1080/14786440408635327.

[2] G. Hamel, "Spiralförmige bewegung zher fissigkeiten jahresber," 1916.

[3] *The effects of magnetic field on the flow between two non-parallel planes*, Proc. Fifth Cong. Theo. and Appl. Mech, 1959.

[4] K. Millsaps and K. Pohlhausen, "Thermal distributions in Jeffery-Hamel flows between nonparallel plane walls," *Journal of the Aeronautical Sciences*, vol. 20, no. 3, 1953. DOI: 10.2514/8.2587.

[5] L. Rosenhead, *Laminar boundary layers*. Oxford University Press, 1963.

[6] R. M. Terrill, "Slow laminar flow in a converging or diverging channel with suction at one wall and blowing at the other wall," *Zeitschrift für angewandte Mathematik und Physik ZAMP*, vol. 16, no. 2, 1965. DOI: 10.1007/bf01587656.

[7] V. M. Falkneb and S. W. Skan, "Solutions of the boundary-layer equations," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, vol. 12, no. 80, 1931. DOI: 10.1080/14786443109461870.

[8] D. K. Phukan, "Hydromagnetic divergent channel flow of a Newtonian electrically conducting fluid," *The Bulletin, GUMA*,, vol. 4, 1998.

[9] T. R. Mahapatra, S. A. Dholey, and S. Gupta, "Magnetohydrodynamic laminar flow of a viscous fluid in a converging or diverging channel with suction at one wall and equal blowing at the other wall.," *The Bulletin, GUMA*, vol. 11, 2010.

[10] D. C. Sanyal, B. Kalita, and A. Adhikari, "Two dimensional laminar MHD boundary layer flow past a wedge with slip velocity," *Journal of Indian Acad. Math.*, vol. 28, no. 2, 2006.

[11] M. S. Alam and M. A. H. Khan, "Critical behaviour of the MHD flow in convergent-divergent channels," *Journal of Naval Architecture and Marine Engineering*, vol. 7, no. 2, 2011. DOI: 10.3329/jname.v7i2.5635.

[12] R. Choudhury and D. Dey, "Hydromagnetic convergent channel flow of a visco-elastic electrically conducting fluid with slip velocity.," *Int. J. of Math. Sci. & Engg. Appls.*, vol. 5, no. II, 2011.

[13] R. Hosseini, S. Poozesh, and S. Dinarvand, "MHD flow of an incompressible viscous fluid through convergent or divergent channels in presence of a high magnetic field," *Journal of Applied Mathematics*, vol. 2012, 2012. DOI: 10.1155/2012/157067.

[14] M. S. Alam and M. A. H. Khan, "MHD effects on mixed convection flow through a diverging channel with circular obstacle," *Procedia Engineering*, vol. 90, 2014. DOI: 10.1016/j.proeng.2014.11.869.

[15] U. Khan, Adnan, N. Ahmed, and S. T. Mohyud-Din, "Soret and Dufour effects on Jeffery-Hamel flow of second-grade fluid between convergent/divergent channel with stretchable walls," *Results in Physics*, vol. 7, 2017. DOI: 10.1016/j.rinp.2016.12.020.

[16] M. Hafeez, Hashim, and M. Khan, "Jeffery-Hamel flow of hybrid nanofluids in convergent and divergent channels with heat transfer characteristics," *Applied Nanoscience*, vol. 10, no. 12, 2020. DOI: 10.1007/s13204-020-01427-6.

[17] J.-H. He, "An elementary introduction to the homotopy perturbation method," *Computers & Mathematics with Applications*, vol. 57, no. 3, 2009. DOI: 10.1016/j.camwa.2008.06.003.

[18] J.-H. He, "Approximate analytical solution for seepage flow with fractional derivatives in porous media," *Computer Methods in Applied Mechanics and Engineering*, vol. 167, no. 1-2, 1998. DOI: 10.1016/s0045-7825(98)00108-x.

[19] J.-H. He, "A review on some new recently developed nonlinear analytical techniques," *International Journal of Nonlinear Sciences and Numerical Simulation*, vol. 1, no. 1, 2000. DOI: 10.1515/IJNSNS.2000.1.1.51.

[20] P. D. Ariel, T. Hayat, and S. Asghar, "Homotopy perturbation method and axisymmetric flow over a stretching sheet," *International Journal of Nonlinear Sciences and Numerical Simulation*, vol. 7, no. 4, 2006. DOI: 10.1515/ijnsns.2006.7.4.399.

[21] A. Beléndez, T. Beléndez, A. Márquez, and C. Neipp, "Application of He's homotopy perturbation method to conservative truly nonlinear oscillators," *Chaos, Solitons & Fractals*, vol. 37, no. 3, 2008. DOI: 10.1016/j.chaos.2006.09.070.

[22] D. D. Ganji and A. Rajabi, "Assessment of homotopy–perturbation and perturbation methods in heat radiation equations," *International Communications in Heat and Mass Transfer*, vol. 33, no. 3, 2006. DOI: 10.1016/j.icheatmasstransfer.2005.11.001.

[23] A. Siddiqui, A. Zeb, Q. Ghori, and A. Benharbit, "Homotopy perturbation method for heat transfer flow of a third grade fluid between parallel plates," *Chaos, Solitons & Fractals*, vol. 36, no. 1, 2008. DOI: 10.1016/j.chaos.2006.06.037.

[24] K. Walters, "The motion of an elastico-viscous liquid contained between coaxial cylinders (II)," *The Quarterly Journal of Mechanics and Applied Mathematics*, vol. 13, no. 4, 1960. DOI: 10.1093/qjmam/13.4.444.

[25] K. Walters, "The solution of flow problems in the case of materials with memory," *J. Mecanique*, vol. 1, no. 4, 1962.

[26] H. Schlichting, *Boundary layer theory*, 6th ed. McGraw-Hill, New York., 1968.

[27] T. C. Chiam, "Hydromagnetic flow over a surface stretching with a power-law velocity," *International Journal of Engineering Science*, vol. 33, no. 3, 1995. DOI: 10.1016/0020-7225(94)00066-s.

RESEARCH ARTICLE

Measurement of radium content in soil samples and commonly used building materials of Jowai city, Meghalaya

A. Khardewsaw*[1], A. Pyngrope[1], A. Saxena[1], A. Vishwa[2], D. Walia[2], and D. Maibam[3]

[1]*Department of Physics, North-Eastern Hill University, Shillong, Meghalaya, India*

[2]*Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, India*

[3]*Don Bosco College of Teacher Education, Tura, Meghalaya, India*

**E-mail:* alfa.kds@gmail.com

ABSTRACT

Human exposure to natural radiation in the indoor environment are mainly because of the radiation that originates from the soil and building materials. In this paper, we are reporting the measured concentration of radium in soil samples collected from various location of Jowai city and in the building materials commonly used for construction purposes. The radium content in soil varies from 44.7 $Bq.kg^{-1}$ to 156.2 $Bq.kg^{-1}$ and in building materials from 1.4±0.1 to 151±5.3 $Bq.kg^{-1}$.

Keywords: Radium, radon exhalation, alpha index

INTRODUCTION

One of the most important sources of natural background radioactivity is soil as it contains the precursors to most naturally-occurring radioactive isotopes. Radium occurs naturally in the environment. As a decay product of uranium and thorium, it is common in virtually all rock soil and water. Radium and its salts are soluble in water, as a result, groundwater in areas where concentrations of radium are high in surrounding bedrock, typically has relatively high radium content. Radium can be absorbed from the soil by plants and then ultimately reach the human body through the food chain. Microscopic quantities of radium in the environment can lead to some accumulation of radium in bone tissue whereby it can be detrimental to health effect [1–5].

Although building materials play an important role in shielding the inhabitants against nature's vagaries, but they are also a source of radiation to the inhabitants; this is because building materials used for the construction of houses and building originate from rocks and earth's crust and contain radium in varying amounts. Exhalation of alpha-radioactive radon inert gas from soil and building material is associated with the presence of radium atoms in the earth crust [6, 7].

The greatest health risk to humanity that has been associated with radium actually comes from the exposure to radiation arising from the decay of radon gas (its daughter nuclei). It is common in many soils and can accumulate in homes and buildings [3]. In this paper, we report the radium activity concentration measured in the densely populated Jowai city located in West Jaintia Hills district of Meghalaya.

As of the 2011 India census, Jowai has a population of about 28,430 people [8]. The general geolog-

ical formation of the district is characterized by the presence of rocks belonging to the age group of achaean and tertiary. The plateau is composed of granites, phyllite, genesis, sandstone and limestone. This is identical with the other parts of Meghalaya plateau. Coal mining is also one of the major activities in the district [9].

Table 1. Location of the sampling sites.

Sample code	Latitude (N)	Longitude (E)
S-1	25° 27′ 38.77″	92° 12′ 59.56″
S-2	25° 28′ 00.37″	92° 13′ 24.30″
S-3	25° 26′ 22.28″	92° 12′ 19.53″
S-4	25° 27′ 27.5″	92° 12′ 22.2″
S-5	25° 27′ 19.9″	92° 12′ 10.8″
S-6	25° 45′ 74.1″	92° 12′ 10.8″
S-7	25° 27′ 07.6″	92° 12′ 13.0″
S-8	25° 27′ 06.2″	92° 12′ 14.0″
S-9	25° 26′ 57.8″	92° 11′ 56.8″
S-10	25° 44′ 64.7″	92° 19′ 85.6″
S-11	25° 26′ 45.5″	92° 11′ 54.4″
S-12	25° 26′ 02.1″	92° 11′ 52.4″
S-13	25° 26′ 08.1″	92° 11′ 40.5″
S-14	25° 26′ 47.64″	92° 11′ 52.27″

EXPERIMENTAL TECHNIQUE

The "Can Technique" [10] has been used for the measurement of radium content and radon exhalation rates in 14 soil samples collected from different location of Jowai area respectively. The soil samples from different location were dried, finely powdered and sieved through a 90-micron mesh sieve. The finely powdered soil sample (100g) from each location was placed and sealed in different bottles for 30 days to attain secular equilibrium. After 30 days, LR-115 type2 plastic track detectors were fixed inside the lid of these glass bottles (acting as emanation chambers) and sealed again and left as such for 90 days. After the exposure period, the films are retrieved from the emanation chamber and etched in 2.5 N NaOH solution at 60°C for 90 minutes using a constant-temperature water bath. The resulting alpha tracks on the exposed face of the track detector are counted using an optical microscope at a magnification of 150X.

The values of exhalation rates are then determined using the relation,

$$\mathrm{E_M} = \frac{CV\lambda}{M\left[T + \frac{(e^{-\lambda T}-1)}{\lambda}\right]} \quad (1)$$

$$\mathrm{E_A} = \frac{CV\lambda}{A\left[T + \frac{(e^{-\lambda T}-1)}{\lambda}\right]} \quad (2)$$

where, $\mathrm{E_M}$ and $\mathrm{E_A}$ are the radon exhalation rate in terms of mass (Bq.kg^{-1}.h^{-1}) and area (Bq.m^{-2}.h^{-1}), C is the integrated radon concentration (Bq.m^{-3}.h^{-1}), V is the effective volume of the can (m^3), λ is the decay constant for radon (h^{-1}), t is the exposure time (h), M is the mass of the soil sample and A is the area of cross-section of the bottle (5.9×10^{-2} m^2).

The radium concentration in soil samples is computed using the relation,

$$\mathrm{C_{Ra}} = \frac{\rho h A}{\mathrm{KT_eM}} \quad (3)$$

where $\mathrm{C_{Ra}}$ is the effective radium content of the soil sample (Bq.kg^{-1}), h is the distance between the detector and the top of the soil sample (m) and $\mathrm{T_e}$ is the effective exposure time (day), ρ is the background corrected track density (tracks.cm^{-2}) and K is the sensitivity factor (0.0245 tracks.cm^{-2}d^{-1} (Bq.m^{-3})$^{-1}$ [11]).

RESULTS AND DISCUSSION

The values of radium content, exhalation rates in terms of mass and area, and alpha index measured of soil samples collected from different locations of Jowai, Meghalaya are given in Table 2. It is evident from the table that the radium content in soil varies from 27.29±1.4 Bq.kg^{-1} to 163.35±3.5 Bq.kg^{-1} with average being 70.4 Bq.kg^{-1}. The alpha index value has also been calculated and the values are found to range from 0.1 to 0.8. Figure 1 shows a graphical representation of the measured radium content.

From table 1, we can see that the maximum (163.3±3.5 Bq.kg^{-1}), minimum (27.3±1.4 Bq.kg^{-1}) and the average value (70.4 Bq.kg^{-1}) of the radium content measured are all well below the permissible value of 370 Bq.kg^{-1} as given by OECD (OECD report, 1979) [12]. From the range of the alpha index value, we can see that the values are well within the recommended value of 1 [12].

