Editor Profile

Dr. Deiborlang Nongsiang

Dr. Deiborlang Nongsiang is an Assistant Professor in the Department of Mathematics, Union Christian College, Meghalaya, India. He has published 6 papers in International peer reviewed journals. His area of research is group theory, graph theory and poset theory. He is also currently the Regional Co-ordinator of the Indian National Mathematical Olympiad (INMO), Meghalaya Region.

Prof. Dibyendu Paul

Prof. Dibyendu Paul is a Ph. D in Ecology (Entomology) from North Eastern Hill University (NEHU), and is currently Head of the Department of Environmental Studies. His current research focuses around Biopesticides, Bioresource utilization for value added products and Pollution abatement through biotic interventions.Professor D. Paul has more than 30 publications in peer reviewed international and national journals and is member of different Scientific committees and Academic bodies of other Universities and expert committees of NGOs and State Government. He has successfully completed 20 externally funded research projects. Professor Paul has wide experience in EIA and EMP related work and has collaborated with Power Grid, Reliance Power, Tato, JICA, LaFarge, MCL, MottMacDonald. MBB and BARC for their impact assessment studies and environmental monitoring and management planning requirements.

Dr. Jimcarbrist P. Marak

Dr. Jimcarbrist P. Marak, Assistant Professor, is currently teaching in the department of Botany, Union Christian College, Meghalaya. He has done his specialization in Forest Ecology and has been working on provenance variations of important timber tree species in Meghalaya. His other area of research includes silviculture, conservation biology, ecological restoration and watershed management. He is presently working on variations of wood density and mechanical properties of Pinus kesiya in Meghalaya.

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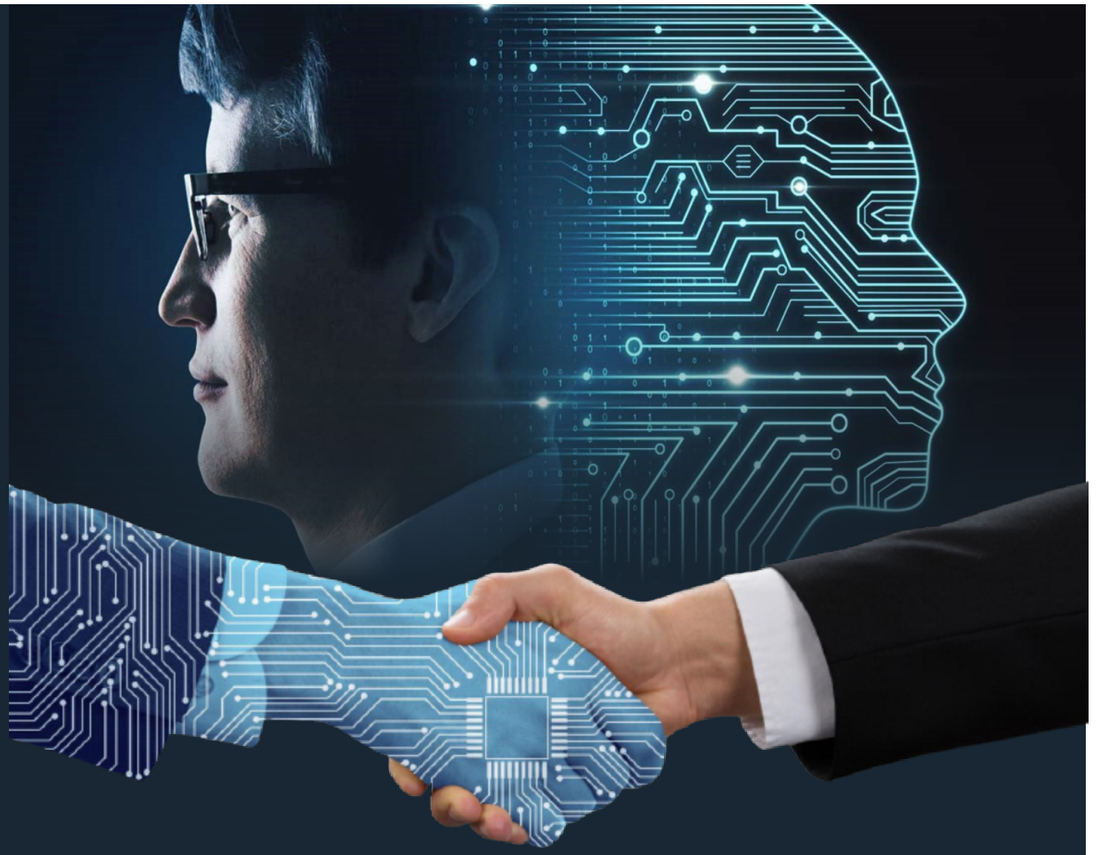

Recent Advancements in Science and Technology

Dr. Deiborlang Nongsiang **Prof. Dibyendu Paul**

Dr. Jimcalbrist P. Marak

RECENT ADVANCEMENTS IN SCIENCE AND TECHNOLOGY

Dr. Deiborlang Nongsiang

Assistant Professor, Department of Mathematics, Union Christian College, Umiam Khwan, Meghalaya, India-793122.

Prof. Dibyendu Paul

Professor, , North-Eastern Hill University, Umshing Mawkynroh, Shillong, Meghalaya, India-793022.

Dr. Jimcarbrist P. Marak

Assistant Professor, Department of Botany, Union Christian College, Umiam Khwan, Meghalaya, India-793122.

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This book is dedicated to the memory of

(L) P. A. Sangma
Former Speaker of the Lok Sabha
(1st September 1947- 4th March 2016)

PREFACE

Science and Technology has always been the decisive field of human activity that moulded the development of the modern world: from the period of the Industrial Revolution to the technological revolution we experience today. The role of science and technology has become inextricable to human existence and survival. New technological innovations which gained acceleration in the 20th century have become an integral part of life in the 21st century.

India's contribution to the world of science and technology is immense. Our country could boast pioneering some of the foundations in the fields of Mathematics, Architecture, Astronomy, Medicine, Physics, and Natural Philosophy. Today, India can reap the benefits from the applications of its scientific contribution. Many scientific researchers in the field of Pharmaceuticals, Nuclear Energy, Space Technology, Biotechnology, Electronics and others have helped to transform the economic status of India and created spaces for the younger generation to grow and flourish in a technologically advanced environment.

Technological development in any field enhances the economy of any nation. In order to improve the power of science and technology in India, the Indian government has formed the Council of Scientific and Industrial Research in the year 1942, and the Board of Scientific and Industrial Research in the year 1940. In order to emphasize the growth of science and technology in the country, the Indian government has established a chain of national laboratories and research institutes in various regions.

After independence, our country has been involved in the promotion of science for national development. A variety of policies by the government has emphasized self-sufficiency, sustainable growth and development all through the country. Both science and technology have impacted the economic growth and social development in the country in an extraordinary manner.

This volume, is the outcome of the National Conference on "Recent Advancements in Science and Technology" held at Union Christian College from the 12th - 14th June 2019, seeks to understand the advancements in science and technology during the year 2019.

Editors
Dr. Deiborlang Nongsiang
Prof. Dibyendu Paul
Dr. Jimcarbrist P. Marak

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LIST OF CONTRIBUTING AUTHORS
(IN ALPHABETICAL ORDER)

1. Aibanjop Pyngrope, Research Scholar, Department of Physics, North-Eastern Hill University, Shillong, Meghalaya, India.

2. Alfanel Khardewsaw, Research Scholar, Department of Physics, North-Eastern Hill University, Shillong, Meghalaya, India.

3. Andrew Cuthbert Lyngdoh, Scientist E (Director), Central Seismological Observatory, Shillong, Meghalaya, India.

4. Atul Saxena, Professor, Department of Physics, North-Eastern Hill University, Shillong, Meghalaya, India.

5. Balawan Joshua Mawrie, Research Scholar, Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, India.

6. Barikor C. Warjri, Assistant Professor, Department of Allied Health Sciences, Martin Luther Christian University, Shillong, Meghalaya, India.

7. Bethesda Sumer, Student, Department of Environmental Science, St. Edmund's College, Shillong, Meghalaya, India.

8. Binod Chetry, Assistant Professor, Department of Mathematics, Digboi College, Digboi, Assam, India.

9. Bonnie Nicole, Associate Professor, Department of Allied Health Sciences, Martin Luther Christian University, Shillong, Meghalaya, India.

10. Damewanmi Suchiang, Assistant Professor, Department of Environmental Science, St. Edmund's College, Shillong, Meghalaya, India.

11. Deiborlang Nongsiang, Assistant Professor, Department of Mathematics, Union Christian College, Umiam, Meghalaya, India.

12. Devesh Walia, Professor, Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, India.

13. Deveshwori Maibam, Assistant Lecturer, Don Bosco College of Teacher Education, Tura, Meghalaya, India.

14. Diamond Salahe, Research Scholar, Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, India.

15. Dibyendu Paul, Professor, Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, India.

16. Double M. Siangshai, Research Scholar, Department of Physics, North-Eastern Hill University, Shillong, Meghalaya, India.

17. Emidaoopaya Sumer, Assistant Professor, Department of Environmental Science, St. Edmund's College, Shillong, Meghalaya, India.

18. Glenn Christo Kharkongor, Professor, Department of Allied Health Sciences, Martin Luther Christian University, Shillong, Meghalaya, India.

19. Jasmine T. Sawian, Assistant Professor, Department of Environmental Science, St. Edmund's College, Shillong, Meghalaya, India.

20. Jimcarbrist P. Marak, Assistant Professor, Department of Mathematics, Union Christian College, Umiam, Meghalaya, India.

21. Krishna Upadhaya, Assistant Professor, Department of Basic Sciences and Social Sciences, North-Eastern Hill University, Shillong, Meghalaya, India.

22. Kuno Chuzho, Research Scholar, Microbial Ecology Laboratory, Department of Botany, North-Eastern Hill University, Shillong, Meghalaya, India.

23. Laldingliani Pachuau, Research Sclolar, Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, India.

24. Laribha Dohtdong, Research Scholar, Department of Allied Health Sciences, Martin Luther Christian University, Shillong, Meghalaya, India.

25. Larihun Jeengaph, Assistant Professor, Department of Environmental Science, St. Edmund's College, Shillong, Meghalaya, India.

26. M. Wanlambok Sanglyne, Research Scholar, Department of Botany, North Eastern Hill University, Shillong, Meghalaya, India.

27. Mamtaj S. Dkhar, Professor, Microbial Ecology Laboratory, Department of Botany, North-Eastern Hill University, Shillong, Meghalaya, India.

28. Mary Lalthakimi, Students, Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, India.

ABBREVIATIONS

BD	-	Brans-Dicke
BDL	-	Below Detectable Limit
DDT	-	Dichlorodiphenyltrichloroethane
DE	-	Dark Energy
FFQ	-	Food Frequency Questionnaire
FRW	-	Friedman-Robertson-Walker
GR	-	Einstein General Relativity
GSLT	-	Generalised Second Law of Thermodynamics
IMC	-	Indian Major Carps
IMD	-	Indian Meteorological Department
IP	-	Indigenous People
ML	-	Local magnitude
MRL	-	Maximum Residual Levels
PDA	-	Phenol Disulphonic Acid
SA	-	Sensilla Ampullaceal
SB	-	Sensilla Basiconica
SC	-	Sensilla Chaetica
SCa	-	Sensilla Campaniformia
SEM	-	Scanning Electron Microscopy
SP	-	Sensilla Placoidea
SST	-	Scalar-Tensor Theories
STr	-	Sensilla Trichoidea
TE	-	Thermodynamics Equilibrium
THPs	-	Traditional Health Practitioners

CHAPTER 1

Introduction

Deiborlang Nongsiang, Dibyendu Paul &
Jimcarbrist P. Marak

Science and technology plays vital role in the modern life and profoundly influenced the course of human civilization. Technological advancement in the modern life has provided us lots of remarkable insights all over the world. Scientific revolutions has taken its full speed from the 20th century and has become more advance in the 21st century. We have entered to the new century in new ways and with all the arrangements for wellbeing of the people. Modern culture and civilization has become dependent over the science and technologies as they have become integral part of life according to the need and requirement of the people.

India has become an important source of the creative and foundational scientific developments and approaches all across the world. All the great scientific discoveries and technological achievements in our country have improved the Indian economic status and have created many new ways to the new generations to grow in the technologically advanced environment. There are many new scientific researches and development have been possible in the field of Mathematics, Architecture, Chemistry, Astronomy, Medicine, Metallurgy, Natural Philosophy, physics, agriculture, health care, pharmaceuticals, astrophysics, nuclear energy, space technology, applications, defence research, biotechnology, information technology, electronics, oceanography and other areas. Many researchers are undergoing research in many fields of Science and Technology.

In the theory of finite groups, one of the fields of mathematics, one of the major problems is the classification of finite nonabelian groups: The classification of the abelian ones being long-known. Over the years, a number of mathematicians have developed different types of invariants to tackle this problem. The present book is a small step in this regard, and it also revolves around the above noted classification problem.

Graph theoretic methods, in the last couple of decades, have been use to characterize algebraic structures like rings, lattices, posets as well groups. The

present book relies on the basic philosophy of such methods which is to associates graphs to Specific algebraic structures and then to study correlate properties of graphs and the associated structure. It may be mentioned here that, a graph consists of two nonempty sets V and E together with an injective map from E into the set of all unordered pairs of elements of V. The elements of V are called vertices and those of E are called edges, and two distinct vertices are said to be adjacent if they constitute the image of an edge under the above mentioned one one map.

Let G be a group and $x_1,\ldots,x_n \in G$. For all n>0 we define inductively $[x_1,\ldots,x_n]$ as follows: $[x_1]=x_1$ and $[x_1,\ldots,x_n]=[x_1,...,x_{n-1}]^{-1}x_n^{-1}[x_1,\ldots,x_{n-1}]x_n$ for all n>1. If $x_2=\cdots=x_n$, then we denote $[x_1,\ldots,x_n]$ by $[x_{1\ n-1}\ x_2]$. Note that $[x_1]=[x_{1\ ,0}\ x_2]=x_1$ and $[x_1,x_2]=x_1^{-1}x_2^{-1}x_1\,x_2$. The Engel graph E_G of a non-Engel group G is a simple graph in which the vertices is the set G\L(G), and two distinct vertices are adjacent if and only if $[x,_k\ y]\neq 1$ and $[y,_k\ x]\neq 1$, where L(G) is the set of left Engel elements of G. This graph can be regarded as a generalization of the commuting graph considered by Das and Nongsiang (2016). Abdollahi (2007) studied some graph properties of the non-Engel graph associated to a group. The ever-increasing popularity of the topic is often attributed to a question, posed in 1975 by Paul Erdös and answered affirmatively by Neumann (1976), asking whether or not a noncommuting graph having no infinite complete subgraph possesses a finite bound on the cardinality of its complete subgraphs.

This book, "Recent Advancements in Science and Technology" is the outcome of the papers and discussions of the national colloquium highlighting the desire of the invitees to continue collaborating in areas of common interest. Nongsiang, in his paper, "*The Genus of the Engel Graphs of some Finite Groups"* determines the genus of some well-known classes of finite non-Engel groups and determines the genus of all non-Engel groups of order less than or equal to 30.

The next Chapter by Chetry on "*Thermodynamics Study of some Viable Scalar-Tensor Gravity Models on the Event Horizon"* investigates the validity of the generalised second law of thermodynamics (GSLT) and thermodynamics equilibrium (TE) in the framework of scalar-tensor gravity. He considers the Friedman-Robertson-Walker (FRW) universe filled with ordinary matter and the boundary of the universe bounded by the event horizon that is in thermal equilibrium with modified Hawking temperature. While the thermodynamical laws hold on a universe bounded by the apparent horizon but these laws breakdown on event horizon. By redefining or modifying the thermodynamical parameters (temperature and entropy), it is found that thermodynamical laws hold on the event horizon in Einstein Gravity. Keeping this in mind he derives the general expression for the GSLT and TE using modified Hawking temperature in the context of scalar-tensor gravity. Next, he checks the validity of the GSLT and TE for some viable models in the scalar-tensor gravity at the event horizon. It is worth noting that the deceleration parameter of the selected models approaches de Sitter limit at late times and modified Hawking temperature helps in making these models fit in a perfect thermodynamical system.

Malngiang in his article, "*A Survey on Prime Number Theorem"* examines the connection between Riemann zeta function and prime numbers using Euler's theorem. The incorporation of analytic function and how does logarithm along with the introduction of θ and ψ functions play their role in the conjecture of prime numbers.

Siangshai et al. in their paper, "*Source Mechanisms of Earthquakes Occurred in the Central Part of Shillong Plateau*" study the Shillong plateau as it is considered to be one of the most seismically active and tectonically complex regions. In their study, broadband data from IMD (Indian Meteorological Department) seismic network and from three seismic stations setup in the different parts of the Shillong plateau are used to determine the types and nature of faulting in the study area. They applied the ISOLA computer inversion code to the waveform data, in the frequency range of 0.04 to 0.09 Hz. Recent local earthquakes of magnitude 2 to 4.3 M_L are used in the waveform inversion. The recorded earthquakes are mostly of focal depth less than 30 km. The focal mechanism solutions of the earthquakes shows mainly thrust and strike slip type of faulting.

Pyngrope et al. in their article, "*Comparative Case Study between Bare-Mode Lr-115 Detector Film and Pin-Hole Dosimeter in the Measurement of Indoor Radon"*, carried out a comparative measurement of indoor radon activity as a case study in a test room using two different modes of measurement. The first is bare-mode and the other is Pin-hole based single entry dosimeter; LR-115 film is used in both. They found significant differences in the results from the two techniques; possible causes for the discrepancy are discussed.

Paul and Mawrie in their article, "*Analysis of Dichlorodiphenyltrichloroethane (DDT) in Several Food Items Collected from a Market in Shillong City*" analyse the presence of DDT in food items from *Iewduh* market area. The food samples selected for the purpose of their study included rice, potato, tomato, apple and banana. The residual levels of DDT found in rice and banana samples were below the prescribed MRL values, it still shows that this particular chemical still found its way into our food despite being banned from agricultural use. It shows that there is still a lapse in preventing DDT from reaching our food and also highlights further improvements in ensuring that harmful chemicals do not contaminate our food.

Salahe et al. in their article, "*Ethno-Botanical Knowledge of Medicinal Plants Used by the Jaintias for Treatment of Cancer*" carried out an ethnobotanical survey of plants used for the treatment of cancer in the Jaintia Hills Districts of Meghalaya, India. Information on the plant species, parts used and methods of preparation were collected from the traditional healers. Information collected reveals the presence of 10 plant species belonging to 9 families that are widely used for the treatment of cancer. The parts of the plants used, methods of preparation, dosage and route of administration are discussed in this article.
Pachuau et al. in their article, "*Estimation of Reducing Sugars in Mirabilis Jalapa*

and Sechium Edule and the Production of Bioethanol" study an array of renewable resources such as plant biomass that can be used by microorganisms as the primary carbon source for production of bioethanol and other value added products. *Mirabilis jalapa* seeds and *Sechium edule* as raw materials were treated using the method of separate sachharification and fermentation process for production of bioethanol. The starch test shows 0.044% ± 0.045 of starch in 0.1µg ml^{-1} sample and 0.19% ± 0.004 of starch in 0.03 µg ml^{-1} for *Mirabilis jalapa* and *Sechium edule*respectively. The reducing sugar test reveal reducing sugar content of 0.07% in 0.5µg ml^{-1} *Mirabilis jalapa* and 0.51% in 0.1 µg ml^{-1} *Sechium edule*. Sachharification increased the reducing sugar level by 20% and 2% in *Mirabilis jalapa* and *Sechium edule* respectively. After sachharification process, separate fermentation by the fungus *Aspergillus niger* reduced the sugar to ethanol and carbon dioxide.

Sawian et al. in their article, "*A Study on the Diversity of Faunal Species Found in Myntdu River, West Jaintia Hills District, Meghalaya*" carried out a study on the diversity of fish species, in Myntdu river, which is one of the main rivers of Jaintia Hills. The result of the study reveals that Myntdu River harbours a rich and diversified variety of fishes and plants species. The study also revealed that many species in the study area are being threatened by various human activities. The major activities include habitat modification, removal of riparian vegetation, AMD, destructive fishing, sand mining, disposal of industrial and domestic wastes and agriculture activities. Thus, there is an urgent need for proper investigation and documentation of this fish diversity in order to develop a fresh water fish inventories which may be an elementary step in freshwater biodiversity conservation.

Chuzho and Dkhar in their article, "*Wood-Rotting Fungi of Nagaland*", gave a proper documentation of wood-rotting fungi from Nagaland. They surveyed a total of 8 forest stands of Nagaland located at various altitudes, ranging from 221.28 to 2315.87 msl. A total of 182 specimens were collected, of which 174 specimens were documented. Four species, *Favolaschia calocera*, *Jackrogersella minutela*, *Pholiota polychroa* and *Porodisculus orientalis* and one genus, *Porodisculus* were reported for the first time from India. Diversity and ecological studies showed that Rusoma community forest, located at an altitude of 890.01 msl has the highest species diversity. It was observed that occurrence of wood-rotting fungi depends on various decay stages of wood and majority of the specimens were found growing on wood at intermediate stage of decay.

Dohtdong et al. in their article, "*Indigenous Dietary Practices and Traditional Knowledge among Khasi Youth, Mylliem Block, Meghalaya*" assess the consumption pattern of traditional food among the Khasi youth of Mylliem Block, East Khasi Hills District, Meghalaya and to document on the therapeutic purpose of indigenous food.

Sanglyne and Ramanujam in their article, "*Study of Trophic Status of few Important Water Bodies in Shillong and around using Algal Index*" used a simple and useful index known as Nygaard's index to indicate the status of few important water bodies of Shillong and around. According to Nygaard, compound index value below 1 indicates the status of the water body as Oligotrophic (clean unpolluted) and above 1 it is Eutrophic (organically polluted). Based on this, all the water bodies studied are in different level of eutrophication. In Ward's Lake and in Umiam reservoir which are important tourist spots and are under regular cleaning process, the compound index values obtained are 2.49 and 2.37 respectively. But, the two rivers Umkhrah and Umshyrpi which are flowing through the city are at alarming state of pollution. Umkhrah River is 25 whereas it is 17 for Umshypi River. This indicates that the rivers are in serious state and need immediate measures to stop the pollution.

Dhar and Paul in their article, "*Sequestration of Exhaust Fume Gases by the Freshwater Alga Spirogyra Species*" deals with sequestration of exhaust gases by freshwater alga *Spirogyra* species, which, revealed that the freshwater macro alga possesses properties of carbon dioxide sequestration when the algae was subjected to exhaust gases, produced by burning petrol.

REFERENCES

Abdollahi, A. (2007). Engel graph associated with a group. *Journal of Algebra 318*, 680–691.

Neumann, B. H. (1976). A problem of Paul Erdös on groups. *Journal of the Australian Mathematical Society (Series A), 21*, 467–472.

Das, A. K., & Nongsiang, D. (2016). On the genus of the commuting graphs of finite non-abelian groups. *International Electronic Journal of Algebra, 19*, 91-109.

CHAPTER 2

The Genus of the Engel Graphs of some Finite Groups

Deiborlang Nongsiang

Introduction

Let G be a group and $x_1,\ldots,x_n \in G$. For all n>0 we define inductively $[x_1,\ldots,x_n]$ as follows: $[x_1]=x_1$ and $[x_1,\ldots,x_n]=[x_1,...,x_{n-1}]^{-1}x_n^{-1}[x_1,\ldots,x_{n-1}]x_n$ for all n>1. If $x_2=\cdots=x_n$, then we denote $[x_1,\ldots,x_n]$ by $[x_1,_{n-1}x_2]$. Note that $[x_1]=[x_1,_0 x_2]=x_1$ and $[x_1,x_2]=x_1^{-1}x_2^{-1}x_1x_2$. An element x of G is called left Engel if for every element a of G, there exists a positive integer k such that $[a,_k x]=1$. The sets of all left Engel elements of G is denoted by L(G). A group G is called an Engel group, if L(G)=G. Associate with a non-Engel group G a (simple) graph E_G as follows: Take G\L(G) as vertices of E_G and join two distinct vertices x and y whenever $[x,_k y]\neq 1$ and $[y,_k x]\neq 1$ for all positive integers k. We call E_G, the Engel graph of G. Abdollahi (2007), studied some graph properties of the non-Engel graph associated to a group. The primary objective of this chapter is to determine the genus of some well-known classes of finite non-Engel groups and to determine the genus of all non-Engel groups of order less than or equal to 30.

Some Prerequisites

In this section, we recall certain graph theoretic terminologies (see, for example, West (2009) and White (1973)) and some well-known results which have been used extensively in the forthcoming sections. Note that all graphs considered in this and the following sections are simple graphs, that is, graphs without loops or multiple edges. Let Γ be a graph with vertex set V(Γ) and edge set E(Γ). Let x,y V(Γ). Then x and y are said to be adjacent if $x\neq y$ and there is an edge x-y in E(Γ) joining x and y. A path between x and y is a sequence of adjacent vertices often written as $x\text{-}x_1\text{-}x_2\text{-}\ldots\text{-}x_n\text{-}y$, where the vertices $x,x_1,x_2,\ldots,x_n,y$ are all distinct. Γ is said to be *connected* if there is a path between every pair of distinct vertices in Γ. A cycle is a sequence of adjacent vertices, $x\text{-}x_1\text{-}x_2\text{-}\ldots\text{-}x_n\text{-}x$, where the vertices $x,x_1,x_2,\ldots,x_n$ are all distinct. The number of edges in a path or a cycle, is called its *length*. A cycle of length n is called an n-cycle, and a 3-cycle is also called a triangle. The *girth* of Γ is the minimum of the lengths of all cycles in Γ, and is denoted by girth(Γ). If Γ is acyclic, that is, if Γ has no cycles, then we write girth(Γ)=∞. A graph Γ is said to be complete if there is an edge between every pair of distinct vertices in Γ. We denote the complete graph with n vertices by K_n. A

bipartite graph is the one whose vertex set can be partitioned into two disjoint parts in such a way that the two end vertices of every edge lie in different parts. Among the bipartite graphs, the complete bipartite graph is the one in which two distinct vertices are adjacent if and only if they lie in different parts. The complete bipartite graph, with parts of size m and n, is denoted by $K_{m,n}$. A complete multi-partite graph is the one whose vertex set can be partitioned into m disjoint parts in such a way that two vertices are adjacent if and only if they lie in different parts. The complete multi-partite graph, with parts of size $n_1,\ldots,n_m$, is denoted by $Kn_1,\ldots,n_m$. If $n_1=n_2=\cdots=n_m$, then the complete multi-partite graph is denoted by $K_{m(n)}$.

The genus of a graph Γ, denoted by γ(Γ), is the smallest non-negative integer n such that the graph can be embedded on the surface obtained by attaching n handles to a sphere. Clearly, if $\tilde{\Gamma}$ is a subgraph of Γ, then $\gamma(\tilde{\Gamma})\leq\gamma(\Gamma)$. Graphs having genus zero are called planar graphs, those having genus one are called toroidal graphs, those having genus two are called double-toroidal graphs and those having genus three are called triple-toroidal graphs.

We conclude the section with the following useful results.

Lemma 2.1 (White (1973)**, Theorem 6-38)** *If n≥3, then*

$$\gamma(K_n) = \left\lceil \frac{(n-3)(n-4)}{12} \right\rceil.$$

Lemma 2.2 (White (1973)**, Theorem 6-37)** *If m,n≥2, then*

$$\gamma(K_{m,n}) = \left\lceil \frac{(m-2)(n-2)}{4} \right\rceil.$$

Lemma 2.3 (White (1973)**, Theorem 6-39)** *If m and n are positive integers, then*

$$\gamma(K_{mn,n,n}) = \frac{(mn-2)(n-1)}{2}.$$

Lemma 2.4 (White (1973), **Theorem 6-43)** *If n is a positive integer, n≠2 (mod 3), then*

$$\gamma(K_{n(2)}) = \frac{(n-3)(n-1)}{3}.$$

Lemma 2.5 (White (1973), **Theorem 6-42)** *If n is a positive integer, n≠3, then*

$$\gamma(K_{4(n)}) = (n-1)^2.$$

Lemma 2.6 (White (1973), **Section 2.3)** *If Γ is a connected graph (but not acyclic) having n vertices and m edges, then*

$$\gamma(\Gamma) \geq \frac{m(k-2)}{2k} - \frac{n}{2} + 1$$

where k=*girth*(Γ).

Genus of the Engel Graphs of some Well-Known Finite Groups

In this section, we determine the genus of the Engel graphs of some well-known finite non-Engel groups.

Given t≥1 and m≥3 with m odd, we now compute the genus of the Engel graphs of the dihedral group $D_{2^{t+1}m} = \langle x, y | y^{2^t m} = x^2 = 1, xyx^{-1} = y^{-1} \rangle$ and the generalized quaternion group . $Q_{2^{t+1}m} = \langle x, y | y^{2^t m} = 1, x^2 = y^{2^{t-1}m}, xyx^{-1} = y^{-1} \rangle$. Note that D_{2^t} and $Q_{2^{t+1}}$ are Engel groups.

Proposition 3.1 *If t≥1,m≥3, and m is odd, then the Engel graphs of* $D_{2^{t+1}m}$ *and* $Q_{2^{t+1}m}$ *are isomorphic to* $K_m(2^t)$*, whereas the Engel graph of* D_{2m} *is isomorphic to* K_m*. In particular, their genera are* $\gamma(K_{m(2^t)})$ *and* $\gamma(K_m)$ *respectively.*

Proof. It is not difficult to see that if G denotes one of the group $D_{2^{t+1}m}$) or $Q_{2^{t+1}m}$), then L(G)=Fit(G)=⟨y⟩, where Fit(G) is the fitting subgroup of G (see Baer (1957)). Thus $G \backslash L(G) = \{x, xy, \ldots, xy^{2^t m-1}\}$. Now,

$$[xy^i, {}_n\, xy^j] = \begin{cases} y^{2^n(i-j)} \text{ if } n \text{ is even,} \\ y^{2^n(j-i)} \text{ if } n \text{ is odd.} \end{cases}$$

Thus, $[xy^i, {}_n\, xy^j] = 1$ if and only if $2^t m \mid 2^n(i-j)$, that is $i \equiv j \pmod m$. Let

$$A_0 = \{xy^i \mid 0 \leq i \leq 2^t m - 1, i \equiv 0 \pmod m\}$$

$$A_1 = \{xy^i \mid 0 \leq i \leq 2^t m - 1, i \equiv 1 \pmod m\}$$

$A_{m-1}=\{xy^i \mid 0 \leq i \leq 2^t m-1, i \equiv m-1 \pmod m\}$

Then $A_0, A_1, \ldots, A_{m-1}$ are all disjoints. Now, $u \in A_i$ and $v \in A_j$ are adjacent if and only if i≠j. Thus $\mathcal{E}_G \cong K_{2^t,\ldots,2^t} = K_{m(2^t)}$ On the other hand, for D_{2m}, $|A_i|=1$ for each i=0,1,…,m-1. Hence, the result follows.

Remark 3.2 *Let G and H be two groups. Suppose* $(u,x),(v,y) \in G \times H$*.. Then,*

$$[(u,x),(v,y)] = (u^{-1}v^{-1}uv, x^{-1}y^{-1}xy) = ([u,v],[x,y])$$

and so,

$$[(u,x),_2 (v,y)] = [[(u,x),(v,y)],(v,y)]$$

$$= [([u, v], [x, y]), (v, y)] = ([[u, v], v], [[x, y], y]) = ([u,_2 v], [x,_2 y])$$

In general, $[(u, x),_m [v, y]) = ([u,_m v], [x,_m y])$. Also, if $[x,_m y] = 1$ for some n, then $[x,_{m+1} y] = [[x,_m y], y] = [1, y] = 1$. Thus $[x,_m y] = 1$ for all $m \geq n$.

Proposition 3.3 *Let H be a finite Engel Group. Let t and m be positive integers with t≥1, m≥3 and m is odd. Then the Engel graph of* $H \times D_{2^{t+1}m}$ *and* $H \times Q_{2^{t+1}tm}$ *are isomorphic. Let* $K = D_{2^{t+1}m}$ *or* $Q_{2^{t+1}m}$, $G = H \times K$ *and* $q = |H|$. *Then, the Engel graph of G is isomorphic to* $K_{m(2^t q)}$, *whereas the Engel graph of* $H \times D_{2m}$ *is isomorphic to* $K_{m(q)}$. *In particular,* $\gamma(\mathcal{E}_G) = \gamma(K_{m(2^t q)})$ *and* $\gamma(H \times D_{2m}) = \gamma(K_{m(q)})$.

Proof. Let (u,x),(v,y) ∈ G. Then by the above remark,

$[(u,x),_n (v,y)]=([u,_n v],[x,_n y])$.

Since H is a finite Engel group, there exist a positive integer m, such that $[u,_m v]=1$. In view of the above remark, we have $[u,_j v]=1$ for all j≥m. Thus if $[x,_n y]=1$ for some n, then $([u,_l v],[x,_l y])=1$, where l≥max {m,n}. Hence, it follows that $([u,_n v],[x,_n y])\neq 1$ if and only if $[x,_n y]\neq 1$ for all positive integer n. Thus, L(G)=H×L(K) and hence $V(E_G)=H\times V(E_K)$. Now, by Proposition 3.1, E_K is isomorphic to $K_m(2t)$). Let $K_1,K_2,\ldots,K_m$ be the partite sets of E_K. Since $([u,_n v],[x,_n y])\neq 1$ if and only if [x,_n y]≠1 for all positive integer n, we have EG is isomorphic to $K_{m(2^t q)}$ with partite sets $H\times K_1,H\times K_2,\ldots,H\times K_m$. This completes the proof.

Genus of the Engel Graphs of Non-Engel Groups of Order less than or Equal to 30

In this section, we determine the genus of the Engel graphs of all non-Engel groups of order less than or equal to 30.

Proposition 4.1 *Let G be a non-Engel group of order less than or equal to 30. Then one of the following assertions hold:-*

1. E_G is planar if and only if $G\cong S_3,D_{12},Q_{12}$.

2. E_G is toroidal if and only if $G\cong D_{10},A_4,D_{14},C_3\times S_3$.

3. E_G is not double-toroidal.

4. If $G\neq D_{20},Q_{20}$, then E_G is triple-toroidal if and only if $G\cong D_{18},(C_3\times C_3)\rtimes C_2,C_3\rtimes C_8,C_4\times S_3,C_2\times C_2\times S_3,Q_{24},D_{24},C_2\times(C_3\rtimes C_4),(C_6\times C_2)\rtimes C_2$.

5. $3\leq\gamma(E_{D20})=\gamma(E_{Q20})\leq 5$.

6. If $G\neq D_{20},Q_{20}$, then $\gamma(E_G)=5$ if and only if $G\cong D_{22}$.

7. $\gamma(E_G)=8$ if and only if $G\cong C_7\rtimes C_3, D_{26}, Q_{28}, D_{28}$.

8. If $G\neq C_3\times D_{10}$, then $\gamma(E_G)=9$ if and only if $G\cong SL(2,3), C_2\times A_4$.

9. $9\leq\gamma(E_{C3}\times D_{10})\leq 11$.

10. If $G\neq C_3\times D_{10}$, then $\gamma(E_G)=11$ if and only if $G\cong D_{30}$.

11. $17\leq\gamma(E_{S4}))\leq 23$.

12. $\gamma(E_G)=46$ if and only if $G\cong C_5\times S_3$.

Proof. Non-Engel groups of order less than or equal to 30 are of order

6,10,12,14,18,20,21,22,24,26,28,30.

Non-Engel groups of these orders, up to isomorphism are given below:-

1. Group of order 6:- S_3.
2. Group of order 10:- D_{10}.
3. Groups of order 12:- A_4, Q_{12} and D_{12}.
4. Group of order 14:- D_{14}.
5. Groups of order 18:-

(a) D_{18},
(b) $C_3\times S_3$,
(c) $(C_3\times C_3)\rtimes C_2=\langle a,b,c|a^2=b^3=c^3=1, aba=b^{-1}, aca=c^{-1}, bcb^{-1}=c\rangle$.