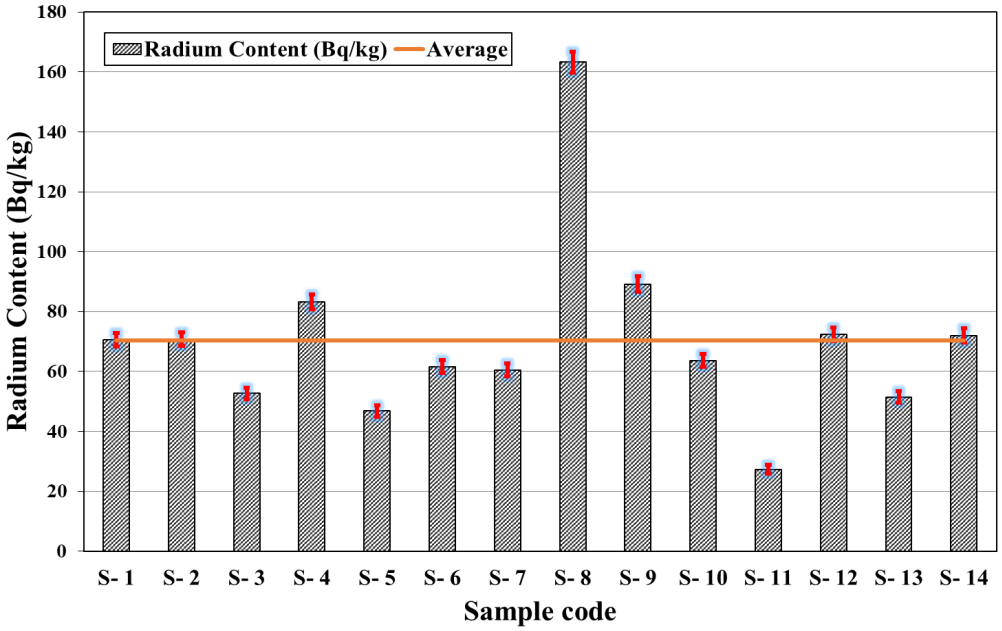


Fig. 1. Bar graph representation of radium content measured in the 14-soil sample with the average value.

Some of the most commonly used building materials such as Bricks, Cement, Rocks and Sand were collected from various shop and supplier. Table 3 show the estimated radium content, radon exhalation rates (in terms of mass and area) and alpha index value measured from bricks, cement, rocks and sand samples. The radium content value is found to range from 7.1±0.7 to 41.4±1.7 Bq.kg^{-1} in bricks samples with an average value of 19.3±1.1 Bq.kg^{-1}, 7.4±0.74 to 10±0.8 Bq.kg^{-1} in cement

Table 2. Measured data of radium content, Exhalation rates (in term of mass and area) and estimated alpha index value.

Sample code	Radium content in Bq.kg^{-1}	Exhalation rate (Area) Bq.m^{-2} h^{-1}	Exhalation rate (mass) Bq.kg^{-1} h^{-1}	Alpha index
S-1	70.56 ± 2.3	11.2	0.6	0.3
S-2	70.84 ± 2.3	11.5	0.7	0.3
S-3	52.65 ± 2	8.5	0.5	0.2
S-4	83.13 ± 2.5	13.2	0.8	0.4
S-5	46.77 ± 1.8	7.4	0.4	0.2
S-6	61.65 ± 2.1	9.9	0.6	0.3
S-7	60.52 ± 2.1	9.6	0.5	0.3
S-8	163.35 ± 3.5	26	1.5	0.8
S-9	89.17 ± 2.5	14.6	0.8	0.4
S-10	63.67 ± 2.1	10.4	0.6	0.3
S-11	27.29 ± 1.4	4.3	0.2	0.1
S-12	72.42 ± 2.3	11.5	0.7	0.3
S-13	51.45 ± 2	8.2	0.5	0.2
S-14	72.05 ± 2.3	11.4	0.7	0.3
Avg.	70.4	11.3	0.6	0.3

Table 3. Consolidated data of radium content, exhalation rates (in term of mass and area) and alpha index value measured from different building materials.

Brand/ Sample no.	Radium content $Bq.kg^{-1}$	Average	Exhalation rate (Area) $Bq.m^{-2}h^{-1}$	Exhalation rate (mass) $Bq.kg^{-1}h^{-1}$	Alpha index
B1	18.1±1.1	19.3±1.1	3.0	0.2	0.1
B2	7.8±0.7		1.3	0.1	0.04
B3	41.4±1.7		6.8	0.4	0.2
B4	22±1.2		3.6	0.2	0.1
B5	7.1±0.7		1.1	0.1	0.04
C1	9.3±0.8	8.8±0.8	1.5	0.1	0.05
C2	9.1±0.8		1.5	0.1	0.05
C3	10±0.8		1.6	0.1	0.05
C4	7.4±0.7		1.2	0.1	0.04
C5	8.3±0.7		1.3	0.1	0.04
R1	18.5±1.1	8.7±0.6	3.0	0.2	0.1
R2	14.3±1		1.3	0.1	0.1
R3	1.4±0.1		6.8	0.4	0.01
R4	4.3±0.4		3.6	0.2	0.02
R5	5.2±0.4		1.1	0.1	0.03
S1	151±5.3	48.3±2.0	3.0	0.2	0.1
S2	30.4±1.6		1.3	0.1	0.01
S3	6.4±0.5		6.8	0.4	0.4
S4	50.6±2.3		3.6	0.2	0.1
S5	3.3±0.3		1.1	0.1	0.01

samples with an average value of 8.8±0.8 $Bq.kg^{-1}$, 1.4±0.1 to 18.5±1.1 $Bq.kg^{-1}$ in rocks samples with an average value of 8.7±0.6 $Bq.kg^{-1}$ and 3.3±0.3 to 151±5.3 $Bq.kg^{-1}$ in sand samples with an average value of 48.3±2 $Bq.kg^{-1}$. The radon exhalation rate in terms of mass and area has also been calculated and their values are shown in Table 3.

The alpha index value has also been calculated and the value ranges from 0.04 to 0.2 in bricks sample with an average value of 0.10, 0.04 to 0.05 in cement sample with an average value of 0.04, 0.01 to 0.1 in rocks sample with an average value of 0.04 and 0.01 to 0.4 in the sand sample with an average value of 0.12.

Figure 2 shows the plot of the average radium content measured from bricks, cement, rocks, sand and also that from soil. From the graph, it can be seen that from among the building materials, the highest radium content is found in sand samples, while overall soil samples contain the highest amount of radium.

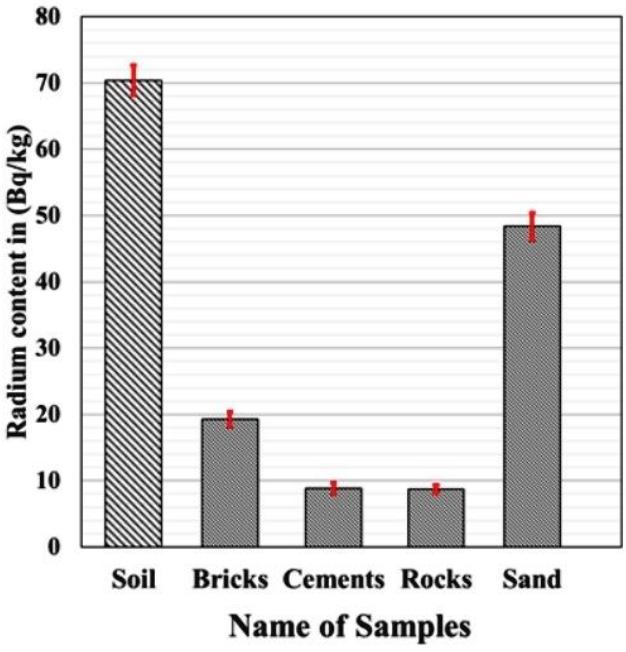


Fig. 2. Comparison plot of the average radium content measured from bricks, cement, rocks and sand.

CONCLUSION

It can be seen from the results that the radium content varies appreciably geographically as well as in different materials but still is found to be safely below the permissible value of 370 $Bq.kg^{-1}$ as recommended by Organization for Economic Co-operation and Development (OECD 1979). From the alpha index value obtained it can be concluded that the radium activity from any of the samples alone is unlikely to produce radon concentration exceeding 200 $Bq.m^{-3}$ inside the dwelling and may be considered safe for use in habitable building construction. The radium content in soil is found to be higher compared to that in building materials. This may be because ground (soil) is the main source of primordial radioactive elements thus having more radium content than the building materials which undergo certain preparation processes during manufacturing that might result in lowering the radium content in them and also it is noticeable that sand, being the closest in the form to soil, has radium content higher than other building materials.

REFERENCES

[1] W. W. Nazaroff and A. V. Nero, *Radon and its decay products in indoor air*, 1st, W. W. Nazaroff and A. V. Nero, Eds. New York: J. Wiley, 1988.

[2] S. A. Durrani and R. Ilic, *Radon Measurements by Etched Track Detectors - Applications in Radiation Protection, Earth Sciences*, 1st, S. A Durrani, Ed. World Scientific Pub Co Inc, 1997, 416 pp.

[3] M. Wilkening, *Radon in the environment*. Elsevier Science Pub. Co, 1990.

[4] W. W. Nazaroff, "Radon transport from soil to air," *Reviews of Geophysics*, vol. 30, no. 2, 1992. DOI: 10.1029/92rg00055.

[5] A. V. Nero and W. W. Nazaroff, "Characterising the source of radon indoors," *Radiation Protection Dosimetry*, vol. 7, no. 1-4, 1984. DOI: 10.1093/oxfordjournals.rpd.a082958.

[6] R. M. Amin, "A study of radon emitted from building materials using solid state nuclear track detectors," *Journal of Radiation Research and Applied Sciences*, vol. 8, no. 4, 2015. DOI: 10.1016/j.jrras.2015.06.001.

[7] P. Bala, V. Kumar, and R. Mehra, "Measurement of radon exhalation rate in various building materials and soil samples," *Journal of Earth System Science*, vol. 126, no. 2, 2017. DOI: 10.1007/s12040-017-0797-z.

[8] Office of the Registrar General & Census Commissioner, India, *Census of India report*, 2011.

[9] Government of Meghalaya, *Website of the West Jaintia Hills district*, https://westjaintiahills.gov.in/, 2020.

[10] F. A. Abu-Jarad, "Application of nuclear track detectors for radon related measurements," *International Journal of Radiation Applications and Instrumentation. Part*, vol. 15, no. 1-4, 1988. DOI: 10.1016/1359-0189(88)90195-1.

[11] A. Azam, A. H. Naqvi, and D. S. Srivastava, "Radium concentration and radon exhalation measurements using LR-115 type II plastic track detectors," *Nuclear Geophysics*, vol. 9, no. 6, 1995.

[12] NEA-OECD, *Exposure to radiation from the natural radioactivity in building materials. Report by an NEA group of experts*, 1979.

RESEARCH ARTICLE

Water scarcity in *Sohra* (Cherrapunjee): A paradox

Bhogtoram Mawroh

Research and Knowledge Management, NESFAS, Shillong

E-mail: bhogtoram.nesfas@gmail.com

ABSTRACT

Sohra (Cherrapunjee) the erstwhile region with the highest amount of rainfall and still among the heaviest rainfall receiving region in the world is beset with persistent domestic water shortage with households in the area getting drinking water only once in three days. This shortage can be attributed to both access issues (distance to the source, availability of storage facilities, socio-economic status, etc.) and geo-environmental conditions of the study area. The present paper tries to understand the role of the climatic factors, viz., rainfall and temperature in determining natural water availability in Sohra and find out the water resource potential in a qualitative manner. In terms of rainfall the study area is characterized by periods of surplus water availability (March to September) accompanied by period of intense water scarcity (November to February) as well. Apart from rainfall, temperature is also a very important element for the development of water resources in the study area. January is the coldest month and June is the hottest month. This variation in temperature plays a very important role in determining water resources development in the study area. In the present work potential *evapotranspiration* has been determined, using the Thornthwaite and Mather's method for calculating potential *evapotranspiration* to understand the water balance in the study area. The water balance is found very high, (>1000 mm) with the highest values during the peak monsoon months of June and July (>2000 mm). On the other hand, the lowest values occur during the lean season months, i.e., November, December and January. These months experience a deficit of more than –20 mm. These two periods thus can be consequently identified as water-surplus (monsoon and pre-monsoon season) and water-deficit (lean season) periods respectively.

Keywords: Water resource potential, evapotranspiration, water-surplus, water-deficit, water balance

INTRODUCTION

The position of *Sohra* (Cherrapunjee) as the area receiving the highest amount of rainfall may have been usurped by Mawsynram which is located 16 km to the west, but it is still among the heaviest rainfall receiving region in the world. During the period 1980-2012 Sohra received an average annual rainfall of 1140.24 cm. However, at the same time the people in the area suffer from severe shortages of domestic water (Dohling, 2003). In 2010, because of the drinking water crisis in Cherrapunjee, the Greater Sohra Water Supply Scheme at a cost of Rs. 4.13 crore with the aim of providing drinking water to about 25,000 families in Sohra was started. However, shortage of domestic water persists with households in the area getting drinking water only once in three days (PTI, 2010). A part of this shortage can be attributed to access issues (distance to the source, availability of storage facilities, socio-economic status, etc.) but a degree depends on natural water availability.

Natural water availability in any region de-

pends on geo-environmental factors that can be divided into two Categories, viz., climatic and non-climatic factors. It is the interaction between these two groups of factors that determine natural water availability. The present paper tries to understand the role of the geo-environmental conditions in determining natural water availability in Sohra and find out the water resource potential in a qualitative manner. In this paper the focus is on the climatic factors, viz., rainfall and temperature.

1 – Sub-tropical deciduous forest; 2 – sub tropical pine forest; 3 – scrub; 4 – grassland; 5 – cropland; 6 – rock outcrop; 7 – built up area; 8 – water.

Source: Prokop and Walanus, 2003

Fig. 1. Land use/land cover map of Cherrapunjee spur and surrounding areas (compiled by P. Prokop on the basis of satellite image IRS-ID).

STUDY AREA AND METHODOLOGY

The study area for this study is the Sohra/Cherrapunjee region, which is located along the southern slopes of the Meghalaya Plateau. The curious case of 'scarcity in the midst of plenty' was what attracted the choice of the study area. It includes the Cherrapunjee spur and the surrounding canyons and deep gorges merging with the alluvial plains which are part of the great Sylhet plain. Apart from rainfall there are other features that can be used for delimitation of this region, horizontally bedded sandstone formations, dissected plateau surfaces, deep gorges, thin soil, highly degraded landscape, etc. All of these in conjunction make up the Cherrapunjee region.

The study is based on secondary data, rainfall and temperature, which was extracted from the website of Cherrapunjee Holiday Resort which has more than 100 years of meteorological data. This data was analysed using SPPS V17. Parametric as well as non-parametric tests were conducted using the software to test the validity of the results. Final results were then collated and presented with explanation.

RESULTS AND DISCUSSION

Climatic factors

The climatic factors that are important for determining natural water availability are rainfall and temperature. Rainfall determines the amount of water an area gains while temperature determines water loss through the process of evaporation and transpiration known in conjunction as *evapotranspiration*. The surplus/deficit that occurs as a result of the operation of these two factors determines natural water availability of an area.

Rainfall

Rainfall over the Cherrapunjee Plateau is the highest in the world. Such a peculiar phenomenon has not gone unnoticed and much work has been done in the recent past in understanding the climatological, hydrological and geomorphological significance of such a phenomenon. Most of the authors (e.g., Kingdon-Ward, 1955) agree that orography is the main cause of the enormous rainfall at this station (Prokop & Walanus, 2003). The extreme wet conditions prevailing in the southern slopes of the Meghalaya Plateau (Cherrapunjee) are because of the orographic effects and wind-ward movements of the South West Monsoon (Singh & Syiemlieh, 2004). There are some however, who attribute the heavy rainfall in the area to factors other

Table 1. Annual rainfall and annual rate of change in Sohra/Cherrapunjee during 1970-2012.

Year	Annual rainfall (in mm)	Rate of change (%)	Year	Annual rainfall (in mm)	Rate of change (%)
1970	17200	0	**1991**	13506	16.45
1971	8469	-50.76	**1992**	8357	-38.13
1972	11656	37.63	**1993**	12801	53.19
1973	10910	-6.4	**1994**	11205	-12.47
1974	24555	125.07	**1995**	14210	26.82
1975	11961	-51.29	**1996**	12897	-9.24
1976	9019	-24.6	**1997**	8994	-30.26
1977	12110	34.26	**1998**	14537	61.64
1978	6950	-42.61	**1999**	12503	-13.99
1979	12095	74.02	**2000**	12262	-1.92
1980	9133	-24.49	**2001**	8972	-26.84
1981	9418	3.12	**2002**	12262	36.68
1982	10381	10.23	**2003**	10499	-14.38
1983	9764	-5.94	**2004**	14791	40.88
1984	16761	71.66	**2005**	9758	-34.03
1985	11816	-29.5	**2006**	8734	-10.49
1986	8140	-31.12	**2007**	12647	44.8
1987	13153	61.6	**2008**	11415	-9.74
1988	17930	36.32	**2009**	9070	-20.54
1989	13460	-24.93	**2010**	13472	48.54
1990	11598	-13.84	**2011**	8732	-35.18
			2012	13364	53.05

Source: Cherrapunjee.com

than just the orography (Dhar & Farooqui, 1973). For example, according to Tang et al., 1999 the heavy rainfall in Cherrapunjee is due to the strong heat source from the Daxiawan Hot Spot (DHS) (a special region with high ground temperature, low density, low magnetism, negative gravity abnormality, frequent earthquake and strong tectonics) in the Yarlung Zangbo River. With the heating of the Tibetan Plateau being very influential on the occurrence of monsoon in the South Asian region, it was observed that the moisture flux around Tibet Plateau is transported to the centre of heat low over

Table 2. Difference in the mean annual rainfall in Cherrapunjee during 1970-1980, 1981-1990, 1991-2000 and 2001-2012.

Period	Mean rainfall (in mm)	σ (in mm)	Levene's Test of Equality of Error Variances		ANOVA		Kruskal Wallis	
			F	Sig.*	F	Sig.*	χ^2	Sig.*
1970-1980	12187	4906	1.151	0.341	0.294	0.83	1.555	0.67
1980-1990	12242	3164						
1990-2000	12127	2058						
2000-2012	11143	2137						

* Significance level at 0.05

Source: Cherrapunjee.com

Tibet, except for the Gauhati station (Cherrapunjee), which is transported to DHS and the moisture flux is the strongest one around the plateau (Gao et al. cited in Tang et al., 1999). This means that it is the DHS that induces the heavy rainfall in the area (Tang et al., 1999).

The present study analyses the trend of rainfall in Cherrapunjee from 1970 to 2012. The highest rainfall during the period was recorded in 1974 when the area received more than 20000 mm of annual rainfall, followed by 1988 and 1970 when the area received more than 17000 mm of annual rainfall. At the lower end of the spectrum, the minimum amount of rainfall was recorded in 1978 - 6950 mm, which is almost 60% less than the average annual rainfall received during the whole period. In general about a third of the study period received rainfall of less than 10000 mm with the remaining years getting more than 10000 mm. The minimum rainfall recorded during the study period was found to be < 2 standard deviation while the maximum rainfall was > 3 standard deviation implying that the difference between years experiencing greater than average annual rainfall is bigger than years receiving lesser than average annual rainfall.

The average annual rainfall during the study period is 11895 mm with 21 years receiving more than average rainfall and 22 years less than average rainfall (i.e. almost equal). Among the years receiving more than the average rainfall around 60 percent of them fall in the post-1990 period; while for the period receiving less than the average rainfall, both pre-1990 and post-1990 period have equal number of years (11 years each). In conjunction with a low measure of dispersion (standard deviation = 3195 mm and CV (%) = 27), it indicates that the annual absolute amount of rainfall in Cherrapunjee has not experienced a great deal of variation. In fact stable precipitation regime is a characteristic feature of the whole eastern region of the country (Starkel, 1972).

However, analysed in terms of rate of change, a slightly different picture emerges. Around 60 percent of the selected time period experienced a negative rate of change with almost 60 percent of them belonging to post-1990 period. On the other hand, post-1990 and pre-1990 period have equal number of years that experienced a positive rate of change (nine years each). In contrast to the pattern of absolute annual rainfall, a greater degree of variability is observed in the annual rate of change of rainfall (standard deviation = 40.67%, CV (%) = 625.15). Thus, though the average rate of change is 6.51 percent the actual rate of change varies greatly from -34.16 percent to + 47.18 percent. This means that although the absolute amount of rainfall has not greatly varied, in relative terms the rainfall pattern has experienced a significant change over the years. To analyse the direction of change, the linear regression method of Ordinary Least Square method is used.

The linear trend of rainfall in Cherrapunjee showed declining trend. For Dhar and Farooqui, 1973 the analysis of the trends in the annual and rainfall data of Cherrapunjee for 1903-1959 showed no linear trend, but some oscillations of the order of 10 years or so. An abrupt rise in totals from 1944 to 1954 was also observed. Prokop and Walanus, 2003, on the other hand, after analysing the instrumental rainfall data for the period 1871-1999 of North Assam sub-division and four meteorological stations of North-East India, found that though, rainfall in Cherrapunjee may show periodic fluctuations but analysed over a long period of time the trend is very stable, i.e., neither increased nor decreased.

The difference in results, compared to the latter study which is more comprehensive, could be due to the shorter time period taken in the present study (only 40 years). Also the present study considers rainfall after 1999 when the trend line goes below the average annual rainfall. The decline, though, is not very high, just 30.38 mm, which is less than one percent of the annual average rainfall of the study period. The decline, therefore, does not seem to be very significant. In order to test whether the decline is statistically significant, both parametric (One Way ANOVA) and non-parametric (Kruskal-Wallis test) tests are used.

The entire study period of 1970-2012 is divided into four parts, viz., 1970-1980, 1981-1990, 1991-2000 and 2001-2012. Except for 1981-1990 when the area received 55 mm more rainfall from the previous period, the remaining periods, 1991-2000 and 2001-2012 experienced a consistent decline in

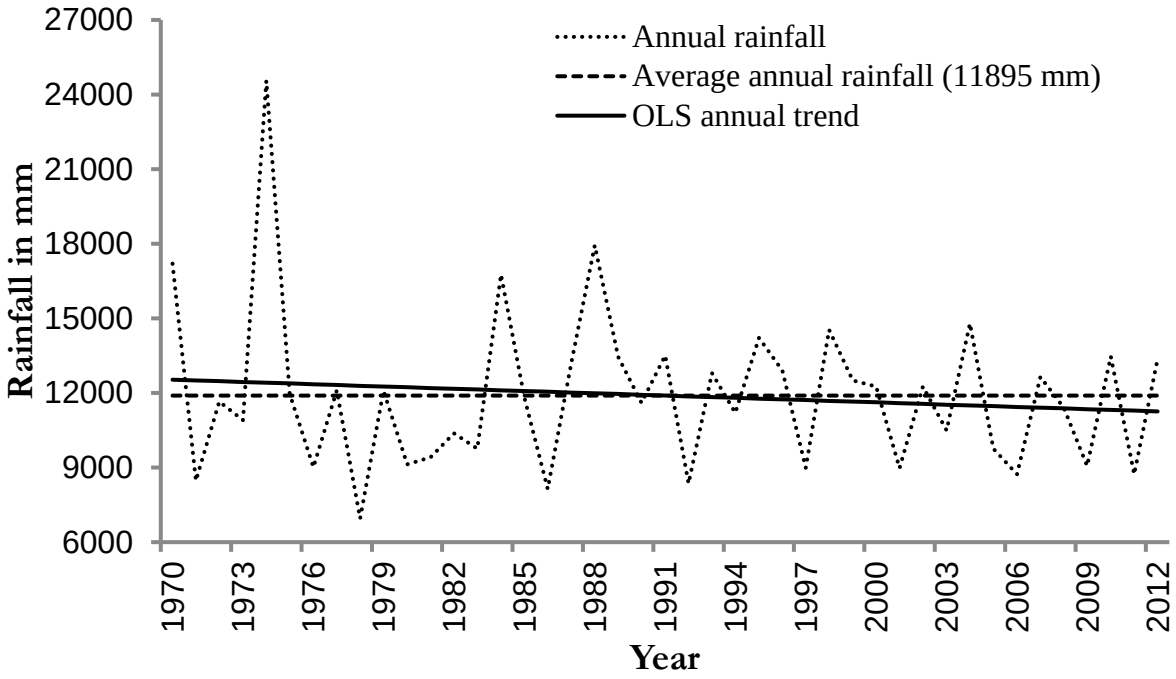


Fig. 2. Pattern of annual rainfall in Sohra/Cherrapunjee during 1970-2012.

rainfall, 115 mm and 984 mm less than the preceding periods. Both the ANOVA and Kruskal Wallis tests have revealed that the difference between the means of the different periods is not statistically significant. Hence, the decline is not significant. This low statistical significance is due to the very high absolute amount of rainfall that Cherrapunjee receives.

Rainfall being the primary source of water resources (both surface and ground-water) on the

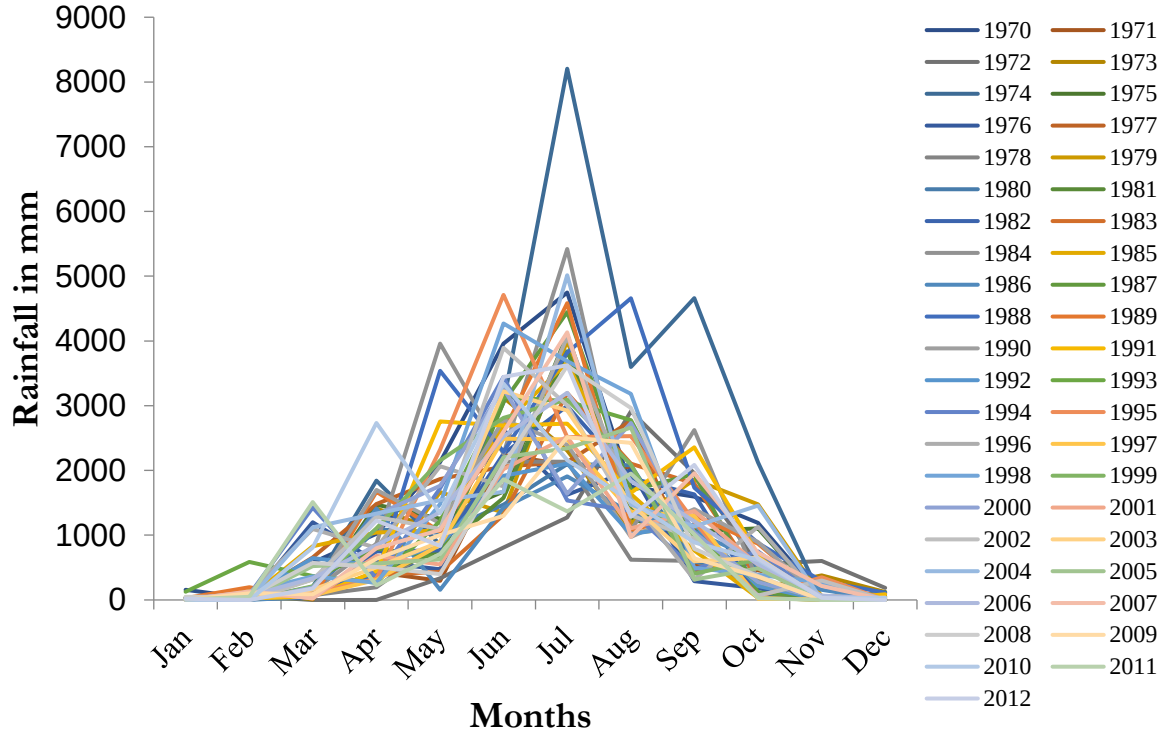


Fig. 3. Distribution of monthly rainfall from 1970 to 2012.