6. Groups of order 20:- D_{20}, Q_{20}.
7. Group of order 21:- $C_7\rtimes C_3=\langle a,b|a^3=b^7=1, a^{-1}ba=b^2\rangle$.
8. Group of order 22:- D_{22}.
9. Groups of order 24:-

(a) $C^3\rtimes C_8=\langle a,b|a^3=b^8=1, b^{-1}ab=a^{-1}\rangle$,
(b) $SL(2,3)$,
(c) $C_4\times S_3$,
(d) $C_2\times C_2\times S_3$,
(e) Q_{24},
(f) D_{24},
(g) $C_2\times(C_3\rtimes C_4)=\langle a,b,c|a^4=b^2=c^3=1, aba^{-1}=b^{-1}), aca^{-1}=c^{-1}, cbc^{-1}=b^{-1}\rangle$,
(h) $(C_6\times C_2)\rtimes C_2=\langle a,b,c|a^4=b^2=c^3=1, aba^{-1}=b^{-1}, aca^{-1}=c^{-1}), cbc^{-1}=b^{-1}\rangle$,
(i) S_4 and
(j) $C_2\times A_4$.

10. Group of order 26:- D_{26}.
11. Groups of order 28:- Q_{28}, D_{28}.
12. Groups of order 30:- $C_5\times S_3$,$C_3\times D_{10}$, D_{30}.

We have $S_3\cong D_6$. Thus by Proposition 3.1, its Engel graph is planar. By Proposition 3.1, the Engel graph of D_{10} is toroidal. By Proposition 3.1, the Engel graph of D_{12} and Q_{12} are isomorphic to $K_{2,2,2}$ and so, by Lemma 2.3, the Engel graphs of D_{12} and Q_{12} are planar. On the other hand, by GAP (2013), the Engel graph of A_4 is isomorphic to $K_{2,2,2,2}$. Now, by Lemma 2.4, $K_{2,2,2,2}$ is toroidal. Hence, the Engel graph of A_4 is toroidal. By Proposition 3.1, the Engel graph of D_{14} is toroidal.

By Proposition 3.1, we have $\gamma(E_{D18})=3$. By Proposition 3.3, the Engel graph of $C_3\times S_3$ is isomorphic to $K_{3,3,3}$ and so by Lemma 2.3 its genus is 1. On the other hand, by GAP (2013), the Engel graph of $(C_3\times C_3)\rtimes C_2$ is isomorphic to K_9 and so its genus is 3.

By Proposition 3.1, the Engel graphs of D_{20} and Q_{20} are isomorphic to $K_{2,2,2,2,2}$. Now, $K_{2,2,2,2,2}$ is a subgraph of $K_{2,2,2,2,2,2}$. By Lemma 2.4, $\gamma(K_{2,2,2,2,2,2})=5$. Also $K_{2,2,2,2,2}$ has 10 vertices and 20 edges. Thus by Lemma 2.6, $\gamma(K_{2,2,2,2,2})\geq 3$. Hence $3\leq\gamma(K_{2,2,2,2,2})\leq 5$.

By GAP (2013), the Engel graph $C_7\rtimes C_3$ is isomorphic to $K_{7(2)}$ and so by Lemma 2.4, the genus of the Engel graph of $C_7\rtimes C_3$ is 8. By Proposition 3.1, the Engel graph of D_{22} is isomorphic to K_{11} and so its genus is 5.

One can see using GAP (2013), that the Engel graph of the group $C_3\rtimes C_8$ is isomorphic to $K_{4,4,4}$, with partite sets $\{y,y^3,y^5,y^7\}$, $\{xy,xy^3,xy^5,xy^7\}$ and $\{x^2y,x^2y^3,x^2y^5,x^2y^7\}$. Thus by Lemma 2.3, its genus is 3. The group SL(2,3) is isomorphic to the binary von Dyck group with the parameter (2,3,3) , i.e. it has the presentation $\langle a,b,c|a^3=b^3=c^2=abc\rangle$. By GAP (2013), the Engel graph of SL(2,3) is isomorphic to $K_{4,4,4,4}$ and thus by Lemma 2.5, its genus is 9. By Proposition 3.3, the Engel graphs of $C_4\times S_3$ and $C_2\times C_2\times S_3$ are isomorphic to $K_{4,4,4}$ and thus by Lemma 2.3, their genera is 3. By Proposition 3.1, the Engel graph of Q_{24} and D_{24} are isomorphic to $K_{4,4,4}$ and thus by Lemma 2.3, their genera is 3. The Engel graph of S_4 has 8 vertices of degree 15 and 12 vertices of degree 16. Thus $m=|E(E_{S4})|$ $= \frac{8\times 15+12\times 16}{2} = 156$ Also $n=|V(E_{S4})|=20$. Thus by Lemma 2.6, $\gamma(E_{S4})\geq 17$.

Again, E_{S4}) is a subgraph of K_{20}. Hence, $\gamma(E_{S4}))\leq\gamma(K_{20})=23$. Thus, it follows that $17\leq\gamma(E_{S4})\leq 23$. We have $E_{A4}\cong K_{2,2,2,2}$. Let P_1,P_2,P_3,P_4 be partite sets for E_{A4} . Then, $\mathcal{E}_{C_2\times A_4}\cong K_{4,4,4,4}$ with partite sets $C_2\times P_1,C_2\times P_2,C_2\times P_3,C_2\times P_4$. Thus, by Lemma 2.5, the genus of $\mathcal{E}_{C_2\times A_4}$ is 9. By GAP (2013), the Engel graph of $C_2\times(C_3\rtimes C_4)$ and $(C_6\times C_2)\rtimes C_2$ are isomorphic to $K_{4,4,4}$ and thus by Lemma 2.3, their genera is 3.

By Proposition 3.1, the Engel graph of D_{26} is isomorphic to K_{13} and so its genus is $\gamma(K_{13})=8$. Again, by Proposition 3.1, the Engel graphs of Q_{28} and D_{28} are isomorphic to $K_{7(2)}$. So, by Lemma 2.4, their genera is 8.

By Proposition 3.3, the Engel graph of $C_5 \times S_3$ is isomorphic to $K_{5,5,5}$. Thus by Lemma 2.3, its genus is 46. Again, by Proposition 3.3, the Engel graph of $C_3 \times D_{10}$ is isomorphic to $K_{3,3,3,3,3}$. The graph $K_{3,3,3,3,3}$ has 15 vertices and 90 edges. Also its girth is 3. Thus by Lemma 2.6, its genus is greater than or equal to 9. Also, $K^{3,3,3,3,3}$ is a subgraph of K_{15}. Now, genus of K_{15} is 11. Hence $9 \leq \gamma(K_{3,3,3,3,3}) \leq 11$. By Lemma 3.1, the Engel graph of D_{30} is isomorphic to K_{15}. Thus its genus is 11.

REFERENCES

Abdollahi, A. (2007). Engel graph associated with a group. *Journal of Algebra, 318*, 680–691.

Baer, R. (1957). Engelsche Elemente Noetherscher Gruppen. *Mathematische Annalen, 133*, 256–270.

West, D. B. (2009). *Introduction to Graph Theory* (Second Edition). PHI Learning Private Limited, New Delhi.

White, A. T. (1973). *Graphs, Groups and Surfaces*, North-Holland Mathematics Studies, no. 8., American Elsevier Publishing Co., Inc., New York.

The GAP Group (2013). *GAP – Groups, Algorithms, and Programming, Version 4.6.4*. http://www.gap-system.org.

CHAPTER 3

Thermodynamics study of some Viable Scalar-Tensor Gravity Models on the Event Horizon

Binod Chetry

In this chapter, we investigate the validity of the generalised second law of thermodynamics (GSLT) and thermodynamics equilibrium (TE) in the framework of scalar-tensor gravity. We consider the Friedman-Robertson-Walker (FRW) universe filled with ordinary matter and the boundary of the universe bounded by the event horizon that is in thermal equilibrium with modified Hawking temperature. While the thermodynamical laws hold on universe bounded by the apparent horizon but these laws break down on event horizon. By redefining or modifying the thermodynamical parameters (temperature and entropy), it is found that thermodynamical laws hold on the event horizon in Einstein Gravity. Keeping this in mind we derive the general expression for the GSLT and TE using modified Hawking temperature in the context of scalar-tensor gravity. Next, we check the validity of the GSLT and TE for some viable models in the scalar-tensor gravity at the event horizon. It is worth noting that the deceleration parameter of the selected models approaches de Sitter limit at late times and modified Hawking temperature helps in making these models perfect thermodynamical system.

Introduction

During the past few years, observational data claimed that the universe is passing through a phase of accelerated expansion [Ade et al., 2014; Riess et al., 1998). This unforeseen observed phenomenon is the most baffling problem in the cosmological context. There are two ways to solve this problem. Firstly, one can introduce a new type of matter having huge negative pressure known as dark energy (DE) in the framework of Einstein general relativity (GR) (for reviews on DE, see e.g. Padmanabhan (2003)). Another way to explain the current acceleration of the Universe by introducing a modified theory of gravity. This is because modified gravity can unify the early-time inflation with late-time acceleration without resorting to the DE (Capozziello, 2002). Moreover, modified gravity may serve as dark matter (Capozziello, 2002).

Scalar-tensor theories (STT) are one of the well-known theories in the context of modified gravity (Faraoni, 2004), which take into account the effects of non-

minimal coupling term between the scalar field (φ) and Ricci scalar curvature (R). STT arise naturally as the dimensionally reduced effective theories of higher dimensional theories, such as Kaluza-Klein and string models. They are also often used as a simple way to self-consistently model possible variations in Newton's constant, G. In STT, one scalar field is included in the gravitational sector of the action (Clifton et al., 2012). STT was first introduced by Jordan (1955) in 1950's and then taken over by Fierz (1956), Brans and Dicke (1961), where they presented a way to incorporate Mach's princi- ple into a covariant theory of gravity. STT also contains a class of models called chameleon gravity (Khoury & Weltman, 2004). in which there is a non-minimal coupling between the scalar field and the matter field. Historically, one of the well known STT is the Brans-Dicke (BD) theory of gravity in which the effective gravitational coupling strength Geff ~ φ^{-1} depend on the space-time position and being governed by distant matter sources. It is worth mentioning that the BD and STT is motivated by the fact that they are obtained as low-energy limits of string theories. It was shown that metric and Palatini (but not metric-affine) modified gravities can be reduced to scalar-tensor theories (Faraoni, 2010).

Gravitational thermodynamics is one of the interesting topics in the accelerating universe. In this context, Hawking and Bekenstein have shown that BH can be considered as a ther-modynamical system with temperature and entropy (Hawking, 1975). Afterward, Jacobson derive the Einstein equations using the first law of thermodynamics on the local Rindler horizons and assuming the Bekenstein-Hawking entropy-area relation (Jacobson, 1995). Subsequently, these results have been extended in the cosmological context assuming the universe as a closed thermo- dynamical system and revealed the connection between gravity and thermodynamics (Padmanabhan, 2005). Then Cai found that the Friedmann equations are equivalent to the first law of ther- modynamics with Hawking temperature and Bekenstein entropy on the apparent horizon (Cai & Kim, 2005). Furthermore, this equivalence was established in various modified gravity theories such as scalar-tensor gravity, the Lovelock gravity, the Einstein-Gauss-Bonnet gravity, the Braneworld gravity and the others gravities for the apparent horizon (Cai & Cao, 2007).

On the other hand, like the first law of thermodynamics, GSLT is a universal principle governing the universe and has been extensively studied on the apparent and event horizon (Karami et al., 2011). Apart from the apparent horizon, the event horizon exists only in the accelerating universe. While in GR, Wang et al. (2006) showed the event horizon is unphysical from the thermodynamic point of view, Chakraborty concluded that the universe bounded by the event horizon may be a Bekenstein system by modifying the Hawking temperature (Chakraborty, 2014). So modified Hawking temperature has a vital role in the formation of Bekenstein system on the event horizon. Therefore, it is natural to ask, whether, with these alternative definitions of thermodynamical parameters (temperature and entropy), thermodynamical laws hold on the event horizon in scalar-tensor gravity. Another physical motivation to study

thermodynamical laws is that if two cosmological models satisfy equally observational constraints but one respects thermodynamical laws and other does not, then later one can be ruled out.

In (Karami et al., 2014), the validity of GSLT has been examined at the apparent horizon. So, it is natural to verify thermodynamical laws (GSLT and TE) in the context of scalar-tensor gravity at the event horizon. It is important to verify at event horizon as an interpretation of gravity is a generic feature near horizon. The aim of this paper is to investigate the GSLT and TE in the framework of STT. Therefore, we consider an FRW universe bounded by the event horizon. We explore the GSLT and TE in STT using modified Hawking temperature and derive the general expression for the GSLT and TE. Throughout the paper, we generally consider geometrical units $8\pi G = 1$ and use the (−, +, +, +) signature convention for the metric tensor.

Scalar-Tensor Gravity

The general form of the action of the scalar-tensor gravity in the Jordan frame can be written as

$$I = \int d^4x\sqrt{-g}\ \left[\frac{1}{2}\big(F(\varphi)R - Z(\varphi)g^{\mu\nu}\,\varphi_{,\mu}\,\varphi_{,\nu} - 2U(\varphi)\big) + E(\varphi)L_m\right], \qquad 1$$

where d^4x is the standard coordinate volume element, R is the Ricci scalar built from $g_{\mu\nu}$, $g=\det g_{\mu\nu}$ and L_m is the matter Lagrangian. Also, F(φ), Z(φ), E(φ) are arbitrary dimensionless functions and U (φ) is the scalar field potential. The section F (φ)R involves a single scalar field coupled non-minimally to the metric. However, the term E(φ)Lm includes the matter Lagrangian that coupled nonminimally to the single scalar field (as a chameleon field).

Taking the variation of action (1) with respect to $g_{\mu\nu}$ and φ, the corresponding Friedmann equations in scalar-tensor gravity can be written as

$$3F(\varphi)H^2 = \rho_m E(\varphi) + \frac{Z(\varphi)}{2}\,\dot{\varphi}^2 - 3H\dot{F} + U(\varphi)\,, \qquad 2$$

$$-2F(\varphi)\dot{H} = (\rho_m + p_m)E(\varphi) + Z(\varphi)\dot{\varphi}^2 + \ddot{F} - H\dot{F}. \qquad 3$$

For special case F(φ)=E(φ)=1 and Z(φ)=U(φ)=0, the above equation reduces to GR. Also, the equation of the evolution of the scalar field is given as

$$2Z(\varphi)(\ddot{\varphi} + 3H\dot{\varphi}) = RF_{,\varphi} - Z_{,\varphi}\,\dot{\varphi}^2 - 2U_{,\varphi} - \frac{1}{2}E_{,\varphi}\,(\rho_m - 3p_m)\,, \qquad 4$$

where

$$R = 6\big(\dot{H} + 2H^2\big)\,, \qquad 5$$

with $H = \frac{\dot{a}}{a}$ is the Hubble parameter. Here the dot denotes differentiation with respect to cosmic time t and $F_{,\varphi} = \frac{dF}{d\varphi}$. The conservation equation for the matter and the scalar field in scalar-tensor gravity can be written as

$$\dot{\rho}_m + 3H(\rho_m + p_m) = -\frac{3}{4}(\rho_m + p_m)\frac{\dot{E}(\varphi)}{E(\varphi)}, \quad 6$$

$$\dot{\rho}_\varphi + 3H(\rho_\varphi + p_\varphi) = \rho_{eff}\dot{F}(\varphi) - \frac{1}{4}\dot{E}(\varphi)(\rho_m - 3p_m), \quad 7$$

where ρ_φ and p_φ are the energy density and pressure due to the scalar field contribution defined as

$$\rho_\varphi = \frac{Z(\varphi)}{2}\dot{\varphi}^2 - 3H\dot{F} + U(\varphi), \quad 8$$

$$p_\varphi = \frac{Z(\varphi)}{2}\dot{\varphi}^2 + \ddot{F} + 2H\dot{F} - U(\varphi), \quad 9$$

Eqs. (6) and (7) gives the evolution of matter and scalar field in the scalar-tensor gravity. The non-zero term obtained on the right-hand side of these equations are due to the non- minimally coupled term F (φ) and E(φ) present in the action (1). However, ρ_φ and p_φ in the scalar-tensor gravity gives the observed acceleration of the universe without resorting to DE. For instance, F (φ) = E(φ) = 1, these two equations reduced to GR. These equations will be used in calculating time derivatives of entropies for five different models discussed below.

Thermodynamics of the Event Horizon

This section will be devoted to discuss the validity of GSLT and TE on the event horizon in the context of STT. The radius of event horizon RE is given by

$$R_E = a(t)\int_t^\infty \frac{dt'}{a(t')}. \quad 10$$

where a and t are the scale factor and the cosmic time respectively. It is worth noting that the event horizon exists only for an accelerated expanding universe. On the other hand, the radius of the apparent horizon in the flat universe is given by $R_A = \frac{1}{H}$. From Eq. (10)

$$\dot{R}_E = HR_E - 1. \quad 11$$

Generally, Universe bounded by event horizon is not a Bekenstein system with usual Hawking temperature. So in order to overcome this problem, recently Hawking temperature has been modified and the modified Hawking temperature is given by (Chakraborty, 2014).

$$T_E = T_E^m = \frac{H^2 R_E}{2\pi}. \quad 12$$

Next, we shall check the validity of the GSLT and TE using temperature relation (12) for the universe bounded by the event horizon. GSLT states that the sum of the horizon entropy (S_E) and the matter entropy bounded with the horizon (S_m) is non-decreasing. However, the equilibrium configuration of an isolated macroscopic physical system corresponds to the maximum entropy. So for the

validity of GSLT and TE we must have the following relations (Pavon & Zimdahl, 2012)

$$\dot{S}_T \geq 0 \text{ (for GSLT)} \quad 13$$

$$\ddot{S}_T < 0 \text{ (for TE)} \quad 14$$

where S_T is the total entropy. Usually, any system bounded by event horizon is not a perfect thermodynamical system (Saha & Chakraborty, 2012), so it is not legitimate to use Bekenstein entropy on the event horizon. Thus, in order to find the event horizon entropy, we assume the first law of thermodynamics (i.e., Clausius relation) on the event horizon given by

$$-dE_m = T_E dS_E \quad 15$$

where dE_m is the amount of energy flow across the event horizon during insignificant time interval dt in which the radius of the event horizon is assumed to be fixed i. e. R_E=0 (Karami et al., 2011) and T_E is the temperature of the matter. Now using Eqs. (6), (12) with $E_m = \rho_m V$ and $V = \frac{4}{3}\pi R_E^3$ where T_E is the radius of event horizon, one can find the horizon entropy from Eq. (15) as

$$\dot{S}_E = \frac{8\pi^2 R_E^2}{H^2}(\rho_m + p_m)(H + \frac{\dot{E}}{4E}) \quad 16$$

Also, the second derivative of horizon entropy is given by

$$\ddot{S}_E = \frac{8\pi^2 R_E}{H^2}\left[\begin{array}{c} 2(\frac{H\dot{R}_E - \dot{H}R_E}{H}(\rho_m + p_m)\left(H + \frac{\dot{E}}{4E}\right) + R_E(\dot{\rho}_m + \dot{p}_m)\left(H + \frac{\dot{E}}{4E}\right) \\ +R_E(\rho_m + p_m)(\dot{H} + \frac{E\ddot{E} - \dot{E}^2}{4E^2}) \end{array}\right] \quad 17$$

The entropy inside the horizon is given by Gibb's equation (Setare, 2006)

$$T_E dS_m = dE_m + p_m dV \quad 18$$

In the present work, we have assumed the local equilibrium hypothesis holds. This requires that the temperature of the matter is same as the temperature of the horizon, i.e., T_m=T_E. Using Eq. (12), the time derivative of the matter entropy is given by

$$\dot{S}_m = -\frac{8\pi^2 R_E^2}{H^2}(\rho_m + p_m)\left(\frac{1}{R_E} + \frac{\dot{E}}{4E}\right) \quad 19$$

The second time derivative of the matter entropy is given by

$$\ddot{S}_E = -\frac{8\pi^2 R_E}{H^2}\left[\begin{array}{c} R_E(\dot{\rho}_m + \dot{p}_m)\left(\frac{1}{R_E} + R_E\frac{\dot{E}}{4E}\right) + R_E(\rho_m + p_m)\left(\frac{(E\ddot{E} - \dot{E}^2)}{4E^2} - \frac{\dot{R}_E}{R_E^2}\right) \\ +2(\rho_m + p_m)\left(\frac{1}{R_E} + \frac{\dot{E}}{4E}\right)\left(\frac{H\dot{R}_E - \dot{H}R_E}{H}\right) \end{array}\right] \quad 20$$

Now adding Eqs. (16), (19) and using Eq. (3) yields the GSLT in scalar-tensor gravity for the universe enclosed with the event horizon as

$$\dot{S}_T = \frac{8\pi^2 R_E^2}{H^2 E(\varphi)}\left(H\dot{F} - \ddot{F} - 2F(\varphi)\dot{H} - Z(\varphi)\dot{\varphi}^2\right)\left(H - \frac{1}{R_E}\right), \quad 21$$

and the second time derivative of total entropy yields

$$\ddot{S}_T = \frac{8\pi^2}{H^2 E(\varphi)}\left[\left(\frac{HE(\varphi)\{\dot{R}_E^2 + R_E(H\dot{R}_E + \dot{H}R_E)\} - R_E\dot{R}_E\left(2\dot{H}E(\varphi) + H\dot{E}(\varphi)\right)}{HE(\varphi)}\right) \times \left(H\dot{F} - \ddot{F} - 2F(\varphi)\dot{H} - Z(\varphi)\dot{\varphi}^2\right) + R_E\dot{R}_E\left(H\ddot{F} - \dot{F}\dot{H} - \dddot{F} - 2F(\varphi)\ddot{H} - \dot{Z}(\varphi)\dot{\varphi}^2 - 2Z(\varphi)\dot{\varphi}\ddot{\varphi}\right)\right] \quad 22$$

Due to the complicated nature of Eqs. (21) and (22), one cannot explore the validity of GSLT and TE explicitly. However, in the Einstein's gravity, the second Friedmann equation (3) takes the form $(\rho_m + p_m) = -2(H)$, $F(\varphi) = E(\varphi) = 1$ and $Z(\varphi) = U(\varphi) = 0$. As a result for a barotropic fluid $p_m = \omega_m \rho_m$, the GSLT (21) and TE (22) take the simple forms

$$\dot{S}_T = \frac{8\pi^2 R_E \rho_m (1+\omega_m)}{H}\left(R_E - \frac{1}{H}\right) \quad 23$$

and

$$\ddot{S}_T = 8\pi^2 \rho_m (1+\omega_m)\left(R_E - \frac{1}{H}\right)\left[R_E\left(1 - \frac{3(1+\omega_m)}{2(HR_E - 1)}\right) - \frac{R_E}{2}(1 - 3\omega_m) - \frac{1}{H} - 3R_E\frac{\dot{p}_m}{\dot{\rho}_m}\right] \quad 24$$

which is compatible with (Saha & Chakraborty, 2012). In (Saha & Chakraborty, 2012), it was showed that under some restrictions both GSLT and TE are satisfied for a universe bounded by the event horizon. In what follows, we are interested in examining the validity of GSLT and TE for some viable scalar-tensor gravity models.

Brans-Dicke Gravity

The BD theory of gravitation is a theoretical framework to explain gravitation. It is an example of a prototype STT. The field equations of BD gravity contain a parameter ω, called the BD coupling constant. The action of BD theory is given by

$$I = \int d^4x\sqrt{-g}\left[\frac{1}{2}\left(\varphi R - \frac{\omega}{\varphi}g^{\mu\nu}\partial_\mu\varphi\partial_\nu\varphi\right) + L_m\right], \quad 25$$

where Lm is the matter Lagrangian. The matter term includes the contribution of ordinary matter (e.g. gaseous matter) and also electromagnetic fields. In a vacuum region, the matter term vanishes identically; the remaining term is the gravitational term. The larger the value of ω the closer BD gravity is to GR. So the GR limit of this model is obtained by letting $\omega \to \infty$ which leads φ to be constant. Taking variation of the action (25) with respect to the metric $g_{\mu\nu}$ and the scalar field φ leads to the field equations in BD gravity. Arik et al. (2008) showed that in the context of BD theory, there is a negligible correction to the matter density component in the famous Friedmann equation. According to them, if the correction term is not zero, data favor the model and as a result, we can consider the model as a strong candidate for Einstein cosmological model with the cosmological constant. By comparing the actions (25) and (1), one can get

$$F(\varphi) = \varphi, \qquad Z(\varphi) = \frac{\omega}{\varphi}, \quad U(\varphi) = 0, \quad E(\varphi) = 1 \tag{26}$$

Replacing the above relations into Eqs. (4) and (6), one can obtain

$$\ddot{\varphi} + 3H\dot{\varphi} = \frac{3\varphi}{\omega}\left(\dot{H} + 2H^2\right) + \frac{\dot{\varphi}^2}{2\varphi}, \tag{27}$$

$$\dot{\rho}_m + 3H(\rho_m + p_m) = 0\,. \tag{28}$$

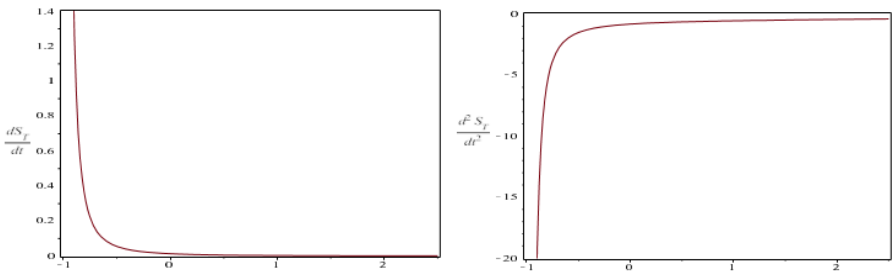
For the pressure less matter (i.e. p_m=0) the equation (28) gives

$$\rho_m = \rho_{m_0}\left(\frac{a}{a_0}\right)^{-3}. \tag{29}$$

From eqs. (26) and (29) the Friedmann equation (3) become

$$-2\varphi\dot{H} = \rho_{m_0}\left(\frac{a}{a_0}\right)^{-3} + \omega\frac{\dot{\varphi}^2}{\varphi^2} + \ddot{\varphi} - H\dot{\varphi}\,. \tag{30}$$

In this model to obtain the evolutionary behavior of the Eqs. GSLT (21) and TE (22), it is necessary that we first solve numerically the Eqs. (27) and (30) with choice of suitable initial conditions. We use $\Omega_{m_0} = \frac{\rho_{m_0}}{(3H_0^2)} = 0.27$ and $\omega = -1.01$. Initial values are a(1) = 1, a (1)=0.84, φ(1) = 1.5 and φ (1)=1 (Karami et al. 2014).



(a) (b)

Figure 1: The GSLT and TE versus the redshift z for BD gravity. Initial values: a(1) = 1, a ′(1)=0.84, φ(1) = 1.5, φ ′(1)=1. Also, ω = −1.01.

The variations of the first and second time derivative of total entropy, Eqs (23) and (24), for BD gravity, versus redshift $(z = \frac{a_0}{a} - 1)$ are plotted in Figures 1(a) and 1(b) respectively. For detail calculation of GSLT and TE in this model, please refer to the Eqs. (47) and (48) in the appendix. From the figures, we can conclude that in the BD gravity the both of GSLT and TE are satisfied from the early times to the present epoch which is compatible with GSLT (Karami et al., 2014). Also in (Karami et al., 2014), it was found that the deceleration parameter shows a transition from the deceleration to the acceleration in the near past, which is

compatible with (Toribio & Waga, 2008) and the effective EoS parameter behaves like quintessence model (Caldwell & Linder, 2005).

The BD theory predicts different values for BD parameter ω in the different scales. So that for the accelerating universe at the late time, Sen & Sen (2001) showed that BD parameters asymptotically acquires a small value. It is worth mentioning that in BD gravity, a small value of ω satisfies GSLT and TE which clearly contradicts the solar system limit ω > 600. Also, La and Steinhardt showed that in the extended inflationary model, ω is 20 (La & Steinhardt, 1989). There is a lot of evidence found in literature where the small value of ω supported the BD gravity. We have seen that in BD theory both GSLT and TE are satisfied in our numerical calculations by considering the BD parameter ω=-1.01.

Chameleonic Generalized BD Gravity

The chameleonic generalized BD action is defined by

$$I = \int d^4x\sqrt{-g}\left[\frac{1}{2}\left(\varphi R - \frac{\omega(\varphi)}{\varphi} g^{\mu\nu}\partial_\mu\varphi\partial_\nu\varphi\right) + f(\varphi)L_m\right]. \qquad 31$$

where ω(φ) is the scalar field dependent BD parameter. Banerjee and Pavon (2001) showed that with scalar field dependent BD parameter ω(φ) we have a decelerating radiation dominated era in the early time and an accelerated matter dominated era in the late time. For limiting case ω(φ) → ∞, φ = constant and f (φ) = 1 the model reduced to GR. Comparing Eq. (31) with action (1) gives

$$F(\varphi) = \varphi, \quad Z(\varphi) = \frac{\omega(\varphi)}{\varphi}, \quad U(\varphi) = 0, \quad E(\varphi) = f(\varphi). \qquad 32$$

From the Eqs. (4) and (6), one can obtain

$$\ddot{\varphi} + 3H\dot{\varphi} = \frac{1}{2\omega(\varphi)+3}\left[(\rho_m - 3p_m)\left(f(\varphi) - \frac{1}{2}\varphi f_{,\varphi}\right) - \omega_{,\varphi}\dot{\varphi}^2\right], \qquad 33$$

$$\dot{\rho}_m + 3H(\rho_m + p_m) = -\frac{3}{4}\frac{\dot{f}(\varphi)}{f(\varphi)}(\rho_m + p_m), \qquad 34$$

For the pressure less matter (p_m=0), the solution of Eq. (34) is given by

$$\rho_m = \rho_{m_0}\left(\frac{a}{a_0}\right)^{-3}\left(\frac{f(\varphi)}{f_0}\right)^{-\frac{3}{4}}. \qquad 35$$

To check the validity of GSLT (49) and TE (50) numerically, let's consider f (φ) and BD parameter ω(φ) as

$$f(\varphi) = f_0 e^{b\varphi}, \ \omega(\varphi) = \omega_0\varphi^n. \qquad 36$$

where f0 and ω0 are arbitrary constant. Considering cosmological constrains on the model parameters (36), can obtain late-time acceleration and phantom divide line crossing for this model (Farajollahi et al., 2012).'

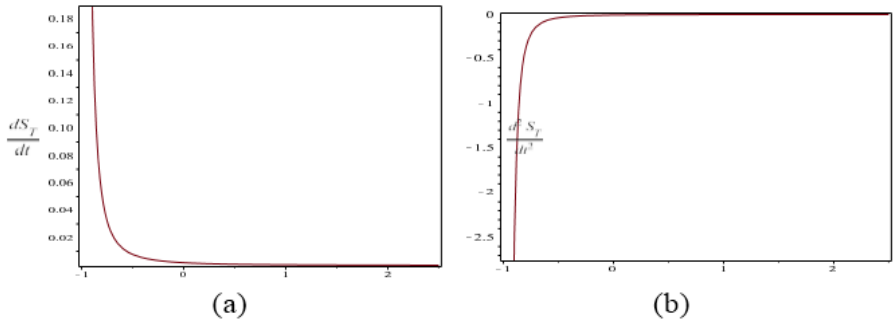
Using Eqs. (35), (36) in (33) for the pressureless matter (p_m=0) gives

$$\ddot{\varphi} + 3H\dot{\varphi} = \frac{1}{3+2\omega_0\varphi^n}\left[f_0\rho_{m_0}\left(\frac{a}{a_0}\right)^{-3}\left(1-\frac{b}{2}\varphi\right)e^{\frac{b\varphi}{4}} - n\omega_0\varphi^{n-1}\dot{\varphi}^2\right]. \quad 37$$

Also, the second Friedmann equation (3) becomes

$$-2\varphi\dot{H} = f_0\rho_{m_0}\left(\frac{a}{a_0}\right)^{-3} e^{\frac{b\varphi}{4}} + \omega_0\varphi^{n-1}\dot{\varphi}^2 + \ddot{\varphi} - H\dot{\varphi}\,. \quad 38$$

Taking Ωm0 = 0.27 [Ade et al., 2014], $\omega_0 = -1.01$, n = −2, $f_0 = -7$ and b = −0.4 (Karami et al., 2014), both the scale factor a(t) and the scalar field φ(t) can be obtained by numerical solving Eqs. (37) and (38) with the initial values a(1) = 1, a (1) = 1, φ(1) = -6.5 and φ (1)= 0.1.



(a) (b)

Figure 2: The GSLT and TE versus the redshift z for chameleonic generalized BD gravity.

Initial values are:a(1) = 1, a˙(1) = 1, φ(1) = -6.5,φ˙(1) = 0.1. Auxiliary parameters are: n = −2, $f_0 = -7$, b = −0.4. Also, ω0 = −1.01.

The variations of the first and second time derivative of total entropy, Eqs (23) and (24), versus redshift for chameleonic generalized BD gravity, are plotted in Figures 2(a) and 2(b) respectively. The figure shows that the GSLT and TE are valid in the BD gravity with a self-interacting potential model (31). On the other hand, for the universe bounded by the apparent horizon, GSLT is violated during the late-time universe (Karami et al., 2014). Also in (Karami et al., 2014), it was found that the deceleration parameter shows a cosmic transition from the deceleration era to the acceleration era in the near past which is compatible with (Ishida et al., 2008)and approaches to de Sitter regime at the late-time universe. Further, the EoS parameter behaves like the ΛCDM model at the late-time universe.

Farajollahi et al. (2012) showed that the solution of this model shows the evolution of the scale factor of the universe is nonsingular in a bouncing scenario, with an initial contracting phase which lasts until to a non-vanishing minimal radius is reached and then smoothly transits into an expanding phase. Also, they found that the dynamics of the EoS parameter with respect to time in the early

universe is a transition from the phantom phase (say phantom inflation) to non-phantom phase towards the matter-dominated era.

Chameleonic BD Gravity with a Self-Interacting Potential

In chameleonic BD gravity with a self-interacting potential, action is in the form

$$I = \int d^4x\sqrt{-g}\left[\frac{1}{2}\left(\varphi R - \frac{\omega}{\varphi}g^{\mu v}\partial_\mu\varphi\partial_v\varphi - V(\varphi)\right) + f(\varphi)L_m\right]. \qquad 39$$

In the limiting case $\omega \to \infty$, V (φ) = 0 and f (φ) = 1, we obtain the standard GR theory. Further for f (φ) = 1, we will get the standard BD theory. Sheykhi and Jamil (2011) obtained that in action (39) can be occurred the phantom crossing for the interacting holographic DE in BD theory with the chameleon scalar field which is nonminimally coupled to the matter field if the model parameters are chosen appropriately.

From the comparison of the action (1) and action (39) we have

$$F(\varphi) = \varphi, \quad Z(\varphi) = \frac{\omega(\varphi)}{\varphi}, \quad U(\varphi) = \frac{V(\varphi)}{2}, \quad E(\varphi) = f(\varphi). \qquad 40$$

Using the above relations, the evolution Eq. (4) and the continuity Eq. (6) for a flat universe take the following forms

$$\ddot{\varphi} + 3H\dot{\varphi} = \frac{1}{2\omega+3}\left[(\rho_m - 3p_m)\left(f(\varphi) - \frac{1}{2}\varphi f_{,\varphi}\right) + 2V(\varphi) - \varphi V_{,\varphi}\right], \qquad 41$$

$$\dot{\rho}_m + 3H(\rho_m + p_m) = -\frac{3}{4}\frac{\dot{f}(\varphi)}{f(\varphi)}(\rho_m + p_m), \qquad 42$$

For the pressureless matter (p_m=0) the solution of Eq. (42) is same as that obtained in (35). In the following, we will check the validity of GSLT and TE for the chameleonic BD gravity with a self-interacting potential (see eqs. (53) and (54) in the appendix) numerically. In order to do that, let us consider the inverse power law potential given by

$$V(\varphi) = \frac{M^{n+4}}{\varphi^n}, \qquad 43$$

where the constant M has a dimension of mass and n is a positive constant. The energy scale M is in order of $(1mm)^{-1}$ and $n \leq 2$. This form of potential has a proper behaviour in quintessence models of the universe (Zlatev et al., 1999). Also, let's consider f(φ) as

$$f(\varphi) = f_0 e^{b\varphi}, \qquad 44$$

where f_0 and b are constant parameters. Inserting Eqs. (35), (43) and (44) into (41), for the pressureless matter (p_m=0) one can obtain

$$\ddot{\varphi} + 3H\dot{\varphi} = \frac{1}{3+2\omega}\left[f_0\rho_{m_0}\left(\frac{a}{a_0}\right)^{-3}\left(1 - \frac{b}{2}\varphi\right)e^{\frac{b\varphi}{4}} + \frac{(n+2)M^{n+4}}{\varphi^n}\right]. \qquad 45$$

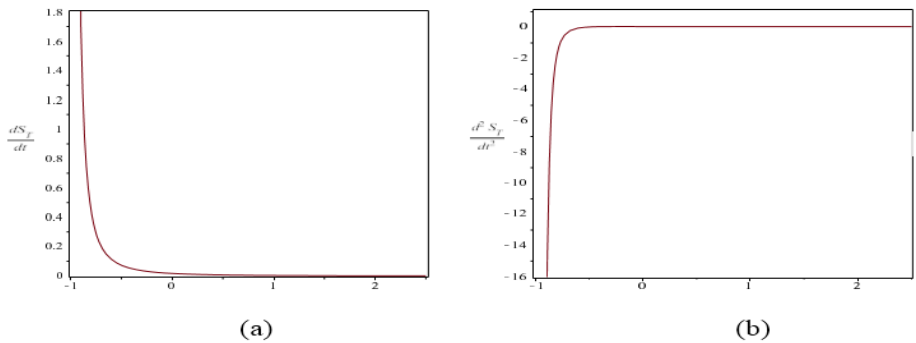
Also, the second Friedmann equation (3) reduces to

$$-2\varphi\dot{H} = f_0\rho_{m_0}\left(\frac{a}{a_0}\right)^{-3} e^{\frac{b\varphi}{4}} + \omega\frac{\dot{\varphi}^2}{\varphi} + \ddot{\varphi} - H\dot{\varphi}\,. \qquad 46$$

From Eqs. (45) and (46), the scale factor a(t) and the scalar field φ(t) can be obtained, numerically. To do so, we take $\Omega m0 = 0.27, \omega = -1.01, f_0 = -7, b = -0.4$ (Karami et al., 2014), n = 2 and use the initial values a(1) = 1, φ (1) = 1, φ(1) = 1 and φ (1) = -1.4.

Due to the complicated results the variations of the first and second time derivative of total entropy, Eqs. (23) and (24), versus redshift for chameleonic BD gravity with a self- interacting potential, only the figures are plotted in Figures 3(a) and 3(b). The figure shows that both the GSLT and TE in the chameleonic BD gravity with a self-interacting potential model (39) are satisfied. But for the universe bounded by apparent horizon (Karami et al., 2014), it was found that GSLT is satisfied from the past to the present epoch and violated in future for $z < -0.53$. In (Karami et al., 2014), it was found that the deceleration parameter acts like de Sitter model at the late universe and shows a cosmic transition from deceleration era to acceleration era. Further, the effective EoS parameter behaves like ΛCDM model at the late universe.

Sen et al. (2003) found that the gravitational coupling grows with time which agrees quite well with the observational facts. This model also allows growing modes for the energy density perturbation of matter implying that the dynamics of the self-interacting BD field does not upset the structure formation scenario.



(a) (b)

Figure 3: The GSLT and TE versus the redshift z for chameleonic BD gravity with a self- interacting potential.

Initial values are: a(1) = 1, a′(1) = 1, φ(1) = 1, φ′(1) = -1.4. Auxiliary parameters are: n = 2, f_0 = -7, b = −0.4, ω_0 = -1.01. Also, $M^{n+4} = H_0^2$, H_0 = 0.84.

Conclusion

This paper deals with the study of GSLT and TE for the universe bounded by the event horizon in the framework of scalar-tensor gravity. Here we extended the

action of ordinary scalar-tensor gravity to the case in which there is a non-minimal coupling between the scalar field and the matter field. We assumed that the boundary of the FRW universe is bounded by the event horizon, which is in thermal equilibrium with modified Hawking temperature. In at FRW model, the event horizon can only exist in the accelerating phase of the universe. As from recent observation, the universe is going through an accelerated phase of expansion, so it is pertinent to consider the universe bounded by the event horizon. Also, the universe bounded by the event horizon is not a Bekenstein system so we have used Clausius relation (i.e. -dE = TdS) to determine entropy variation on the event horizon. Using the modified Hawking temperature, we examined the validity of GSLT and TE for some viable models scalar-tensor gravity including BD gravity, chameleonic generalized BD gravity and chameleonic BD gravity with a self-interacting potential. It is worth mentioning that the deceleration parameter of most of the models approaches to de Sitter regime and effective EoS parameter behaves like the ΛCDM model at the late-time universe.

Further, in order to understand the complicated expressions, the validity of GSLT and TE are examined graphically. We plotted the GSLT and TE versus redshift z for aforesaid models. Our numerical results showed that for all aforementioned models, GSLT and TE are satisfied. But for the universe bounded by an apparent horizon, GSLT is valid only under some restriction of redshift parameter z (Karami et al., 2014). We have seen that by changing the temperature and horizon thermodynamical laws are always respected. Therefore, thermo- dynamical parameter like modified Hawking temperature has a crucial role in the formation of the perfect thermodynamical system in scalar-tensor gravity for the universe bounded by the event horizon. Finally, based on the above analysis, we can conclude that the event horizon with modified Hawking temperature has an edge over the apparent horizon at least for these models of scalar-tensor gravity.

Appendix

In this appendix, we will give the expressions of S_T and S_T for five different models of scalar-tensor gravity with modified Hawking temperature.

Model I: Brans-Dicke gravity

With the help of relations (26), the first time derivative of total entropy i.e. the GSL (21) reduces to

$$\dot{S}_T = \frac{8\pi^2 R_E \dot{R}_E}{H^2}\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega}{\varphi}\dot{\varphi}^2\right) \qquad 47$$

and the second time derivative of total entropy i.e., TE (22) reduces to

$$\ddot{S}_T = \frac{8\pi^2}{H^2}\left[\begin{array}{c}\left(\frac{H\left(\dot{R}_E^2 + R_E(H\dot{R}_E + \dot{H}R_E)\right) - 2\dot{H}R_E\dot{R}_E}{H}\right)\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega}{\varphi}\dot{\varphi}^2\right) \\ + R_E\dot{R}_E\left(H\ddot{\varphi} - \dot{\varphi}\dot{H} - \ddot{\varphi} - 2\varphi\ddot{H} - \frac{\omega\dot{\varphi}}{\varphi^2}(2\varphi\ddot{\varphi} - \dot{\varphi}^2\right)\end{array}\right] \qquad 48$$

Model II: Chameleonic Generalized BD gravity

With the help of relations (32), the GSL (21) we have

$$\dot{S}_T = \frac{8\pi^2 R_E \dot{R}_E}{H^2 f(\varphi)}\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega(\varphi)}{\varphi}\dot{\varphi}^2\right) \quad 49$$

and the TE (22) becomes

$$\ddot{S}_T = \frac{8\pi^2}{H^2 f(\varphi)}\left[\begin{array}{c}\left(\frac{Hf(\varphi)\{\dot{R}_E^2 + R_E(H\dot{R}_E + \dot{H}R_E)\} - R_E\dot{R}_E(2\dot{H}f(\varphi) + H\dot{f}(\varphi))}{Hf(\varphi)}\right)\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega(\varphi)}{\varphi}\dot{\varphi}^2\right) \\ +R_E\dot{R}_E\left(H\ddot{\varphi} - \dot{\varphi}\dot{H} - \dddot{\varphi} - 2\varphi\ddot{H} - \left(\frac{\dot{\varphi}}{\varphi^2}\right)^2(\varphi\dot{\omega}(\varphi) - \omega(\varphi)\dot{\varphi}) - 2\dot{\varphi}\ddot{\varphi}\frac{\omega(\varphi)}{\varphi}\right)\end{array}\right] \quad 50$$

Substituting f(φ) and ω(φ) from (36) in GSLT (49) and TE (50) yields respectively

$$\dot{S}_T = \frac{8\pi^2 R_E \dot{R}_E}{H^2 f_0 e^{b\varphi}}\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \omega_0\varphi^{n-1}\dot{\varphi}^2\right) \quad 51$$

$$\ddot{S}_T = \frac{8\pi^2}{H^2 f_0 e^{b\varphi}}\left[\begin{array}{c}\left(\frac{H\dot{R}_E^2 + HR_E(H\dot{R}_E + \dot{H}R_E) - R_E\dot{R}_E(2\dot{H} + Hb\dot{\varphi})}{H}\right)\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \omega_0\varphi^{n-1}\dot{\varphi}^2\right) \\ +R_E\dot{R}_E\left(H\ddot{\varphi} - \dddot{\varphi} - \dot{H}\dot{\varphi} - 2\varphi\ddot{H} - \omega_0\dot{\varphi}\varphi^{n-1}\left(\frac{(n-1)\dot{\varphi}^2}{\varphi} + 2\ddot{\varphi}\right)\right)\end{array}\right] \quad 52$$

Model III: Chameleonic BD Gravity with a Self-Interacting Potential

Using the relations (40) into (21) gives the GSLT for the chameleonic BD gravity with a self-interacting potential as

$$\dot{S}_T = \frac{8\pi^2 R_E \dot{R}_E}{H^2 f(\varphi)}\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega}{\varphi}\dot{\varphi}^2\right) \quad 53$$

and the TE (22) becomes

$$\ddot{S}_T = \frac{8\pi^2}{H^2 f(\varphi)}\left[\begin{array}{c}\left(\frac{Hf(\varphi)\{\dot{R}_E^2 + R_E(H\dot{R}_E + \dot{H}R_E)\} - R_E\dot{R}_E\left(2\dot{H}f(\varphi) + H\dot{f}(\varphi)\right)}{Hf(\varphi)}\right)\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega}{\varphi}\dot{\varphi}^2\right) + \\ R_E\dot{R}_E\left(H\ddot{\varphi} - \dot{\varphi}\dot{H} - \dddot{\varphi} - 2\varphi\ddot{H} - \frac{\omega\dot{\varphi}}{\varphi^2}(2\varphi\ddot{\varphi} - \dot{\varphi}^2\right)\end{array}\right] \quad 54$$

Now using (43) and (44) in GSLT (53) and TE (54) yields respectively

$$\dot{S}_T = \frac{8\pi^2 R_E \dot{R}_E}{H^2 f_0 e^{b\varphi}}\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega}{\varphi}\dot{\varphi}^2\right) \quad 55$$

$$\ddot{S}_T = \frac{8\pi^2}{H^2 f_0 e^{b\varphi}}\left[\begin{array}{c}\left(\frac{H\dot{R}_E^2 + HR_E(H\dot{R}_E + \dot{H}R_E) - R_E\dot{R}_E(2\dot{H} + Hb\dot{\varphi})}{H}\right)\left(H\dot{\varphi} - \ddot{\varphi} - 2\varphi\dot{H} - \frac{\omega}{\varphi}\dot{\varphi}^2\right) + \\ R_E\dot{R}_E\left(H\ddot{\varphi} - \dot{\varphi}\dot{H} - \dddot{\varphi} - 2\varphi\ddot{H} - \frac{\omega\dot{\varphi}}{\varphi^2}(2\varphi\ddot{\varphi} - \dot{\varphi}^2\right)\end{array}\right] \quad 56$$

REFERENCES

Arik, M., Calik, M.C. & Sheftel, M.B. (2008). Friedmann equation for Brans-Dicke cosmology. *International Journal of Modern Physics D* 17, 225-235.

Banerjee, N. & Pavon, D. (2001). Cosmic acceleration without quintessence. *Physical Review D* 63, 043504-043512.

Brans, C & Dicke, R. H. (1961). Mach's principle and a relativistic theory of gravitation. *Physical Review 124*, 3, 925-935.

Caldwell, R.R. & Linder, E. V. (2005). The Limits of quintessence. *Physical Review Letters* 95, 141301-141309.

Cai, R. G. & Cao, L. M. (2007). Unified first law and thermodynamics of apparent horizon in FRW universe. *Physical Review D 75*, 064008-064018.

Cai, R. G. & Kim, S. P. (2005). First law of thermodynamics and Friedmann equations of Friedmann-Robertson-Walker universe. *Journal of High Energy Physics* 02, 050-056.

Chakraborty, S. (2014). Generalized Bekenstein-Hawking system: Logarithmic Correction. *European Physical Journal* C 74, 2876-2880.

Clifton, T., Ferreira, P. G., Padilla, A. & Skordis, C. (2012). Modified Gravity and Cosmology. *Physics Reports* 513, 1, 1-189.

Farajollahi, H., Farhoudi, M., Salehi, A. & Shojaie, H. (2012). Chameleonic Generalized Brans--Dicke model and late-time acceleration. *Astrophysics and Space Science* 337, 415-423.

Faraoni, V. (2004). *Cosmology in scalar tensor gravity*. Kluwer Academic Publishers, Dordrecht, Netherlands.

Faraoni, V. (2010). Black hole entropy in scalar-tensor and f(R) gravity: An Overview. *Entropy 12*, 1246-1254.

Fierz, M. (1956). On the physical interpretation of P.Jordan's extended theory of gravitation. *Helvetica Physica Acta* 29, 128-134.

Hawking, S.W. (1975). Particle Creation by Black Holes. *Communications in Mathematical Physics 43*, 199-220.

Ishida, E. E. O., Reis, R. R. R., Toribio, A. V. & Waga, I. (2008). When did cosmic acceleration start? How fast was the transition?. *Astroparticle Physics* 28, 547-552.

Jacobson, T. (1995). Thermodynamics of space-time: The Einstein equation of state. *Physical Review Letters 75*, 1260-1263.

Jordan, P. (1955). *Schwerkraft und Weltall. Grundlagen der theoretischen Kosmologie*. Friedrich Vieweg und Sohn, Braunschweig.

Karami, K., Najafi, T. & Abdolmaleki, A. (2014). Generalized second law of thermodynamics in scalar-tensor gravity. *Physical Review D* 89, 104041- 104050

Karami, K., Sahraei, N. & Ghaffari, S. (2011). Thermodynamics of apparent horizon in modified FRW universe with power-law corrected entropy. *Journal of High Energy Physics 08*, 150-158.

Khoury, J. & Weltman, A. (2004). Chameleon cosmology. *Physical Review D 69*, 044026-044035.

La, D. & Steinhardt, P. J. (1989). Extended Inflationary Cosmology. *Physical Review Letter* 62, 376-383.

Padmanabhan, T. (2005). Gravity and the thermodynamics of horizons. *Physics Reports 406*, 49-125.

Pavon, D. & Zimdahl, W. (2012). A thermodynamic characterization of future singularities?. *Physics Letters* B 708, 217-220.

Riess, A. G., Filippenko, A. V., Challis, P., Clocchiattia, A., Diercks, A., Garnavich, P. M., Gilliland, R. L., Hogan, C. J., Jha, S., Kirshner, R. P., Leibundgut, B., Phillips, M. M., Reiss, D., Schmidt, B. P., Schommer, R. A., Smith, R. C., Spyromilio, J., Stubbs, C., Suntzeff, N. B. & Tonry, J. (1998). Observational evidence from supernovae for an accelerating universe and a cosmological constant. *The Astronomical Journal* 116, 3, 1009-1038.

Saha, S. & Chakraborty, S. (2012). A redefinition of Hawking temperature on the event horizon: Thermodynamical equilibrium. *Physics Letters* B 717, 319-322.

Sen, S. & Sen, A.A. (2001). Late time acceleration in Brans-Dicke cosmology. *Physical Review D* 63, 124006-124012.

Sen, S. & Seshadri, T.R. (2003). Selfinteracting Brans-Dicke cosmology and quintessence. *International Journal of Modern Physics D* 12, 445-460.

Setare, M.R. (2006). Generalized second law of thermodynamics in quintom dominated universe. *Physics Letters* B 641, 130-133.

Sheykhi, A. & Jamil, M. (2011). Interacting HDE and NADE in Brans-Dicke chameleon cosmology. *Physics Letters* B 694, 284-288.

Wang, B., Gong, Y., & Abdalla, E. (2006). Thermodynamics of an accelerated expanding universe. *Physical Review D 74*, 083520-083526.

Zlatev, I., Wang, L. M. & Steinhardt, P.J. (1999). Quintessence, cosmic coincidence, and the cosmological constant. *Physical Review Letter* 82, 896-899.

CHAPTER 4

A Survey on Prime Number Theorem

Stefferson Malngiang

Introduction

Prime Number is a positive integer > 1 which is not divisible by any number except 1 and itself. Prime numbers are thus natural numbers which do not have a specific pattern or sequence and there is no explicit formula about the distribution of primes as well as the number of primes less than or equal to a given real number.

This paper examines the connection between Riemann zeta function and prime numbers using Euler's theorem. The incorporation of analytic function and how does logarithm along with the introduction of θ and ψ functions play their role in the conjecture of prime numbers.

Definition: Prime Counting Function. The prime counting function π(x) is defined by

$\pi(x) = \sum_{p \le x} 1$, $\forall x \in R$, i.e. the number of primes less than or equal to a given real number x. For example $\pi(2) = 1, \pi(6) = 3, \pi(8) = 4 = \pi(9) = \pi(10)$.

Prime Number Theorem: The prime number theorem states that $\pi(x) \sim \frac{x}{\log x}$, where $x \in R$ i.e. $\frac{\pi(x)\log x}{x} \to 1$ as . However the theorem does not say anything about $\lim_{x\to\infty}\left(x - \frac{\pi(x)}{\log x}\right)$. According to the Riemann Hypothesis $\frac{\pi(x)}{\frac{x}{\log x}} = 1 + O\left(x^{\frac{1}{2}+\varepsilon}\right)$, $\varepsilon > 0$, where the error term o approaches o as approaches ∞ (Edwards, 2001).

Riemann zeta function: The Riemann zeta function is defined by

$$\zeta(z) = \sum_{n=1}^{\infty} \frac{1}{n^z} \text{ where } z \in C, \text{ Re } z > 1$$

$$= 1 + \frac{1}{2^z} + \frac{1}{3^z} + \frac{1}{4^z} + \frac{1}{5^z} + \frac{1}{6^z} + \frac{1}{7^z} + \ldots\ldots$$

$$= \left(1 + \frac{1}{2^z} + \frac{1}{4^z} + \frac{1}{8^z} + \ldots..\right)\left(1 + \frac{1}{3^z} + \frac{1}{9^z} + \ldots\right)\left(1 + \frac{1}{5^z} + \frac{1}{25^z} + \ldots\right)\ldots$$

$$= \prod_p \sum_{k=0}^{\infty} \frac{1}{p^{kz}} \text{ where the product } \prod_p \text{ ranges over all primes}$$

$$= \prod_p \frac{1}{1 - \frac{1}{p^z}} = \prod_p (1 - p^{-z})^{-1}$$

This is also known as Euler's product formula which converge uniformly on compact subsets of $\text{Re } z > 1$, hence ζ is analytic for $\text{Re } z > 1$. The product representation of ζ shows that for $\text{Re } z > 1$, $\zeta(z)$ has no zeroes (Sabbach, 2002).

Some historical remarks on the development of the theory.

The Riemann zeta function was introduced by Euler around 1738. Later in around 1790, Gauss and Legendre were able to illustrate that $\pi(x) \sim \frac{x}{\log x}$ for all real values of $x > 0$ after widespread and substantial numerical calculations. Sixty years later in 1850, Chebyshev ascertained that there are constants k_1 and k_2 such that "$0<k_1<1<k_2$" and $k_1 < \frac{\pi(x)}{\frac{x}{\log x}} < k_2$ Chebyshev also introduced the functio $\theta(x) = \sum_{p \le x} \log p$ and $\psi(x) = \sum_{p^n \le x} \log p = \sum_{n=1}^{\infty} \theta(x^{\frac{1}{n}})$ which is finite, since for $x<2^n$, $\theta(x^{\frac{1}{n}}) = 0$. He also proved that if $\psi(x) \sim x$, then $\theta(x) \sim x$, which then implies The Prime Number Theorem (Chebysev (1852)).

Riemann introduced the estimate of $\pi(x)$ in terms of logarithmic integral, $Li(x) = \int_0^x \frac{dt}{\log t}, \; x > 1.$

It was in his 1859 paper that Riemann discovered an analytic expression for $\pi(x)$ and

that $\frac{\pi(x)}{Li(x)} = 1 + error\ term$, where the error term grows to infinity at a measured rate. However, Riemann did not prove The Prime Number Theorem. Incredibly, forty years later, Hadamard and de la valle Poussin, proved The Prime Number Theorem.

Extension for Riemann zeta function: The essential step in the proof of Prime Number Theorem is that $\zeta(z)$ has no zeroes for $\text{Re } z > 1$.. It was proven by Hadamard and Poussin that $\zeta(z)$ has an analytic extension for $\text{Re } z > 0$

i.e. $\zeta(z) - \frac{1}{1-z}$ is holomorphic for $\text{Re } z > 0$ and $\zeta(z) \neq 0$ for $Re\ z = 1$ (Zagier, 1997).

Asymptotic behaviour (~) of ψ and θ leading to the Prime Number Theorem:

Define a function $\psi_1(x) = \int_1^x \psi(t)dt$, it is clear that $\psi_1(x)$ is continuous. It was also

proved that

$$\psi_1(x)=\frac{x^2}{2\pi i}\int_{c-\infty i}^{c+\infty i}\frac{x^{z-1}}{z(z+1)}\left(-\frac{\zeta'(z)}{\zeta(z)}\right)dz,\quad c>0,\quad \mathrm{Re}\,z>1 \text{ and } \quad \psi_1(x)\sim\frac{x^2}{2}$$

(Chebysev, 1852).

According to Chebyshev, the PNT (Prime Number Theorem) holds that if

$\psi_1(x)\sim\frac{x^2}{2}$, then $\psi(x)\sim x$, $\theta(x)\sim x$ and consequently $\pi(x)\sim\frac{x}{\log x}$ as $x\to\infty$.

Asymptotic behaviour: Let us look at $\psi(x)=\sum_{p^n\le x}\log p$, where p is a prime

e.g. $\psi(10)=\log 2+\log 3+\log 5+\log 7+\log 2+\log 3+\log 2$

$=3\log 2+2\log 3+\log 5+\log 7$

$=\log 2^3+\log 3^2+\log 5+\log 7$

So $\psi(x)=\sum_{p\le x}m_p(x)\log p$, where $m_p(x)$ is the largest positive integer such that $p^{m_p(x)}\le x$

i.e. $p^{m_p(x)}\le x$ if and only if $m_p(x)\log p\le\log x$ if and only if $m_p(x)\le\frac{\log x}{\log p}$ i.e. $m_p(x)=\left[\frac{\log x}{\log p}\right]$. Now, $\psi(x)=\sum_{p\le x}\left[\frac{\log x}{\log p}\right]\log p\le\sum_{p\le x}\frac{\log x}{\log p}\log p=\log x\sum_{p\le x}1=\log x\,\pi(x)$

Therefore, if $\frac{\psi(x)}{x}\to 1$ as $x\to\infty$, then $\frac{\log x\times\pi(x)}{x}\to 1$ i.e. $\pi(x)\sim\frac{x}{\log x}$ as $x\to\infty$.

Again, let us look at $\theta(x)=\sum_{p\le x}\log p$

e.g. $\theta(8)=\log 2+\log 3+\log 5+\log 7$

$=(\pi(2)-\pi(1))\log 2+(\pi(3)-\pi(2))\log 3+.....+(\pi(7)-\pi(6))\log 7+(\pi(8)-\pi(7))\log 8$

$=\pi(8)\log 8+\sum_{n=1}^{7}\pi(n)(\log n-\log(n+1))$

$=\pi(8)\log 8-\sum_{n=1}^{7}\pi(n)\int_n^{n+1}\frac{1}{t}dt$

$=\pi(8)\log 8-\int_1^8\frac{\pi(t)}{t}dt$

So, $\frac{\theta(8)}{8}=\frac{\pi(8)\log 8}{8}-\frac{1}{8}\int_1^8\frac{\pi(t)}{t}dt$

In general, $\frac{\theta(x)}{x} = \frac{\pi(x)\log x}{x} - \frac{1}{x}\int_1^x \frac{\pi(t)}{t}\,dt$

The error term $\frac{1}{x}\int_1^x \frac{\pi(t)}{t}dt \to 0$ as $x \to \infty$ and $\frac{\theta(x)}{x} \to 1$. Consequently, if $\frac{\theta(x)}{x} \to 1$ as $x \to \infty$, then $\frac{\pi(x)\log x}{x} \to 1$. This also means that $\theta(x) \sim x$, then $\pi(x) \sim \frac{x}{\log x}$.

Conclusion

The Prime Number Theorem has come a long way since three centuries back. It has been one of the most researched and intricate theorem in finding better approximation to the number of primes less than or equal to a given real number. Several mathematicians have tried to prove or disprove the Riemann hypothesis about the zeroes of ζ(z) lying on the line $\mathrm{Re}\, z = \frac{1}{2}$ in turn giving better estimate to the error term. To this day, there are some other approaches to prove the theorem other than the analytic approach but they are not easy.

REFERENCES

Chaudhuri, A. R. (2017). A short review on prime number theorem. *International Journal of Mathematics Trends and Technology, 47*, 225-228.

Chebysev, P. L. (1852). La totalite des nombers premiers infericurs a uni lemite done. *Journal de Mathématiques Pures et Appliquées, 17*, 341-365.

Edwards, H. M. (2001). *Riemann's zeta function.* Dover Publications, New York.

Hadamard, J. (1896). Sur la distribution des zeroes de la function ζ(s) et consequences arithmetiques. *Bulletin de la Société Mathématique de France, 14,* 199-220.

Poussin, C. J., Recherches analytiques sur la theorie des numbers; Premiere particle; la fonction ζ(s) de Riemann et les numbers.

Sabbach, K. (2002). *The Riemann Hypothesis – The Greatest unsolved Problem in Mathematics*, Farrar, Strass and Giroux, Newyork.

Zagier, D. (1997). Newman's Short Proof of the Prime Number Theorem. *The American Mathematical Monthly, 104*, 705-708.

CHAPTER 5

Source Mechanisms of Earthquakes that occurred in the Central part of Shillong Plateau

**Double M. Siangshai, Devesh Walia,
Atul Saxena and Andrew Cuthbert Lyngdoh**

Introduction

The north-eastern part of India is buttressed by the north-south convergence along the Himalayan ranges and the east-west convergence and folding within the Indo-burman ranges (Chen and Molnar, 1990). Shillong plateau is proposed to be a pop-up tectonic structure, bounded by two reverse faults, the Dauki fault to the south and Oldham fault to the north (Bilham and England, 2001). The plateau is demarcated by the N-S Dhubri fault to the west, NW-SE 400 km long Kopili fault to the northeast, Dauki fault to the south and Brahmaputra fault system to the north (Figure 4). The presence of these faults has made the Shillong plateau most seismically active and tectonically complex region. The Shillong plateau shows high seismicity on comparing with upper Assam valley and Bengal basin. The Tyrsad Barapa thrust/shear zone is building up stress causing numerous earthquakes (1987 Kayal) in the recent past. Geological evidence suggests that the Shillong Plateau has been uplifted as a block since Jurassic times to its present elevation of about 600-2000 m (Krishnan, 1980; Evans, 1964). The crustal thickness of Shillong plateau is about 46 km which is more than the normal thickness of the continental crust (Tandon 1954; Verma and Mukhopadhyay, 1977).

The aim of our study is to delineate the highly active zones and types and nature of faulting in the area for better understanding the tectonics region as well as for future planning for mitigative measures.

Data Analysis

The earthquakes recorded from our three seismic stations and those from IMD, Shillong are processed and merge together in Seisan format. The P and S wave arrival onset time and the maximum amplitude of all the registered earthquakes are plotted and marked to locate the earthquake epicentres and to calculate their Local magnitude (ML). Seventeen earthquake waveforms are found to be good for waveform inversion. Fault plane solutions are determined using the ISOLA code of Zahradnik *et al.* (2001, 2005). The inversion is done at low frequency range (0.04 to 0.09 Hz) to avoid the interference of background noise with the earthquake data. The crustal velocity model of Bhattacharya *et al.* (2005) is used

in the inversions program. The obtained fault plane solutions are plot in the map using Generic Mapping Tool (GMT).

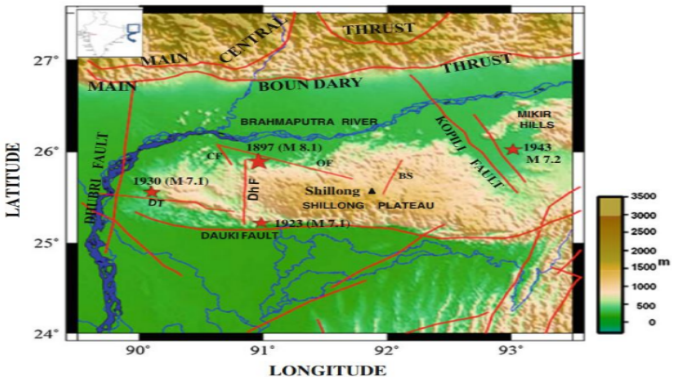


Figure 4: Tectonic map of Shillong plateau (after Biswas *et al.* 2013)

Results and Conclusion

The seimicity map (Figure 5) shows that Shillong Plateau is in a state of high seismic activity. The earthquake epicentres distributions are not linear but rather randomly distributed. The plateau is seen to be more active in its central parts compared with its eastern and western part. As observed through seismicity map the seismicity is highly concentrated in between 90.5° to 92.1° E in the study area. These earthquakes are originated from the Dudhnoi fault, Kulsi fault and the Barapani-Tyrsad lineaments. The Dauki fault which is the major tectonic feature shows some seismic activities along the fault zone. Numerous earthquakes are recorded in and around the Shillong city. The area toward the east of Shillong plateau (92. 1° – 92.5° E) is not active as observed by micro-earthquakes survey (Figure 5). Kayal (1987) assigned this area as aseismic zone.

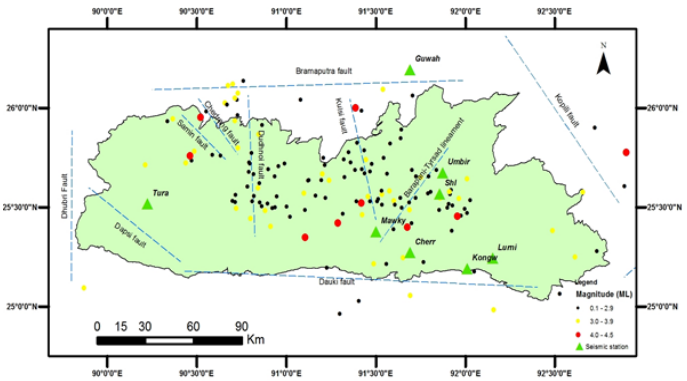


Figure 5 : Microseismicity map showing the distribution of earthquake epicentres for the period of 2013 to 2015

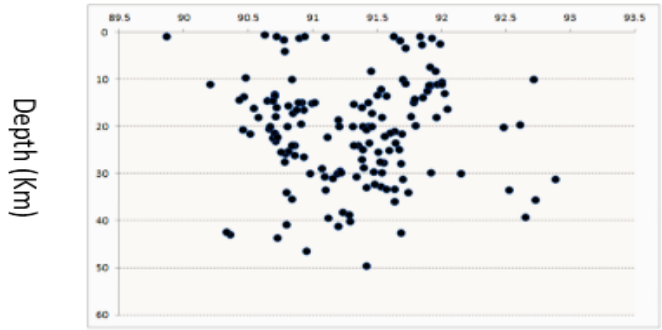


Figure 6 : East-West Earthquake's depth distribution

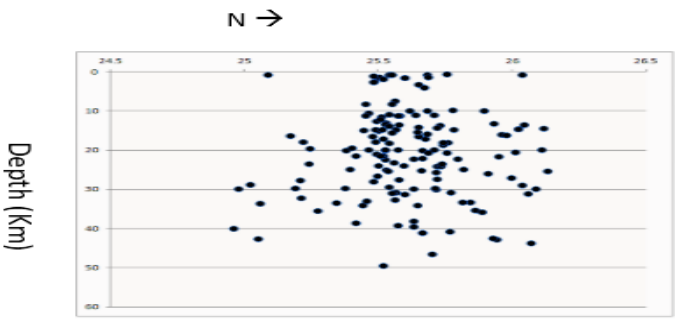


Figure 7 : North-South Earthquake's depth distribution

The depths of earthquakes are well confined ranging from near surface to a maximum of 50 km (Figure 6 and Figure 7) both in the east-west and north-south direction.

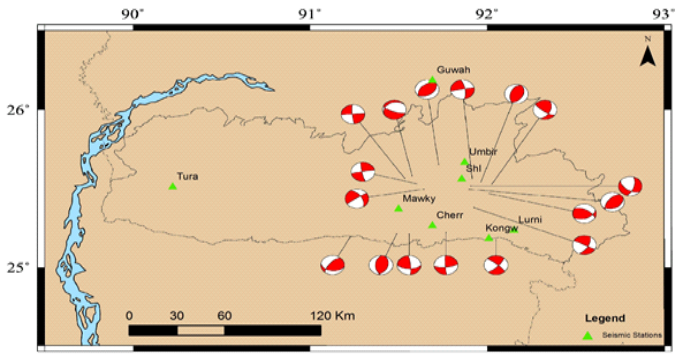


Figure 8 : Map showing fault plane solution of the recorded earthquakes

The result obtained from inversion (Figure 8) indicates that earthquakes occur along the Dauki fault shows thrust type faulting toward its centre and strike-slip type of faulting on moving toward east. Whereas the fault plane solutions in the

central part of the plateau shows a mixture of thrust, normal with strike-slip component and strike slip faulting.

REFERENCE

Bhattacharya, P. M., Pujol, J., Majumdar, R. K., & Kayal, J. R. (2005). Relocation of earthquakes in the Northeast Indian region using joint hypocentre determination method. *Current Science, 89* (8), 25.

Bilham, R., & England, P. (2001). Plateau "pop up" in the great 1897 Assam earthquake. *Nature, 410*, 806-809.

Biswas, R., Baruah, S., Bora, D. K., Kalita, A., & Baruah, S. (2013). The Effects of Attenuation and Site on the Spectra of Microearthquakes in the Shillong Region of Northeast India. *Pure and Applied Geophysics, 170* (11), 1833–1848.

Chen, W. P., & Molnar, P. (1990). Source Parameters of Earthquakes and Intraplate Deformation Beneath the Shillong Plateau and the Northern Indo-Burman Range. *Journal of Geophysical Research, 95*(B8), 12527–12552.

Evans, P. (1964). The Tectonic Framework of Assam. *Journal of the Geological Society of India, 5*, 80-96.

Kayal, J. R. (1987). Microseismicity and source mechanism study: Shillong Plateau, Northeast India. *Bulletin of the Seismological Society of America, 77* (1), 184-194.

Krishnan, M. S. (1988). Geology of India and Burma (Higgin. Bothams, Madras, India), 553.

Nandy, D. R. (2001). *Geodynamics of Northeastern India and the Adjoining Region*. ACB Publication, Kolkata, 209.