Earth, annual rainfall is crucial for water resources availability. Due to the very high amount of rainfall Cherrapunjee's potential annual renewable water resource is very high. The potential annual renewable water resource for Cherrapunjee (taking the total area and 2001 population of Shella Bholaganj C.D. Block) based on annual average rainfall is to the tune of 126419 m^3 $capita^{-1}$. This figure is much higher than the 17000 m^3 $capita^{-1}$ identified by Falkenmark, 1997 and Gleick as the threshold below which water stress condition develops (Brown & Matlock, 2011).

Table 3. Pattern of monthly rainfall in Cherrapunjee during 1970-2012.

Season	Month	Average monthly rainfall (mm)	σ (mm)	CV (%)
Pre-Monsoon	March	355	405	114
	April	844	561	67
	May	1258	810	64
Monsoon	June	2499	862	34
	July	3124	1305	42
	August	1869	821	44
	September	1225	794	65
	October	551	451	82
Post-Monsoon/ Lean	November	82	136	166
	December	25	44	175
	January	18	30	165
	February	61	94	155

Source: Cherrapunjee.com

However, the seasonal distribution of this high amount of rainfall is highly skewed creating conditions of surplus and scarcity. This is in keeping with the general nature of the Monsoon type-climatic system where more than 2/3rd of the annual rainfall is concentrated in just a few months of the year (Dhar & Farooqui, 1973; Singh & Syiemlieh, 2004). The maximum amount of rainfall in this period is received during the month of July that records an average monthly rainfall of 3124 mm followed by June with an average monthly rainfall of 2499 mm. Rainfall declines from July reaching the average minimum monthly rainfall of 551 mm in October. Around 78% of the annual rainfall is received by Cherrapunjee during the five months of June to October. This leads to the re/emergence of the many waterfalls in the area. For e.g., the arrival of the monsoon rejuvenates the Nohsngithiang Falls (also known as Sister Falls) which has very little discharge in the lean season. The amount and intensity of rainfall during this season is very high. In fact, one of the reasons of the observation of high rainfall in Cherrapunjee is the positive intensity-duration relationship (Singh & Syiemlieh, 2004). It is during this season that the 'break monsoon' phenomenon occurs when the axis of the season monsoon trough shifts northwards from its normal position and lies close to the foothills of the Himalayas causing extreme rainfall in the North East (Cherrapunjee) but dry conditions elsewhere in the country (Dhar & Nandargi, 2003). This high rainfall affects not just the geo-hydrology of Cherrapunjee but also of downstream Bangladesh (Murata, Hayashi, et al., 2007; Murata, Terao, et al., 2008). The highly disastrous floods of 1988 in Bangladesh was caused by the heavy monsoon rainfall in the north-east of Bangladesh and Meghalaya (Cherrapunjee) causing the Meghna and Brahmaputra (in Bangladesh) to flow above the danger level (Brammer, 1990; Mirza, 2003). Except for 1984, the severe flood years in Bangladesh correspond to the top five largest annual rainfalls at Cheerapunjee (Murata, Hayashi, et al., 2007). Water sources get recharged but unless they are protected there is a high likelihood of contamination. The potential water resources during this season is 19700 m^3 $capita^{-1}$ which is still very high compared to the annual threshold. This season is the water surplus period.

Table 4. Water status in different seasons based on water barrier differentiation proposed by Falkenmark, 1997 according to rainfall distribution.

Seasons	Potential water availability (m^3 $capita^{-1}$)		Water status
	Seasonal	Monthly	
Pre-Monsoon	8701	2900	No stress
Monsoon	19700	3940	No stress
Post-Monsoon/ Lean	374	94	Stress

Source: Cherrapunjee.com

Apart from the rainfall received during the Monsoon months, significant amount of rainfall,

21 percent is also received from April to June. The average monthly rainfall increases from 355 mm in March to reach a maximum of 1258 mm in May. The highest intensity of rainfall is also recorded during this season, i.e., pre-monsoon period Singh and Syiemlieh, 2004. In fact, a typical feature of Cherrapunjee is the heavy downpours during the pre-monsoon months every year with their intensity passing 1 mm h^{-1}. Annually these pre-monsoon rains reach 7.7 days for rainfall above 100 mm and 1.6 days for rainfall above 300 mm (Soja & Starkel, 2007). These rains are mostly due to the local convection activity and the effects of the tropical cyclones in the Bay of Bengal. Sometimes storms with very high wind speed are experienced during this period which causes great damage to improperly constructed and weakly protected water sources like small springs. Water tables however start rising and this brings relief to the people and an end to the period of water shortage of the preceding months, i.e., lean season. With a potential water resource of 8701 m^3 $capita^{-1}$ the area is comfortably placed and experiences no water stress problems.

The lean season begins from November when the Monsoon finally retreats from the area and continues to February. This period receives just 1% of the annual rainfall. The highest average monthly rainfall (82 mm) recorded is during November while the minimum average monthly rainfall of 18 mm is recorded during January. Apart from the very low amount it is the very high variability of more than 150% that greatly constraints water availability during this period. Most of the sources become completely dry or greatly reduced in the amount of water they possess. The flow in the smaller streams becomes sluggish and in the larger ones the water level goes down. The water tables, especially in the valley, fall drastically necessitating digging deeper to reach water. Most of the waterfalls, especially the smaller and perennial ones, also disappear. Severe water stresses have been reported during this season (Breitenbach et al., 2010; Soondas, 2013). This period is the water deficit period. The study area thus is characterized by periods of surplus water availability accompanied by period of intense water scarcity as well. However, rainfall is not the only factor that determines climatic natural water availability unless climatic water loss through *evapotranspiration* is also considered. The latter depends on the temperature characteristics and variation in the study area.

Table 5. Monthly variations in Potential Evapotranspiration (PET) and water balance (P-PET) during 2009-2012.

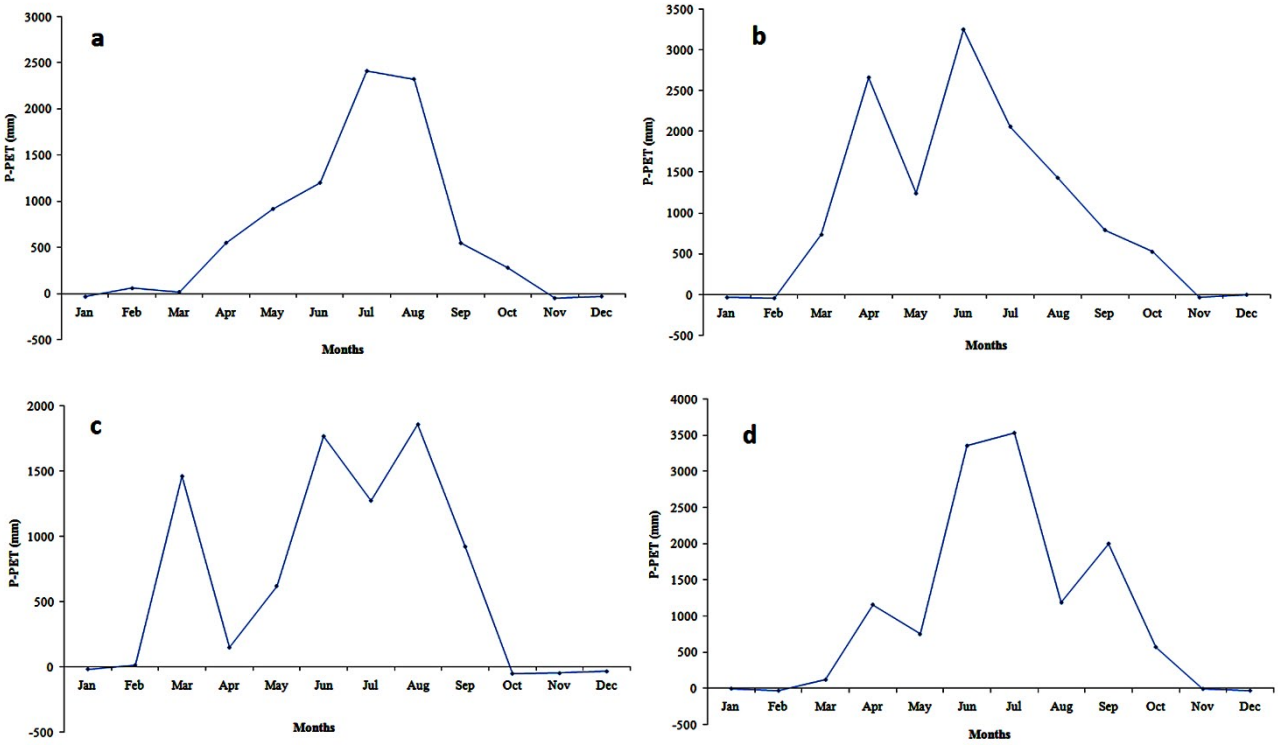
Months	Temperature (Degree Celsius)	PET (mm)	P (mm)	P-PET (mm)
January	12.01	29.30	7.20	-22.10
February	14.20	38.05	37.05	-1.00
March	17.22	63.35	645.75	582.41
April	19.05	77.12	1205.00	1127.89
May	19.93	91.43	971.90	880.48
June	20.44	95.76	2487.18	2391.42
July	20.70	98.28	2416.23	2317.95
August	20.97	98.28	1796.93	1698.65
September	21.17	91.04	1155.80	1064.77
October	20.09	80.93	411.75	330.82
November	16.64	51.19	16.50	-34.69
December	13.06	32.76	8.40	-24.36

Source: Cherrapunjee.com

Temperature

Apart from rainfall, temperature is also a very important element for the development of water resources in the study area. The most significant factor controlling the climate in Cherrapunjee is the South-West Monsoon and altitude (Dohling, 2003) with the South-West Monsoon determining the amount of rainfall and altitude determining the temperature conditions. As a consequence, Cherrapunjee experiences cold temperate climate with foggy winter months while the southern part of the terrain along the Bangladesh border experiences hot summer with cool winter (Biswas, 1990). While studying the variations of surface air temperature over the land areas in and around the Bay of Bengal for the time period of 1951-1990, Quadir et al., 2004 found that Cherrapunji has observed a cooling at the rate of $-0.018^{\circ}C\ year^{-1}$ respectively. Annually, temperature in the study area varies from minimum of 5°Celsius to a maximum of 26°C. The heavy rainfall helps in bringing down the temperature and the average temperature throughout the year is just over 17°C. January is the coldest month with average temperature just above 10°C, although the minimum temperature may drop below than 10°C. June is the hottest month with maximum temperature approaching 25°C. This variation in temperature plays a very important role in determining water resources development in the study area.

The rainfall that falls in a region is transported back to the atmosphere through the process of evaporation and transpiration. The energy that drives these processes is the heat energy of the sun, i.e., the temperature. In conjunction evaporation and transpiration are known as *evapotranspiration*. *Evapotranspiration* is the combined evaporation from the soil surface and transpiration from the plants which represents the transport of water back to the atmosphere, the reverse of precipitation (Thornthwaite, 1948). There are two types of *evapotranspiration*, viz., *potential evapotranspiration* and *actual evapotranspiration*. The former is based on theoretical formulations. It is derived from an understanding of the factors responsible for the process and their relationships that gives a potential value. In actual *evapotranspiration* an attempt is made to find out the amount



Note: a – 2009; b – 2010; c – 2011; d – 2012 **Source:** Cherrapunjee.com.

Fig. 4. Water balance (P-PET) in Cherrapunjee from 2009 to 2012

of *evapotranspiration* that has taken place from an area. This is done by multiplying suitable crop coefficients with the *potential evapotranspiration* (Nokes, 1995). In the present work only *potential evapotranspiration* has been determined as it is considered to be sufficient.

There are many methods available for determining the *potential evapotranspiration*. The present study, however, uses the Thornthwaite and Mather's method for calculating *potential evapotranspiration* which is given below.

$$e = 1.6\left(10\,\frac{t}{I}\right)^{a} \tag{1}$$

where,

e = Monthly *Potential Evapotranspiration* in mm or cm for standardized month of 360 hours of sunshine.

t = Mean monthly air temperature in °C.

I = annual heat index which is summation of the monthly indices, i, which is defined as,

$$i = \left(\frac{t}{5}\right)^{1.514} \tag{2}$$

The 'a' is the location coefficient that has to be determined in the following manner,

$$a = 0.000000675I^3 - 0.0000771I^2 + 0.017921I + 0.49239 \tag{3}$$

Temperature starts increasing by the end of February and continues till September after which temperature starts falling. This subsequently coincides with the rise in PET values (from more than 60 mm to over 90 mm). Cherrapunjee, as has already been discussed, receives very high amount of rainfall. As such the water balance is also very high, (>1000 mm) with the highest values during the peak monsoon months of June and July (>2000 mm of excess water is available after considering *evapotranspiration* losses). On the other hand, by the end of October, the Monsoon fully retreats from the region and as such the lowest values occur during the lean season months, i.e., November, December and January. These months experience a deficit of more than -20 mm, i.e., *evapotranspiration* demand is more than rainfall received. These two periods thus can be consequently identified as water-surplus (monsoon and pre-monsoon season) and water-deficit (lean season) periods respectively. This pattern is found to be consistent over the period undertaken for study, 2009 to 2012 with small variations. During the monsoon and pre-monsoon season excess water is available. Potentially this water can contribute to recharge of the various water sources, surface as well as subsurface, from which people collect water. Water sources recharged during the water surplus seasons could provide water during in the water deficient season.