Tandon, A. N. (1954). A study of Assam earthquake of August 1950 and its aftershocks. *Indian journal of meteorology and geophysics, 5*, 95-137.

Verma, R. K., & Mukhopadhyay, M. (1977). An analysis of the gravity field in northeastern India. *Tectonophysics, 42*, 283-317.

Zahradník, J., Janskí, J., & Papatsimpa, K. (2001). Focal mechanisms of weak earthquakes from amplitude spectra and polarities. *Pure and Applied Geophysics, 158*, 647-665.

Zahradnik, J., Serpetsidaki, A., Sokos, E., & Tselentis, G. A. (2005). Iterative deconvolution of regional waveforms and double-event interpretation of the 2003 Lefkada earthquake, Greece. *Bulletin of the Seismological Society of America, 95*, 159-17.

CHAPTER 6

Comparative Case Study between Bare-Mode Lr-115 Detector Film and Pin-Hole Dosimeter in the Measurement of Indoor Radon

A. Pyngrope, A. Khardewsaw, Y. Sharma, D. Maibam and A. Saxena

Introduction

Radon (^{222}Rn) is a colourless and odourless gas which exists in different isotopic forms namely, ^{222}Rn (called radon), ^{220}Rn (called thoron) and ^{119}Rn (called actinon). This gas is of special interest due to the fact that it is radioactive and also inert in nature. Unfortunately, on inhalation this gas may reach the lungs and cause impairment of lung tissues by irradiating them with alpha particles. Overtime it can cause cancer. Radon gas originates from ^{238}U, a primordial constituent of the earth's crust. With a half-life of 3.82 days and considerable permeability range (2.9×10^{-9} to 1.4×10^{-7} cm^2) in soil; this gaseous element is easily transported from soil matrix (source) to atmosphere and finally percolates the basement through some cracks, lose plumbing etc., thereafter reaching the interior of the house (UNSCEAR, 2000; Matiullah & Steck, 2011; Durrani & Illi c, 1997).

Radioactive radon daughters which are solids under ordinary conditions, attach themselves to atmospheric dust. The health hazard is more from the inhale dust particles thathad adsorbed radioactive radon progeny on their surfaces (Cember & Johnson, 2009; Nazaroff & Nero Jr, 1988). Due to such fatal issue as a result of inhalation of these gaseous elements, there arose the necessity of designing accurate detector. Earlier, bare-mode technique was largely used [Khardewsaw et al., 2017; Khan et al., 2011; Srivastavaa et al., 2001), but with the passage of time sources of errors/accuracies in the methodology were discovered and better techniques were devised. One of the recently developed devices to measure these elements is the single entry pin-hole dosimeter based solid state nuclear track detector (Sahoo et al., 2013), which have also been deployed in some parts of Meghalaya for indoor radon and thoron measurements (Pyngrope et al., 2018). The aim of this study is to compare the response of these two techniques by exposing equal number of detectors under same environmental conditions for about three months. The detailed results of radon concentration using both the technique are presented and discrepancy between two results are noted.

Materials and Methods

LR-115 film which belongs to the class of Solid State Nuclear Track Detector,

have been used. It is a 12 μm thick cellulose nitrate film coloured deep red and coated onto 100 thick polyester backing. When an energetic alpha particle strikes the surface of the film, it leaves a trail of damage/track that can be made permanent and optically visible by chemical etching process. In bare-mode technique, LR-115 film of size 2.5 x 2.5cm^2 is pasted on a card and then hanged in a test room. In pin-hole technique the dosimeter used has two chambers with single entry fitted with filter paper of thickness 0.56 µm. The first chamber is called radon + thoron chamber and the second chamber is called radon chamber. Each chamber is cylindrical having length of 4.1cm ad radius 3.1cm. Chambers are internally coated with metallic powders to have neutral electric field inside the chamber volume, so that the deposition of progenies formed from this gas will be uniform throughout the volume (Sahoo et al., 2013).

Methodology

LR-115 (type-II) films are fitted on a bare-mode exposure sheet and inside the Pin-hole as well. Both have been exposed in the same test room. After exposure of about 99 days, these exposed films are retrieved and then undergo chemical etching in 2.5N NaOH solution at 60 ºC for 90 minutes. The alpha track formed is then counted using a Spark Counter at an operating voltage of 500V prior to pre-spark of 900V. The track density obtained is then converted into radon activity concentration using the following equations:'

$$C_{R_b}\,(Bq.m^{-3}) = \frac{\rho}{k_b.T} \qquad 1$$

$$C_{R_p}\,(Bq.m^{-3}) = \frac{\rho - B}{k_p.T} \qquad 2$$

Where ρ is the density of tracks (number of tracks counted per unit area of the film), B is the background track density, T is the duration in days for which the detectors were exposed, k_b= 0.02 tr."cm$^{-2"}$. d^{-1} (Bq.m^{-3})$^{-1}$ and k_p=0.017 ±0.002 tr.cm^{-2} d^{-1} (Bq.m^{-3})$^{-1}$ are the calibration factors used for bare-mode and pin hole technique respectively (Sahoo et al., 2013; Eappen & Mayya, 2004).

Results and Discussions

The respective radon concentration and track density for bare-mode and pin-hole techniques are presented in Table 1. Radon concentration varies from 161.62 ± 9.03 to 411.62 ± 14.42 Bq.m^{-3} in bare-mode technique and 54.39 ± 5.58 to 172.63 ± 10.07 Bq.m^{-3} in pin-hole technique. From the box plot of the data shown in Figure 9, it is clearly seen that bare-mode technique gives much higher concentration of radon as compared to pin-hole. The reason may be due to the experimental procedure followed while exposing the detector. Besides, there is a high possibility of contribution from thoron and daughter products as well to track formation in the case of bare-mode technique. The lower radon concentration in case of pin-hole technique may be due to the intrinsic design of the device which restrict radon daughters from entering the chamber due to the presence of filter paper, thus allowing only radon and thoron to enter the first

chamber (radon + thoron chamber). The presence of four small holes at the separation layer between the two chambers facilitate the passage of radon only to the second chamber (radon chamber), this is due to its comparatively longer half-life (Durrani & Illi c, 1997; Sahoo, 2013).

Table 1: Radon concentration in bare-mode and pin-hole techniques.

Detector ID	Exposure time (days)	Bare-Mode		Pin-Hole	
		Track Density (ρ)	Radon Conc. ($Bq.m^{-3}$)	Track Density (ρ)	Radon Conc. ($Bq.m^{-3}$)
C-T1	99	419	211.62 ± 10.34	208	121.53 ± 8.43
C-T2	99	374	188.88 ± 9.77	95	54.39 ± 5.58
C-T3	99	320	161.62 ± 9.03	105	60.33 ± 5.89
C-T4	99	541	273.23 ± 11.75	294	172.63 ± 10.07
C-T5	99	815	411.62 ± 14.42	131	75.78 ± 6.62

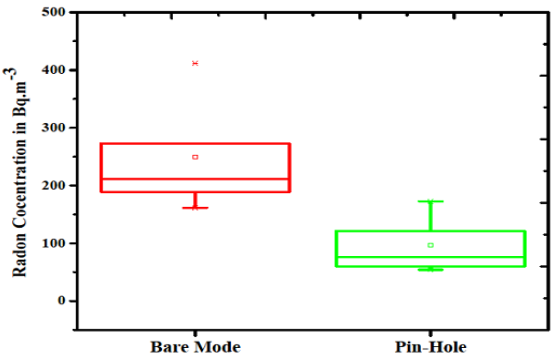


Figure 9 : Box plot of the radon concentration values obtained using the bare-mode and the pin-hole dosimeter techniques.

Conclusion

From the results obtained of the comparative study of indoor radon measurement given above (Figure 9), which clearly shows that radon concentration is shown to be much higher by the bare-mode as compared to pin-hole technique, we may infer this that the bare-mode exposure method clearly allows much more false positives to be identified than the pin-hole technique. Plate-out effects can also be a factor in the higher number shown by the bare-mode (Abu-Jarad, 1981). A supplementary thorough comparison exercise is required to put our conjecture, which was based on the results of limited experiments on firmer footing.

REFERENCES

Abu-Jarad, F., Wilsont, C. K., & Fremlin, J. H. (1981). The registration of the alpha-particles from polonium isotopes plated-out on the surface of the plastic detectors LR-115 and CR-39. *Nuclear Tracks, 5* (3), 285-290.

Cember, H., & Johnson, T. E. (2009). *Health Physics*. McGraw-Hill Medical, New York, 111-117.

Durrani, S. A., & Illi c, R. (1997). *Radon Measurements by Etched Track Detector*. World Scientific Publishing co. Pte. Ltd, New Jersey London, 3-17.

Eappen, K. P., & Mayya, Y. S. (2004). Calibration factors for LR-115 (type-II) based radon thoron discriminating dosimeter. *Radiation Measurements, 38*, 5-17.

Khan, M. S., Zubair, M., Verma, D., Naqvi, A. H., Azam, A., & Bhardwaj, M. K. (2011). The study of indoor radon in the urban dwellings using plastic track detectors. *Environmental Earth Science, 63*, 279–282.

Khardewsaw, A., Maibam, D., Sharma, Y., & Saxena, A. (2017*). Studies on indoor radon activity concentration in two villages of West-Khasi Hills District of Meghalaya, India*. 9th National Conference on Thermophysical Properties-2017, AIP Conference Proceedings 1950, 02011, American Institute of Physics, Melville, New York, 1-8.

Matiullah, R. S., & Steck, D. J. (2011). *Indoor Radon, Thoron and Natural Radioactivity Measurements*. Lambert Academic Publishing, Deutschlad, 1-3.

Nazaroff, W. W., & Nero Jr, V. A. (1988). *Radon and its decay products in indoor air*. Wiley Inter Science Publication, California, 5-24.

Pyngrope, A., Khardewsaw, A., Maibam, D., Sharma, Y., Saxena, A., & Sahoo, B. K. (2018). Measurement of indoor radon and thoron in East Khasi Hills district of Meghalaya, India. *Journal of Applied and Fundamental Sciences, 4* (1), 37-40.

Srivastavaa, A., Zamanb, M. R., Dwivedic, K. K., and Ramachandrand, T. V. (2001). Indoor radon level in the dwellings of the Rajshahi and Chuadanga regions of Bangladesh. *Radiation Measurements, 34*, 497– 499.

Sahoo, B. K., Sapra, B. K., Kanse, S. D., Gaware, J. J., & Mayya, Y. S. (2013). A new pin-hole discriminated $^{222}Rn/^{220}Rn$ passive measurement device with single entry face. *Radiation Measurements, 58*, 52-60.

UNSCEAR (2000), United Nations Scientific Committee on the Effects of Atomic Radiation.

CHAPTER 7

Analysis of Dichlorodiphenyltrichloroethane (DDT) in Several Food Items Collected From a Market in Shillong City

Dipyendu Paul and Balawan Joshua Mawrie

Chemical pesticides are used on a regular basis in the agricultural and health sectors for pests and disease control. They are important in lowering crop loss due to pest and thus help maintain the food security of any nation. Sustaining agricultural production is a challenge with number problems affecting it. One of the major factors that reduce crop production is the losses due to pest infestation and various diseases. Dhaliwal *et al.* (2015) mentioned that although crop losses have declined since the Green Revolution, but it still results in India incurring crop losses to the tune of 36 billion U.S. dollars annually. In the health sector, pesticides also play a major role in containing the spread of vector borne diseases. These diseases pose a great threat especially in those countries where they are endemic and various control programmes are dependent on the use of pesticides to fight against various disease carrying vectors (Gratz *et al.,* 1994). Although, pesticides have helped reduce crop losses and combat diseases, their use have resulted in unwanted effects on both humans and the environment.

In 1940s the use of synthetic pesticides came into light DDT (Dichlorodiphenyltrichloroethane) became very popular because of its effectiveness against vectors of various diseases (Unsworth, 2010). DDT is a very toxic organochlorine pesticide that operates as a broad spectrum contact which fleas, lice, mosquitoes and also againstvarious crop pests (Encyclopaedia Britannica, 2018). Technical DDT is of three forms which include *p,p′* DDT, *o,p′* DDT and minute amounts of *o,o′* DDT. DDT breakdown products include 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane and ,1-dichloro-2,2-bis(p-chlorophenyl)ethylene which are respectively known as DDD and DDE (ATSDR, 2002). The IARC (2017) has classified DDT under class 2A carcinogen that may be related to liver and testicular cancer as well as Non-Hodgkin lymphoma. A possible link between increased risks for Alzheimer Disease due DDT exposure has also been suggested by Richardson *et al*., in 2014. Therefore, this particular study was taken up to bring to light of any possible contamination in the food products by DDT and whether contamination levels are at a dangerous level or not.

Study Area

The study was conducted in Shillong City, the state capital of Meghalaya which is located in the North Eastern Region of India. Meghalaya extends between latitudes 20°1'N to 26°5'N and longitudes 85°49'E to 92°52'E. Its ranged is about 300km from east to west and about 100km from north to south. The total geographical cover area of Meghalaya is around 22,429 sq km (Department of Agriculture-Meghalaya, 2018). Usually, Shillong is represented by the Shillong Urban Agglomerate which constitutes seven main towns that is comprised of five census towns, namely, Mawlai, Nongthymmai, Pynthorumkhrah, Madanriting and Nongmynsong along with the Shillong Municipal Area and Shillong Cantonment. (Meghalaya State Development Report, 2008-2009).

Iewduh, is the largest market within the Shillong Urban Agglomeration. The market coveres an area of approximately 2.4 square kilometres and for centuries has been the heart of major socio economic activities of the Khasi people (Hynniewta, 2015). *Iewduh* is the single largest market of the Hima which feeds the rest of the smaller markets within the city of Shillong.

Methodology

Random sampling of the food samples was carried out within the *Iewduh* market area. One kilogram of each of the food products were collected from a minimum of 5 random areas of the market totaling to 5 kilograms for each of the food products. A 1 kilogram composite sample was then segregated for analysis of the pesticide residues. A set of maximum three replicate composite samples were selected for each food samples. The food samples selected for the purpose of this study included rice, potato, tomato, apple and banana.

Analysis of DDT was carried out as per the AOAC 2007.01 and QuEChERS with Dispersive Solid Phase Extraction as a sample preparation and cleanup process.

Results and Dicussions

Analysis of the samples of rice, potato, tomato, apple and banana for contamination by residues of DDT was carried out. The contamination levels were compared with the MRL values set by the FSSAI and for the MRL values that are not available under the FSSAI, the values were compared with the MRLs provided by the Codex Alimentarius of the Food and Agriculture Organisation of the United Nations. Total DDT is the sum of both the *p,p′* DDT and *o,p′* DDT isomers of DDT. The results are presented in Table 2

Table2: Total DDT Residues (mg/kg) in Several Food Items

Total DDT					
Sl. No.	**Food Items**	**LOQ**	**MRL**	**Mean**	**S.D**
1	Rice	0.01	0.1**	0.076	0.0933
4	Potato		3.5	BDL	-

5	Tomato		3.5	BDL	-
6	Apple		3.5	BDL	-
7	Banana		3.5	0.0137	0.0052

MRL: Maximum Residual Levels by Food Safety and Standards Authority of India.

MRL*: Codex Alimentarius of FAO. (**At or about the limit of determination)
MRL (NA): Not Available

BDL: Below Detectable Limit (< 0.01 mg/kg).

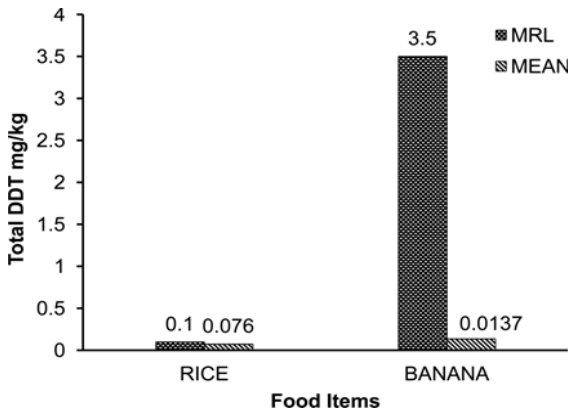


Figure 10 : Total DDT Residues (mg/kg) in Food Items

The results indicate that samples of 2 food items were contaminated with residues of DDT. Rice showed contamination level at 0.076± 0.0933 mg/kg of DDT and banana contained 0.0137±0.0052 mg/kg of DDT. The residual levels in the samples of the potato, tomato and apples were all Below Detectable Limit (0.01 mg/kg). Although, residues of DDT were detected in rice, the levels did not exceed the MRL value of 0.1mg/kg as set by Codex Alimentarius of FAO and similarly the residual level found in banana did not exceed the MRL value as mentioned by the FSSAI which is set at 3.5 mg/kg.

The Central Insecticide Board and Registration Committee (2015) of the Government of India had enlisted DDT under Restricted for use which means that DDT is restricted to be used, produced, and exported for controlling the populations of disease carrying vectors only and use of DDT in the agriculture has been withdrawn. Therefore, one possible explanation for the likely source of DDT residues that were detected in rice and banana is due to cross contamination during the use of DDT in the health sector. Another possible reason is that DDT is illegally used in agriculture at various capacities, or cross contamination maybe from food items coming in contact with contaminated soil which may still contain DDT due to its persistent nature.

Conclusion

Although the residual levels of DDT found in rice and banana samples were below the prescribed MRL values, it still shows that this particular chemical still found its way into our food despite being banned from agricultural use. It shows that there is still a lapse in preventing DDT from reaching our food and also highlights further improvements in ensuring that harmful chemicals do not contaminate our food. DDT being persistent and bio-accumulative, it may pose a serious human and environmental threat. Therefore it is important to regularly monitor food items for the presence of any possible unwanted chemical in order to ensure the safety of the people who consume them.

REFERENCES

Dhaliwal, G. S., Jindal, V., & Mohindru, B. (2015). Crop Losses Due To Insect Pest: Global and Indian Senario. *Indian Journal of Entamology, 77*(2), 165.

Gartz, G. N., Jany, C. W. (1994). What role for insecticides in vector control programs?. *The American Journal of Tropical Medicine and Hygiene, 50*(6), 11 – 20.

Unsworth, J. (2010). History of Pesticide. *International Union of Pure and Applied Chemisty*. Available fromhttp://agrochemicals.iupac.org/index.php?option=com_sobi2&sobi2Task=sobi2Details&catid=3&sobi2Id=31. (Retrieved on 18/3/2018).

Encyclopaedia Britannica (2018). *DDT*. Encyclopaedia Britannica Inc. https://www.britannica.com/science/DDT / viewed on 30.05.18.

Agency for Toxic Substances and Disease Registry (2002). *Toxicological Profile for DDT, DDE, and DDD*. U.S. Department Of Health And Human Services, 1-2. International Agency for research on Cancerand World Health Organisation (2015). *IARC Monographs Evaluate DDT, Lindane and 2,4-D*. World Health Organization, 1-2.

Richardson, J. R., Roy, A., Shalat, S. L., von Stein, R. T., Hossain, M. M., Buckley, B., Gearing, M., Levey, A. I., & German, D. C. (2014). Elevated Serum Pesticide Levels and Risk for Alzheimer Disease. *JAMA Neurology 71*(3), 284-290.

Department of Agriculture Government of Meghalaya.http://www.megagriculture.gov.in/State of Environment Report. Meghalaya. (2005).http://www.moef.nic.in/sites/default/files/SoE%20report%20of%20Meghalaya_0.pdf. Hynniewta, I. (2015). Organised retailing and its structure in the city of Shillong. *Journal of International Scientific Publications, 9*, 740-753.

AOAC International (2007). Pesticide Residues in Foods by Acetonitrile Extraction and Partitioning with Magnesium Sulfate Gas Chromatography/Mass

Spectrometry and Liquid Chromatography/Tandem Mass Spectrometry. AOAC Official Method 2007.01.

Codex Alimentarius. International. Food Standards. Food and Agriculture Organisation. World Health Organisation. http://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/pesticides/en/.

Food Safety and Standards Authority of India (2011). Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011. Ministry of Health and Family Welfare.

Central Insecticide Board and Registration Committee. 2015. List of Pesticides Which Are Banned, Refused Registration and Restricted In Use. Ministry of Agriculture and Farmers Welfare, Government of India. http://cibrc.nic.in/list_pest_bann.html/ viewed on 20.03.2018.

CHAPTER 8

Ethno-Botanical Knowledge of Medicinal Plants used by the Jaintias for Treatment Of Cancer

Diamond Salahe, Dibyendu Paul and Krishna Upadhaya

Introduction

Cancer is a generic term for a broad group of various diseases characterized by unregulated cell growth. In a cancerous state, cells division and growth are uncontrollable resulting in the formation of tumors that, if malignant, may metastasize to other parts of the body (Ochwangi *et al*., 2014; WHO 2018). From the perspective of genome scientists, cancer is a disease of the genome. All cancers harbor mutations in their genome. Some of these mutations have profound effects on the biology of the cancer cell by driving tumor growth. These genetic instabilities include mutations in DNA repair genes (p21, p22, p27, p51, p53 and tool box for DNA), some mutations can inactivate genes that usually protect cells from abnormal proliferation; these are classically referred to as tumor suppressor genes (p53, NF1, NF2, RB, and biological breaks), oncogenes [MYC, RAF, Bcl-2, RAS (biological accelerators)] and genes involved in cell growth metabolism (Krishnamurthi, 2007; Ochwangi *et al*., 2014 and WHO, 2014). The causes of rising in cases of cancer are not known. However, 5–10% of all cancer cases are often attributed to genetic defects, whereas the remaining 90–95% has their roots in the environment and lifestyle which includes tobacco use, certain infections, radiation, and lack of physical activity, age, poor diet, obesity, and environmental pollutants (Anand *et al*., 2008). These factors may damage genes directly or combine with existing genetic faults within cells to cause the disease (Anand *et al*., 2008 and NCI, 2015). Globally, cancer is the second leading cause of death and is responsible for an estimated 9.6 million deaths in 2018 with the most common being lung (1.76 million deaths) colorectal (862 000 deaths) stomach (783 000 deaths) liver (782 000 deaths) breast (627 000 deaths). Lung, prostate, colorectal, stomach and cancer of liver measure the foremost common types of cancer in men, while breast, colorectal, lung, cervix, and thyroid cancer are the most common among women (WHO, 2018).

According to GLOBOCAN (WHO, 2018) there were 11,57,294 new cancer cases in India in both men and women that includes 7,84,821 deaths and 22,58,208 people living with cancer (within 5 years of diagnosis). The five most frequent cancers cases in India in men and women are breast, cervical, oral cavity,

lung and colorectal. Even in India, Cancer is the second most common cause of death next to cardiovascular disease (WHO, 2018). The disease is treated in various ways including surgery of tumors, radiotherapy, immunotherapy, chemotherapy, precision medicine, hormone therapy, targeted therapy, and stem cell transformation or in any combination of these. Patient survival varies greatly depending on the type, location, and stage of the disease and the onset of treatment (NCI, 2015). Chemotherapy in addition to surgery has proved to be helpful in a range of various different cancer types including breast, colorectal, pancreatic, osteogenic sarcoma, testicular, ovarian and certain lung cancers (Ochwangi *et al*., 2014). However, all of these treatments are often accompanied by side effects and limitations which include limited bioavailability, toxicity, no specificity, fast clearance and restriction in metastasis (Ochwangi *et al*., 2014; NCI, 2015; WHO, 2018). Consequently, cancer patients' consultations of traditional healers, complementary and alternative therapies such as herbal therapies are increasingly high. Such interventions have however not been rigorously studied or tested for their therapeutic value (Vickers, 2004; Alnaggar *et al*., 2012 and Marriam *et al*., 2013). Use of plants for treatment of cancer is not new (Ochwangi *et al*., 2014), indeed plants have been considered a valuable source of bioactive compounds for treatment of many conditions in almost all cultures and communities for thousands of years (Aiyegoro *et al*., 2009; Mohan *et al*., 2011 and Iqbal *et al*., 2017).

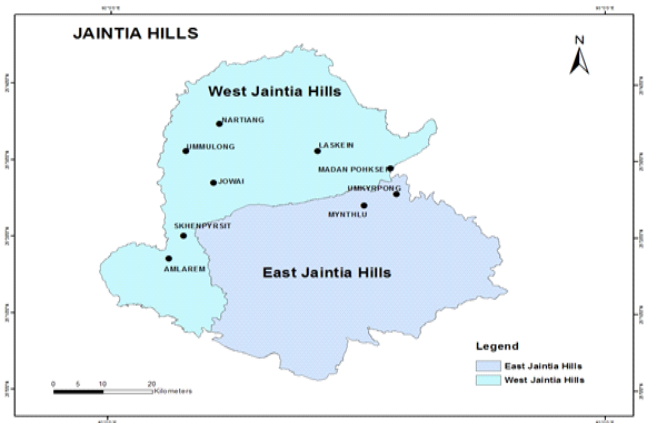


Figure 11: Location map of Jaintia Hills Districts showing study villages

Methodology

Study Area: The present study was conducted in nine villages viz., Mynthlu and Umkyrpong in East Jaintia Hills and Amlarem, Skhenpyrsit, Jowai, Ummulong, Nartiang, Laskein and Madan Pohsker in West Jaintia Hills (Figure 11). Selection of the study area was based on the availability of traditional healers in these villages and their willingness to share the rich and undocumented traditional knowledge about herbal medicines. East Jaintia Hills District is located at the

easternmost part of Meghalaya. It covers an area of 2040 sq. km. and lies between 25°.17~30: 25°.22~40 Latitude and 92°.15~20:92°.23~30 Longitude. It is bounded by Bangladesh in the south, North Cachar Hills District in the east and West Jaintia Hills District in the north and west. West Jaintia Hills District (25.5021° N, 92.3419° E) is bounded by Assam in the North, Bangladesh and East Jaintia Hills District in the South, Assam in the East and East Khasi Hills District in the West. The total population of Jaintia Hills Districts is 3,95,124.

Selection of Healers and Data Collection: In April 2018, an ethnobotanical survey was conducted with the respondents being Traditional Health Practitioners (THPs). Semi-structured questionnaires were administered to Traditional Health Practitioners (THPs). The questionnaires collected information on the medicinal plants; the local name of the plant(s) and part(s) used, method of preparation, dosage, and route of administration. A total of 20 healers from the study area were initially approached through peer recommendations. However, data were collected from 13 traditional healers through interviews. The purpose of the study as well as the research objectives, methods of data collection, and intention to publish data were thoroughly explained to each individual healer that was approached. The interviews were largely conducted in their homes followed by field visit to those places from where the plants are collected for treatments.

Specimen Collection and Plant Identification: The medicinal plants reportedly used by the THPs in cancer treatment were collected along with the healers. The plants were properly pressed using a herbarium press, dried, and mounted on herbarium sheet. The collected specimens were identified with the help of local floras viz., Flora of Assam (Kanjilal *et al*., 1934-1940), Forest Flora of Meghalaya (Haridasan and Rao 1985-1987), Flora of Jowai (Balakrishnan 1981-1983) and Flora of Nongpoh (Joseph 1986). The Herbaria at Botanical Survey of India, Eastern Regional Centre, Shillong were also consulted for correct identification of the specimens. The nomenclature of the species follows The Plant List database (http://www.theplantlist.org). The voucher specimens of all species were numbered and deposited in the Department of Environmental Studies, North-Eastern Hill University, Shillong.

Data analysis: Informants' use reports and frequency of citation were calculated for each species. The use-value was also calculated to see the relative importance of selected traditional medicinal plant species used for treating cancer in the study area according to Phillips *et al* (1994). The relative importance of species was calculated according to use-value formula as below:

$$UV = \frac{UVi}{Ni}$$

Where, UVi is the number of citations for species across all healers and Ni is the number of healers interviewed (Phillip et al., 1994).

Table 3: List of medicinal plants used by the Traditional Health Practitioners of Jaintia tribes for the treatment of cancer

Scientific name	Family	Local name	Part Used	Preparation, Route of administration and Dosage	FC	RFC	UV
Acorus calamus L.	Acoraceae	Rniaw Larse	Rhizome	Cold infusion (5ml) of the plant rhizome is taken orally for the treatment of cancer. Rhizome paste is applied topically onto tumor once daily.	5	0.11	0.3
Aegle marmelos (L.) Corrêa	Rutaceae	Sohbel	Bark	Powdered bark is used in the treatment of mouth cancer. About 2g of dried powdered bark is taken orally with water two times daily.	6	0.13	0.4
Bidens pilosa L.	Asteraceae	Syrthied	Leaf, Root	Leaf decoction (50-60 ml) is given three times daily to treat cancer. 50ml of root infusion is given three times daily in the treatment of cancer.	3	0.06	0.2
Buddleja asiatica Lour.	Scrophulariaceae	Raphilieh	Leaf	Leaf decoction prepared with either dried or fresh leaves (50ml) is taken orally three times daily in the treatment of cancer. Leaf paste is applied topically onto tumor once daily.	5	0.11	0.3
Centella asiatica (L.) Urb.	Apiaceae	Tyngkheh	Whole plant	About 15-20ml decoction is taken orally three times daily for the treatment of cancer.	6	0.13	0.4
Cinnamomum zeylanicum Blume	Lauraceae	Deinmuka	Bark	Bark decoction (20ml) is taken orally 3 times daily to treat cancer	2	0.04	0.1

Cuscuta reflexa Roxb.	Convolvulaceae	Seinraij	Whole plant	Whole plant decoction (3-5ml) is taken orally two times daily to treat mouth cancer. Paste is applied topically onto tumor once daily.	7	0.15	0.5
Emilia sonchifolia (L.) DC. ex DC.	Asteraceae	Phlangckhor	Leaf	Leaf decoction prepared with either dried or fresh leaves (50ml) is taken orally three times daily in the treatment of cancer. Leaf paste is applied topically onto tumor once daily.	3	0.06	0.2
Kaempferiagalanga L	Zingiberaceae	Krahtubeng, Syiensmoh,Khlabyrtap	Rhizome leaf	Rhizome decoction (20ml) is taken three times daily to treat cancer. Leaf poultice spread on clean cloth or banana trunk is tied on cancer tumor once daily until it heals.	7	0.15	0.5
Rumex nepalensis Spreng.	Polygonaceae	Iada	Whole plant	Fresh plant can be eaten raw or juice (20 ml) obtained from the above ground part of the plants is given orally three times daily.100ml of root infusion is given three times daily in the treatment of cancer.	3	0.06	0.2

(Abbreviations: FC- frequency of citation, RFC-relative frequency of citation, UV- use value)

Table 4 : Cross-reference of cancer treatment plant species collected from published literature.

Scientific name	Phytochemicals/Anticancer activity
Aegle marmelos	Skimmianine. Extracts of *Aegle marmelos* have anti-proliferative effects on human tumor cell (Lamprontie*t al.,* 2003), inhibits the proliferation of transplanted ehrlich ascites carcinoma (Jagetia *et al.,* 2005), cytotoxic effect on human colon adenocarcinoma cell lines (Baskar *et al*., 2012).

Acorus calamus	Sesquiterpenes, phenylpropanoid (Jain *et al.,* 2016). Extracts of rhizome of *Acorus calamus* were found to be cytotoxic against cancer cells (Rajkumar*et al.,* 2009) and possesses antitumor properties against prostate cancer (Koca*et al.,* 2018) gastric cancer cells (Haghighi*et al.,* 2017) oral cancer cells (Antony *et al.,* 2017) colon cancer (Funde 2015)
Bidens pilosa	Polyacetylenes (Kviecinski *et al.,* 2011). Extracts of *Bidens pilosa* have anti-tumor properties (Kviecinski *et al.,* 2008),anti-leukemic activity (Chang etal.,2001)
Buddleja asiatica	Methanol extracts of *Buddleja asiatica*leaves showed significant cytotoxic activity against HepG2 cell line (Mohamed *et al.,* 2013)
Centella asiatica	Asiatic acid extract of *Centellaasiatica*was found to induce apoptosis on human breast cancer cells(Babykutty*et al.,* 2009)
Cinnamomum zeylanicum	Cinnamaldehyde (Haung*et al*., 2007). Extract *Cinnamomum zeylanicum* bark exhibits antitumor activity (Gomez*et al.,* 2010), cytotoxic effect against cancer cells (Singh *et al.,* 2009)
Cuscuta reflexa	Extract of *Cuscuta reflexa* induces apoptosis of cancer cells (Suresh *et al.,* 2011), antitumor activity (*Chatterjee, 2011*)
Emilia sonchifolia	Flavanoids. *Emilia sonchifolia* extract inhibit the proliferation of human cancer cells (Cibin*et al.,* 2006)
Kaempferia galanga	Polysaccharides (Yang *et al.,* 2018) Ethyl-p-methoxycinnamate, kaempferol (He *et al.,* 2012). Methanolic extract of *Kaempferia galanga* exhibit anti neoplastic effect against Ehrlich ascites carcinoma (Ali *et al.,* 2018), selective toxicity towards cancer cells (Jagadish*et al.,* 2010),cholangiocarcinoma (Mahavorasirikul *et al.,*2010)
Rumex nepalenses	Emodin, chrysophanol, physcion, citreoresin. Extracts *Rumex nepalenses* have cytotoxic effect against lung cancer (Hussain *et al.,* 2010, Hameed *et al.,* 2013)

Result and Discussion

In the present study a total of ten medicinal plants belonging to 9 families have been reported that are widely used by the *Jaintias*/*Pnar* tribes for curing cancer. All the plants are commonly found in the area. The parts of plants that were used for the preparation of the remedies include bark (2 species), root (2 species), rhizome (2 species), leaf (3 species) and whole plant (3species) (Table 3). The methods of preparation reported in this study were decoction (41%), paste (29%), infusion (17%) powder and juice (6% each).

Generally, there were no standards followed by the healers in the preparation of the anticancer herbal medicines and diversity was seen even by the same healer. In the study area, diversity existed in the preparations of decoctions and infusions

among healers and from place to place in the amount of menstruum used which is mainly water, length of time of boiling and duration of use of decoctions. Infusions were made by adding water to the pulverized plant materials although the amount of water added and duration of use of infusions differed among healers. The most common route of administration was oral (66.7%) followed by topical route (33.3%). The relative importance of two plants namely, *Cuscuta reflexa* and *Kaempferia galanga* was found to be the highest each securing Use Value of 0.5 which are also the most familiar with RFC of 0.15.

Acorus calamus

Bidens pilosa

Buddleja asiatica

Centella asiatica

Cinnamomum zeylanicum

Cuscuta reflexa

Emilia sonchifolia

Kaempferia galanga

Rumex nepalensis

Figure 12: Photo of plant species used in the treatment of cancer.

The reported species were further validated for the presence of bioactive compound through secondary literature. For instance, Polyacetylenes in *Bidens pilosa* (Kviecinski *et al.,*2011), kaemferol and ethyl-pmethoxycinnamate in *Kaempferia galanga* (He *et al.,* 2012), Sesquiterpenes, phenylpropanoid in *Acorus calamus* (Jain *et al.,*2016) (Table 4).The plants reported in this study have been reported by in vitro and in vivo studies to possess strong anticancer activity namely *Acorus calamus* ((Rajkumar*et al.,*2009; Koca*et al.,* 2018;Haghighi*et al.,* 2017;Antony *et al.,*2017and Funde 2015). *Bidenspilosa* (Chang *et al.,* 2001; Kviecinskietal *et al*., 2008; Sundararajan *et al.,* 2006), *Centella asiatica*(L.) Urb. (Babykutty *et al.,* 2009), *Cinnamomum zeylanicum (*Gomez*et al.,* 2010 and Singh *et al.,*2009*)Emilia sonchifolia* (Cibin*et al.,* 2006), *Kaempferia galanga* (Jagadish *et al.,*2010;Mahavorasirikul *et al.,* 2010), *Rumex nepalensis* (Hussain *et al.,*2010; Hameed *et al.,*2008 and 2013).