CONCLUSION

As stated in the beginning, Sohra/Cherrapunjee suffers from the paradoxical situation of 'scarcity in plenty'. The subsequent discussion tried to analyse the role of the geo-environmental factors in understanding this condition. Though annual rainfall is very high, its distribution is highly skewed with lean season receiving very less rainfall. This has important implication in terms of climatic water loss through the process of *evapotranspiration*. Indeed, lean season is found to have deficit water balance values indicating severe water shortage. This seasonal shortage could be overcome if there is proper recharge and storage of rainfall that is available during the water surplus pre-monsoon and monsoon season. The geo-environmental conditions especially climatic factors in Sohra/Cherrapunjee are highly unfavourable for water resources development and this sufficiently explains the condition of 'scarcity in plenty'.

REFERENCES

Biswas, S. (1990). *Geomorphic studies around Cherrapunjee, East Khasi Hills, Meghalaya* (M. Phil. Thesis). North-Eastern Hill University. Shillong.

Brammer, H. (1990). Floods in Bangladesh: Geographical background to the 1987 and 1988 floods. *The Geographical Journal*, *156*(1). https://doi.org/10.2307/635431

Breitenbach, S. F. M., Donges, J. F., Kharpran Daly, B., Kohn, T., & Kohn, T. (2010). Two sandstone caves on the southern edge of the Meghalaya plateau, India. *Cave and Karst Science*, *37*(2).

Brown, A., & Matlock, M. D. *A review of water scarcity indices and methodologies: White paper #106* (The Sustainability Consortium, Ed.). Ed. by The Sustainability Consortium. 2011.

Dhar, O. N., & Farooqui, S. M. T. (1973). A study of rainfalls recorded at the Cherrapunji observatory. *Hydrological Sciences Bulletin*, *18*(4). https : / / doi . org / 10 . 1080 / 02626667309494059

Dhar, O. N., & Nandargi, S. (2003). Hydrometeorological aspects of floods in India. *Natural Hazards*, *28*(1). https://doi.org/10.1023/A:1021199714487

Dohling, A. (2003). *Hydrogeomorphological study around Cherrapunjee* (M. Phil. Thesis). North-Eastern Hill University. Shillong.

Falkenmark, M. (1997). Meeting water requirements of an expanding world population (D. J. Greenland, P. J. Gregory, & P. H. Nye, Eds.). *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *352*(1356). https : / / doi . org / 10 . 1098/rstb.1997.0072

Kingdon-Ward, F. (1955). Aftermath of the great Assam earthquake of 1950. *The Geographical Journal*, *121*(3).

Mirza, M. M. Q. (2003). Three recent extreme floods in Bangladesh: A hydrometeorological analysis. In M. M. Q. Mirza, A. Dixit, & A. Nishat (Eds.), *Flood problem and management in south asia*. Springer Netherlands. https://doi.org/10.1007/978-94-017-0137-2_2

Murata, F., Hayashi, T., Matsumoto, J., & Asada, H. (2007). Rainfall on the Meghalaya plateau in northeastern India–one of the rainiest places in the world. *Natural Hazards*, *42*(2). https://doi.org/10.1007/s11069-006-9084-z

Murata, F., Terao, T., Hayashi, T., Asada, H., & Matsumoto, J. (2008). Relationship between atmospheric conditions at Dhaka, Bangladesh, and rainfall at Cherrapunjee, India. *Natural Hazards*, *44*(3). https://doi.org/10.1007/s11069-007-9125-2

Nokes, S. E. (1995). Evapotranspiration. In A. D. Ward, S. W. Trimble, & S. R. Burckhard (Eds.), *Environmental hydrology*. CRC Press LLC, Boca Raton, Florida.

Prokop, P., & Walanus, A. (2003). Trend and periodicity in the longest instrumental rainfall series for the area of most extreme rainfall in the world, northeast India. *Geographia Polonica*, *76*(2).

PTI. (2010). Water supply scheme for dry cherrapunjee. *The Hindu*.

Quadir, D. A., Shrestha, M. L., Khan, T. M. A., Ferdousi, N., Rahman, M., & Mannan, A. (2004). Variations of surface air temperature over the land areas in and around the bay of Bengal. *Natural Hazards*, *31*(2). https : / / doi . org / 10 . 1023 / B : NHAZ . 0000023368.81668.e3

Singh, S., & Syiemlieh, H. J. (2004). Rainstorm characteristics of extremely humid area of the world-Cherrapunjee. *Vayu Mandal*, *31*.

Soja, R., & Starkel, L. (2007). Extreme rainfalls in eastern Himalaya and southern slope of Meghalaya plateau and their geomorphologic impacts. *Geomorphology*, *84*(3). https://doi.org/10.1016/j.geomorph.2006.01.040

Soondas, A. (2013). 'Wettest' Cherrapunjee is bone dry. *The Times of India*.

Starkel, L. (1972). The modeling of monsoon areas of india as related to catastrophic rainfall. *Geographia Polonica, Special issue for the 22nd International Geographical Congress*.

Tang, M., Zhong, D., Li, W., & Feng, S. (1999). Evidence for the Daxiawan as a hot spot in the earth. *Science in China Series D: Earth Sciences*, *42*(1). https : / / doi . org / 10 . 1007 / BF02878495

Thornthwaite, C. W. (1948). An approach toward a rational classification of climate. *Geographical Review*, *38*(1). https://doi.org/10.2307/210739

REVIEW ARTICLE

Rejuvenation of springs utilizing corporate social responsibility (CSR) fund

Aksana Neah Ch. Marak

Department of Environment, Don Bosco College, Tura, Meghalaya, India

E-mail: aksananeahc@gmail.com

ABSTRACT

The springs are major sources of drinking water in rural areas of Meghalaya. Villagers in Meghalaya use spring water for drinking, irrigation and rearing livestock. However, this dependency on springs by the people living in the hills are hampered due to drying up of many springs, degradation in the quality of water, increase in demand and reduction in water yield due to many anthropogenic activities like deforestation, mining etc. There has been growing awareness and efforts to rejuvenate the drying springs are gaining momentum. Few government agencies and NGOs are contributing towards restoration and rejuvenation of springs. Afforestation, rain water harvesting, ground water recharge etc. can help in rejuvenation of springs. These activities can be funded by the companies through their Corporate Social Responsibility (CSR) fund. Part of the CSR fund can be utilized to make trenches on hill slopes, protecting existing springs, protecting these springs from contamination etc. The paper discusses how CSR can be a potential tool in rejuvenation and regeneration of primary sources of drinking water.

Keywords: Springs, Spring rejuvenation, CSR, CSR activities, Sustainability

INTRODUCTION

Springs are the major source of water for domestic and irrigation purposes in Meghalaya. For many people, mostly in the rural areas, springs are the sole source of water. Even the water supplies in the urban areas have their origin from the springs. This dependency on springs however need protection because it is hampered due to various factors like deforestation, drying up of springs, over-usage due to increase in demand, expansion of land use for urbanisation and other livelihood changes. Various anthropogenic activities have pose threats to the existing springs and there is an urgent need to revive and rejuvenate these springs and these can be done through afforestation programmes, rain water harvesting, construction of retention dams, trenches etc. These activities require financial aides. Projects and programmes by few government agencies and NGOs have initiated towards revival of springs and huge contribution can be made through CSR fund resulting in long-lasting and sustainability of springs.

CAUSES FOR SPRING DISAPPEARANCE

The reason we need to revive the springs is because of its visible disappearance caused due to factors like deforestation, mining, over usage and extraction of groundwater, eroding away of soils and introduction of exotic plant species, mostly those that are planted without environmental checks and balances resulting in competition with native species. Many of these exotic species

consume more water than they retain in the ground (Cavaleri & Sack, 2010).

APPROACHES TOWARDS SPRING REJUVENATION

Growing awareness about the drying springs have led to approaches from scientists, government agencies, communities and various organisations. Some of the initiatives and projects that have given successful results in rejuvenating springs are building retention dams, bunds, terraces, and trenches and planting native tree species in the depleting forested catchment areas, construction of wells and tanks.

Fig. 1. Construction of dam at source for water supply at Warisep Stream at the foot of Tura Peak.

Digging up trenches in the forest land capture run-off by breaking the slope and reduce the velocity of surface run-off and ensures that water percolates down to recharge the springs. It is also an important measure to prevent soil erosion.

Pits and check dams improve the natural recharge in the catchment zones by not wasting the excess water and allowing more time for it to go into the ground.

Trees have an immense role to play in rejuvenation of springs. Afforestation measures reduce erosive force of water through soil cover provided by the tree canopy and litter. It not only conserve springs but also soil and moisture in the area. Natural vegetation conserves rainwater and accelerate water infiltration.

Rainwater harvesting methods like collection and storage of water in a tank can meet the water need during dry months and digging up pits can let the water percolate into the soil that enhances ground water recharge (Kashiwar et al., 2016).

Bunds are small embankments type structures made from locally available earthen materials. Bunds also help check the velocity of run-offs, to carry excessive rainfall safely downstream and to let off stream flow in natural channels. It increases the time of concentration of rain water where it falls thus allowing it to percolate down the soil.

Co-operation, gathering knowledge and collective efforts from government, researchers, funders and corporations will help revive springs.

Fig. 2. Plantation of indigenous tree species and retention of spring water by assistance from the Government through MGNREGA Scheme.

Fig. 3. Storage of spring water for household use.

All the above mentioned methods besides others need financial aids and contribution of funds. Government organisations, NGOs and other or-

ganisations have put efforts and are involved in spring rejuvenation programmes. One such potential funding source is Corporate Social Responsibility (CSR).

CORPORATE SOCIAL RESPONSIBILITY (CSR)

Healthy and sound environment is a basic for all kinds of development including the economy. Environmental sustainability and economic development are considered to be contrasting to each other however with proper measures and responsibility, both can flourish together (Basiago, 1998). Business organisation and corporation are a part of environment and social entity. Various studies have found that Industrial activities are damaging to environment and they have a responsibility towards their counterparts. Companies have realised their responsibility and have come up with activities to remunerate the impacts they have on the environment. Such activities come under the ambit of CSR (Shyam, 2016). Thus, CSR is an act of responsibility towards the environment, people and society by the corporate. CSR has also been linked with Sustainable Development because the concept of CSR also covers the operation of businesses in an environmentally, socially and economically sustainable manner (DPE, 2013).

CSR is not a new concept. It has been in practice since a very long time throughout the world including India as a philanthropic activity (CII, 2013). It has been the practice of many corporate houses to contribute to the society by building schools and colleges, hospitals, charitable trusts etc. these activities were taken voluntarily by major corporate houses without having legal requirements to do so. The companies set aside funds for such activities to meet the desired CSR objectives such as promotion of education and healthcare facilities by building schools and hospitals, providing medical and sanitation facilities, and empowering the villagers by way of providing vocational training and skill and other similar activities. Protection of environment by way of planting trees and increasing green cover, creating environmental awareness, protecting wildlife etc. has also been undertaken under CSR, in recent years (Marak, 2019).

The Ministry of Corporate Affairs in the year 2013 enacted new Companies Act refining the sixty years old Companies Act 1956. The Act introduced new concepts, provisions and significant changes. One such provision was Section 135, which is on CSR. By making CSR mandatory for companies, India became one of the first countries to legalise CSR for the corporation. Section 135 of the Companies Act, 2013 is applicable to companies having a net worth of INR 500 or more or a turnover of INR 1000 crore or more or a net profit of INR 5 Crore or more. The CSR provision was notified on 28th February 2014 under the Companies (Corporate Social Responsibility) Rules, 2014. This Act is effective from the 1st April 2014 and companies need to spend at least 2% of the average profits they made in the preceding three years towards CSR activities. The act also lists out activities that a company can take up under their CSR and is notified in the Scheduled VII of the Act.

ACTIVITIES UNDER CSR

Of various activities list out in the Scheduled VII of the Companies Act, 2013, item iv consists of the activities directly relating to environmental protection and sustainability. The Scheduled VII of the Companies Act, 2013 list out the following CSR activities and are to be carried out only in India.

i. Eradicating hunger, poverty and malnutrition, promoting preventive health care and sanitation and making available safe drinking water;

ii. Promoting education, including special education and employment enhancing vocational skills especially among children, women, elderly, and the differently-abled and livelihood enhancement projects;

iii. Promoting gender equality, empowering women, setting up homes and hostels for women and orphans; setting up old age homes, day care centres and such other facilities for senior citizens and measures for reducing inequalities faced by socially and economically backward groups;

iv. **Ensuring environmental sustainability, ecological balance, protection of flora**

and fauna, animal welfare, agroforestry, conservation of natural resources and maintaining quality of soil, air and water;

v. Protection of natural heritage, art and culture including restoration of buildings and sites of historical importance and works of art; setting up public libraries; promotion and development of traditional arts and handicrafts;

vi. Measures for the benefit of armed forces veterans, war widows and their dependents;

vii. Training to promote rural sports, nationally recognised sports, Paralympics and Olympic sports;

viii. Contribution to the Prime minister's National Relief Fund or any other fund set up by the central Government for socio-economic development and relief and welfare of the scheduled caste, the scheduled tribes, other backward classes, minorities and women;

ix. Contributions or funds provided to technology incubators located within academic institutions which are approved by the central government;

x. Rural development projects Besides these activities, amendment was made to this schedule where "Swach Bharat Kosh" and Clean Ganga Fund were incorporated (Ministry of Corporate Affairs, 2014).