Conclusion

These indigenous therapeutic practices of treatment based on medicinal plants and consultation of THPs for various diseases especially in rural areas are still an important part of the culture among the *Jaintias***.** The extent to which people living with cancer in the area consult the healers is unknown but it is important to understand this in order to determine the proper role of herbal medicine and also the role played by the THPs in the health care system of the people. The THPs, other than herbal medicines also provide the cancer patients with emotional comfort and spiritual healing. It is also essential to scientifically evaluate the claimed therapeutic values of these reported medicinal plants from the area through pharmacological, toxicological, and clinical studies in order to ensure the effectiveness, their uses in community healthcare and safety of the people consuming the medicines and for possible drug development now and in the future.

REFERENCES

Aiyegoro, O. A., & Okoh, A. I. (2009). Used of bioactive plant products in combination with standard antibiotics: Implications in antimicrobial chemotheraphy. *Journal of Medicinal Plants Research*, *3*(13), 1147-1152.

Ali, H., Yesmin, R., Satter, M. A., Habib, R., & Yeasmin, T. (2018). Antioxidant and antineoplastic activities of methanolic extract of Kaempferiagalanga Linn. Rhizome against Ehrlich ascities carcinoma cell. *Journal of King Saud University, 30*(3), 386-392.

Al-Naggar, R. A., Bobryshev, Y. V., Abdulghani, M. A. A. M., Rammohan, S., & Al-Jashamy, K. (2013). Knowledge and Perceptions of Cancer and Cancer Prevention among Malaysian Traditional Healers: a Qualitative Study. *Asian Pasific Journal of Cancer Prevention, 13*, 3841-3850.

Anand, P., Kunnumakara, A. B., Sundaram, C., Harikumar, K. B., Tharakan, S. T., Lai, O. S., Sung, B. & Aggarwal, B. B. (2008). Cancer is a preventable disease

that requires major lifestyle changes. *Pharmaceutical Research*, *25*, 9.

Antony, M., Gayathri, R., & Vishnu, P. V. (2017). Apoptotic activity of Acorus calamus on Oral cancer cell lines. *International Journal of Pharmaceutical Science*, *44*(1), 30-32.

Babykutty, S., Padikkala, J., Sathiadevan, P. P., Vijayakurup, V., Azis, T. K. A., Srinivas, P., & Gopala, S. (2009). Apoptosis induction of centellaasiatica on human breast cancer cell. *African Journal of Traditional, Complementary and Alternative Medicines, 6*(1), 9-16.

Balakrishnan, N. P. (1981–1983). *Flora of Jowai and Vicinity*, Meghalaya, 2 Vols. BSI, Howrah, India.

Baskar, A. A., Numair, K. S. A., Alsaif, M. A., & Ignacimuthu, S. (2012). In vitro antioxidant and antiproliferative potential of medicinal plants used in traditional Indian medicine to treat cancer. *Redox Report*, *17*(4), 145-156.

Chang, J. S., Chiang, L. C., Chen, C. C., Lui, L. T., Wang, K. C., & Lin, C. C. (2001). Antileukemic Activity of BidenspilosaL.var.minor (Blume) Sherff and HouttuyniacordataThunb. *The American Journal of Chinese Medicine*, *29*(2), 303-312.

Chatterjee, D., Sahu, R. K., Jha, A. K., & Dwivedi, J. (2011). Evaluation of Antitumor Activity of CuscutaReflexaRoxb (Cuscutaceae) Against Ehrlich Ascites Carcinoma in Swiss Albino Mice. *Tropical Journal of Pharmaceutical Research*, *10*(4), 447-54.

Cibin, T. R., Srinivas, G., Gayathri, D. D., Priya, S., Lija, Y., & Annie, A. (2006). Antioxidant and Antiproliferative Effects of Flavonoids from Emilia sonchifoliaLinn on Human Cancer Cells. *International Journal of Pharmacology*, *2*(5), 520-4.

Funde, S. G. (2015). Phytochemicals evaluation, anticancer, antioxidant and antimicrobial activity of *Acoruscalamus* different solvent extracts. *Journal of Chemical and Pharmaceutical Research, 7*(6), 495-504.

Gomez-Flores, R., Martínez, H. H., Guerra, P. T., Guerra, R. T., Licea, R. Q., Enriqueta, C. M., & Padilla, C. R. (2010). Antitumor and immunomodulating potential of Coriandrumsativum, Piper nigrumand Cinnamomumzeylanicum. *Journal of Natural Products, 3*, 54-63.

Haghighi, S. R., Asadi, M. H., Akrami, H., & Baghizadeh, A. (2017). Anti-carcinogenic and anti-angiogenic properties of the extracts of Acoruscalamus on gastric cancer cells. *Original Research Article, 7*(2), 145-156.

Hameed, I., Dastagir, G., & Hussain, F. (2008). Nutritional and elemental analyses of some selected medicinal plants of the family Polygonaceae. *Pakistan Journal of Botany*, *40*(6), 2493-2502.

Hameed, I., Hussain, F., Sher, Z., Bacha, N., & Khan, A. A. (2013). Cytotoxicity and phytotoxicity of some selected Medicinal plants of family Solanaceae. *Pakistan Journal of Botany*, *45*(5), 1749-1754.

Haridasan K., & Rao, R. R. (1985–1987). *Forest Flora of Meghalaya*, 2 Vols. Bishen Singh Mahendrapal Singh, DehraDun, India.

He, Z. H., Yue, G. G. L., Lau, C. B. S., Ge, W., & But, P. P. H. (2012). Antiangiogenic Effects and Mechanisms of trans-Ethyl p-Methoxycinnamate from Kaempferia galangal L. *Journal of Agricultural and Food Chemistry*, *60*(45), 11309-11317.

Huang, T. C., Fu, H. Y., Ho, C. T., Tan, D., Huang, Y. T., & Pan, M. H. (2007). Induction of apoptosis by cinnamaldehyde from indigenous cinnamon CinnamomumosmophloeumKaneh through reactive oxygen species production, glutathione depletion and caspase activation in human leukemia K562 cells. *Food Chemistry*, *103*(2), 434-43.

Hussain, F., Hameed, I., Dastagir, G., Nisa, S., Khan, I., & Ahmad, B. (2010). Cytotoxicity and phytotoxicity of some selected medicinal plants of the family Polygonaceae. *African Journal of Biotechnology*, *9*(5), 770-774.

Iqbal, J., Abassi, B. A., Mahmood, T., Kanwal, S., Ali, B., Shah, S. A., & Khalil, A. T. (2017). Plant derived anticancer agents: A green anticancer approach. *Asian Pacific Journal of Tropical Biomedicine*, *7*(12), 1129-1150.

Jagadish, P. C., Chandrashekar, H. R., & Latha, K. P. (2010). Potent Selective Cytotoxic Activity of KaempferiaGalanga L. rhizomes against cancer cell cultures. *International Journal of Pharma and Bio Science, 2*(9), 105.

Jagetia, G. C., Venkatesh, P., & Baliga, M. S. (2005). Aegle marmelos(L.) Correa Inhibits the Proliferation of Transplanted Ehrlich Ascites Carcinoma in Mice. *Biological and Pharmaceutical Bulletin, 28*(1), 58-64.

Jain, S., Dwivedi, J., Jain, P. K., Satpathy, S., & Patra, A. (2016). Medicinal plants for treatment of cancer: A brief review. *Pharmacognosy Journal*, *8*, 2, 87-102.

Joseph, J. (1982). *Flora of Nongpoh and its vicinity, Khasi and Jaintia Hills district of Meghalaya*. Botanical Survey of India, Calcutta.

Kanjilal, V. N., Kanjilal P. C., Das, A., De, R. N., & Bor, N. L. (1934–1940). *Flora of Assam*, 5 Vols. Government Press, Shillong, India.

Koca, H. B., Koken, T., Ozkurt, M., Kus, G., Kabadere, S., Erkasab, N., Koca, O., & Colak, O. (2018). Effects of Acoruscalamus plant extract on prostate cancer cell culture. *Anatolian Journal of Botany*, *2*(1), 46-51.

Krishnamurthi, K. (2007). 17-Screening of natural products for anticancer and antidiabetic properties. *Health Administrator*, *XX*(1&2), 69-75.

Kviecinski, M. R., Felipe, K. B., Schoenfelder, T., Wiese, L. P. L., Rossi, M. H., Goncalez, E., Felicio, J. D., Filho, D. W., & Pedrosa, R. C. (2008). Study of the antitumor potential of Bidenspilosa (Asteraceae) used in Brazillian folk medicine. *Journal of Ehthnopharmacology*, *117*, 69-75.

Kviecinski, M. R., Banelli, P., Felipe, K. B., Correia, J. F. G., Pich, C. T., Ferreira, S. R. S., & Pedrosa, R. C. (2011). SFE from BidenspilosaLinne to obtain extracts rich in cytotoxic polyacetylenes with antitumor activity. *The Journal of Supercritical Fluids*, *56*(3), 243-248.

Lampronti, I. D., Martello, N., Bianchi, M., Borgatti, E., Lambertini, R., & Piva, S., *et al.,*(2003). In vitro antiproliferative effects on human tumor cell lines of extracts from the Bangladeshi medicinal plant Aeglemarmelos Correa. *Phytomedicine*, *10*(4), 300-8.

Mahavorasirikul, W., Viyanant, V., Chaijaroenkul, W., Itharat, A., & Na-Bangchang, K. (2010). Cytotoxic activity of Thai medicinal plants against human cholangiocarcinoma, laryngeal and hepatocarcinoma cells in vitro. *The official journal of the International Society for Complementary Medicine Research (ISCMR)*, *10*, 55.

Merriam, S., & Muhamad, M. (2013). Roles Traditional Healers Play in Cancer Treatment in Malaysia: Implications for Health Promotion and Education. *Asian Pasific Journal of Cancer Prevention, 14*(6), 3593-3601.

Mohamed, M., Abdou, A., Saad, A., & Ibrahim, M. (2013). Cytotoxic activity of Buddleja asiatica. *Life Science Journal*, *10*(1), 2773-2777.

Mohan, S., Bustamam, A., Ibrahim, S., Al-Zubairi, A. S., Aspollah, M., Abdullah, R., & Elhassan, M. M. (2011). In vitro ultramorphological assessment of Apoptosis on CEMss induced by Linoleic Acid-Rich fraction from Typhonium flagelliforme Tuber. *Hindawi Publishing Corporation Evidence-Based Complementary and Alternative Medicine*, doi:10.1093/ecam/neq010

NCI. National Cancer Institute (2015). Cancer treatment. Retrieved from https://www.cancer.gov/about- cancer/treatment.

Ochwang'i, D. O., Kimwele, C. N., Oduma, J. A., Gathumbi, P. K., Mbaria, J. M., & Kiama, S. G. (2014). Medicinal plants used in treatment and managementtt of

cancer in Kakamega County, Kenya. *Journal of Ethnopharmacology*, *151*, 1040-1055.

Phillips, O., Gentry, A. H., Reynel, C., Wilkin, P., & Galvez-Durand, C. (1994). Quantitative Ethnobotany and Amazonian Conservation. *Society of Conservation Biology*, *8*(1), 255-248.

Rajkumar, V., Guha, G., Ashoke, K. R., & Mathew, L. (2009). Evaluation of Cytotoxic Potential of Acoruscalamus Rhizomes. *Ethnobotanical Leaflets, 13*, 832-39.

Singh, R., Koppikar, S. J., Paul, P., Gilda, S., Paradkar, A. R., & Ghanekar, R. K. (2009). Comparative analysis of cytotoxic effect of aqueous cinnamon extract from Cinnamomumzeylanicum bark with commercial cinnamaldehyde on various cell lines. *Pharmaceutical Biology*, *47*(12), 1174-9.

Sundararajan, P., Dey, A., Smith, A., Doss, A. G., Rajappan, M., & Natarajan, S. (2006). Studies of anticancer and antipyretic activity of Bidenspilosa whole plant. *African Health Science*, *6*(1), 27-30.

Suresh, V., Sruthi, V., Padmaja, B., & Asha, V. V. (2011). In vitro anti-inflammatory and anti-cancer activities of CuscutareflexaRoxb. *Journal of Ethnopharmacology*, *134*(3), 872-7.

Vickers, A. (2004). Alternative cancer cures: 'unproven' or 'disproven'?. *CA: Cancer Journal for Clinicians, 54* (2), 110–118.

Yang, X., Ji, H., Feng, Y., Yu, J., & Liu, A. (2018). Structural Characterisation and antitumor activity of Polysaccharides from Kaempferia galanga L. *Oxidative Medicine and Cellular Longevity*, 10, https://doi.org/10.1155/2018/9579262

CHAPTER 9

Estimation of Reducing Sugars in Mirabilis Jalapa and Sechium Edule and the Production of Bioethanol

Laldingliani Pachuau, Dibyendu Paul and Mary Lalthakimi

Introduction

Ethyl alcohol or ethanol was first quoted by Henry Ford in 1925 as "the fuel of the future". He further more stated, "The fuel of the future is going to come from apples, weeds, saw dust – almost anything. There is fuel in every bit of vegetable that can be fermented". The ultimate aim for the search of alternative energy source is to provide a raw material which will suffice the growing need of energy in a sustainable manner. Currently, the primary source of energy comes from burning of fossil fuels, the byproducts of which are the major contributors of green house gases. The industrial revolution followed by the tremendous expansion of the transportation sector resulted in extensive burning of fossil fuels giving rise to an exponential increase in carbon dioxide level in the atmosphere which alters the ecosystem balance. Apart from green house gas emission, we are also facing the threat of resource depletion. In this context, alternative fuels such as bioethanol from biomass pose a potential fuel as a substitute to fossil fuels in vehicles (Kadar et al., 2004).

"Current production of bioethanol relies on ethanol from starch and sugars but there has been considerable debate about its sustainability. In order to develop the new technologies regarding the biofuels production, it is essential to address the challenges and opportunities of biofuels in the context of food security and sustainable development needs." (FAO, 2008).

In order to address the context of food security, lignocellulosic biomass serves as an interesting alternative to ethanol from starch. However, the production of ethanol from cellulosic biomass is much more expensive as compared to starch ethanol (Sun et al*.,* 2015).

It is necessary to select plants with low lignin, high cellulose content with high reducing sugars to achieve higher ethanol yield from biomass feedstock. The production cost of ethanol will also be greatly minimized. Based on these criterias, the plants *Sechium edule* and *Mirabilis jalapa* (Nyctaginaceae) are investigated as a potential candidate for bioethanol production. The production

of bioethanol from such starchy biomass involves the liquefaction of starch by an endoamylase followed by enzymatic sachharification and fermentation of glucose to ethanol. The sachharification process, using commercial enzymes such as amylases (frequently those produced by Aspergillus species), are of concern regarding the cost - benefit in the production of fuel from starchy materials.

Material and Methods

Feedstock: *Sechium edule* and *Mirabilis jalapa* seeds were collected during the month of July and August from NEHU Campus. The unwanted components were removed carefully using knife. *Sechium edule* was crushed and dried at room temperature. After removing the undesired components, the seeds of *Mirabilis jalapa* were crushed to powder to increase the surface area. The samples were stored in a plastic bag at 4°C for further use.

Estimation of starch: 0.1 – 0.5 g of the sample was treated with 80% alcohol to remove sugars. After centrifugation, the residue was washed repeatedly with hot 80% ethanol till the washings do not give colour with anthrone reagent. Then starch was extracted with 52% perchloric acid. In hot acidic medium, starch was hydrolysed to glucose and then dehydrated to hyroxymethyl furfural. This compound forms a green colored product with anthrone which is measured at 630nm (Sadasivam & Manickam, 2016).

Determination of reducing sugars (DNS method): For sugar estimation, an alternative to Nelson-Somogyi is the dinitrosalicylic acid. 1g of DNS, 200mg crystalline phenol and 50 mg sodium sulphite was dissolved by stirring in 100 ml of 1% NaOH. Store at 4° C. For long storage, add sodium sulphite at the time of use.

0.5ml of the extract was pipette out in test tubes and equalized to 3 ml with distilled water in all the tubes. 3ml of DNS reagent was then added. Put in water bath for 5 min. When the contents of the tubes are still warm, 1 ml of 40% Rochelle salt solution was added. Cool and read the intensity at 510 nm (Sadasivam & Manickam, 2016). All reagents and chemicals used were of analytical reagent grade.

Sachharification: For the enzymatic sachharification, the samples were treated with enzyme amylase in a conical flask. 0.5 ml of amylase was taken in different test tubes each containing 10 ml (v/v) of samples and incubated at 37°C for 15 mins. After incubation, put it in a hot water bath. From each of the test tubes, 0.5ml each was taken and reducing sugar analysis was carried out by Dinitrosalicylic acid method.

Ethanol Fermentation: Ethanol fermentation was carried out in a 50 ml conical flask containing 5g of the hydrolysate. The samples were inoculated with *Aspergillus niger* isolated from curd and incubation was done for 48 hours at

37°C. The Chromic Oxidation Test confirms the presence of ethanol by reducing the orange chromium Cr^{6+} ion to blue green Cr^{3+} ion.

Result and discussion

Estimation of starch for *Mirabilis jalapa* and *Sechium edule:* The estimation of starch content for *Mirabilis jalapa* and *Sechium edule* showed 0.44% ± 0.045 of starch in 0.1µg ml^{-1} sample and 0.19% ± 0.004 of starch in 0.03 µg ml^{-1} respectively. All determinations are mean of three replicates.

Determination of Reducing sugars using DNS method: The reducing sugar test of *Mirabilis jalapa* was 0.07% and *Sechium edule* was 0.51% respectively. All determinations are mean of three replicates.

Sachharification: The hydrolysis by enzymes is a crucial step in production of bioethanol from biomass. The enzymatic loading and hydrolytic duration determines the overall economics of the process (Sahoo et al., 2018). Enzymatic sachharification for the samples was conducted and the Dinitrosalicylic acid test resulted in 20% increase in reducing sugar for *Mirabilis jalapa* and 2% increase for *Sechium edule.* The higher conversion of reducing sugar in *Mirabilis jalapa* as compared to *Sechium edule* is due to the overall higher content of starch in *Mirabili jalapa* than *Sechium edule*. All determinations are mean of three replicates.

Table 5: Amount of reducing sugars before and after sachharification

Sample	Reducing Sugar before sachharification	Reducing Sugar after sachharification
Mirabilis jalapa	0.07%	0.09%
Sechium edule	0.51%	0.53%

Fermentation of hydrolysate of *Mirabilis jalapa* and *Sechium edule:* After fermentation of hydrolysates with *Aspergillus niger*, the chromic oxidation test, in the presence of ethanol, oxidizes the OH- bearing carbon reducing the orange chromium Cr^{6+} to blue green Cr^{3+} ion indicating the presence of ethanol.

Conclusion

From the study, we can conclude that the plants *Mirabilis jalapa* and *Sechium edule* have a great potential for bioethanol production. They can grow almost in every kind of soil and are ubiquitous particularly in the North Eastern region of India. The reducing sugar test reveal higher reducing sugars in *Sechium edule* as compared to *Mirabilis jalapa.* The plant *Mirabilis jalapa* in particular do not compete with food crops besides providing other value added products. The quantitative analysis of ethanol and the optimization of various parameters affecting fermentation process are not included. Further studies in the different parameters for optimization have to be carried out.

REFERENCES

Aboujied, M. M., & Reddy, C. A. (1986). Direct fermentation of potato starch to ethanol by cocultures of Aspergillus niger and Saccharomyces cerevisiae. *Applied and Environmental Microbiology, 52* (5), 1055 – 1059.

Gogoi, J., Nakhuru, K. S., Policegoudra, R. S., Chhatopadhyay, P., Rai, A. K., & Veer, V. (2016). Isolation and characterization of bioactive components from Mirabilis jalapa L. radix. *Journal of Traditional and complimenatary Medicine, 6* (1), 41 – 47.

Hagerdal, B. H., Galbe, M., Gorwa – Grauslund, M. F., Liden, G., & Zacchi, G. (2006). Bioethanol-the fuel of tomorrow from the residues of today. *Trends in biotechnology, 24* (12), 549-556.

Kadar, Z. S., Szengyel, Z. S. and Reczey, K. (2004). Simultaneous sachharification and fermentation (SSF) of industrial waste for the production of ethanol. *Industrial crops and products, 20*, 103-110.

Lee, J. (1997). Biological conversion of lignocellulosic biomass to ethanol. *Journal of Biotechnology, 56* (1), 1 – 24.

Sadasivam, S. and Manickam, A. (2016) Biochemical methods.

Sahoo, D., Ummalyma, S. B., Okram, A. K., Sukumaran, R. K., George, E., & Pandey, A. (2017). Potential of Brachiaria mutica (Para grass) for bioethanol production. *Bioresource Technology, 242*, 133 – 138.

Sahoo, D., Ummalyma, S. B., Kumar, O. A., Pandey, A., Sankar, M., & Sukumaran, R. K. (2018). *Effect of dilute acid pretreatment of wild rice grass (Zizania latifolia) from Lotak Lake for enzymatic hydrolysis*. Bioresource Technology*, doi: https://doi.org/10/1016/j.bioetech.2018.01.048.*

Sun, S., Cao, X. and Sun, R. (2015). The role of pretreatment in improving the enzymatic hydrolysis of lignocellulosic materials. *Bioresource technology, 199,* 49 – 58.

The State of Food and Agriculture (2008). Retrieved from http://www.fao.org/3/ai0100e.pdf. Visited on 15/3/2017.

CHAPTER 10

A Study on the Diversity of Faunal Species found in Myntdu River, West Jaintia Hills District, Meghalaya

Damewanmi Suchiang, Bethesda Sumer, Emidaoopaya Sumer, Larihun Jeengaph and Jasmine T. Sawian

Introduction

Fresh water resources are very precious for life on our planet. Rivers and their catchment areas constitute an important part of the natural environment and play an integral part in the sustainability and livelihood of communities in the vicinity of such river basins (Ekwere et al., 2011). The quality of water is an important aspect that affects the health and wellbeing of a number of living organisms that depend on this vital resource. Many species evolved in running waters and subsequently invaded stagnant waters. Biodiversity in river systems is therefore the most diverse and complex of the world's fresh water bodies (Higler, 2009). The ecosystem of a river is viewed as a system operating in its natural environment, and includes biotic (living) interactions amongst plants, animals and micro-organisms, as well as abiotic (nonliving) physical and chemical interactions (Angelier, 2003; Campbell et al., 2003).

Fresh water ecosystems support large numbers of species of plants and animals. Fish inhabiting freshwaters comprise 25% of living vertebrates (about 55,000 described species) and represent 13-15% of the 100,000 freshwater animal species (Le´veˆque, 2005). Fresh water ecosystems are now one of the most vulnerable and threatened ecosystems in the world. As a consequence of human development, nature has been adapted to our needs, and rivers are foremost among the habitats to have been conquered (Higler, 2009). Aquatic ecosystems are important and have a large number of economically important animals, especially fishes, which are an important source of food. Fresh water resources are used for various purposes like agricultural, industrial, household, recreational, environmental activities etc. Several authors have documented a number of freshwater fish fauna with a high level of endemism from Western Ghats (Sanjay et al., 2012).

India, being a mega-diverse country, harbors many freshwater fish species in the riverine systems. In recent years much interest has developed in the study of the phylogeny and taxonomy of the freshwater fishes in the country (Sutar, 2018). The freshwater fishes are well studied and documented across the country

(Jayaram, 2010). In India, there are approximately 2500 species of fishes; of which approximately 930 live in freshwater and approximately 1570 are marine (Kar, 2003). The ichthyofauna of northeastern region of India has elements of the Indo-Gangetic region; and to some extent, of the Myanmarese and South-Chinese regions (Yadava and Chandra, 1994). Further, according to Sen (2000), of the approximate 806 species of fishes inhabiting the freshwaters of India (Talwar and Jhingran, 1991), the northeastern region of India is represented by 267 species belonging to 114 genera under 38 families and 10 orders.

Fish diversity represents as much as one third of all vertebrate species, and declines in freshwater fish is occurring at a greater rate than species loss in the most affected terrestrial ecosystems (Sala et al., 2000; Dudgeon et al., 2006). Fish appear to be good indicators of the status of aquatic communities and river environments (Schneiders et al., 1993) and fish are often a key element in environmental planning (Schiemer, 2000). Throughout the last century, riverine ecosystems have suffered from intense human intervention resulting in habitat loss and degradation and as a consequence, many fish species have become highly endangered, particularly in rivers where heavy demand is placed on freshwaters (Rahman et al., 2012).

A number of anthropogenic activities have caused severe damage to the natural habitat of living beings. In most cases, the original inhabitants of rivers have suffered from human impacts like deforestation of the catchment area, damming, embankments and pollution. It is now quite difficult to find pristine environments where rivers are free-flowing and contain the natural flora and fauna. In many places, the upper courses of the river are still relatively undisturbed but downstream stretches get more and more influenced by agriculture, forestry and human settlements (Higler, 2009).

Jaintia Hills in Meghalaya is blessed with a large number of rivers and streams that drain the undulating topography of the area and serve as important sources of domestic water, in agriculture and support a diverse assemblage of floral and faunal diversity. Unfortunately, urbanization and rampant coal mining has adversely affected the quality of water of most water bodies (Swer and Singh, 2004). The diversity of fish in rivers and their tributaries are rapidly declining due to anthropogenic stress. This ichthyodiversity is not only the wealth of our region, but it also has some serious implications on fishery. Thus, there is an urgent need for proper investigation and documentation of the fish diversity in our freshwater ecosystems in order to develop a fresh water fish inventory which may be an elementary step in freshwater biodiversity conservation.

Study site and Methodology

Jaintia Hills is situated on the Eastern most part of the state of Meghalaya, with a total geographical area of 3819 sq. kms, which is about 17 percent of the total area of the state. It lies between East Longitudes at 91°59" and 92°45" and North Latitudes 24°58" and 25°45". According to the census 2011 the population of Jaintia Hills is 395,124. Jowai is the Headquarters of Jaintia Hills District which

was established in the year 1972. Due to the upgradation of Khliehriat Civil Sub-Division of Jaintia Hills into a District, which has been named as East Jaintia Hills district with its headquarters at Khliehriat, Jaintia Hills district has been renamed as West Jaintia Hills district with its headquarters at Jowai. In Jaintia Hills, the main occupation is agriculture.

The present study, to document the diversity of fish species, was carried out in Myntdu river, which is one of the main rivers of Jaintia Hills. The river originates, at an elevation of 1,420 metres (4,660 ft) above sea level, at a place called Mihmyntdu, adjacent to the town of Jowai. The Myntdu river is one of the major water bodies in Jaintia Hills and is locally known as "*Ka Tawiar Ka Takan*" which means 'Our Guardian Angel', in the Pnar dialect. The Myntdu river encircles the Jowai town and receives domestic discharge from the tributaries such as Wahthanat, Thlumusniang, Rampyrthai and Mutwa. Like most of the rivers in the state, the rivers of Jaintia Hills district are fed by rains. The flow of water in the river is abundant during the monsoons and low during the dry season. Surveys were carried out in the Myntdu river in Jowai town. The river was visited regularly to observe and document the species present in there. Moreover, interviews with fishermen and women about the fishes available, including inspection of their catch, were carried out on a regular basis. Discussions with the Department of Fishery, Government of Meghalaya, Jowai on the fishes in Myntdu river was also carried. The different species have been identified with the help of Department of Fishery, Government of Meghalaya and with the help of standard literature (Talwar and Jhingran, 1991; Jayaram, 2010). Details on their nomenclature and information were verified later from literature, including books, journals and reports.

Results and Discussion

The main river in Jaintia Hills is the Myntdu river which is the beloved river of the Jaintias and features in much of their folklore. It has its origin near Jowai and almost encircles the Jowai townships through the picturesque '*Syntu Ksiar'* or 'Golden Flower' valley near its source and flowing southwards and becoming the Hari river of Bangladesh.

In the present study, a total of 27 species of fishes were recorded from the Myntdu river, representing 9 families (Table 6) of Bagridae, Channidae, Claridae, Cobitidae, Cyprinidae, Heteropneustidae, Nanidae, Nemacheilidae and Sisoridae. The Cyprinidae family was found to be the most dominant family with 16 species; followed by Clariidae, Channidae and Nemacheilidae with 2 species each; Bagridae, Cobitidae, Heteropneustidae, Nanidae, and Sisoridae were represented by 1 species each. Surveys also showed the presence of a number of smaller indigenous fish species like *Danio* sp., *Devario* sp., *Puntius* sp. etc. in Myntdu river.

Table 6: **Diversity of fishes in Myntdu river**

Sl. No.	Scientific name	Family name	Common name	Local name
1	*Badis badis*	Nanidae	Blue perch	Kha lawei

2	*Bagarius bagarius*	Sisoridae	Dwarf goonch	Kha kala
3	*Barilius bendelisis*	Cyprinidae	Indian hill trout	Dakha myntdu
4	*Catla catla*	Cyprinidae	Indian carp	Dakha so
5	*Channa channa*	Channidae	Snake head	Dathli
6	*Channa stewartii*	Channidae	Golden snakehead	Dathli wyrthoh
7	*Cirrhinus mrigala*	Cyprinidae	Mrigal carp	Dakha mirka
8	*Clarias batrachus*	Clariidae	Walking catfish	Mukur
9	*Clarias brachysoma*	Clariidae	Magur	Mukur
10	*Ctenopharyngo don idella*	Cyprinidae	Grass carp	Dakha bamphlang
11	*Cyprinus carpio*	Cyprinidae	Common carp	Dakha so
12	*Danio dangila*	Cyprinidae	Moustached danio	Dabyrthieh
13	*Danio jaintianensis*	Cyprinidae	-	Dabyrthieh
14	*Danio rerio*	Cyprinidae	Zebra fish	Dabyrthieh
15	*Devario aequipinnatus*	Cyprinidae	Giant danio	Kha lynnai
16	*Heteropneustes fossilis*	Heteropneustidae	Asian stinging catfish	Syngke
17	*Hypophthalmich thys molitrix*	Cyprinidae	Silver carp	Dakha silver
18	*Labeo rohita*	Cyprinidae	Rohu	Dakha bah
19	*Lepidocephalus guntea*	Cobitidae	Peppered loach	Sher syngkai
20	*Mystus cavasius*	Bagridae	Gangetic mystus	Tengra
21	*Neolissocheilus hexagonolepis*	Cyprinidae	Chocolate Mahseer	Dakha pnar
22	*Puntius chola*	Cyprinidae	Swamp barb	Shalynnai tungtap
23	*Puntius javanicus*	Cyprinidae	Silver barb	Tungtap
24	*Puntius sarana*	Cyprinidae	Olive barb	Ktung
25	*Puntius shalynius*	Cyprinidae	Shalyni barb	-

26	*Schistura savona*	Nemacheilidae	Half banded loach	-
27	*Schistura sikmaiensis*	Nemacheilidae	River loach	-

In the present findings, cyprinids dominate the assemblage which may be due to their high adaptive variability. Their distribution and their common abundance suggest that most of these species are capable of tolerating a wide range of environmental conditions (Johnson and Arunachalam, 2009). Carp are various species of oily freshwater fish of the family Cyprinidae, and are the main source of proteins for a number of people in Jowai. A number of fishes have been introduced into the Myntdu river, and are slowly replacing the indigenous fish species of the river. Some of these introduced species include the three Indian Major Carps (IMC), namely rohu (Labeo rohita), catla (Catla catla), and mrigal (Cirrhinus mrigala) can now be found in Myntdu river. Other fish species including silver carp (Hypophthalmichthys molitrix), grass carp (Ctenopharyngodon idella), common carp (Cyprinus carpio), and chocolate mahseer (Neolissocheilus hexagonolepis) have also been found in the river. Two species of catfish, the walking catfish (Clarias batrachus) and magur (Clarias brachysoma), were observed in Myntdu river. Besides these fishes, a number of prawns, snails, tadpoles and crabs are also found in the river system.

Table 7 : Fish fauna of Myntdu river - their distribution and present status.

Scientific name	Food Habit	Economic importance	Distribution (within NE)	Status
Badis badis	Carnivorous	Ornamental fish	Wide	Unknown
Bagarius bagarius	Carnivorous	Food fish	Not Evaluated	Vulnerable
Barilius bendelisis	Omnivorous	Food fish, Ornamental fish	Wide	Vulnerable
Channa stewartii	Carnivorous	Food fish	Wide	Least concern
Cirrhinus mrigala	Omnivorous	Food fish	Wide	Vulnerable
Danio dangila	Carnivorous	Ornamental fish	Wide	Vulnerable
Danio jaintianensis	Carnivorous	Food fish	Meghalaya, Assam	Vulnerable
Danio rerio	Carnivorous	Ornamental fish	Wide	Vulnerable
Devario aequipinnatus	Carnivorous	Ornamental fish	Meghalaya	Least concern
Heteropneustes fossilis	Omnivorous	Food fish	Wide	Vulnerable
Hypophthalmichthys molitrix	Herbivorous	Food fish	Wide	Not evaluated

Labeo rohita	Herbivorous	Food fish	Wide	Least concern
Lepidocephalus guntea	Carnivorous	Ornamental fish	Wide	Vulnerable
Mystus cavasius	Omnivorous	Food fish, Ornamental fish	Wide	Vulnerable
Neolissocheilus hexagonolepis	Herbivorous	Food fish	Wide	Vulnerable
Puntius chola	Carnivorous	Ornamental fish	Wide	Vulnerable
Puntius javanicus	Carnivorous	Food fish	Lmeghalaya, Manipur Tripura	Lnot evaluated
Puntius sarana	Carnivorous	Food fish	Wide	Vulnerable
Puntius shalynius	Carnivorous	Food fish	Meghalaya, Assam	Vulnerable
Schistura savona	Omnivorous	Ornamental fish	Meghalaya	Least concern
Schistura sikmaiensis	Omnivorous	Ornamental fish	Meghalaya, Manipur	Vulnerable

A number of the fish species observed in Myntdu river are widely distributed in the region, except for a few species such as *Danio jaintianensis, Devario aequipinnatus, Puntius javanicus, P. shalynius, Schistura savona* and *S. sikmaiensis* which are localised in the rivers in Meghalaya and the neighbouring states. Based on their food habits, the fishes in the river are either carnivorous or omnivorous in nature, with the exception of herbivorous fishes *Hypophthalmichthys molitrix, Labeo rohita* and *Neolissocheilus hexagonolepis*. The fishes of Myntdu river serve as an important source of food for the local inhabitants, with many species also having ornamental value, which if harnessed properly can boost the livelihood of the locals. From the findings, it was also observed that the threats affecting the fish species are mainly of anthropogenic origin. Almost all the fish species observed in the Myntdu river falls under the category of vulnerable, an indication that if proper management to conserve them is not initiated at the earliest, many of the fish species might be affected in the near future.

Fishing gears used in Myntdu river

Fishing is the one of the livelihoods of the local people of the area and it helps to supplement the income of a number of households. A number of local inhabitants also depend on fish resources for their protein needs. Recreation and sport fishing are also seen to be enjoyed amongst the locals and visitors in the Myntdu river. A number of fishing gears are used by the local fishermen and women folk to trap and catch the fishes from Myntdu river. A brief description of these are given below.

Gills nets: Gills nets are brown multifilament nets normally set in a straight line, with stretch mesh sizes from 22 to 150 mm. Gill nets are panels of netting held vertically in the water column by a series of floats attached to their upper edge and weights attached to their lower edge (Laxmappa and Bakshi, 2014). When fishes swim into the area where the nets are set up in the river, they become trapped within the panels of the net and can be easily removed. This is a widely used technique for catching fish, but now there are some areas where the use of this net is prohibited. These nets are mostly used during winter season where the current of the flow of river water is low.

Cast nets: A cast net is used for catching small fish, and can be hand operated by a single person. The cast net spreads out, when thrown in the water and the fishes are caught as the net is pulled back in. This gear is usually employed in the river channel or other areas where natural congregation of fish takes place.

Hook lines (*Pyrsieh Khwe*): The method of capture (angling) is to offer the fish some bait in such a manner that it is difficult for the fish to let go once it bites, or to pierce the fish body once it comes within range. Hook lines are widely used in Myntdu river. Earthworms are normally used as living bait, whereas snail-flesh is used as dead bait by the fisherman for catching fishes from the river. Sometimes, the fishermen place the hook and lines in water for the whole night and collect the fish early in the morning. This is not a commercial fishing method and mostly the fish caught is consumed by the fishermen themselves. The size of the fish caught by hook lines are normally 250 gms to 2 kg, but occasionally even 10 kg or even more size fishes are caught by such gears.

Cylindrical fish trap (*Khnaam Beh Kynjun):* An effective gear to catch fish in small streams and gullies, the *khnaam beh kynjun* is made of bamboo strips. It has a wide mouth opening with a tapering base. The length of the trap is about 4.5 ft long with a 2.5 ft wide mouth opening. The tip of the base further extends to about 1.5 ft in a cylindrical shape.

Cylindrical fish trap (*Khnaam Sien hiar):* It is used to trap small fish like channas, danios, etc. when water is released from paddy fields and gullies into the river. It is made of bamboo strips and its shape is cylindrical with a pointed base. The length of this trap is about 1.5 ft long with a 0.5 ft wide mouth opening. Bait such as flour and earthworms are placed inside the bamboo trap to attract fishes**.**

Cylindrical fish trap (*Khnaam Sien pah):* This trap is similar to the *khnaam sien hiar* in make and use; but it only differs in the opening which is 0.3 ft in diameter.

Plant species in Myntdu river

A variety of plant species were also recorded from the Myntdu river. A total of 20 plants species were recorded representing, 15 families (Table 8). Asteraceae, with 5 species was the dominant family, followed by Apiaceae (with 2 species);

and Areaceae, Cactaceae, Musaceae, Nephrolepidaceae, Oxalidaceae, Plantaginaceae, Poaceae, Polygonaceae, Rosaceae, Solanaceae, Saururaceae, Verbenaceae, and Zingiberaceae are represented by 1 species each.

Table 8: Plant species found in Myntdu river

Sl. No.	Scientific name	Family name	Common name	Local name
1	*Artemisia vulgaris*	Asteraceae	Mugwort	Yrlud khlo
2	*Biden pilosa*	Asteraceae	Black jack	Sabyrthit
3	*Centella asiatica*	Apiaceae	Indian Pennywort	Tynkhieh
4	*Colocasia esculenta*	Areaceae	Elephant ear	Wang
5	*Cymbopogon citratus*	Poaceae	Lemon Grass	Kynbat phlang
6	*Eryngium foetidum*	Apiaceae	Wild coriander	Dhania khlo
7	*Eupatorium adenophorum*	Asteraceae	Sticky snake root	Sla iong
8	*Eupatorium riparium*	Asteraceae	Creeping crofton weed	Rajot
9	*Fagopyrum esculentum*	Polygonaceae	Buckwheat	Yarain
10	*Galinsoga parviflora*	Asteraceae	Gallant soldier	Sla rami
11	*Houttuynia cordata*	Saururaceae	Chameleon plant	Myrdoh
12	*Lantana camara*	Verbenaceae	Wild sage	Syntu lahari
13	*Musa paradisiaca*	Musaceae	Banana	Ladaw
14	*Nephrolepis cordifolia*	Nephrolepidaceae	Ladder fern	Tyrkhang
15	*Opuntia dillenii*	Cactaceae	Prickly pear	Syntu chieh
16	*Oxalis corniculata*	Oxalidaceae	Creeping wood sorrel	Ladaw kyndeh
17	*Plantago erosa*	Plantaginaceae	Broadleaf plantain	Schkur blang
18	*Rubus ellipticus*	Rosaceae	Golden Himalayan Raspberry	Sohpru
19	*Solanum xanthocarpum*	Solanaceae	Yellow berried nightshade	Sathang
20	*Zingiber sp.*	Zingiberaceae	-	Sying

Out of the 20 species of plants encountered in the Myntdu river, 11 species are found to be edible. The wild edibles such as *Centella asiatica, Eryngium foetidum, Fagopyrum esculentum, Houttuynia cordata* and others are consumed raw as salad. A number of these plants have a good potential to be harvested,

either to be consumed at household level or they can be sold in the local markets. Moreover, the presence of a number of plants along the banks of the river helps to filter runoff, stabiles soil and improve the general quality of the river water.

Conclusion

The result of the present study reveals that Myntdu river harbours a rich and diversified variety of fishes and plants species. A total of 27 species of fishes were recorded from the river, representing 9 families of Bagridae, Channidae, Claridae, Cobitidae, Cyprinidae, Heteropneustidae, Nanidae, Nemacheilidae and Sisoridae. The Cyprinidae family was found to be the most dominant family with 16 species. The cyprinids dominate the assemblage which may due to their high adaptive variability. Surveys also showed the presence of a number of smaller indigenous fish species like *Danio* sp., *Devario* sp., *Puntius* sp. Etc. A number of different fishing gears used in the area indicate a plethora of skill and ingenuity of the local people which have merged with the knowledge of people of different cultures.

The study also revealed that many species in the Myntdu river are being threatened by various human activities. The major activities include habitat modification, removal of riparian vegetation, AMD, destructive fishing, sand mining, disposal of industrial and domestic wastes and agriculture activities. To conserve this inherent treasure, a long-term management plan should be adopted. Identification of natural breeding grounds should be carried so as to bring them under proper conservation.

Moreover, effective implementation of the regulations on fishing gear and a complete ban on destructive fishing is much needed to prevent over exploitation of the fishes from the river. It is also hoped that with the recent NGT ban on coal mining would effectively stop the flow of acidic discharges into the river, which would otherwise harm the aquatic organisms including fishes. Strict management measures along with large scale public awareness would be essential to save the species of this river.

REFERENCES

Angelier, E. (2003). *Ecology of Streams and Rivers*. Enfield, United States: Science Publishers Inc.

Campbell, N. A., Mitchell, L. G., & Reece, J. B. (2003). *Biology Concepts & Connections* (4th ed.). San Francisco, United States: Pearson Education, Inc.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z-I, Knowler, D. J., Leveque, C., Naiman, R. J., Prieur-Richard, A. H., Soto, D., Stiassny, M. L. J., & Sullivan, C. A. (2006). Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews, 81*, 163-182.

Ekwere., A, Edat, A., Ukpong, A., & Obim, V. (2011). Assessment of seasonal variations of hydrochemical signatures of surface water quality using

multivariate statistical methods. *Journal of Sustainable Development in Africa, 13*(8), 51-64.

Higler, L. W. G. (2009). Biology and Biodiversity of River Systems. In J.C.I, Dooge (Ed.), *Freshwater surface water Volume 2: Encyclopedia of Life Support Systems*. Oxford, United Kingdom: EOLSS Publishers/UNESCO.

Jayaram, K. C. (2010). *The fresh water fishes of Indian region*. Narendra Publishing House, Delhi.

Johnson, J. A., & Arunachalam, M. (2009). Diversity, distribution and assemblage structure of fishes in streams of southern Western Ghats, India. *Journal of Threatened Taxa, 1*(10), 507-513.

Kar, D. (2003). *Fishes of Barak drainage, Mizoram and Tripura*. In A., Kumar, C. Bohra & L. K. Singh (Eds.), *Environment, Pollution and Management* (pp. 203-211). New Delhi: APH Publishing Corporation.

Laxmappa, B., & Bakshi, R. R. (2014). Types of fishing gears operating and their impact on Krishna river fishery in Mahabubnagar district, T. S. India. *International Journal of Fisheries and Aquatic Studies*, *2*(1), 30-41.

Le´veˆque, C. B. (2005). An assessment of animal species diversity in continental waters. *Hydrobiologia*, 39-67.

Rahman, M. M., Hossain, M. Y., Ahamed, F., FatematuzzhuraSubba, B. R., Abdallah, E. M., & Ohtomi, J. (2012). Biodiversity in the Padma Distributary of the Ganges River, Northwestern Bangladesh: Recommendations for Conservation. *World Journal of Zoology, 7*(4), 328-337.

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, R., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D., Mooney, H. A., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M., & Wall, D. H. (2000). Global biodiversity scenarios for the year 2100. *Science, 287*, 1770-1774.

Sanjay, S. K., Mandar, P., & Neelesh, D. (2012). Freshwater fish fauna of Krishna River at Wai, northern Western Ghats, India. *Journal of Threatened Taxa, 4*(6), 2644-2652.

Schiemer, F. (2000). Fish as indicators for the assessment of the ecologist integrity of large rivers. *Hydrobiologia*, 422-423, 178-271.

Schneiders, A., Verhaert, E., Blust, G. D., Wils, C., Bervoets, L., & Verheyen, R. F. (1993). Towards an ecological assessment of water courses. *Journal of Aquatic Ecosystem Health, 2*, 29-38.

Swer, S., & Singh, O. P. (2004). Status of water quality in coal mining areas of Meghalaya, India. In I. N. Sinha, M. K. Ghose & G. Singh (Eds.), *Proceedings of the National Seminar on Environmental Engineering with special emphasis on Mining Environment (NSSME)* (pp. 173-181). Dhanbad, India.

Sutar, A.U. (2018). A survey of freshwater fishes of Koyna river near Karad in Satara district (M. S.), India. *European Journal of Biomedical and Pharmaceutical Sciences*, *5*(1), 563-566.

Talwar, P. K., & Jhingran, A. G. (1991). *Inland Fishes of India and Adjacent Countries, Vol I & II.* New Delhi: Oxford and IBH Co., Pvt. Ltd.

Yadava, Y. S., & Chandra, R. (1994). Some threatened carps and catfishes of Brahmaputra River System. In P.V. Dehadrai, P. Das & S.R. Verma (Eds.), *Threatened Fishes of India* (pp. 45-55). Muzaffarnagar, India: Natcon Publication.

CHAPTER 11

Wood-Rotting Fungi of Nagaland

Kuno Chuzho and Mamtaj S. Dkhar

Introduction

A proper documentation of species is important as it reflects the biological diversity of a particular region. There is urgency for documentation of species owing to the rapid changing global climatic pattern which has accelerated the rate of species disappearance and it is very likely that many species have gone extinct without being documented. The eariliest documentation of wood-rotting fungi in India tracks back to Koltzsch's (1832) monograph on Indian polyporaceae. Indian polypore species from various regions is well documented (Bose, 1919, 1937, 1944 and 1946; Sundaramani and Madurajan, 1925; Puri, 1956; Bakshi, 1971; Roy, 1996 and Leelavathy and Ganesh, 2000, Chuzho and Dkhar, 2018). Other wood-rotting fungal families are less investigated. Monographs on the families such as Thelephoraceae and Hymenochaetaceae are worked out by Thind and Rattan (1968) and Sharma (1995) respectively. The genus *Phellinus* (Hymenochaetaceae) was first studied by Rabba (1994) and Vaida et al. (1994). In 1931, a compilation of "Fungi from India" was contributed by Bulter and Bisby. Other mycologists have also worked on the overall Aphyllophorale community from different regions of India (Bagchee and Bakshi, 1950; Bagchee et al., 1954; Bakshi et al., 1963; Harsh, 1982; Vaidya et al., 1991 and Nanda, 1996). A taxonomical account on the genus *Ganoderma*, the largest genus under the order Aphyllophorales was compiled by Bhosle et al. (2010) from Western Maharashtra. As of 2012, fungifromindia.com database holds a record of 1,175 species of Aphyllophorales, distributed under 190 genera and 52 families has been recorded (Ranadevi, 2013).

Besides Aphyllophorales (Basidiomycota), the order Xylariale is another dominant group of wood-rotting fungi under the phylum Ascomycota. Studies on Ascomycoteous wood-rotting fungi are not well established all over India. A few literature on Xylariales from India are recorded from recent years (Nejakar and Nejakar, 2009; Nejakar et al., 2012; Ramesh et al., 2012; Ramesh et al., 2012; Karun and Sridhar, 2015; Koyani et al., 2016; Nagadesi and Arya, 2017; Patil and Patil, 2017; Debnath et al., 2018, Chuzho and Dkhar, 2019).

Northeast India is a well-known diversified region of India and a part of it falls under the Indo-Burma Biodiversity hotspot of the world (Moghe, 2011). The region comprised a wide range of geographical variation ranging from the tropical foot plains of Assam to the temperate mountains of Arunachal Pradesh however due to inaccessibility, bad roads and limited research interest, the region remain largely unexplored. Nagaland is a small mountainous state of Northeast India, with an area of 16, 579 Km^2. Research studies on macrofungi is still at its preliminary phase and the region remains hugely unexplored. Limited macrofungal studies from Nagaland have been conducted in the past and only few literatures on macrofungal studies exist (Bhaben et al, 2011, Kumar et al., 2013, Ao et al., 2016a, b). Wood-rotting fungal studies in Nagaland are still at its thresholed (Chuzho et al., 2017, Chuzho and Dkhar, 2018a, b and Chuzho and Dkhar, 2019). This is the first documentation of the overall wood-rotting fungi from Nagaland.

Materials and Methods

Survey and collection of fungal fruiting bodies were done from 8 selected forest stands on seasonal basis for a period of 3 years (January 2015 and December 2017). Transect and quadrat methods were used for sampling following the protocol recommended by Mueller et al. (2004a). The specimens were kept in Microbial Ecology laboratory, NEHU, Shillong Campus for study and future references. Sections were prepared on clean slides, stained with appropriate reagent and observed under microscope for studying microscopic structures. Melzer reagent, Lactophenol cotton blue and 4% KOH were the ragents used. Identification was done following standard macroscopic and microscopic observations by consulting appropriate monographs and literatures (Smith and Hesler, 1968; Bakshi, 1971; Singer, 1974; Ryvarden and Johansen, 1980; Nunez and Ryvarden, 2000, 2001; Wendt et al., 2018).

The decay stage of substrata and type of substrata were studied. Decay stage of substrata was classified following Pouska et al., 2010 where 5 stages of wood (substrata) were recognized.

Study Sites

Table 9: **Collection sites with elevation (in meters above sea level) and geographical coordinates.**

Collection sites	Elevation	Latitude and longitude
1. Nagaland Zoological Park, Rangapahar (Dimapur)	221.28	25º40.22' N, 093º 58.78' E
2. Ngwalwa community forest, Ngwalwa (Peren)	463.29	25º41.14' N, 093º 48.90' E
3. Rusoma community forest , Rusoma (Kohima)	890.01	25º44.88' N, 094º 08.35'E

4. Tuophema reserved forest, Tuophema (Kohima)	1469.13	25º51.57' N, 094º 09.62'E
5. Kikruma community forest, Kikruma (Phek)	1615.44	2537.38' N, 094º 13.71'E
6. Phusachodu community forest, Phusachodu (Phek)	1819.65	25º35.90' N, 094º 17.29'E
7. Puliebadze reserved forest, Jotsoma (Kohima)	2027.52	25º38.71' N, 094º 04.12'E
8. Puliebadze *Rhododendron* reserved forest, Jotsoma (Kohima)	2315.87	25º30.79' N, 094º 04.37'E

Results

A total of 182 specimens were collected, of which 174 specimens were identified and documented in this manuscript. One hundred and fifty six specimens were identified upto species level and 18 specimens were identified upto genus level. Thirty species falls under the division Ascomycota and 144 specimens under the division Basidiomycota. The specimens were classified under 37 families with family Polyporaceae having the highest number of specimens (50 specimens), followed by family Hymenochaetaceae (16 specimens), Xylariaceae (15 specimens) and Hypoxylaceae (9 specimens). Among these, 4 species, *Favolaschia calocera*, *Jackrogersella minutela*, *Pholiota polychroa* and *Porodisculus orientalis* and one genus, *Porodisculus* were reported for the first time from India. The identified species with their synonyms, family and site of occurrence are given in Table 10.

Diversity and ecological studies showed that Rusoma community forest, located at an altitude of 890.01 msl has the highest species diversity with a total of 85 specimens. Least number of wood-rotting fungi (8 specimens) was recorded from Puliebadze *Rhododendron* reserve forest, located at an altitude of 2315.87 msl. It was observed that logs and twigs provided maximum support for growth of wood-rotting fungi (98 and 77 specimens respectively). The occurrence of wood-rotting fungi depends on various decay stages of wood and majority of the specimens were found growing on wood at intermediate stage of decay. One hundred and four specimens were recorded from wood at decay stage III whereas only 6 specimens were recorded from substrata at decay stage V (Table 11).

Table 10: **Documented wood-rotting fungi and their synonym, family and site of occurrence.**

Sl. no.	Specimen	Family	Site of occurrence							
DIVISION ASCOMYCOTA			1	2	3	4	5	6	7	8
1	***Aleuria aurantia*** (Pers.) Fuckel = *Helvella coccinea* Bolton	Pyronemataceae	-	-	-	+	-	-	-	-

2	***Annulohypoxylon bovei*** (Speg.) Y.M. Ju, J.D Rogers & H.M. Hsieh = *Hypoxylon bovei* Speg.	Hypoxylaceae	-	-	-	+	-	-	-	-
3	***Bisporella citrina*** (Batsch) Korf & S.E. Carp = *Peziza citrina* Batsch	Helotiaceae	-	-	-	+	-	-	-	-
4	***Bisporella pallescens*** (Pers.) S.E. Carp & Korf = *Peziza lenticularis* Hoffm.	Helotiaceae	-	-	-	+	-	-	-	-
5	***Chlorociboria aeruginosa*** (Nyl.) Kanouse ex. C.S. Ramamurthi, Korf & L.R. Batra = *Peziza aeruginascens* Nyl.	Chlorociboriaceae	-	-	-	+	-	+	+	-
6	***Cookeina insititia*** (Berk. & M.A. Curtis) Kuntze = *Peziza insititia* (Berk. & M.A. Curtis) Sacc.	Sarcoscyphaceae	-	-	+	-	-	-	-	-
7	***Daldinia concentrica*** (Bolton) Ces. & De Not. = *Sphaeria concentrica* Bolton & Traverso	Hypoxylaceae	+	+	+	+	+	+	+	-
8	***Entonaema liquescens*** A. Moller = *Xylaria splendens* Berk. & M.A. Curtis	Xylariaceae	-	-	+	-	-	-	-	-
9	***Hypoxylon fragiforme*** (Pers.) J. Kickx f. = *Sphaeria fragiforme* Pers.	Hypoxylaceae	+	-	-	-	-	-	-	-
10	***Hypoxylon fuscum*** (Pers.) Fr. = *Sphaeria fusca* Pers.	Hypoxylaceae	-	-	-	-	-	-	+	-
11	***Hypoxylon hematostroma*** Mont.	Hypoxylaceae	+	-	+	-	-	-	-	-

12	***Hypoxylon rubiginosum*** (Pers.) Fr. = *Sphaeria rubiginosa* Pers.	Hypoxylaceae	-	+	+	-	+	-	-	-
13	***Hypoxylon* species**	Hypoxylaceae	-	-	-	+	-	-	-	-
14	***Jackrogersella cohaerens*** (Pers.) L. Wendt, Kuhnert& M. Stadler = *Sphaeria cohaerens* Pers.	Hypoxylaceae	-	-	-	-	-	-	+	-
15	***Jackrogersella minutella*** (Syd. & P. Syd.) L. Wendt, Kuhnert & M. Stadler = *Hypoxylon minutellum* (Syd. & P. Syd.)	Hypoxylaceae	-	-	-	-	-	-	+	-
16	***Kretzschmaria deusta*** (Hoffm.) P.M.D. Martin = *Ustulina deusta* (Hoffm.) Maire	Xylariaceae	-	-	+	+	+	+	+	-
17	***Sarcoscypha coccinea*** (Scop.) Sacc. = *Havella coccinea* Scop.	Sarcoscyphaceae	-	-	-	+	-	-	-	-
18	***Xylaria apiculata*** Cooke = *Xylosphaera apiculata* (Cooke) Dennis	Xylariaceae	-	-	+	-	-	+	+	-
19	***Xylaria arbuscula*** Sacc. = *Hypoxylon mellisii* Berk.	Xylariaceae	-	-	+	-	-	-	-	-
20	***Xylaria carpophila*** (Pers.) Fr. = *Sphaeria carpophila* Pers.	Xylariaceae	-	-	+	-	-	-	-	-
21	***Xylaria filiformis*** (Alb. & Schwein.) Fr. = *Sphaeria filiformis* (Alb. & Schwein.)	Xylariaceae	-	-	+	+	-	-	-	-
22	***Xylaria grammica*** (Mont.) Mont. = *Hypoxylon grammicum* Mont.	Xylariaceae	-	+	+	+	+	+	+	-

23	***Xylaria hypoxylon*** (L.) Grev. = *Clavaria hypoxylon* L.	Xylariaceae	+	+	+	+	+	-	+	-
24	***Xylaria longipes*** Nitschke = *Xylosphaera longipes* (Nitschke) Dennis	Xylariaceae	+	+	+	+	+	-	+	-
25	***Xylaria multiplex*** (Kunze ex. Fr.) Fr. = *Sphaeria multiplex* Kunze ex. Fr.	Xylariaceae	-	-	+	-	-	-	-	-
26	***Xylaria polymorpha*** (Pers.) Grev. = *Sphaeria polymorpha* Pers.	Xylariaceae	+	+	+	+	+	+	+	+
27	***Xylaria tabacina*** (J. Kickx f.) Fr. = *Hypoxylon tabacinum* J. Kickx f.	Xylariaceae	-	+	-	-	-	-	-	-
28	***Xylaria* species 1**	Xylariaceae	-	+	-	-	-	-	-	-
29	***Xylaria* species 2**	Xylariaceae	-	-	+	-	-	-	-	-
30	***Xylaria* species 3**	Xylariaceae	-	-	-	+	-	-	-	-
DIVISION BASIDIOMYCOTA										
31	***Agaricus squarrosus*** Oeder = *Pholiota squarrosus* Oeder	Strophariaceae	-	-	+	-	-	+	-	-
32	***Aleurodiscus ahmadii*** (Biodin) Biodin = *Stereum ahmadii*.	Stereaceae	-	-	-	-	+	-	-	-
33	***Antrodiella zonata*** (Berk.) Ryv. = *Irpex zonatus* Berk.	Phanerochaetaceae	-	-	+	+	-	+	+	-
34	***Auricularia auricula-judae*** (Bull.) J. Schrot. = *Tremella auricula-judae* Bull.	Auriculariaceae	+	+	+	+	+	+	+	-
35	***Auricularia cornea*** Ehrenb. = *Exidia cornea* (Ehrenb.) Fr.	Auriculariaceae	-	+	-	-	-	-	-	-
36	***Auricularia delicata*** (Mont.) Henn. = *Laschia delicata*Fr.	Auriculariaceae	-	-	+	+	+	+	-	-

37	***Auricularia mesenterica*** (Dicks.) Pers. = *Helvella mesenterica* Dicks.	Auriculariaceae	-	+	+	-	-	-	-	-
38	***Auricularia nigaricans*** (Sw.) Birkebak = *Peziza nigrescens* Sw.	Auriculariaceae	-	-	-	-	-	+	-	-
39	***Auricularia polytricha*** (Mont.) Sacc. = *Exidia polytricha* Mont.	Auriculariaceae	+	+	+	+	+	+	+	+
40	***Basidioradulum radula*** (Fr.) Nobels = *Hydnum radula* Fr.	Schizoporaceae	-	-	+	+	-	-	-	-
41	***Bjerkandera adusta*** (Willd.) P. Karst = *Polystictus adustus* (Willd.) Fr.	Hapolopiliaceae	-	-	+	+	+	+	+	-
42	***Calyptella capula*** (Holmsk.) Quel. = *Peziza capula* Holmsk.		-	-	+	-	-	-	-	-
43	***Cerrena unicolor*** (Bull.) Murrill = *Boletus unicolor* Bull.	Polyporaceae	-	-	+	-	-	-	-	-
44	***Chondrostereum purpureum*** (Pers.) Pouzar = *Stereum purpureum* Pers.	Cyphellaceae	-	-	-	+	-	-	-	-
45	***Clavulina cristata*** (Holmsk.) J. Schrot. = *Ramaria cristata* Holmsk.	Clavulinaceae	+	-	-	-	-	-	-	-
46	***Coprinellus desseminatus*** (Pers.) J.E. Lange = *Agaricus desseminatus* Pers.	Psathyrellaceae	-	-	+	+	-	-	-	-
47	***Coprinellus micaseus*** (Bull.) Fr. = *Agaricus micaseus* Bull.	Psathyrellaceae	-	-	+	+	+	+	+	-
48	***Coprinopsis atramentaria*** (Bull.) Redhead = *Coprinus atramentarius* (Bull.) Fr.	Psathyrellaceae	-	-	-	-	-	+	-	-

49	***Corioplosis aspera*** (Jungh.) Teng. = *Polyporus asper* Jungh.	Polyporaceae	-	-	-	+	-	-	-	-
50	***Coriolopsis gallica*** (Fr.) Ryv. = *Boletus fuvus* Bull.	Polyporaceae	-	-	-	-	-	-	+	-
51	***Coriolopsis polyzona*** (Pers.) Ryv. = *Polyporus polyzonus* Pers.	Polyporaceae	-	-	-	-	+	-	-	-
52	***Coriolopsis telfrii*** (Klotzsch) Ryv.= *Polyporus telfrii* Klotzsch	Polyporaceae	-	-	-	+	-	-	+	-
53	***Coriolopsis trogii*** (Berk.) Domanski = *Trametes trogii* Berk.	Polyporaceae	-	-	-	-	-	+	-	-
54	***Crepidotus applanatus*** (Pers.) P. Kumm. = *Agaricus applanatus* Pers.	Inocybaceae	+	+	+	+	-	+	-	-
55	***Crepidotus luteolus*** Sacc. = *Agaricus luteolus* Lambotte	Inocybaceae	+	-	+	-	-	-	-	-
56	***Crepidotus mollis*** (Schaeff.) Staude = *Agaricus mollis* Schaeff.	Inocybaceae	-	-	-	+	-	-	-	-
57	***Crepidotus variabilis*** (Pers.) P. Kumm. = *Agaricus sessilis* Bull.	Inocybaceae	+	-	+	-	-	-	-	-
58	***Cyathus olla*** (Batsch) Pers. = *Peziza ollaris* Schaeff.	Agaricaceae	-	-	+	-	-	-	-	-
59	***Cyathus striatus*** (Huds.) Willd. = *Peziza lentifera* L.	Agaricaceae	-	-	+	+	+	-	+	-
60	***Dacrymyces palmatus*** (Schwein.) = *Tremella palmata* (Schwein.)	Dacrymycetaceae	-	-	-	-	-	-	+	+
61	***Dacryopinax spathularia*** (Schwein.) G.W. Martin = *Merulius spathularia* Schwein.	Dacrymycetaceae	+	+	+	+	+	-	-	-

62	***Daedalea flavida*** (Lev.) Kuntze = *Daedeleopsis flavida* (Lev.) A. Roy & M. Mitra	Fomitopsidaceae	-	+	+	-	-	-	-	-
63	***Daedalea quercina*** (L.) Pers. = *Agaricus quercina* L.	Fomitopsidaceae	-	-	-	-	+	-	-	-
64	***Datronia mollis*** *(Sommerf.) Donk* = *Daedalea mollis Sommerf.*	Polyporaceae	-	-	+	-	-	-	-	-
65	***Deconica horizontalis*** (Bull.) Noordel = *Melanotus horizontalis* (Bull.) P.D. Orton	Strophariaceae	-	+	-	-	-	-	-	-
66	***Deflexula subsimplex*** *(Henn.) Corner* = *Pterula subsimplex Henn.*	Pterulaceae	-	-	-	-	-	-	+	-
67	***Earliella scabrosa*** *(Pers.) Gilb. & Ryvarden* = *Polyporus scabrosus Pers.*	Polyporaceae	-	+	+	-	-	-	-	-
68	***Exidia glandulosa*** *(Bull.) Fr.* = *Tremella arborea Hoffm.*	Exidiaceae	-	-	-	-	-	-	-	+
69	***Exidia recisa*** *(Ditmar) Fr.* = *Peziza gelatinosa Bull.*	Exidiaceae	-	-	+	+	-	-	-	-
70	***Favolaschia calocera*** R. Heim	Marasmiaceae	-	-	-	-	-	+	-	-
71	***Favolaschia tonkinensis*** (Pat.) Kuntze = *Laschia tonkinensis* Pat.	Marasmiaceae	-	-	+	-	-	-	-	-
72	***Favolus tenuiculus*** P. Beauv. = *Polyporus tenuiculus* (P. Beauv.) Fr.	Polyporaceae	-	-	+	+	-	-	-	-
73	***Filoboletus manipularis*** (Berk.) Singer = *Favolus manipularis* (Berk.) Sacc.	Tricholomataceae	-	-	+	-	-	-	-	-
74	***Flavodon flavus*** (Kl.) Ryv. = *Irpex flavus* Klotzsch	Meruliaceae	-	+	+	-	-	-	-	-

75	***Fomes fomentarius*** (L.) Fr. = *Boletus fomentarius* L.	Fomitopsidaceae	-	-	+	-	-	-	-	-
76	***Fomitopsis cajanderi*** (Karst.) Kotl. & Pouz. = *Fomes cajanderi* P. Karst.	Fomitopsidaceae	-	-	-	+	-	-	-	-
77	***Fomitopsis pinicola*** (Sw.) P. Karst. = *Boletus pinicola* Sw.	Fomitopsidaceae	-	-	-	-	+	-	-	-
78	***Ganoderma applanatum*** (Pers.) Pat. = *Boletus applanatus* (Pers.) Pat.	Ganodermataceae	+	-	+	-	-	+	+	-
79	***Ganoderma lucidum*** (Curtis) P. Karst. = *Boletus rugosus* Jacq.	Ganodermataceae	+	-	-	-	+	-	-	-
80	***Ganoderma tsugae*** Murrill = *Fomes tsugae* (Murrill) Sacc. & D. Sacc.	Ganodermataceae	-	-	+	-	-	-	-	-
81	***Ganoderma* species**	Ganodermataceae	-	-	-	-	-	-	+	-
82	***Gloeophyllum sepiarium*** (Wulfen) P. Karst. = *Agaricus sepiarius* Wulfen	Gloeophyllaceae	-	-	-	-	+	-	-	-
83	***Guepiniopsis alpina*** (Tracy & Earle) Brasf. = *Geupinia alpina* Tracy & Earle	Dacrymycetaceae	-	-	-	+	-	-	-	-
84	***Hemimycena cucullata*** (Pers.) Singer = *Agaricus cucullatus* Pers.	Tricholomataceae	-	-	-	+	-	-	-	-
85	***Hemimycena* species**	Tricholomataceae	-	-	-	+	-	-	-	-
86	***Heterobasidion insulare*** (Murrill) Ryvarden = *Trametes insulare* Murrill	Polyporaceae	-	-	-	-	+	-	-	-
87	***Hexagonia badia*** (Berk.) Imazeki	Polyporaceae	-	-	-	+	-	-	-	-
88	***Hexagonia tenuis*** (Hook.) Fr. = *Boletus tenuis* (Hook.) Fr.	Polyporaceae	+	+	+	+	+	+	+	-

89	***Hexagonia tenuis* var. *pulchella*** (Lev.) Cleland & Cheel	Polyporaceae	-	-	+	+	-	-	-	-
90	***Hymenochaete cyclomellata*** T. Wagner & M. Fisch = *Inonots fuscus* Kunze ex. Fr.	Hymenochaetaceae	-	-	-	-	-	-	+	-
91	***Hymenochaete rubiginosa*** (Dicks.) Lev. = *Helvella rubiginosa* Dicks.	Hymenochaetaceae	-	-	-	+	-	-	-	-
92	***Hymenochaete tabacina*** (Sowerby) S.H. He. & Jiao Yang = *Auricularia tabacina* Sowerby	Hymenochaetaceae	+	+	+	+	+	+	+	-
93	***Hypholoma* species**	Strophariaceae	-	-	-	-	-	-	+	-
94	***Inonotus radiates*** (Sowerby) P. Karst. = *Boletus radiates* (Sowerby) Fr.	Hymenochaetaceae	+	-	-	-	-	+	-	-
95	***Inonotus* species**	Hymenochaetaceae	+	-	-	-	-	-	-	-
96	***Irpex lacteus*** (Fr.) Fr. = *Sistotrema lacteum* Fr.	Phanerochaetaceae	+	+	+	-	-	-	-	-
97	***Lentinus ciliatus*** Lev. = *Pocillaria ciliata* (Lev.) Kuntze	Polyporaceae	-	-	+	-	-	-	-	-
98	***Lentinus faciatus*** Berk. = *Panus faciatus* (Berk.) Singer	Polyporaceae	-	-	-	-	-	-	+	-
99	***Lentinus sajor-caju*** (Fr.) Fr. = *Agaricus sajor-caju* Fr.	Polyporaceae	+	-	-	-	+	-	-	-
100	***Lentinus squarrosulus*** Mont. = *Pocillaria squarrosula* (Mont.) Kuntze	Polyporaceae	-	-	+	-	-	-	-	-
101	***Lentinus velutinus*** Fr. = *Pocillaria velutina* (Fr.) Kuntze	Polyporaceae	-	+	+	-	-	-	-	-

102	***Lenzites betulina*** (L.) Fr. = *Agaricus betulinus* L.	Polyporaceae	-	+	-	-	-	-	-	-
103	***Lenzites elegans*** (Spreng.) Pat. = *Daedalea elegans* Spreng.	Polyporaceae	-	-	+	-	-	-	-	-
104	***Lenzites vespacea*** (Pers.) Pat. = *Polyporus vespaceus* Pers.	Polyporaceae	-	-	+	-	-	+	-	-
105	***Lepiota magnispora*** Murrill = *Lipiota fusispora* Kauffman	Agaricaceae	-	-	+	-	-	-	-	-
106	***Lopharia cinerascens*** (Schwein.) G. Cunn. = *Thelephora cinerescens* (Schwein)	Polyporaceae	+	+	+	+	+	+	+	-
107	***Lopharia spadicea*** (Pers.) Hortstam & Ryvarden = *Thelophora spadicea* Pers.	Polyporaceae	-	-	+	-	-	-	-	-
108	***Lycoperdon pyriforme*** Schaeff. = *Utraria pyriformis* (Schaff.) Quel.	Agaricaceae	-	-	+	-	-	+	-	-
109	***Marasmiellus candidus*** Fr. Singer = *Marasmius candidus* Fr.	Omphalotaceae	-	-	+	-	-	-	-	-
110	***Marasmius rotula*** (Scop.) Fr. = *Agaricus rotula* Scop.	Marasmiaceae	-	-	+	-	-	-	-	-
111	***Microporus affinis*** (Blume & T. Nees) Kuntze. = *Polyporus affinis* Blume & T. Nees	Polyporaceae	-	-	+	+	-	-	+	-
112	***Microporus vernicipes*** (Berk.) Imazeki = *Polyporus vernicipes* Berk.	Polyporaceae	-	-	-	-	-	-	+	-
113	***Microporus xanthopus*** (Fr.) Kuntze = *Polyporus xanthopus* Fr.	Polyporaceae	+	+	+	+	+	+	+	-

114	***Mycena maculata*** Cleland = *Mycena austromaculata* Gugur. & T.W. May	Mycenaceae	-	-	-	-	-	+	-	-
115	***Mycena* species**	Mycenaceae	-	-	-	+	-	-	-	-
116	***Nigrofomes melanoporus*** (Mont.) Murrill = *Polyporus melanoporus* Mont.	Polyporaceae	-	-	-	-	+	-	-	-
117	***Nigroporus vinosus*** (Berk.) Murrill = *Polyporus vinosus* Berk.	Polyporaceae	-	-	+	+	+	-	-	-
118	***Perenniporia* species**	Polyporaceae	-	-	+	+	+	-	-	-
119	***Phallus indusiatus*** Vent. = *Dictyophora indusiatus* (Vent.) Desv.	Phallaceae	-	-	+	-	-	-	-	-
120	***Phellinus adamantinus*** (Berk.) Ryvarden = *Polyporus adamantinus* (Berk.) Cooke.	Hymenochaetaceae	-	-	+	-	-	-	-	-
121	***Phellinus ferruginosus*** (Fr.) Pat. = *Boletus ferruginosus* Schrad. ex. J. F. Gmel	Hymenochaetaceae	-	-	-	-	-	-	+	+
122	***Phellinus gilvus*** (Schwein.) Pat. = *Boletus gilvus* Schwein.	Hymenochaetaceae	-	+	+	+	+	+	+	-
123	***Phellinus punctatus*** (P. Karst.) Pilat = *Polyporus punctatus* Fr.	Hymenochaetaceae	-	-	-	-	-	-	+	+
124	***Phellinus senex*** (Nees & Mont.) Imazeki = *Fomes senex* (Nees & Mont.) Cooke	Hymenochaetaceae	-	-	+	-	-	-	-	-
125	***Phellinus tricolor*** (Bres.) Kotl. = *Pyrofomes tricolor* (Murr.) Ryv.	Hymenochaetaceae	+	-	-	-	-	-	-	-