CSR FUNDS FOR SPRING REJUVENATION

Various interventions from the general public, government agencies, community efforts, NGOs towards spring shed initiatives have brought positive changes towards the water bodies. These interventions are also met through financial aides from funding sources. Rejuvenation of springs come with monetary requirements. The project of rejuvenating a spring in Nainital district costs INR 53,300 covering activities like tree plantation, grass planting, pits, drainage, contour trench, check dam, terrace levelling, bunds and percolation pits (Chakravarty, 2015). Also, Sikkim Government covered 400 hectares of land under spring-shed development programme with a total investment of INR 2.5 Crore. This project resulted in an annual ground water recharge of 900 million litres (Jamwal, 2018).

There are companies that have a set budget from their CSR funds towards environmental sustainability sector that covered spring rejuvenation. CSR project by Bharat Petroleum Corporation Limited under the 'Project Boondh' undertook project to rejuvenate springs covering activities like construction of revival tanks, plantation of fruit-bearing trees along the bunds, construction of ponds, wells, gabions and cordoning off springs. These activities besides rejuvenating springs also promoted sustainable livelihood activities like horticulture and agriculture and mitigate the water related crises and difficulties faced by the people. These projects were taken up in Tumkur and Kolar districts of Karnataka, Wardha and Yavatmal districts of Maharashtra and Bharatpur, Rajasthan. The project budget was INR 3.26 Crore (csrbox.org, 2016).

CSR ACTIVITIES BY THE COMPANIES OPERATING IN MEGHALAYA

More than 76% of Meghalaya's geographical area is under forest cover. The state is also blessed with hilly terrains accompanied by gushing waterfalls and streams. However, the state has been witnessing increasing number of environmental problems. Some of them are decrease in forest cover ultimately resulting to loss of springs leading to water scarcity. These problems are evident from the decrease in forest cover by 116 sq. Km within two years span by the state (FSI, 2018). The water once perennial is also scarce during dry months. The state houses comparatively less corporate sector that come under the ambit of CSR. However, these companies are taking up projects towards education, health sector, disaster relief funds and environmental sustainability activities. Paying homage to economically profitable organisations and economy of the region, there is an immediate need for environment protection and conservation. It is a necessity that corporate sectors pay attention to these needs.

Most number of companies operating in

Meghalaya are involved in environmental sustainability sector under CSR. Tree plantation is the most favoured activity towards environmental sustainability besides promotion of solar energy, biodiversity, conservation of soil and water (Marak & Singh, 2017). Afforestation programmes and other activities undertaken by the companies are appreciative and has contributed towards the welfare of the environment and society of the region. The companies are however yet to take up activities to rejuvenate springs.

The people in the region of Meghalaya are highly dependent on the springs for their livelihood. Lyngdoh stated that the state has around 60,000 springs (Jamwal, 2019). However, these springs are under threat as most of them have either dried up or once perennial springs have become seasonal. Another cause of concern is the degrading quality of springs which has imposed threats to the availability of fresh water and cause acute shortage in drinking water. Spring protection initiatives in the state are being taken up by Meghalaya Basin Development Authority (MBDA) to revive the disappearing springs. There are also few communities based managed springs. Such activities need funding and financial requirements can also be contributed from the CSR funds. If companies invest their CSR activities on spring rejuvenation and revival, not only people will benefit but it will also sustain the environment.

CONCLUSION

Approaches towards sustainable rejuvenation of springs are an immediate need today. Activities towards rejuvenation and restoring of springs are a welcome call. These demand co-operation from all stakeholders including the general public, government and the corporation. Corporation can be vigilant and address the needs of the society, one of those being, the necessity of having clean water bodies. Companies in Meghalaya can diversify their CSR activities and can utilise the funds towards spring rejuvenation. These can be done through awareness about CSR and sensitizing the corporation about our need to protect the springs. If done with seriousness, CSR can be a potential tool and can contribute massively towards water security of the people of the region.

REFERENCES

Basiago, A. D. (1998). Economic, social, and environmental sustainability in development theory and urban planning practice. *Environmentalist*, *19*(2). https://doi.org/10.1023/A:1006697118620

Cavaleri, M. A., & Sack, L. (2010). Comparative water use of native and invasive plants at multiple scales: A global meta-analysis. *Ecology*, *91*(9). https://doi.org/https://doi.org/10.1890/09-0582.1

Chakravarty, A. (2015). Springing back to life. *Down to earth*, Available at: *https://www.downtoearth.org.in/coverage/springing-back-to-life-43895*.

CII, Confederation of Indian Industry. *Handbook on Corporate Social Responsibility in India.* Available at: https://www.pwc.in/assets/pdfs/publications/2013/handbook-on-corporate-social-responsibility-in-India.pdf. 2013.

csrbox.org. (2016). Project Boond 2015-16 (2015-16).

DPE, Department of Public Enterprises. (2013). Guidelines on Corporate Social Responsibility and sustainability for central public sector enterprises. *Government of India*, (New Delhi).

FSI, Forest Survey of India. (2018). India State of Forest Report 2017. *Ministry of Environment, Forest and Climate Change*, *243–247*.

Jamwal, N. (2018). In Sikkim, a spring rejuvenation scheme is helping villages tide over summer water shortage. *Water Watch*, Available at: *https://scroll.in/article/892748/in-sikkim-a-spring-rejuvenation-scheme-is-helping-villages-tide-over-summer-water-shortage*.

Jamwal, N. (2019). In parched Northeast, a spring of hope. *Gaon Connection*, Available at: *https://www.gaonconnection.com/swayamproject/in-parched-northeast-a-spring-of-hope-45612*.

Kashiwar, S. R., Dongarwar, U. R., Mondal, B., & Kundu, M. C. (2016). An overview on the ground water recharge by rain water harvesting. *Journal of Energy Research and Environmental Technology*, *3*(2).

Marak, A. N. C. (2019). *Environmental protection through corporate social responsibility in Meghalaya: Current status and future prospects* (Ph.D. Thesis). North-Eastern Hill University. Shillong, India.

Marak, A. N. C., & Singh, O. P. (2017). Tree plantation is the most favoured CSR activity under environmental sustainability by the companies operating in Meghalaya, India. *Journal of Environmental Research and Development*, *12*(2).

Ministry of Corporate Affairs. (2014). *The Companies Act, 2013*. Government of India.

Shyam, R. (2016). An analysis of corporate social responsibility in India. *International Journal of Research-Granthaalayah*, *4*(5).

REVIEW ARTICLE

Unfolding the world of Tea: A critical review

Upasana Deb* and Sheena Haorongbam

Department of Agri-business Management and Food Technology, North-Eastern Hill University, Tura, Meghalaya, India

**E-mail:* upasanadeb123@gmail.com

ABSTRACT

Tea is an essential part of our life. But we know very less about the drink that we consume every day. Therefore, an attempt has been made in this review to know about the background of tea, how it originated, the science behind its chemical composition and taste. The various steps of manufacture of tea have also been studied. A special focus has been given on the different varieties of teas and knowing the basic difference among the varieties of teas. Finally, the beneficial effects of tea have been highlighted, which led us to the conclusion that tea is safe and can be consumed every day to enjoy the goodness it offers.

Keywords: Tea, composition, varieties of tea, health effects

INTRODUCTION

Every morning and evening in an Indian family is incomplete without a cup of tea. The drink that is served to guests by most Indians is a cup of tea. Tea, often known as the elixir of life, is only after water in being the most popular and consumed drink all over the world (Williaamson Tea, 2019). Tea is prepared from the leaves of the tea plant (*Camellia sinensis var sinensis*). *Camellia sinensis* is a native to China, but today it is grown in almost all the corners of the world, especially in India. It is often a myth that the best tea comes from the plants grown at a higher elevation with a cooler climate. The famous Assam tea comes as an exception as it is grown in the plains of the Brahmaputra with a slightly warmer climate (Brand India Plantations, 2019).

Tea is the one of the most loved and consumed drink all over the world but very few people know about the history, culture and types of tea. India produced an average of 1,325,050 tonnes of tea annually thus coming second in the world in tea production (Szenthe, 2019). With the consumption rate of 1090 million kilograms of tea in 2019, India is the highest consumer of tea in the world. Assam is the highest producer of tea in India (Keelery, 2019).

HISTORY OF TEA

According to Chinese legends, tea was discovered accidentally by Shen Nung, a Chinese emperor around 5,000 years ago. It was when a tea leaf fell into his pot of boiling water and on consuming it; he felt the taste of water to have improved. He also felt some stimulation in his body (Teaclass, n.d.-c).

The history of Indian tea dates back to 750 BC. In the 16th century, tea leaves were used to make a vegetable curry with garlic and oil. However, the commercial cultivation of tea in India was started by the British in the 1770s. In 1774, Warren Hastings, the Governor General of Ben-

gal, selected some tea seeds and sent them from China to Bhutan embassy. Sir John Banks, who was an eminent English botanist, suggested in 1776 that tea cultivation could be done in India. Later, in 1780, Colonel Robert Kyd tried cultivating the Chinese tea seeds in the Indian Botanical Garden, Howrah. With the help of an Assamese nobleman, Mr. Maniram Dutta Barbhandari Dewan, a Scottish explorer named Robert Bruce discovered the native tea plant of Assam (*Camellia sinensis var. assamica (Masters) Kitamura*) in 1823. Mr. Maniram Dewan became the first Indian to start private tea cultivation in Assam (Brand India Plantations, 2019).

COMPOSITION OF TEA

Tea leaves are composed of thousands of chemical compounds (Tea epicure, 2020). These compounds on being processed break down and give rise to a different type of compounds that are responsible for the aromatic taste of the tea. However, the full structure of tea has not yet been known. So, tea is also called the "Master of Chemical Diversity" (Tea Epicure, n.d.). Some of the important compounds that gives tea its distinctive characteristics are discussed as follow:

Polyphenol:

As the name suggests, it means a compound with many phenol groups. They are the most abundant compound found in tea leaves, accounting for 30-40% composition of the leaves (Harbowy et al., 1997). Polyphenols are produced from amino acids with the help of sunlight. In case, the tea is grown in shade, the concentration of amino acids will be more than that of polyphenols (Ercisli et al., 2008). The polyphenols levels decrease in the descending order of leaves in the plant, as a result the first leaves and buds have the highest percentage of polyphenols (Bhatia, 1961). Around thirty thousand polyphenolic compounds are found in tea and most important among them is flavonoids (Tea Epicure, n.d.).

The flavonoid group comprised of flavanols, flavonols, flavones, isoflavones and anthocyanin. The most common flavonoid is flavanols, which is also known as tannins or catechins. The important flavanols in tea are catechin (C), epicatechin (EC), epicatechin gallate (ECG), gallocatechin (GC), epigallocatechin (EGC) and epigallocatechin gallate (EGCG). The most active catechin is epigallocatechin gallate (EGCG) which is often studied because of its antioxidant activity (Tea Epicure, n.d.).

The process of oxidation converts flavanols to theaflavins and thearubigins which gives the tea its dark colour and robust flavours (Tea Epicure, n.d.).

Amino acids:

The sweetness and brothiness of tea (umami) is due to the presence of amino acids. Amino acids contribute around 6% in the tea leaf's composition (Tea Epicure, n.d.). Theanine is the most important amino acid present in tea leaf. L-Theanine promotes alpha wave activity of the brain giving a feeling of relaxation. The combination of L-theanine and caffeine will induce "mindful alertness" in the tea drinker (Tea Epicure, n.d.).

Enzymes:

The important enzymes in tea leaves are polyphenol oxidase and peroxidise. They lead to enzymatic browning of tea leaves during oxidation. The enzymes get inactive at 150 degree F and when deprived of moisture for a long time (Tea Epicure, n.d.).

Pigments:

The pigments, mainly chlorophyll and carotenoids impart the tea leaves its colour. These pigments get darker as a result of oxidation and withering. The green chlorophylls after oxidation degrade and turn black pigments known as pheophytins, resulting in a darker appearance of the finished oxidised teas (Tea Epicure, n.d.).

Tea carotenoids can be broken into two groups namely orange carotenes and yellow xanthophylls. On processing of tea leaves, the carotenoids degrade into many derivate compounds such as damascenone that gives a sweet flavour to the tea (Preedy, 2013).

Carbohydrates:

Carbohydrates in tea leaf accounts for 11% of the tea composition (Harbowy et al., 1997). It helps in enzymatic brewing and in the production of polyphenols. The three forms of carbohydrate-monosaccharide, disaccharides and oligosaccharides are present in the tea leaves (Chen et al.,

2010). Carbohydrates render sweetness to the tea liquor (Tea Epicure, n.d.).

Methylxanthine:

It will make up to 5% of the dry weight of the fresh leaves. Plants produce methyxanthine to protect itself from the insects. The important methylxanthine in tea is caffeine, followed by theobromine and theophylline. It adds bitter taste to the tea (Zhen, 2002).

It should be noted that the caffeine level in tea is much lower than that of other similar drinks like coffee. It has been studied that the average level of caffeine in a cup of tea is 40 mg while a cup of coffee offers 105 g of caffeine (Teaclass, n.d.-d).

Minerals:

The tea leaves contain around 28 mineral elements (Zhen, 2002). A higher percentage of aluminium, arsenic, fluorine, iodine, manganese, nickel, potassium and selenium have been observed by Zhen, 2002 compared to other plants.

Volatiles:

Volatile substances hold 0.01% in the composition of tea leaves (Preedy, 2013). They give the tea its aroma and flavour. These compounds are usually absent in fresh leaves and are derived from other compounds during the processing of tea leaves. Compounds such as linalool and linalool oxide gives floral notes and sweetness, phenylacetaldehyde and geraniol gives floral aromas while fruity flavour is imparted by benzaldehyde, methyl salicylate, nerolidol, and phenyl ethanol. While the tea's fresh flavour is given by b-ionone, cis-3-hexenol, n-hexanal and trans-2-hexenal (TRA Tocklai, n.d.).

PROCESSING OF TEA LEAVES

Different types of tea follow different steps. However, the processing of tea comes under two board categories: Orthodox style and Non-orthodox or Crush tear curl method (CTC).

Orthodox method:

It is also known as the traditional method that has been used since ages. It involves five different steps which are discussed as follows:

1. **Plucking:** The unopened bud and the top three tea leaves are picked by hand. After harvesting of the leaves, the sorting is done to maintain the uniformity of the leaves. The unwanted articles like broken leaves, twigs, stems etc are removed (Teaclass, n.d.-a).

2. **Withering:** The fresh leaves are not the best option for the next step i.e. rolling; as they will break while being rolled. Hence, the fresh collected leaves are laid out, fluffed, rotated and allowed to dry in air for hours to prepare them for rolling (Teaclass, n.d.-a).

3. **Rolling:** This method brings out the flavours in tea leaves. The withered leaves are rolled and flattened so that the cell wall of the leaves breaks, leaking out the juices from inside. This will expose the enzymes and essential oils of the leaves to interact with oxygen (Teaclass, n.d.-a).

4. **Oxidation:** In this step, the rolled leaves are laid for hours to allow the interaction of oxygen with the exposed enzymes of the leaves. The colour of the tea leaves turn to reddish-brown as the chemical composition of the leaves also gets altered. This step is the flavour and type determining steps in the processing of tea. The duration of this process determines which type of tea is being made (Teaclass, n.d.-a).

5. **Firing:** It is the final step in the processing of tea where the tea leaves are set to "fire" (heated quickly) to dry them and limit the moisture content below 3%. It will stop the oxidation process as well. This step is required to store the leaves for a longer duration (Teaclass, n.d.-a).

CTC method

The CTC method follows the same five steps as the orthodox method, but much more quickly compared to the orthodox method. The CTC method was invented to save time in the processing of tea leaves in the tea industry.

The three major differences between the orthodox and CTC method are as follows:

i. The wholeness of the leaves is maintained in the orthodox method as the leaves are not cut, although the shapes and sizes of the leaves may vary. On contrast to that, CTC does not count on the wholeness of leaves as the leaves are often broken down (Teaclass, n.d.-a).

ii. The use of machineries is involved in the CTC method which is not used in the orthodox method. In CTC method, the leaves are completely broken down by the machines which make all the parts of the leaves accessible for easy processing unlike, the orthodox method, where processing of the whole leaves takes a lot of time (Teaclass, n.d.-a).

iii. The CTC method was invented specially for the black tea. The CTC method will not serve to produce other varieties of teas like oolong, white etc because the small surface area of the leaves done by the machineries in the CTC method will be prone to quick oxidation which is not desirable in such teas. While, varieties of teas can be produced through the traditional orthodox method as it focuses on the wholeness of tea leaves that can withstand different oxidation conditions (Teaclass, n.d.-a).

VARIETIES OF TEA

There are five types of tea: black tea, green tea, oolong tea, pu-erh tea and white tea. All the varieties of tea come from the same tea plant, *Camellia Sinensis (L) O. Kuntze* (Brand India Plantations, 2019). The different types of tea depend on the manner the tea leaves are processed after being plucked (Brand India Plantations, 2019).

i. **White tea:** The white tea will undergo the least processing. The plucked tea leaves are spread and dried completely. No further processing is required. The white teas have a sweet and delicate floral flavour. It is also the greatest source of anti-oxidants among all the other types of teas as it undergoes least processing. Hence, it is also the best variety of tea because of its complexity, natural sweetness and unmatched subtlety (Brand India Plantations, 2019; Teaclass, n.d.-e).
The white tea leaf is composed of caffeine (3.35-5.74 %), Polyphenol (16.23–25.95%), flavonol glycosides (0.06-1.44 %) and catechins (7.94-16.56 %) (Pawar, 2018).

ii. **Green tea:** Green tea is prepared by minimum processing which includes withering the leaves, followed by steaming, rolling and firing. The application of heat prevents the leaves to go into the next step of oxidation. Thus, the final tea leaves obtained are green and the liquor will be either lemon-yellow or mild, pale green. These leaves contain catechins (30-40%), flavonols (5-10%), other flavonoids (2-4%), Theogallin (2-3%), Other depsides (1%), Ascorbic acid (1-2%), Gallic acid (0.5%), Quinic acid (2%), other organic acids (4-5%), Theanine (4-6%), Other amino acids (4-6%), Methylxanthines (7-9%), carbohydrates (10-15%), Minerals (6-8%) and Volatiles (0.02%) (Usmani et al., 2016).
There are different types of green teas which vary due to the different steps taken like steaming, pan-firing, rolling etc during its processing. Some popular varieties of green teas are Dragonwell, Genmai Cha, Gunpowder, Gyokuro, Hojicha, Sencha etc (Brand India Plantations, 2019; Teaclass, n.d.-e).

iii. **Oolong tea:** The word "Oolong" means black dragon. The oolong teas are the intermediate of green and black teas. It is a semi-fermented tea. The plucked leaves are withered to reduce the moisture content; and then rolled (twisting, curling into tight balls etc). The leaves are then left to oxidise for a while. The steps of rolling and oxidizing may be repeated several times to create different aromas and flavours (Teaclass, n.d.-e).
In the process of oxidation, lower temperatures are required which will delay the process of oxidation. Thus, making the processing complicated and time taking. Each 100ml of oolong tea is composed of Catechin (1.65 mg), Gallocatechin (6.68 mg), Epigallocatechin (16.14 mg), Epicatechin (5.08

mg), Catechin gallate (0.6 mg), Epicatechin gallate (5.73 mg), Epigallocatechin gallate (25.73 mg), Allocatechin gallate (1.85 mg), Gallic acid (2.19 mg), Caffeine (23.51 mg), Polymerized (33.65 mg), Total polyphenols (99.32 mg) (Weerawatanakorn et al., 2015).
The oolong teas have fragment flavour and sweet aromas which makes it great in taste. It is recommended for those who prefer lower caffeine in their tea (Brand India Plantations, 2019; Teaclass, n.d.-e).

iv. **Black tea:** It is the most common type of tea. The processing of tea leaves involve all the five steps of processing: plucking, withering, rolling, oxidizing and firing. But none of the steps are repeated. A batch of black tea can be processed within a day (Teaclass, n.d.-e).
The infused tea leaves give a dark brown colour. The taste varies greatly from sweet, flowery, malty, spicy to nutty (Teaclass, n.d.-e).
The composition of black tea leaves are Catechins (3–10%), Theaflavins (3– 6%), Carbohydrates (15%), Thearubigins (12–18%), Protein (1%), Flavonols (6– 8%), Mineral matter (10%), Phenolic acids (10–12%), Volatiles (1%), Amino acids (13–15%) and Methylxanthine (8–11%) (Butt, Imran, et al., 2014).

v. **Pu-erh:** It is different from all the types of tea. It is derived from the assamica variety of *Camellia sinensis*. During its processing, both fermentation and oxidation methods are involved. Pu-erh is divided into two categories:

   a. **Raw (Sheng) Pu-erh:** It's processing involves withering, rolling, re- wetting and pan-firing. The process will take several years, hence is also known as "living tea" and is the most expensive tea (Teaclass, n.d.-b).

   b. **Ripened (Shou) Pu-erh:** The processing is faster than that of raw pu-erh. It takes around 3 months time to undergo deeper aging process by piling the leaves together and addition of moisture to encourage oxidation and fermentation. Since, the aging process is shortened, so the leaves are less expensive than the raw counterparts. The colour is also deeper and its texture is thick and full (Teaclass, n.d.-b).

SOME BENEFICIAL PROPERTIES OF TEA

Tea is safe for consumption:

Tea is classified into the "Generally Regarded as Safe" category (Stargrove et al., 2007).

Low calorific value

A plain cup of tea offers 2 calories per cup of tea (240 ml). It is negligible, and can be said that tea has no role in the addition of calories in our body (Lang, 2019).

Reduces blood pressure level:

The polyphenols present in the tea have some anti-oxidant activity which influences the blood pressure level in humans. Regular consumption of tea at around 120ml per day lowers the development of hypertension in Chinese population (Negishi et al., 2004; Yang et al., 2004).

Controls cardio-vascular diseases (CVD):

A study by Steptoe et al., 2007 showed that consumption of tea for six weeks lowers the aggregation of monocytes, neutrophils and leukocytes by 9%. The polyphenols reduces the activation of platelets while the inhibitory effect of arachidonic acid (peroxinitrite) on platelet aggregation is eliminated by EGCG (epigallocatechin gallate). Thus, the inflammation is reduced which will help against CVD.

A great source of anti-oxidants:

Tea contains EGCG which traps the reactive oxygen species (ROS) such as superoxide radicals, single oxygen of hydroxyl and peroxyl, nitrogen dioxide, etc. These ROS damage the cells by targeting the lipid membranes, nucleic acids and proteins. Thus, by reacting with the ROS, the anti-oxidants in tea ensure a longer and healthy life of the cells. The anti-oxidant capacity of the plasma of healthy adults has also improved within an hour of consumption of tea (Hayat et al., 2015). Khan

and Mukhtar, 2007 have also stated that regular intake of tea and tea extracts for four weeks reduces the biomarkers for ROS.

Effect on brain and psychology:

The catechins present in the tea access the barrier of brain and prevent neuronal death with the help of its anti-oxidant, anti-inflamatory and metal chelating properties (Hayat et al., 2015). Niu et al., 2009 reported that Japanese individuals aged above 70 consuming green tea had lower depression levels.

As neurotransmitter:

Green tea contains the amino acid theanine, which reduces the blood pressure and generates alpha waves that produce a relaxing nature in humans. Thus, theanine acts as a neurotransmitter and is used as a medical food for relaxation and reduction of stress (Hayat et al., 2015).

Shankar et al., 2007 suggested that green tea reduces the risk of cancer and diabetes while Panagiotakos et al., 2009 found that consumption of black tea for a long time can lower the occurrence of diabetes. Black tea contains compounds such as anthocyanins, catechins, gallic acid, polyphenols and some polysaccharides which inhibits the functioning of the enzymes- alpha-glucosidase and alpha-amylase that in turn impairs the carbohydrate digestion (Hayat et al., 2015).

Reduces obesity:

The consumption of different varieties of tea contains catechins that help to reduce the body weight, plasma triglyceride and cholesterols (Khan & Mukhtar, 2007; Kuo et al., 2005; Lin & Lin-Shiau, 2006; Murase et al., 2002; Zheng et al., 2004).

Strengthens bones and anti-arthritis in nature:

Green tea restrains the function of cytokine IL-17 which is inflammatory in nature and also prevents the action of antibodies Bhsp65 which is an arthritis inducing protein. Further, the production of cytokine IL-10, an anti-inflammatory substance is favoured, thus green tea acts as a shield against rheumatoid arthritis (Kim et al., 2008). Hayat et al., 2015 reported that higher consumption of black tea (more than four cups a day) increases the Bone mineral density (BMD) especially in older women. It may be due to the presence of caffeine, fluoride and phytoestrogens in tea. According to Kanis et al., 1999, black tea can reduce the occurrence of hip fracture in men in the study of Mediterranean Osteoporosis.

Fights cancer:

The polyphenols present in the tea contains powerful anti-oxidants that detoxify the phase 2 enzymes, which will then reduce the damage done to DNA. The changes in DNA i.e. mutation is therefore reduced, thus reducing the chances of occurrence of cancer (Beltz et al., 2006; Sharangi, 2009; Shim et al., 1995). Butt and Sultan, 2009 also reported the anti-carcinogenic and anti-mutagenic effects of green tea. Tea has been known to protect against cancers of prostrate, lungs, liver and breast (Hayat et al., 2015).

Anti-microbial and probiotic properties:

Tea extracts are known to have anti-bacterial activity which inhibits the strains of *Salmonella typhimurium* and *Staphylococcus aureus*. The EGCG present in tea have anti-viral properties as it restricts the HIV infection and the polyphenols in tea are known to inhibit rotavirus and influenza A (Banerjee et al., 2005; Khan & Mukhtar, 2007; Nance & Shearer, 2003). Tea also helps in the growth of beneficial enterobacteria like *Lactobacilli* and *Bifidobacteria* (Weisburger, 1999).