126	***Phellinus wahlberghii*** (Fr.) D.A. Reid = *Polyporus zealandicus* Cooke	Hymenochaetaceae	-	-	-	-	-	-	+	-
127	***Phellinus* species 1**	Hymenochaetaceae	-	-	+	-	-	-	-	-
128	***Phellinus* species 2**	Hymenochaetaceae	-	-	-	-	+	-	-	-
129	***Phellinus* species 3**	Hymenochaetaceae	-	-	-	+	-	-	-	-
130	***Pholiota polychroa*** (Berk.) A.H. Sm. & H.J. Brodie = *Flammula polychroa* Berk.	Strophariaceae	-	-	+	-	-	-	-	-
131	***Piptoporus betulinus*** (Bull.) P. Karst. = *Boletus betulinus* Bull.	Fomitopsidaceae	-	+	-	-	-	-	-	-
132	***Pleurocybella porringens*** (Pers.) Singer = *Agaricus abeitinus* Schrad.	Marasmiaceae	-	+	+	+	-	-	-	-
133	***Pleurotus ostreatus*** (Jacq.) P. Kumm. = *Agaricus ostreatus* Jacq.	Agaricaceae	-	-	+	+	+	-	+	-
134	***Podoscypha petalodes*** (Berk.) Pat. = *Stereum petalodes* (Berk.)	Meruliaceae	-	-	+	-	-	-	-	-
135	***Polyporus arculiarius*** Rostk.	Polyporaceae	-	+	+	+	-	+	-	-
136	***Polyporus dictyopus*** Mont. = *Melanopus dictyopus* (Mont.) Pat.	Polyporaceae	-	-	-	+	-	-	-	-
137	***Polyporus grammocephalus*** (Berk.) = *Polyporellus grammocephalus* (Berk.) P. Karst	Polyporaceae	-	-	-	+	-	-	-	-
138	***Polyporus tuberaster*** (Jacq. ex. Pers.) Fr. = *Boletus tuberaster* Jacq. ex. Pers.	Polyporaceae	-	-	-	+	-	-	-	-

139	***Porodisculus orientalis*** (J. S. Lee & H. S. Jung)	Polyporaceae	-	-	-	-	-	-	+	-
140	***Punctularia atropurpurescens*** (Berk. & Broome) Petch = *Thelephora atropurpurescens* Berk. & Broome	Corticaceae	-	-	-	+	-	-	-	-
141	***Pycnoporus cinnabarinus*** (Jacq.) P. Karst. = *Boletus cinnabarinus* Jacq.	Polyporaceae	+	+	-	-	-	-	-	-
142	***Pycnoporus sanguineus*** (L.) Murrill = *Boletus sanguineus* L.	Polyporaceae	-	+	+	+	+	-	+	-
143	***Pyrrhoderma noxium*** (Corner) L.W. Zhou & Y.C. Dai = *Phellinus noxius* (Corner) G. Cunn.	Hymenochaetaceae	-	+	-	-	-	-	-	-
144	***Ramaria*** **species**	Gomphaceae	-	-	-	-	+	-	-	-
145	***Rigidoporus microporus*** (Sw.) Overeem = *Polyporus microporus* (Sw.) Fr.	Polyporaceae	-	-	-	-	+	-	-	-
146	***Regidoporus ulmarius*** (Sowerby) Imazek = *Polyporus ulmarius* (Sowerby) Fr.	Polyporaceae	-	-	-	-	-	-	+	-
147	***Rickenella fibula*** (Bull.) Raithelh. = *Agaricus fibula* Bull.	Rickenellaceae	-	-	-	+	-	-	-	-
148	***Schizophyllum commune*** Fr. = *Schizonia vulgaris* Pers.	Schizophyllaceae	+	+	+	+	+	+	+	-
149	***Steccherinum ochraceum*** (Pers. ex J.F. Gmel.) Gray = *Hydnum ochraceum* (Pers. ex J.F. Gmel.)	Phanerochaetaceae	-	+	+	-	-	-	-	-

150	***Stereum complicatum*** (Fr.) Fr. = *Thelophora complicate* Fr.	Stereaceae	-	-	-	-	+	-	-	-
151	***Stereum gausapatum*** (Fr.) Fr. = *Thelophora gausapata* Fr.	Stereaceae	-	-	-	-	+	-	-	-
152	***Stereum hirsutum*** (Willd.) Pers.	Stereaceae	-	+	+	+	+	+	+	-
153	***Stereum ostrea*** (Blume & T. Nees) = *Thelephora fasciata* Schwein.	Stereaceae	-	-	+	+	+	-	-	-
154	***Tetrapyrgos nigripes*** (Fr.) E. Horak = *Agaricus nigripes* Schwein.	Marasmiaceae	-	+	-	+	-	-	-	-
155	***Trametes gibbosa*** (Pers.) Fr. = *Pseudotrametes gibbosa* Pers.	Polyporaceae	-	-	-	+	-	-	-	-
156	***Trametes hirsuta*** (Wulfen) Pil. = *Boletus hirsutus* Wulfen	Polyporaceae	-	+	+	+	+	+	+	-
157	***Trametes lactinea*** (Berk.) Sacc. = *Polyporus lactineus* Berk.	Polyporaceae	-	-	+	-	-	-	-	-
158	***Trametes pubescens*** (Schumach.) Pilat = *Boletus pubescens* Schumach.	Polyporaceae	-	-	+	-	-	-	-	+
159	***Trametes tephroleuca*** Berk. = *Polystictus tephroleucus* (Berk.) Sacc.	Polyporaceae	-	-	-	+	-	-	-	-
160	***Trametes versicolor*** (L.) Lloyd = *Boletus versicolor* L.	Polyporaceae	+	+	+	+	+	+	+	-
161	***Trametes villosa*** (Sw.) Kreisel = *Polyporus villosus* (Sw.) Fr.	Polyporaceae	-	-	-	-	-	+	-	-
162	***Trametes* species 1**	Polyporaceae	-	-	-	+	-	-	-	-

163	***Trametes* species 2**	Polyporaceae	-	-	-	+	-	-	-	-
164	***Trametes* species 3**	Polyporaceae	-	-	-	+	-	-	-	-
165	***Trametes* species 4**	Polyporaceae	-	-	-	-	-	+	-	-
166	***Trichaptum abietinum*** (Pers. ex. J.F. Gmel.) Ryv.	Polyporaceae	-	-	-	+	-	+	+	-
167	***Trichaptum biforme*** (Fr.) Ryv. = *Polyporus biformis* Fr.	Polyporaceae	-	-	+	-	-	+	-	-
168	***Trichaptum byssogenum*** (Jungh.) Ryv. = *Polyporus byssogenus* Jungh.	Polyporaceae	-	-	-	-	-	-	+	+
169	***Tremella fuciformis*** Berk. = *Nakaiomyces nipponicus* Kobayasi	Tremellaceae	-	-	-	+	-	+	-	-
170	***Tremella mesnterica*** Retz. = *Tremella lutescens* Pers.	Tremellaceae	-	-	-	+	-	-	-	-
171	***Tricholomopsis rutilans*** (Schaef.) Singer = *Agaricus rutilans* Schaeff.	Tricholomataceae	-	-	+	-	-	-	-	-
172	***Xylobolus frustulatus*** (Pers.) Boidin = *Thelephora frustulata* Pers.	Stereaceae	-	-	-	-	-	-	+	-
173	***Xylobolus subpileatus*** (Berk. & M.A. Curtis) Boidin = *Stereum subpileatum* Berk. & M.A. Curtis	Stereaceae	-	-	-	-	-	-	+	-
174	***Xylodon paradoxus*** (Schrad.) Chevall = *Hydnum paradoxum* Schrad.	Schizoporaceae	-	-	+	+	-	-	-	-

1: Nagaland Zoological Park, Rangapahar; 2: Ngwalwa community forest, Ngwalwa; 3: Rusoma community forest, Rusoma; 4: Tuophema reserved forest, Tuophema; 5: Kikruma community forest, Kikruma; 6: Phusachodu community

forest, Phusachodu; 7: Puliebadze reserved forest, Jotsoma; 8: Puliebadze *Rhododendron* reserved forest, Jotsoma.

Table 11: Wood-rotting fungi and their season of occurrence, type and decay stage of substrata.

Sl.no.	Specimens	Type of substrata					Decay stage of substrata				
		Li	Lo	St	Tw	Ba	I	II	III	IV	V
ASCOMYCOTA											
1	*Aleuria aurantia*	-	-	-	+	-	-	-	-	+	-
2	*Annulohypoxylon bovei*	-	-	-	+	-	-	-	+	-	-
3	*Bisporella citrina*	-	+	-	+	-	-	-	-	+	-
4	*B. pallascens*	-	+	-	+	-	-	-	-	+	-
5	*Chlorociboria aeruginosa*	-	+	+	-	-	-	-	-	+	-
6	*Cookeina insititia*	-	+	-	+	-	-	-	-	+	-
7	*Daldinia concentrica*	-	+	+	+	-	-	-	+	+	-
8	*Entonaema liquiscens*	-	+	-	-	-	-	-	+	-	-
9	*Hypoxylon fragiforme*	-	-	-	+	-	-	-	+	-	-
10	*H. fuscum*	-	-	-	+	-	-	-	-	+	-
11	*H. haematostroma*	-	-	-	+	-	-	-	+	-	-
12	*H. rubiginosum*	-	-	-	+	-	-	-	+	-	-
13	*Hypoxylon* sp.	-	-	-	+	-	-	-	+	-	-
14	*Jackrogersella cohaerens*	-	-	-	+	-	-	+	+	+	-
15	*J. Minutella*	-	-	-	+	-	-	-	+	+	-
16	*Kretzschmaria deusta*	-	+	-	-	-	-	-	-	+	-
17	*Sarcoscypha coccinea*	-	-	-	+	-	-	-	-	+	-
18	*Xylaria apiculata*	-	+	-	+	-	-	-	+	+	-
19	*X. arbuscula*	-	-	-	+	-	-	-	-	+	-
20	*X. carpophila*	-	-	-	+	-	-	-	-	+	-

21	*X. filiformis*	-	-	-	+	-	-	-	-	+	-
22	*X. grammica*	-	+	+	+	-	-	-	+	+	-
23	*X. hypoxylon*	-	+	-	+	-	-	-	-	+	-
24	*X. longipes*	-	+	+	+	-	-	-	+	+	+
25	*X. multiplex*	-	-	-	+	-	-	-	-	+	+
26	*X. polymorpha*	-	+	+	+	-	-	-	+	+	-
27	*X. tabacina*	-	-	-	-	+	-	-	-	-	-
28	*Xylaria* sp. 1	-	+	-	-	-	-	-	+	-	-
29	*Xylaria* sp. 2	-	+	-	-	-	-	-	-	+	-
30	*Xylaria* sp. 3	-	+	-	-	-	-	-	+	-	-
BASIDIOMYCOTA											
31	*Agaricus squarrosus*	+	+	-	-	-	+	-	+	-	-
32	*Aleurodiscus ahmadii*	-	-	+	-	-	-	-	+	-	-
33	*Antrodiella zonata*	-	-	+	-	-	-	+	-	-	-
34	*Auricularia auricula-judae*	-	+	+	+	-	-	-	+	-	-
35	*A. cornea*	-	-	+	-	-	-	-	+	-	-
36	*A. delicata*	-	+	+	-	-	-	-	+	+	-
37	*A. mesenterica*	-	+	-	-	-	-	-	+	-	-
38	*A. nigaricans*	-	+	-	-	-	-	-	+	-	-
39	*A. polytricha*	-	+	+	+	-	-	+	+	-	-
40	*Basidioradulum radula*	-	-	-	+	-	-	-	-	+	-
41	*Bjerkandera adusta*	-	+	-	+	-	-	+	+	-	-
42	*Calyptella capula*	-	-	-	+	-	-	-	-	+	-
43	*Cerrena unicolor*	-	+	-	-	-	-	+	-	-	-
44	*Chondrostereum purpureum*	-	+	+	+	-	-	+	+	-	-
45	*Clavulina cristata*	-	-	+	-	-	-	+	-	-	-
46	*Coprinellus desseminatus*	-	-	+	-	-	-	-	+	-	-
47	*C. micaceus*	-	+	+	+	-	-	-	+	-	-
48	*Coprinopsis atramentaria*	+	-	-	-	-	+	-	-	-	-

49	*Coriolopsis aspera*	-	+	-	-	-	-	-	+	-	-
50	*C. gallica*	-	+	-	-	-	-	+	+	-	-
51	*C. polyzona*	-	+	-	-	-	-	+	+	-	-
52	*C. telfarii*	-	-	+	-	-	-	+	+	-	-
53	*C. trogii*	-	-	+	-	-	-	+	-	-	-
54	*Crepidotus applanatus*	-	+	-	+	-	-	-	+	-	-
55	*C. luteolus*	-	-	-	+	-	-	-	+	-	-
56	*C. mollis*	-	+	-	-	-	-	-	+	-	-
57	*C. variabilis*	-	+	-	-	-	-	+	-	-	-
58	*Cyathus olla*	-	+	-	-	-	-	-	+	+	-
59	*C. striatus*	-	-	-	+	-	-	+	-	-	-
60	*Dacrymyces plamatus*	-	+	-	+	-	-	+	-	-	-
61	*Dacryopinax spathularia*	-	+	+	+	-	-	+	+	+	-
62	*Daedalea flavida*	-	+	+	-	-	-	+	-	+	-
63	*D. quercina*	-	-	+	-	-	-	+	-	-	-
64	*Datronia mollis*	-	-	-	+	-	-	+	-	-	-
65	*Deconica horizontalis*	-	-	-	+	-	-	-	-	+	-
66	*Deflexula subsimplex*	-	+	-	-	-	-	-	+	-	-
67	*Earliella scabrosa*	-	+	+	-	-	-	-	+	+	-
68	*Exidia glandulosa*	-	-	-	+	-	-	-	-	+	-
69	*E. recisa*	-	+	-	-	-	-	-	-	+	-
70	*Favolaschia calocera*	-	-	-	+	-	-	-	-	+	-
71	*F. tonkinensis*	-	-	-	-	+	-	-	-	-	-
72	*Favolus tenuiculus*	-	+	-	-	-	-	+	+	-	-
73	*Filoboletus manipularis*	-	+	-	-	-	-	-	-	+	-
74	*Flavodon flavus*	-	-	+	-	-	-	+	+	-	-
75	*Fomes fomentarius*	-	+	-	-	-	-	-	+	-	-

76	*Fomitopsis cajanderi*	-	+	-	-	-	-	-	+	-	-
77	*F. pinicola*	-	+	+	-	-	-	-	+	-	-
78	*Ganoderma applanatum*	+	+	+	-	-	+	+	+	+	-
79	*G. lucidum*	-	-	+	-	-	-	-	-	+	+
80	*G. tsugae*	-	+	-	-	-	-	-	+	-	-
81	*Ganoderma* sp.	-	-	-	+	-	-	-	+	-	-
82	*Gloeophyllum sepiarium*	-	+	-	-	-	-	+	-	-	-
83	*Guepiniopsis alpina*	-	-	-	+	-	-	-	+	-	-
84	*Hemimycena candida*	-	+	-	-	-	-	-	-	+	-
85	*Hemimycena* sp.	-	-	-	+	-	-	-	-	+	-
86	*Heterobasidion insulare*	-	-	+	-	-	-	-	+	-	-
87	*Hexagonia badia*	-	-	-	+	-	-	-	+	-	-
88	*H. tenuis*	-	+	+	+	-	-	+	+	-	-
89	*H. tenuis* var. *pulchella*	-	+	-	+	-	-	-	+	-	-
90	*Hymenochaete cyclomellata*	-	+	-	-	-	-	-	+	-	-
91	*H. rubiginosa*	-	-	-	+	-	-	-	-	+	-
92	*H. tabacina*	-	-	-	+	-	-	-	-	-	-
93	*Hypholoma* sp.	-	-	+	-	-	-	-	-	+	-
94	*Inonotus radiates*	-	+	+	-	-	-	+	+	-	-
95	*Inonotus* sp.	+	-	-	-	-	+	-	-	-	-
96	*Irpex lacteus*	-	-	-	+	-	-	-	+	+	-
97	*Lentinus ciliatus*	-	-	-	+	-	-	-	+	-	-
98	*L. fasciatus*	-	-	+	-	-	-	-	+	-	-
99	*L. sajor-caju*	-	+	+	-	-	-	-	+	-	-
100	*L. squarrosulus*	-	-	+	-	-	-	-	+	-	-
101	*L. velutinus*	-	+	+	+	-	-	-	+	-	-
102	*Lenzites betulina*	-	+	+	+	-	-	+	+	-	-
103	*L. elegans*	-	+	+	-	-	+	+	-	-	-
104	*L. vespacea*	-	+	+	+	-	-	+	+	-	-

105	*Lepiota magnispora*	-	+	-	-	-	-	-	+	-	-
106	*Lopharia cinerascens*	-	+	+	+	-	-	+	+	-	-
107	*L. spadicea*	-	-	-	+	-	-	-	+	-	-
108	*Lycoperdon pyriforme*	-	+	-	+	-	-	-	-	+	-
109	*Marasmiellus candidus*	-	-	-	-	+	-	-	-	+	-
110	*Marasmius rotula*	-	-	-	+	-	-	-	-	+	-
111	*Microporus affinis*	-	+	-	+	-	-	-	+	-	-
112	*M. vernicipes*	-	+	-	-	-	-	-	-	+	-
113	*M. xanthopus*	-	+	+	+	-	-	+	+	+	-
114	*Mycena maculata*	-	+	-	-	-	-	-	-	+	-
115	*Mycena* sp.	-	+	-	-	-	-	-	-	+	-
116	*Nigrofomes melanoporus*	-	-	+	-	-	-	-	+	-	-
117	*Nigroporus vinosus*	-	+	+	-	-	-	-	-	+	+
118	*Perenniporia* sp.	-	+	-	-	-	-	-	+	-	-
119	*Phallus indusiatus*	-	-	+	-	-	-	-	-	+	-
120	*Phellinus adamantinus*	-	+	-	-	-	-	+	+	-	-
121	*P. ferruginosus*	-	-	-	+	-	-	-	+	-	-
122	*P. gilvus*	-	+	+	+	-	-	-	+	-	-
123	*P. punctatus*	-	-	-	+	-	-	-	+	-	-
124	*P. senex*	-	-	+	-	-	-	-	+	-	-
125	*P. tricolor*	-	-	+	-	-	-	-	-	+	-
126	*P. wahlberghii*	+	+	-	-	-	+	+	+	-	-
127	*Phellinus* sp. 1	-	+	-	-	-	-	-	-	+	-
128	*Phellinus* sp. 2	-	+	-	-	-	-	-	+	-	-
129	*Phellinus* sp. 3	-	+	-	-	-	-	-	+	-	-
130	*Pholiota polychroa*	-	-	-	-	+	-	-	-	-	-
131	*Piptoporus betulinus*	-	-	+	-	-	-	-	+	-	-

132	*Pleurocybella porrigens*	-	+	-	-	-	-	-	+	-	-
133	*Plurotus ostreatus*	-	+	-	-	-	-	-	+	-	-
134	*Podoscypha petalodes*	-	-	+	-	-	-	+	-	-	-
135	*Polyporus arcularius*	-	+	+	-	-	-	-	+	+	-
136	*P. dictyopus*	-	-	-	+	-	-	-	-	+	-
137	*P. grammocephalus*	-	+	-	-	-	+	+	-	-	-
138	*P. tuberaster*	-	+	-	-	-	-	-	+	-	-
139	*Porodisculus orientalis*	-	-	-	+	-	-	-	+	-	-
140	*Punctularia atropurpurescens*	-	+	-	-	-	-	-	-	+	-
141	*Pycnoporus cinnabarinus*	-	+	-	-	-	-	-	+	-	-
142	*P. sanguineus*	-	+	-	+	-	-	-	+	-	-
143	*Pyrrhoderma noxium*	-	-	+	-	-	-	-	-	+	-
144	*Ramaria* sp.	-	-	+	-	-	-	-	-	+	-
145	*Rigidoporus microporus*	-	-	+	-	-	-	-	+	-	-
146	*R. ulmarius*	+	-	-	-	-	+	-	-	-	-
147	*Rickenella fibula*	-	-	-	+	-	-	-	-	-	+
148	*Schizophyllum commune*	-	+	+	+	+	-	+	+	+	-
149	*Steccherinum ochraceum*	-	-	-	+	+	-	-	+	-	-
150	*Stereum complicatum*	-	-	+	+	-	-	+	+	-	-
151	*S. gausapatum*	-	-	+	+	-	-	-	+	-	-
152	*S. hirsutum*	-	+	+	+	-	-	+	+	-	-
153	*S. ostrea*	-	+	-	-	-	-	-	+	-	-
154	*Tetrapyrgos nigripes*	-	-	-	+	-	-	-	-	+	-
155	*Trametes gibbosa*	+	+	-	-	-	+	-	+	-	-
156	*T. hirsuta*	-	+	+	+	-	-	+	+	-	-
157	*T. lactinea*	+	+	+	-	-	+	+	-	-	-

158	*T. pubescens*	-	+	-	-	-	-	-	-	+	-
159	*T. tephroleuca*	-	+	-	+	-	-	+	+	-	-
160	*T. versicolor*	-	+	+	+	-	-	+	+	-	-
161	*T. villosa*	-	+	-	-	-	+	+	-	-	-
162	*Trametes* sp. 1	-	+	-	-	-	-	-	+	-	-
163	*Trametes* sp. 2	-	-	-	+	-	-	-	+	-	-
164	*Trametes* sp. 3	-	+	-	-	-	-	-	-	+	-
165	*Trametes* sp. 4	+	-	-	-	-	+	-	-	-	-
166	*Tremella fuciformis*	-	+	-	-	-	-	-	+	-	-
167	*T. mesenterica*	-	-	+	-	-	-	-	+	-	-
168	*Trichaptum abietinum*	-	+	+	+	-	-	-	+	-	-
169	*T. biforme*	-	-	+	+	-	-	-	+	+	-
170	*T. byssogenum*	-	+	-	+	-	-	+	+	-	-
171	*Tricholomopsis rutilans*	-	+	-	-	-	-	-	+	-	-
172	*Xylobolus frustulatus*	-	+	-	+	-	-	-	-	+	+
173	*X. subpileatus*	+	-	-	-	-	+	-	-	-	-
174	*Xylodon paradoxus*	-	+	-	-	-	-	-	+	-	-

Discussion

Wood-rotting fungi are characterized by their large variations in shapes, sizes, texture and habitat and are dominated by members of Basidiomycota, particularly those belonging to the family Polyporaceae. Studies conducted by Sailo (2010) and Lyngdoh and Dkhar (2014a, b) from Northeast India also reported the dominance of Polyporaceae members among other wood-rotting fungal families. Among Ascomycetous fungi, Xylariaceae and Hypoxylaceae members are dominant. This result is also in conformity with studies done by Sailo (2010) and Lyngdoh (2014). The family Hypoxylaceae is a newly introduced family and is a segregation of Hypoxyloid species from other Xylariaceae members based on the differences in multigene phylogenetic descriptions (Wendt et al., 2018).

Ecological studies of wood-rotting fungi showed that the occurrence of wood-rotting fungi is dependent on the availability of substrata and the type of forest stand. Rusoma community forest is a partially disturbed forest where agricultural, hunting and forest clearing practices exist however it harboured more variety of wood-rotting fungi as compared to other protected forest stands. This can be explained by analyzing the availability of substrata. The partially

disturbed Rusoma community forest has more falled logs and twigs due to disturbances. On the contrary, protected forests are healthy forest with few disturbances and less substrate availability. Another reason explaining the high diversity of wood-rotting fungi is the type of existing forest vegetation. Rusoma community forest, Tuophema reserved forest and Puliebadze reserve forest stands are mixed forest stands with high tree species diversity as compared to Kikruma community forest and Puliebadze *Rhododendron* reserve forest stands which are hugely dominated by *Quercus serrata* and *Rhododendron arboreum* respectively. Consequently, mixed forest stands provide more chance for wood-rotting fungi to thrive thus increasing the diversity of wood-rotting fungi where as only those species specific to *Quercus serrata* and *Rhododendron arboreum* could be found in Kikruma community forest and Puliebadze *Rhododendron* reserve forest stands respectively. The effect of forest vegetation type on diversity of wood-rotting fungi and substrate specificity of wood-rotting fungi were also reported by Hattori (2005) and Unterseher et al. (2005).

Apart from macro-environmental factors, micro-environmental factors such as type of substrata and decay stage of play a key role on the establishment and growth of wood-rotting fungi. Our study showed that logs and twigs provided maximum support for growth of wood-rotting fungi. Depending on the decay stage and type of substrata, occurrence of wood-rotting fungi in a particular forest stand is determined. Occurrence of wood-rotting fungi depends on various decay stages and of wood and majority of the specimens, particularly those belonging to Basidiomycota were found growing on wood at intermediate stage of decay (stage III). Our finding is supported by Pouska et al. 2011, where they reported that majority of the species favored intermediate stage of decaying wood. We also observe that majority of the Ascomycetous fungi preferred later stages of wood decay (Chuzho and Dkhar, 2019). Among the various type of substrata, logs harbored maximum number of wood-rotting fungi. Logs provide a large surface area, allowing many wood-rotting fungi to colonize (Gates et al., 2011). Micro-environmental effects on diversity and growth of wood-rotting fungi need to be further investigated.

Macrofungal diversity, particularly wood-rotting fungal diversity in Northeast India, is still not investigated to a large extent. Previous studies from Meghalaya by Sailo (2010), Lyngdoh and Dkhar (2014a, b) and Pongen et al., (2018) has reported a total of 5 new species from India and along with 4 new reports form the current investigation, there is enough evidence that more exploration will only unearth the biological richness of North east India. With this, we further suggest that a proper documentation on wood-rotting fungi of Northeast India should be done.

REFERENCES

Ao, T., Deb, C. R., & Khruomo N. (2016b). Wild edible mushroom of Nagaland India: A potential food resource. *Journal of Experimental Biological and Agricultural Sciences 4*(1), 59-65.

Ao, T., Seb, J., Ajungla, T., & Deb, C. R. (2016a). Diversity of wild mushroom in Nagaland, India. *Open Journal of Forestry, 6*, 404-419.

Bagchee, K. D., & Bakshi, B. K. (1950). Some fungi as wound parasite on Indian trees. *Ind. Forest 76*(6), 244-253.

Bagchee, K. D., Puri, Y. N., & Bakshi, B. K. (1954). Principal diseases and decay of oaks and other hardwood in India- II. *Indian Phytopathology 7*, 18-42.

Bakshi, B. K. (1971). *Indian Polyporaceae (on trees and timber)*. Indian Council of Agricultural Research, New Delhi, 1-246.

Bakshi, B. K., Rehill, P.S., & Choudhury, T. G. (1963). Field studies in heartrot in sal (Shorea robusta) Gaertn. *Indian For., 83*, 2-17.

Bhaben, T., Lisha, G., & Chandra, S. G. (2011). Wild edible fungal resources used by ethnic tribes of Nagaland, India. *Indian Journal of Traditional Knowledge, 10*, 512–515.

Bhosle, S., Ranadive, K., Bapta, G., Garad, S., Deshpande, G., & Vaida J. (2010). Taxonomy and diversity of Ganoderma from the Western parts of Maharashtra (India). *Mycosphere, 1*(3), 249-262.

Bose, S. R. (1946). Polyporaceae of Bengak-XI. *J. Dept. Sci. Calcutta University, 2*,53-87.

Bose, S. R. (1919). Description of Fungi in Bengal. *Proc.Ind.Assoc. Cult. Sci., and Proc. Sci. Convention for the year 1918, 4*, 136-143.

Bose, S. R. (1937). Polyporaceae of Lokra Hills (Assam). *Annals of Mycology, 35*,119-137.

Bose, S. R. (1944). Importance of Anatomy in systematics of Polyporaceae. *Journal of the Indian Botanical Society, 23*, 153-157.

Bulter, E. J., & Bisby, G. R. (1931). The fungi of India. The Imperial Council of Agricultural Research. India Sci. Monogr. 1:237, published by ICAR, New Delhi, 1960, 1-552.

Chuzho, K., & Dkhar, M. S. (2018). Ecological Determinants of Wood-rotting Fungal Diversity and First Report of Favolaschia calocera, an invasive species from India. *Proceedings of the National Academy of Sciences, India, Section B: Biological Sciences,* doi: 10.1007/s40011-018-1038-1.

Chuzho, K., & Dkhar, M. S. (2018). Effects of environmental and host characteristics on diversity and distribution of wood-rotting fungi of Mount

Puliebadze, Nagaland. *Studies in Fungi 3*(1), 241-247, doi: 10.5943/sif/3/1/24.

Chuzho, K., & Dkhar, M. S. (2019). Diversity of Ascomycetous wood-rotting fungi along an altitudinal gradient in forests of Nagaland and first report of Jackrogersella minutela from India. *Journal of Indian Academy of wood Sciences*, doi: 10.1007/s13196-109-00233-0.

Chuzho, K., & Dkhar, M. S. (2017). Diversity, ecology and biogeography of the family polyporaceae along an altitudinal gradient in forests of Nagaland. *International Journal of Current Research in Life Sciences 6*, 754-760.

Chuzho, K., Dkhar, M. S., & Lyngdoh, A. (2017). Wood-rotting fungi in two forest stands of Kohima, North-east India - a preliminary report. *Current Research in Environmental and Applied Mycology, 7*, 15-21.

Debnath, S., Majumdar, K., Das Panna, & Saha, A. K. (2018). New distribution record of five species of Xylaria from Tripura, Northeast India. *Research & Reviews: A journal of Life Sciences, 8*, 1-10.

Gates, M. G., Mohammed, C., Wardlaw, T., Ratkowsky, D. A., & Davidson, N. J. (2011). The ecology and diversity of wood-inhibiting macrofungiin native Eucalyptus obliqua forest of Southern Tasmania, Australia. *Fungal Ecology, 4*, 56-67.

Harsh, N. S. K. (1982). *Studies on wood-decaying fungi of Kumaun hills*. Ph. D. Thesis, Departemnt of Botany, Government Science College, Jabalpur.

Harsh, N. S. K., & Bisht, N. S. (1983). Altitudinal distribution of some common wood-rotting fungi in Kumaun hills. *International Journal of Tropical Plant Diseases, 1*, 93-98.

Hattori, T. (2005). Diversity of wood-inhabiting polypores in temperate forest with different vegetation types in Japan. *Fungal Diversity, 18*, 73-88.

Karun, N. C., & Sridhar, K. R. (2015). Xylaria complex in the South Western India. *Plant Pathology and Quarantine, 5*, 83-96.

Klotzsch, J. F. (1832). Mycologische Berichtigungen. *Linnaea, 7*, 193-204.

Koyani, R. D., Patel, H. R., Vasava, A. M., & Rajput, K. S. (2016). Xylariaceae: Overview and addition to the fungal diversity of Gujarat state. *Studies in Fungi, 1*, 69-79. Doi 10.5943/sif/1/1/6

Kumar, R., Tapwal, A., Pandey, S., Borah, R. K., Borah, D., & Borgohain, J. (2013). Macrofungal diversity and nutrient content of some edible mushrooms of Nagaland, India. *Nusantura Bioscience, 5*, 1-7.

Leelavathy, K. M., & Ganesh, P. N. (2000). *Polypores of Kerela*. Daya Publishing House, Delhi, pp. 166.

Lyngdoh, A., & Dkhar, M. S. (2014a). First report of two wood-rotting fungi, Cyclomyces fuscus and Humphreya coffeatum, form India. *Journal of New Biological Reports, 3*, 25-28.

Lyngdoh, A., & Dkhar, M. S. (2014b). Wood-rotting fungi in East Khasi Hills of Meghalaya, Northeast India, with special reference to Heterobasidion perplexa (a rare species - new to India). *Current Research in Environmental & Applied Mycology, 4*, 117-124.

Moghe, G. (2011). *Biodiversity hotspots on India* (www.biodiversityofindia.org Accessed August 6th 2018)

Mueller, G. M., Gerald, F. B., & Mercedes, S. F. (2004). *Biodiversity of fungi: Inventory and monitoring methods*. Elsevier Academic Press, 1-777.

Nagadesi, P. K., & Arya A. 2017. Germplasm of Xylariales fungal diversity of Gujarat, India. *World Scientific News, 66*, 43-55.

Nanda, M. K. (1996). *Wood rotting fungi from Bhimashankar*. Ph. D. Thesis, Department of Botany, University of Pune, Pune, India.

Nejakar, D., Belur, P., Mali, S., & Patil, R. (2012). Xylarials of Sharavathi wildlife sanctuary Karnataka. *International Journal of Plant Sciences, 7*, 97-110.
Nejakar, D., & Nejakar, S. (2009). Effect of environmental factors on Xylarials in Western Ghats (Ecological economics: An approach towards socio-economic and environmental sustainability). *ISEC Publication*, 248-266.

Nunez, M., & Ryvarden, L. (2000). *East Asian Polypores – Volume 1 (Ganodermataceae and Hymenochaetaceae)*. Synopsis fungorum 13. Funfiflora, Oslo, 1-168.

Nunez, M., & Ryvarden, L. (2001). *East Asian Polypores – Volume 2 (Polyporaceae)*. Synopsis fungorum 14. Funfiflora, Oslo, 170–522.

Patil, A. R., & Patil, K. P., (2017). Annulohypoxylon Y. M. JU., J.D. Rogers and Hsieh, new generic report to the fungi of India. *International Journal of Researches in Biosciences, Agriculture and Technology, 3*, 326-328.

Pongen, A. S., Chuzho, K., Harsh, N. S. K., Dkhar, M. S., & Kumar, M. (2018). Coltriciella dependens (Berk. & M.A. Curtis) Murrill, a new addition to wood-rotting fungi of India. *Journal of Threatened Taxa, 10*(8), 12140-12143, doi: 10.11609/jott.4123.10.8.12140-12143.

Pouska, V., Leps, J., Svoboda, M., & Lepsova, A. (2011). How do log characteristics influence the occurrence of wood fungi in a mountain spruce forest?. *Fungal Ecology, 4*, 201-209.

Pouska, V., Svoboda, M., & Lepsova, A. (2010). The diversity of wood-decaying fungi in relation to changing site conditions in an old-growth spruce forest, Central Europe. *European Journal of Forest Research, 129*, 219-231.

Puri, Y. N. (1956). Studies on Indian Poria. *Journal of the Indian Botanical Society, 35*, 277-283.

Rabba, A. S. (1994). *Studies in the genus Phellinus Quel. from Maharashtra*. Ph. D. Thesis, University of Pune, Pune, India.

Ramesh, V., Thalavaipandian, A., & Karunakaran, C. (2012). Identification and comparision of Xylaria curta and Xylaria sp. from Western Ghats-Courtallum Hills, India. *Mycosphere, 3*, 607-615. Doi 10.5943/mycosphere/3/5/8

Ranadive, K. R. (2013). An overview of Aphyllophorales (wood rotting fungi) of India. *International Journal of Current Microbiology and Applied Sciences, 2*(12), 112-139.