CONCLUSION

The elixir of life, tea, originated in China but today India is the second highest producer and consumer of tea in the world. The original tea comes from the plant, *Camellia sinensis varsinensis*, and it is the source of all the varieties of tea. Chemically, the composition of the different varieties of tea varies in proportion but the constituents are same. White tea has the highest anti-oxidant properties while the caffeine concentration is more in black tea. However, we may get almost the same benefits from the different varieties of tea, though it may be more or less depending upon the varieties of tea. We should be aware of the brands fooling us by selling the different varieties of tea mentioning various health benefits. All the varieties of tea have properties that enhance our health. The caffeine concentration in tea is comparatively lesser

than the other drinks like coffee. Tea is also regarded as safe and a plain cup of tea has negligible calories, so, we should enjoy a cup of tea daily to lead a happy and healthy life.

REFERENCES

Banerjee, S., Manna, S., Saha, P., Kr Panda, C., & Das, S. (2005). Black tea polyphenols suppress cell proliferation and induce apoptosis during benzo(a)pyrene-induced lung carcinogenesis. *European Journal of Cancer Prevention*, *14*(3). https://doi.org/10.1097/00008469-200506000-00004

Beltz, L. A., Bayer, D. K., Moss, A. L., & Simet, I. M. (2006). Mechanisms of cancer prevention by green and black tea polyphenols. *Anti-Cancer Agents in Medicinal Chemistry*, *6*(5). https://doi.org/10.2174/187152006778226468

Bhatia, I. (1961). Composition of leaf in relation to liquor characters of made tea. *Two and a Bud*, *8*(3).

Brand India Plantations. (2019). *Origin of indian tea*. https://www.teacoffeespiceofindia.com/tea/tea-origin

Butt, M. S., Imran, A., Sharif, M. K., Ahmad, R. S., Xiao, H., Imran, M., & Rsool, H. A. (2014). Black tea polyphenols: A mechanistic treatise. *Critical Reviews in Food Science and Nutrition*, *54*(8). https://doi.org/10.1080/10408398.2011.623198

Butt, M. S., & Sultan, M. T. (2009). Green tea: Nature's defense against malignancies. *Critical Reviews in Food Science and Nutrition*, *49*(5). https://doi.org/10.1080/10408390802145310

Chen, Y. L., Duan, J., Jiang, Y. M., Shi, J., Peng, L., Xue, S., & Kakuda, Y. (2010). Production, quality, and biological effects of oolong tea (Camellia sinensis). *Food Reviews International*, *27*(1). https://doi.org/10.1080/87559129.2010.518294

Ercisli, S., Orhan, E., Ozdemir, O., Sengul, M., & Gungor, N. (2008). Seasonal variation of total phenolic, antioxidant activity, plant nutritional elements, and fatty acids in tea leaves (Camellia sinensis var. sinensis clone Derepazari 7) grown in Turkey. *Pharmaceutical Biology*, *46*(10-11). https://doi.org/10.1080/13880200802215818

Harbowy, M. E., Balentine, D. A., Davies, A. P., & Cai, Y. (1997). Tea chemistry. *Critical Reviews in Plant Sciences*, *16*(5). https://doi.org/10.1080/07352689709701956

Hayat, K., Iqbal, H., Malik, U., Bilal, U., & Mushtaq, S. (2015). Tea and its consumption: Benefits and risks. *Critical Reviews in Food Science and Nutrition*, *55*(7). https://doi.org/10.1080/10408398.2012.678949

Kanis, J., Johnell, O., Gullberg, B., Allander, E., Elffors, L., Ranstam, J., Dequeker, J., Dilsen, G., Gennari, C., Vaz, A. L., Lyritis, G., Mazzuoli, G., Miravet, L., Passeri, M., Cano, R. P., Rapado, A., & Ribot, C. (1999). Risk factors for hip fracture in men from southern europe: The MEDOS study. *Osteoporosis International*, *9*(1). https://doi.org/10.1007/s001980050115

Keelery, S. (2019). *Consumption volume of tea in india from financial year 2015 to 2019*. Statista Research Development, India. https://www.statista.com/statistics/870829/india-consumption-volume-of-tea/

Khan, N., & Mukhtar, H. (2007). Tea polyphenols for health promotion. *Life Sciences*, *81*(7). https://doi.org/10.1016/j.lfs.2007.06.011

Kim, H. R., Rajaiah, R., Wu, Q.-L., Satpute, S. R., Tan, M. T., Simon, J. E., Berman, B. M., & Moudgil, K. D. (2008). Green tea protects rats against autoimmune arthritis by modulating disease-related immune events. *The Journal of Nutrition*, *138*(11). https://doi.org/10.3945/jn.108.089912

Kuo, K.-L., Weng, M.-S., Chiang, C.-T., Tsai, Y.-J., Lin-Shiau, S.-Y., & Lin, J.-K. (2005). Comparative studies on the hypolipidemic and growth suppressive effects of oolong, black, pu-erh, and green tea leaves in rats. *Journal of Agricultural and Food Chemistry*, *53*(2). https://doi.org/10.1021/jf049375k

Lang, A. (2019). *Does tea contain calories? all you need to know*. https://www.healthline.com/nutrition/tea-calories

Lin, J.-K., & Lin-Shiau, S.-Y. (2006). Mechanisms of hypolipidemic and anti-obesity effects of tea and tea polyphenols. *Molecular Nutri-*

tion & Food Research, *50*(2). https://doi.org/10.1002/mnfr.200500138

Murase, T., Nagasawa, A., Suzuki, J., Hase, T., & Tokimitsu, I. (2002). Beneficial effects of tea catechins on diet-induced obesity: Stimulation of lipid catabolism in the liver. *International Journal of Obesity*, *26*(11). https://doi.org/10.1038/sj.ijo.0802141

Nance, C. L., & Shearer, W. T. (2003). Is green tea good for HIV-1 infection? *Journal of Allergy and Clinical Immunology*, *112*(5). https://doi.org/10.1016/j.jaci.2003.08.048

Negishi, H., Xu, J.-W., Ikeda, K., Njelekela, M., Nara, Y., & Yamori, Y. (2004). Black and green tea polyphenols attenuate blood pressure increases in stroke-prone spontaneously hypertensive rats. *The Journal of Nutrition*, *134*(1). https://doi.org/10.1093/jn/134.1.38

Niu, K., Hozawa, A., Kuriyama, S., Ebihara, S., Guo, H., Nakaya, N., Ohmori-Matsuda, K., Takahashi, H., Masamune, Y., Asada, M., Sasaki, S., Arai, H., Awata, S., Nagatomi, R., & Tsuji, I. (2009). Green tea consumption is associated with depressive symptoms in the elderly. *The American Journal of Clinical Nutrition*, *90*(6). https://doi.org/10.3945/ajcn.2009.28216

Panagiotakos, D. B., Lionis, C., Zeimbekis, A., Gelastopoulou, K., Papairakleous, N., Das, U. N., & Polychronopoulos, E. (2009). Long-term tea intake is associated with reduced prevalence of (type 2) diabetes mellitus among elderly people from mediterranean islands: MEDIS epidemiological study. *Yonsei medical journal*, *50*(1). https://doi.org/10.3349/ymj.2009.50.1.31

Pawar, H. A. (2018). White tea a day keeps disease away: A review. *Current Trends in Biomedical Engineering & Biosciences*, *15*(5). https://doi.org/10.19080/ctbeb.2018.15.555925

Preedy, V. R. (Ed.). (2013). *Tea in health and disease prevention*. Elsevier. https://doi.org/10.1016/c2010-0-64948-0

Shankar, S., Ganapathy, S., & Srivastava, R. K. (2007). Green tea polyphenols: Biology and therapeutic implications in cancer. *Front Biosci*, *12*(4881-4899).

Sharangi, A. B. (2009). Medicinal and therapeutic potentialities of tea (Camellia sinensis L.) – a review. *Food Research International*, *42*(5-6). https://doi.org/10.1016/j.foodres.2009.01.007

Shim, J. S., Kang, M. H., Kim, Y. H., Roh, J. K., Roberts, C., & Lee, I. P. (1995). Chemopreventive effect of green tea (Camellia sinensis) among cigarette smokers. *Cancer Epidemiology and Prevention Biomarkers*, *4*(4).

Stargrove, M. B., Treasure, J., & McKee, D. L. (2007, December 6). *Herb, nutrient, and drug interactions: Clinical implications and therapeutic strategies*. Elsevier Health Sciences.

Szenthe, A. (2019). *The world's top 10 tea producing nations*. Retrieved 2019, from https://www.worldatlas.com/articles/the-worlds-top-10-tea-producing-nations.html

Tea Epicure. (n.d.). *Chemical compounds in tea*. https://teaepicure.com/tea-chemistry/

Teaclass. (n.d.-a). *How is tea made?* https://www.teaclass.com/lesson_0106.html

Teaclass. (n.d.-b). *Pu-erh*. https://www.teaclass.com/lesson_0208.html

Teaclass. (n.d.-c). *Tea stories*. https://www.teaclass.com/lesson_0107.html

Teaclass. (n.d.-d). *The truth about caffeine*. https://www.teaclass.com/lesson_0112.html

Teaclass. (n.d.-e). *Types of tea*. https://www.teaclass.com/lesson_0102.html

TRA Tocklai. (n.d.). *Tea chemistry*. https://www.tocklai.org/activities/tea-chemistry/

Usmani, A., Mishra, A., Mujahid, M., Aftab, M., & Ahmad, A. (2016). An amazing herb with extraordinary payback: Camellia sinensis. *Research & Reviews: A Journal of Pharmacology*, *6*(2).

Weerawatanakorn, M., Hung, W.-L., Pan, M.-H., Li, S., Li, D., Wan, X., & Ho, C.-T. (2015). Chemistry and health beneficial effects of oolong tea and theasinensins. *Food Science and Human Wellness*, *4*(4). https://doi.org/10.1016/j.fshw.2015.10.002

Weisburger, J. H. (1999). Tea and health: The underlying mechanisms. *Proceedings of the Society for Experimental Biology and*

Medicine, *220*(4). https://doi.org/10.1046/j.1525-1373.1999.d01-46.x

Williaamson Tea. (2019, December 24). *Tea, the elixir of life.* https://www.williamsontea.com/health/tea-elixir-life/

Yang, Y.-C., Lu, F.-H., Wu, J.-S., Wu, C.-H., & Chang, C.-J. (2004). The protective effect of habitual tea consumption on hypertension. *Archives of Internal Medicine*, *164*(14). https://doi.org/10.1001/archinte.164.14.1534

Zhen, Y.-S. (2002). *Tea : Bioactivity and therapeutic potential* (Y.-S. Zhen, Ed.). CRC Press. https://doi.org/10.1201/b12659

Zheng, G., Sayama, K., Okubo, T., Juneja, L. R., & Oguni, I. (2004). Anti-obesity effects of three major components of green tea, catechins, caffeine and theanine, in mice. *In Vivo*, *18*(1).

ABOUT THE COVERS

The cover design of this volume is primarily made of three pictures. The edited photo of the sculpture '*the Thinker*'[1] by the French sculptor Auguste René Rodin is placed on the top right of the front page. The image represents for us the simple fact that science is all about human thought - nature is what she is, but, debatably, science is all about what can be grasped by the human mind.

The second image is that of '*The Great Wave off Kanagawa*'[2] a woodblock print by the Japanese artist Katsushika Hokusai and is placed at the bottom of the front page. The allegory that we saw in the image is the transience of even the mighty waves of the sea and it is used to emphasise the title of the journal - **Transient**. The acknowlegement of the transience of human understanding is an essential gear in the machinery that makes science work and helps avoid dogma; our currently most successful theories are at best a trivial limiting case of the next great revolution in scientific understanding.

The third image used is the panoramic picture[3] of the college campus of Don Bosco College, Tura, placed on bottom of the back cover. This image is a dedication to the support rendered by the esteemed institution in making the publication of this journal possible.

Attribution:

1. Andrew Horne, Public domain, via Wikimedia Commons.
2. Katsushika Hokusai, Public domain, via Wikimedia Commons.
3. Don Bosco College, Tura, With permission.

ISSN: 2250-0650

TRANSIENT

A Journal of Natural Sciences and Allied Subjects
(a peer reviewed Journal)
VOLUME VIII 2019-20

ABOUT THE JOURNAL

Transient - A Journal of Natural and Allied Subjects - A peer reviewed journal (ISSN: 2250-0650) is published by Don Bosco College, Tura since 2011. The journal from its inception (this being its 8th volume) has been involved in catering to the needs of the students, researchers and faculty in the field of natural and allied sciences. It has been a platform to publish ideas, scientific queries and critical views and also communicate observations in the field of science. It is of prerogative that the journal provide space for sharing of opinions by upcoming and young research scholars, particularly in fields of interdisciplinary research. The journal provides a canvas to the scholars to showcase their findings and to augment the existing knowledge bank of the world. Before a paper gets published in the journal, the manuscript first undergoes a preliminary screening and then is sent for peer-review by experts in relevant fields and then a final scrutiny by the editorial board. If the paper (manuscript) fulfils the standards of the journal then the paper gets published.

ABOUT THE COLLEGE

Don Bosco College, Tura, established in 1987 and accredited by NAAC with 'B' in 2011, is an educational institution established by Don Bosco International Education Society. The College is affiliated to the North-Eastern Hill University (NEHU) for the degree courses in Arts, Science and Commerce. The College has the avowed mission of bringing holistic higher education within easy reach of the people of Garo Hills in Meghalaya and North East India. True to its motto *'In Pursuit of Excellence'*, the college is passionate about excellence in every sphere of academic knowledge, value education and social responsibility, and labours tirelessly to produce well founded men and women with a sense of civic consciousness and outlook.