Roy, A. (1996). *Polyporaceae of India*. R. P. Singh Gahlot, International Book Distributors, Dehra Dun, 1-309.

Ryvarden, L., & Johansen, I. (1980). A Preliminary Polypore Flora of East Africa. *Fungiflora, Oslo*, 1-636.

Sailo, J. Z. (2010). *Studies on the wood rotting fungi of Meghalaya*. Ph.D. Thesis. North Eastern Hill University, Shillong, India.

Sharma, J. R. (1995). *Hymenochaetaceae of India*. Culcutta, India. Botanical survey of India. 1-219.

Singer, R. (1974). A monograph of Favolaschia. *Beihefte zur Nova Hedwigia, 50*, 1-180.

Smith, A. H., & Hesler, L. R. (1968). *The North American species of Pholiota*, New York, 1-402.

Sundaramani, S., & Madurajan, D. (1925). *Some Polyporaceae of Madras Presidency*. Madras Agricultural Dapartment, Year Book, 1924, 69-75.

Thind, K. S., & Ratan, S. S. (1968). Thelephoraceae of North Western Himalayas. *Indian Phytopath. Soc. Bull., 4*, 14-24.

Unteseher M., Otto P., & Morawetz W. (2005). Species richness and substrate specificity of lignicolous fungi in the canopy of a temperate, mixed deciduous forest. *Mycological Progress, 4*(2), 117-132.

Vaida, J. G., Rabba, A. S., & Nanda, M. K. (1994). *Systematic study of the genus Phellinus from Bhimashankar forest*. Biologia Indica.

Wendt, L., Benjamin, E., Kuhnert, E., Heitkamper, S., Lambert, C., Hladki, A. I., Romero, A. I., Luangasaard, J. J., Srikitikulchai, P., Persoh, D., & Stadlaler, M. (2018). Resurrection and emendation of the Hypoxylaceae, recognised from a multigene phylogeny of the Xylariales. *Mycological Progress, 17*, 115-154.

CHAPTER 12

Indigenous Dietary Practices and Traditional Knowledge among Khasi Youth, Mylliem Block, Meghalaya

Laribha Dohtdong, Bonnie Nicole, G.C. Kharkongor and B.C. Warjri

Introduction

India is considered to be the second largest country with a concentration of 104.3 million tribal inhabitants, and constitute 8.6 percent of its population (Census of India, 2011). Among them 93.8 percent reside in the rural areas far from the social and modernised technology.

According to the Indian constitution, Scheduled tribes are referred as Adivasis which is an umbrella term for a heterogeneous set of ethnic and indigenous tribal group claiming to belong to the aboriginal population of India.

Indigenous people (IP) are often regarded as nature's caretaker and keeper as they have a close bond with the environment. Tribal population still depends on agriculture and forests products for sustainability and follow a homogenous food habit and dietary practice. In view of the food habits of IP, they form a distinct group when compared with other populations. Mostly their food habits are influenced by nature, seasonal variation, availability of agricultural and forest produce. A close association is found to be linked with tribal ecosystem and their health status. Though there are breakthroughs and developments in many dimensions, the country is still precariously in solving and offering succour to the poor and tribal populations on emerging issues. Studies revealed that the health status of IP is drastically degrading due to a change in the environment and their lifestyle brought about by modernisation.

The present study was carried out to assess the frequency of intake of traditional food among the Khasi youth who are indigenous inhabitants from Meghalaya, one of the North Eastern states of India. Meghalaya is known as the 'Abode of Clouds' and is the 21st largest state of the Indian Union having an area of 22,429 sq km and a population of 23,06,069 (census 2001) , where the higher ridges of the state lies in the coniferous belt, gradually sloping down to sub-tropical & tropical ecoregion with less influence from the outside world.

The diets of the Khasi(s) are mostly based on the agriculture products and availability of wild edibles. Considering the typical Khasi diet, it consists mostly

of a plateful of rice, mixed vegetables which are indigenous and some animal protein. However, the diets of people in the urban and rural areas are determined a lot by the availability of choices of food, culture, traditions etc. The availability of choices of food in today's context has led to changes in dietary patterns of people in urban areas. In today's context, because of globalization and commercialisation, many of these indigenous foods are not consumed by the general public. The children and youth of today's generation are not acquainted with such foods and in the ways in which they are prepared and cooked. Moreover, there is little awareness about the indigenous crops and fruits grown in these parts as indicated from studies on the dietary practices

Wild plants and fruits consumed by most tribes are found to be more nutritious and nutrient dense than other common vegetables, and if proper channelization and marketing strategies are being provided, it can be a factor for cash generation thus increasing the economic condition of the state.

With this focus, this study an assessment of the diet patterns of Khasi youth in terms of dependency on indigenous foods and entry of modern foods into the diets. The study also intends to demystify the practice of traditional knowledge in improving the health of the Khasi tribal people.

Objective

Keeping in view of these aspects the present study is undertaken with the following objectives to

1. To assess the consumption pattern of traditional food amongst the Khasi youth
2. To document the therapeutic purpose of indigenous food

Materials and Methods

The study was carried out in Mylliem block of East Khasi Hills districts of Meghalaya. One hundred and sixty five respondents were randomly selected from four educational institutions after availing permission from the respective administrative authorities. The data on indigenous food intake was collected by using a self administered food frequency questionnaire.

Dietary assessment forms an integral part of the nutritional survey (Deshpande, 2001) where information on the food consumption of an individual can be elicited. Hence, to assess the intake of traditional food by the respondent a food frequency questionnaire (FFQ) was provided where the participants filled the relevant food preference consumed by them and scoring procedure is adopted to assess the frequency of food consumption of indigenous food.

Information on indigenous knowledge for treating different health problems was collected with the help of pretested and modified questions to ascertain the therapeutic purpose of food.

The collected data was tabulated and analyzed with the help of statistical tools and techniques and are discussed below.

Results and Discussions

The results of the study were compiled and discussed below.

a. Food preference of Khasi youth:

It was observed that all respondents were non vegetarian and took two meals per day. They consumed a heavy breakfast i.e. rice with vegetables or dhal, chilli or dry fish, etc. and before going to school with packed lunch. The preference of consumption over home cooked meal over outside cook meal among the respondent and is depicted in Table 12 and also their preferences on consumption over traditional and non traditional snack is shown in the Table 13.

Table 12: Consumption preference of Khasi youth on Home cooked food over outside cooked food

Preference	Female (n=92)				Male (n=73)			
	Taste	Hygienic	Other	Total	Taste	Hygienic	Other	Total
Home cooked food	20	68	11	99	44	46	7	97
Outside cooked food	0	0	1	1	2	0	1	3
Total				100				100

Table13: Consumption preference of Khasi youth on Traditional snack over Non traditional snack

Preference	Female (n=92)				Male (n=73)			
	Taste	Hygienic	Other	Total	Taste	Hygienic	Other	Total
Traditional Snack	48	8	2	58	47	9	3	59
Non traditional Snack	35	4	3	42	36	3	2	41
Total				100				100

a. Indigenous Food:

The consumption of indigenous food such as snacks, fruits and plants is depicted in Table 14. The frequency of consumption of indigenous snacks such as pukhlein, pumaloi, etc is not on a daily basis as they are consumed on occasions or market days. It is also interesting to see that most of the indigenous snacks are made from rice of different varieties except for few items such as pu riewhadem which is made from corn and rymbai ja made from soya bean.

The frequency of consumption of indigenous plants and fruits by the Khasi youth depends on seasonal availability and accessibility.

Table 14: Common indigenous food consumed by tribal adolescents

Indigenous Snack	Indigenous plants	Indigenous Fruits
Local cake	Jamyrdoh	Sohplang
Putharo	Jarain	Sohshur
Pukhlein	Jathang	Sohphie
Pumaloi	Jamansyiar (Batsohlang, Khleinsyiar)	Sohling
Pudoh	Jatira	Sohpen
Pusaw	Jangew	Sohshang
Punei	Ja-ut	Sohlait
Puthap	Jyllang	Sohklong,
Puhadem	Tyrkhang	Sohkynphor,
-	Jada	Sohiong,
-	-	Sohbrab
-	-	Sohkrot
-	-	Sohot
-	-	Sohprew
-	-	Sohmyndong

c. Entry of modern foods:

The respondents are aware of modern food, as they do consume the modern foods such as wai wai (noodle) and potato chips almost on a daily to weekly basis. These two items are easily available in the shops at the villages, thus the consumption is frequent. However other snacks such as bread, suji, chow, momo, fried rice and Indian sweets are consumed when they visit the markets or on occasions.

b. Foods taken during disease condition

Health culture and health practices of the tribal vary according to their communities and geographical location. Prior to the development of modern medicine, plants were used to treat for various diseases. Indigenous plants are still used in various communities till date by traditional healer as remedial measures for health problems, but there is a lack of documentation to preserve the traditional procedure on the use of indigenous foods for treatment.

It is interesting to note that they consumed different types of foods to get recovery from illness for improving the health & nutrition status. Table 15 depicts the use of common indigenous plants as a remedial measure.

Table 15 : Most common edible plants used in health problems

Health Condition	Local Plants used	Part and Method used
Blood Count		
Anaemia	Jatira	Leaves mixed with lemon

Anaemia	Jada	Boiled leaves
Anaemia	Jarain	Fried Leaves
Gastrointestinal illness		
Gastric	Sla Phankaro	Leave is fry with ginger paste
Dysentery	Khlien syiar	Leaves are eaten raw or mixed
Gastric	Sohphe	Juice extract
Deworming	Sohphlang	Tip of the root
Deworming	Jatira	Tender Stem
Diarhoae	Sohbrap	Leaves or fruit
Others		
Elevated Blood Pressure	Jamyrdoh	Leaves eaten in raw form
Cough	Sohphe	Juice extract

Generally, they used the above listed food and leaves for getting relief from diseases at their household level and in case of emergency they consult doctor or traditional healers. In a study done among the tribal of Similipal biosphere reserve use different types of mushrooms as a source of food as well as for treating malnutrition, weakness and other nutritional disorders.

Conclusion

The present dietary study has brought out important insights into the diets of the Khasi youth in both rural and urban areas. Their preference on traditional foods was the highest stating the reason being fresh and healthy. However the concern is on the diminishing source of traditional food, its availability and accessibility due to deforestation and declining awareness of the youth on traditional foods (wild edibles). Through the study, it was found that there is also a threat to traditional food as certain kinds of fruits, or wild green edibles are not found in the forests anymore. There are various reasons such as deforestation, broom cultivation, changing life style of the present generation and modernisation. The youth had a a knowledge on use of indigenous plants as an ailment for illnesses but it is not practical due to the change in the environmental system. Therefore there is a need to sensitise the youth on the significance and the simplest preservation methods of indigenous plants that have therapeutic properties and to educate on consumption of indigenous food which is packed with nutrients.

REFERENCES

Malhotra, A., & Passi, S. J. (2007). Diet quality and nutritional status of rural adolescent girl beneficiaries of ICDS in north India. *Asia Pacific Journal of Clinical Nutrition, 16* (1), 8-16.

Ali, A. (1980). *Health and nutritional status of Pauri Bhuniyas of Jaldih village in Sundergarh district, Orissa*. The Newsletter 13 [April], Tribal Development Division, Ministry of Home Affairs, New Delhi.

Basu, & Kshatriya (1993). Demographic features and health care practices in Dudh Kharia Tribal population of Sundergarth district Orissa Baryam S, (1982). Biodemographic factors associated with offspring morality among the Jahongs of Meghalaya. *Journal of the Indian Anthropological Society, 17* (2), 143-146.

Sawain, J. T., Jeeva, S., Lyndem, F. G., & Laloo, R. C. (2007). Wild edible plants of Meghalaya, North-east India. *Natural Product Radiance, 6* (5), 410-426.

MLCU (2012), Brief report on Indigenous event.

Meghalaya Census (2011). Meghalaya Population Nearly 3 Million. Manipurhub, April 7, 2011.

Mishra, C. P., Sing, N., & Chakravarty, A. (2002). Dietary pattern of tribal community of Naugarh block. *Tribal Health Bulletin 8* (1), 6-11.

Nandi1, B. K., & Bhattacharjee. Indigenous Foods and Nutrition Security in India: A Case Study, 155-166.

Sachan, S. K. S., Patra, J. K., & Thatoi**,** H. N. (2013). Indigenous knowledge of ethnic tribes for utilization of wild mushrooms as foods and medicine in Similipal biosphere reserve, Odisha. *India Journal of Agricultural Technology, 9* (2), 403-416.

Status paper for the national Workshop on "Status of Tribal Women in India" organised by Council for social Development, New Delhi and sponsored by National Commission for Women, New Delhi (22-23 Dec'93).

Qamra, S. R., Roy, J., & Mishra, D. K. (2006). *Food consumption pattern and associated habits of the Bhil tribe of Dhar district of Madhya Pradesh*. Proceedings of National Symposium on Tribal health, Regional Tribal Medical Centre, ICMR, Jabalpur, 211-219.

Xaxa, V. (2011). *The Status of Tribal Children in India: A historical perspective*. A Report: IHD - UNICEF Working Paper Series Children of India: Rights and Opportunities Working Paper No. 7,.

Mohanta, Y., & Lenka, C. (2016). A study on use of local food stuffs and traditional knowledge for improving public health nutrition in mayurbhanj district, odisha. *Asian Food Safety And Food Security Association*, 2306-2150.

CHAPTER 13

Study of Trophic Status of few Important Water Bodies in Shillong and Around Using Algal Index

M Wanlambok Sanglyne and P. Ramanujam

Introduction

Phytoplankton serves as a very good indicator of water quality. The occurrence and diversity of phytoplankton varies from one water body to another depending on their trophic status. Due to unplanned management, and disposal of untreated public sewage water, agricultural runoff and other human and animal wastes into rivers, lakes, reservoirs and others, water bodies are continuously shrinking and getting degraded in water quality and ultimately affecting biotic resources (Venkatesan, 2007; Elmaci et al., 2008). The health of lakes and rivers depend on the algal diversity, which form the most important component of the ecosystem as the primary producer of energy (Saxena, 2012). Human anthropogenic activities are the main causative agents that increase the nutrients like nitrates, phosphates (N and P) in the water bodies and ultimately lead to eutrophication (Chukwu and Odunzeh, 2006; Shekhar et al., 2008). Excessive nutrient loading into surface water system is considered to be one of the major factors of eutrophication (Fang et al., 2004; Tong et al., 2003). The nutrient level of many lakes and rivers have increased drastically over the past 50 years in response to increased discharge of domestic wastes and non-point pollution from agricultural practices and urban development (Mainstone and Parr, 2002).Nygaard (1976) proposed five indices to evaluate the organic pollution of water bodies based on the presence of different planktonic algal groups which are known to have different capacity to tolerate different nutrients. These indices include Cyanophycean or Myxophycean index, Chlorophycean index, Bacillariophycean index, Euglenophycean index and a combination of all called Compound Coefficient index. According to Nygaard, presence of high number of Desmids a group belonging to Chlorophyceae and now separated as Zygnematophyceae are considered to be the indicator of oligotrophic water bodies whereas presence of more number of Cyanophycean, and Euglenophycean members, Chlorococales members of Chlorophyceae, in comparison to Desmids are considered as indicator of eutrophic water body. Among diatoms, presence of more Pennate diatoms are considered as oligotrophic water body whereas presence of more central diatoms are considered as eutrophic water body.

Study sites

1. Umkhrah River: Umkhrah River runs through the heart of Shillong city located at an altitude of 1375 m above sea level with latitudes and longitude coordinates of 25°36'54.3"N and 91°53'34.7"E. Width and depth of the river where sampling was done were 3.7 m and 1.82 m respectively. Dumping of domestic and industrial sea wage is a common occurrence throughout the length of the river(Figure 13)

Figure 13 : Umkhrah River

2. Umshyrpi River: Umshyrpi River running through the outskirts of Shillong City is located at an altitude of 1457 m above sea level with latitude and longitude coordinates of 25°34'28.3"N and 91°52'22.1"E respectively. The width and depth of the river where sampling was done was 7 m and 0.32m respectively. Human activities throughout the river include bathing, washing of vehicles and clothes etc. (Figure 14)

Figure 14 : Umshyrpi River

3. Umiam Reservoir: Located at an altitude of 950 m above sea level with latitude and longitude coordinates of 25°37'59" N and 91°51'43"E, with an area of 10.27 square Kilometer and an average depth of 4.63 m The reservoir is a famous tourist spots and activities like water sports, boating, kayaking as well as adventurous trekking is common in the area. Rivers like Umkhrah and Umshyrpi

both flows to this reservoir resulting in excessive accumulation of minerals (Eutrophication). Algal bloom is a common sighting especially during summer months. (Figure 15)

Figure 15: Umiam Reservoir

4. Ward's Lake: Ward's Lake, located at an altitude of 1525 m above sea level with latitude and longitude coordinates of 25°34'56.9"N and 91°52'53" E, with an area of 15,400 square meters and an average depth of 5.2 m attracts tourists all year round. Activities like Boating is common in the Lake. (Figure 16)

Figure 16: Ward's Lake:

Materials and Method

Samples were collected during April-May, 2018. Temperature, pH, water current, transparency and turbidity were recorded on the spot and water samples

were brought to the laboratory. Measurement of conductivity and analysis of nutrients like phosphate, nitrite and nitrate was done following APHA (2012). Algal samples were collected from the surface with phytoplankton's net and from the peripheral regions with the help of scalpel and toothbrush from different substrata like stones, rocks, pebbles, dead leaves and sediments. The algal sample were preserved in 4% formaldehyde solution and brought to the laboratory for further study. Algal sample were observed under a Trinocular microscope and photographed (using Delphi-X observer series microscope). Taxonomic classification up to species level were carried out with the help of standard books and monograph like Fritsch (1935), Prescott (1982), Desikachary (1985), Gandhi (1998), ADIAC (1999), John et.al.. (2002). Taxonomy was updated using the online database, Algae Base [World-wide electronic publication (www.algaebase.org)]. Trophic status of the selected water bodies was calculated after taxonomic identification using Nygaard's Algal Indices as given below:

Myxophyceaen index= Myxophyceae/Desmids(the value 0.0-0.4 indicate oligotrophic and 0.0-3.0 indicate eutrophic status of the water body)

Chlorophyceaen index= Chlorococcales/Desmids (the value 0.0-0.7 indicate oligotrophic and 0.2-9.0 indicate eutrophic status of the water body)

Baccilariophyceaen index= Centric Diatoms/ Pinnate Diatoms (the value 0.0-0.3 indicate oligotrophic and 0.0-1.7 indicate eutrophic status of the water body)

Euglenophyceaen index= Euglenophyceae/ Myxophyceae+Chlorococcales (the value 0.0-0.2 indicate oligotrophic and 0.0-1.0 indicate eutrophic status of the water body)

Compound Quotient Index= Myxophyceae + Chlorococcales + Baccilariophyceae + Euglenophyceae/Desmids (the value 0.0-1.0 indicate oligotrophic and 1.2- 2.5 indicate eutrophic status of the water body)

Value < 2 oligotrophic, 2-6 moderately Eutrophic and above 6 highly eutrophic.

Results

Temperature in different water bodies varied from 16- 20^0 C. The pH varied from (6.20- 6.45) except in Umiam Reservoir where it was 7.2, Conductivity in general was low and varied from (0.006-0.096) only in Ward's,lake, it was (0.19 mS).Transparency was minimum in Umkhrah River (24 cm) and it was maximum in Umiam Reservoir (100 cm).Phosphate was recorded minimum in Umiam Reservoir (1.77 mg/l) and it was maximum in Umshyrpi River (8.30 mg/l), Nitrate was recorded minimum in Umiam Reservoir (0.22 mg/l) and it was maximum in Umshyrpi River (2.10 mg/l), Nitrite was minimum in Umkhrah River (1.10 mg/l) and it was (2.56 mg/l) maximum in Umshyrpi River (Table 17).

Table 16: **Physico-chemical parameters of four different selected water bodies**

Serial No.	Name of the water body	Temperature (°C)	pH	Conductivity (mS)	Transparency (cm)	Phosphate (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)
1	Umkhrah River	16	6.20	0.096	24	7.20	0.88	1.10
2	Umshyrpi river	16.5	6.45	0.068	47.5	8.30	2.10	2.56
3	Umiam Reservoir	20	7.20	0.006	100	1.77	0.22	1.97
4	Ward's Lake	20	6.43	0.19	36	1.78	0.45	1.65

Algal Community Structure

A total of 367 algal species belonging to 8 classes were recorded from four study sites. Class Bacilliariophyceae were represented by maximum number of species (124 species) followed by Zygnematophyceae (94 species), Chlorophyceae (86 species), Myxophyceae or Cyanobacteria (38 species), Euglenophyceae (22 species), Xanthophyceae (1 species), Dinophyceae (1 species), Chrysophyceae (1 Species). The number of algal species varied significantly in the four water bodies, maximum number of species from all the groups has been recorded from Ward's Lake followed by that of Umiam reservoir. In both the rivers number of algal species recorded were 27 and 20 respectively (Table 18).

Table 17: Distributional pattern of algae in four different selected water bodies

Sl. No	Algal Groups	Total number of species recorded	Ward's lake	Umiam Reservoir	Umkhrah River	Umshyrpi River
1	CHLOROPHYCEAE	86	68	15	8	6
2	BACILLARIOPHYCEAE	124	105	26	12	4
3	CYANOPHYCEAE	38	29	06	04	07
4	EUGLENOPHYCEAE	22	18	02	02	02
5	ZYGNEMATOPHYCEAE	94	80	19	01	01
6	XANTHOPHYCEAE	01	01	-	-	-
7	DINOPHYCEAE	01	01	-	-	-
8	CHRYSOPHYCEAE	01	01	-	-	-
	Total	367	303	68	27	20

Nygaard's index value mainly the compound quotient value revealed that the trophic status of four selected water bodies are in different stages of Eutrophication. Umiam reservoir and Ward's lake are moderately polluted, whereas both the rivers are highly polluted, river Umkhrah being the maximum (25).

Table 18: Calculated Nygaard's Algal Index value for four selected water bodies

Sl. No	Nygaard's Algal Index	Name of the water body			
		Ward's Lake	Umiam Reservoir	Umkhrah River	Umshyrpi River
1	Myxophyceae/ Desmids	29/80=0.36	6/19=0.31	4/1= 4	7/1=7
2	Chlorococcales/ Desmids	47/80=0.59	11/19=0.58	7/1=7	4/1=4
3	Centric/ Pinnate Diatoms	5/100=0.05	6/20=0.30	0/12=0	1/3=0.33
4	Euglenophyceae / Myxophyceae+ Chlorococcales	18/29+47=0.24	2/6+11=0.12	2/4+7= 0.18	2/7+4=0.18
5	Compound Quotient	29+47+105+18 /80=2.49	6+11+26+2/1 9=2.37	4+7+12+2/1 =25	7+4+4+2/1 =17

Discussion

The mechanism of eutrophication is one of the most serious threats to the environment. Fresh water bodies in Meghalaya are undergoing serious degradation as a results of coal mining and sand quarrying (Das and Ramanujam, 2010; Siangbood and Ramanujam, 2014). Eutrophication due to deposition of domestic garbage and sewage is another important cause for deterioration of the quality of water mainly the rivers flowing through Shillong city. The significant reduction in the growth of algal species clearly indicated the degradation level. Khan and Mohammad (2014) reported that the most recognizable causes of eutrophication were the excessive use of fertilizers and pesticides, sea wage from industries and excessive domestic sea wage generated due to population growth. Saxena (2012) reported that the trophic status of any water body depended on the level of nutrients present. Water bodies with high nutrients level and high net primary productivity are always eutrophic. Algal Index proposed by Nygaard are extensively because of it is very handy tool which involves only algal identification and do not need a detailed analysis of physico-chemical parameters of the water systems (Hosmani, 1980). In Eutrophic water bodies where huge amount of nutrients is being supplied, higher levels of nutrients in general support the growth of Cyanobacteria producing high biomass as bloom. High nutrients also favor the growth of Chlorococcales of Chlorophyceae, Central diatoms and also the Euglenoids. Therefore, in such water bodies, comparatively

smaller number of species can grow and the number of phytoplankton is low (Nygaard, 1976). This is very evident in the present study where out of four selected water bodies, Ward's lake with optimal nutrients is the richest source of algal resource which in turn well support the growth of fishes and other heterotrophic organisms whereas in highly polluted rivers only few phytoplankton like *Chaetophora* sp, *Oscillatoria* sp which has the ability to uptake high nutrients are able to grow.

REFERENCES

Algae Base [World- wide electronic publication (www.algaebase.org)].

American Public Health Association (APHA). 2012 Standard methods for the examination of water and waste water, 22nd Ed. Washington DC, P. 1496.

Automatic Diatoms Identification and Classification (ADIAC). Funded by the European MAST [Marine Science and Technology Programme (1999), Contract MAS3-CT97-0122]

Chukwu, L. O., & Odunzeh., C. C. (2006). Relative toxicity of spent lubricant oil and detergent against benthic macro-invertebrates of a West African estuarine lagoon. *Journal of Environmental Biology, 27*, 479-484.

Das, M., & Ramanujam, P. (2010). A comparative study on diversity of algae in coal mining impacted and un impacted streams of Jaintia Hills, Meghalaya. *Journal of Indian botanical society, 89*, 204-209

Desikachary, T.V. 1985 Cyanophyta. Indian Council of Agriculture Research: New Delhi.

Elmaci, Ayse, Topac, F. O., Ozengin, N., Teksoy, A., Kurtoglu, S., & Baskaya, H. S. (2008). Evaluation of physical, chemical and microbiological properties of lake Ulubat, Turkey. *Journal of Environmental Biology, 29*, 205-210.

Fang, Y. Y., Yang, X. E., Pu, P. M., Chang, H. Q., Ding, X. F. (2004). Water eutrophiocation in Li-Yang Reservoir and its ecological remediation countermeasures. *Journal of Soil and Water Conservation, 18*, 183-186

Fritsch, F. E. (1935). *The structure and reproduction of Algae: Vol. I and II.* Cambridge University Press. London.

Gandhi, H. P. (1998). *Freshwater diatoms of central Gujarat-With a review and some others*. Shiva offset Press, Dehradun, India.

Hosmani, S. P., & Bharati, S. G. (1980). Algae as indicator of organic pollution. *Phykos, 19*, 23-26

John, D. M., Whitton, B. A., & Brook, A. J. (2002). *The freshwater Algae Flora of the British Isles: An Identification Guide to freshwater and Terrestrial Algae*. Cambridge University Press, Cambridge.

Khan, M. N., Mohammad, F. (2015). Eutrophication: Challenges and Solutions. DOI: 10.13140/2.1.3673.8884

Mainstone, C. P., Parr, W. (2002). Phosphorus in rivers-ecology and management. *The Science of the Total Environment*, 282-283:25-47. [DOI:10.1016/S0048-9697(01)00937-8]

Nygaard, G. (1976). Talverna fra Danst.Phytoplanktons Cycledandl. Pp.22

Ogawa, Y., & Ichimura, S. (1984). Phytoplankton Diversity in Inland Waters ofDifferent Trophic Status. *Japanese Journal of Limnology, 45*, 173-177

Prescott, G. W. (1982). *Algae of the Western great lakes area*. Otto Koelts Science Publishers, Koenigstein, West Germany, Pp. 977.

Saxena, M. (2012). Water quality and trophic status of Raipur reservoir in Gwalior, Madhya Pradesh. *Journal of Natural Sciences Research, 2*, 8.

Shekhar, T. R. S., Kiran, B. R., Puttaiah, E. T., Shivaraj, Y., & Mahadevan, K. M. (2008). Phytoplankton as index of water quality with reference to industrial pollution. *Journal of Environmental Biology, 29*, 233-236

Siangbood, H., & Ramanujam, P. (2014). Effect of anthropogenic activities on Algal assemblage in Umiew river, Meghalaya. *Phykos, 44*, 41-51

Tong, C. H., Yang, X. E., & Pu, P. M., (2003). Degradation of aquatic ecosystem in the catchment of Mu-Ge Lake and its Remediation countermeasures. *Journal of Soil and Water Conservation, 17*, 72-88

Venkatesan, J. (2007). Protecting Wetlands. *Current Science, 93,* 288-290

Yang, X. E., Wu, X., Hao, H., & He, Z. (2008). Mechanisms and assessment of water eutrophication. *Journal of Zhejiang University, 9*, 197-209.

CHAPTER 14

Sequestration of Exhaust Fume Gases by the Freshwater Alga *Spirogyra* Species

Rhea Dhar and Dibyendu Paul

Introduction

The rise in temperature in the environment that threatens all life forms on the planet is associated with the release of green house gases. It has been widely accepted that global warming is mainly because of green house gas emissions from anthropogenic activities out of which carbon dioxide accounts for up to 68% of total emissions (Maeda *et al.*, 1995; Sakai *et al.*, 1995; Stewart and Hessami, 2005). At present, reducing the use of fossil fuels or promoting carbon dioxide capture and sequestration seem to be the only way to mitigate carbon dioxide emissions. Carbon dioxide fixation by algae has the potential to lower the release of potential carbon dioxide into the atmosphere, helping reducing the effect of global warming. Algae are the dominant primary producers in aquatic ecosystems and are widely distributed around the world and closely connected with human life (Ramaraj *et al.*, 2015). Carbon dioxide fixation using algae is a promising method for carbon dioxide capture and storage (Masakazu and Masahiro, 1997; Naoto and Masahiro, 1997; Razzak *et al.*, 2013; Zhao and Su, 2014). *Chlorella* species, *Chlorococcum littorale*, *Scenedesmus obliquus*, *Spirulina* species, *Spirogyra* species, *Oedogonium* species have been reported to grow in elevated carbon dioxide concentrations when fuel gases from various plants were used. These algal species have also been studied for the production of algal biomass, thus, being identified as potential species for biomass applications (Sung et al., 1999; de Morais and Costa, 2007; Kurano and Miyachi, 2005; Lawton et al., 2013).

Materials and Methods

Study area: Water samples and algae species were collected from various locations within the Wahdienglieng stream (Figure 17) at Risa Colony, Shillong, East Khasi Hills District, Meghalaya.

Collection of samples: The algae samples were washed with the stream water to remove any loosely attached debris and put in zip lock plastic bags filled with stream water to avoid desiccation and transported to the laboratory for further processing. In the laboratory, the samples were further washed with distilled water to remove any other impurities.

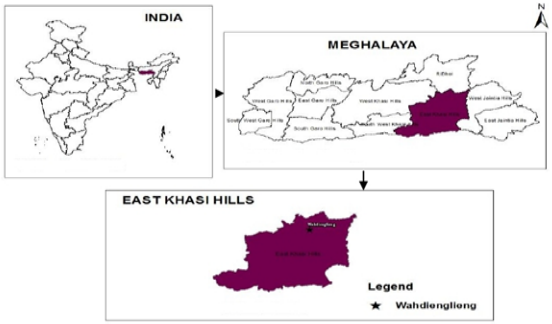


Figure 17: Map showing the site of sample collection

Identification of the algae species: The alga was identified by microscopic examinations (Magnus MLM, Olympus Pvt. Ltd., India) according to morphological properties based on descriptions (Dutta, 1996).

Isolation and culturing of the algae species: The colonies of the algae species collected were isolated and cultured in Algae Culture Broth, having the following composition: - Sodium nitrate ($NaNO_3$, 1.000 g/L), Dipotassium phosphate (K_2HPO_4, 0.250 g/L), Magnesium sulphate ($MgSO_4$, 0.513 g/L), Ammonium chloride (NH_4Cl, 0.050 g/L), Calcium chloride ($CaCl_2$, 0.058 g/L) and Ferric chloride ($FeCl_3$, 0.003 g/L) in a 1 litre conical flask. 1.87 grams of the broth was dissolved in 1000 ml distilled water and was sterilized by autoclaving at 15 lbs pressure for 15 minutes. The culture was maintained under light condition provided by two fluorescent lamps of 15 watts each. The initial pH was measured at 7.2. The species was maintained in continuous batch culture for 60 days so as to acclimatize it to the laboratory conditions.

Experimental Setup: The experimental setup for estimation of exhaust fume gas sequestration was undertaken through the following sequence:-

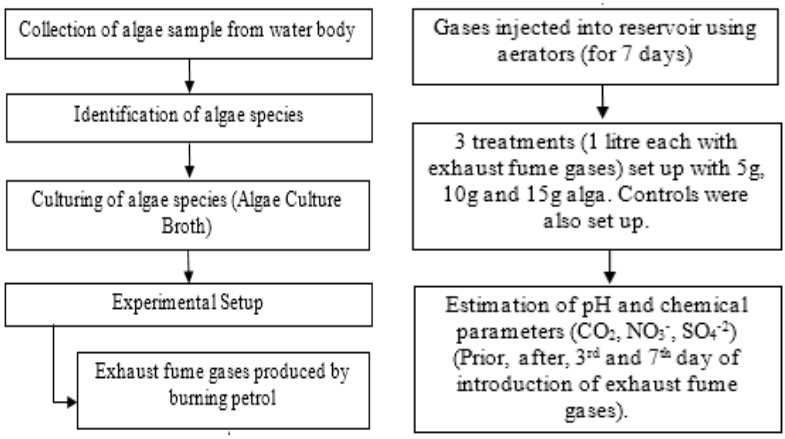


Figure 18 : Flow chart of the experimental setup

Estimation of pH

I. pH of the water samples were measured by the electronic pH meter (EI Deluxe pH Meter -101).

Estimation of chemical parameters

I. Dissolved free carbon dioxide was measured by Titrimetric Method (Michael, 1986).

II. Nitrate in the water samples was determined by the Phenol Disulphonic Acid (PDA) Method (Michael, 1986).

III. Sulphate in the water samples was determined by the Turbidimetric Method (Maiti, 2004).

Results and Discussion

Identification of the alga species: Spirogyra, one of the most common freshwater algal species, is green filamentous in nature and belongs to the class Chlorophyceae and family Zygnemataceae. Each Spirogyra species is an un-branched filament, and is identified by the presence of single row of cylindrical cells (Dutta, 1996).

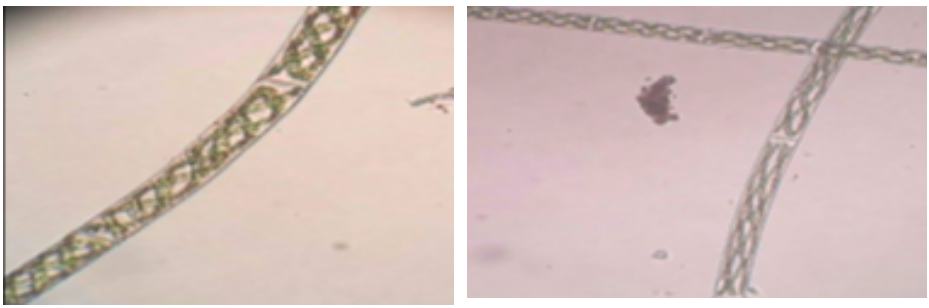


Figure 19 : Plate 1: Microscopic observation of Spirogyra.

Estimation of change in pH: Changes in pH values within the week's period are as shown in Figure 20. The introduction of the exhaust fume gases in the water resulted in decrease in the pH of the water from 6.80 to 6.48 which led to acidic conditions of the water. After the inoculation of the alga, pH was found to be significantly higher in the experiment of 15g alga (7.01±0.03) than in experiments of 5g (6.95±0.03) and 10 g (6.97±0.02) alga. Since carbon dioxide becomes carbonic acid when it dissolves in water, the removal of carbon dioxide results in a higher pH and the water becomes more alkaline, or basic. Moreover, in a well-lit condition, algae give off more oxygen than they generally use, resulting in increase in the overall pH condition of water. This lowering of acidic condition of water also comes in term with Goldman et al. (1974), where, it was proposed that addition of carbon dioxide into an algal growth media, increases the total carbon availability which in turn, increases the great efficiency of taking up carbon dioxide resulting in high pH conditions (King, 1970).

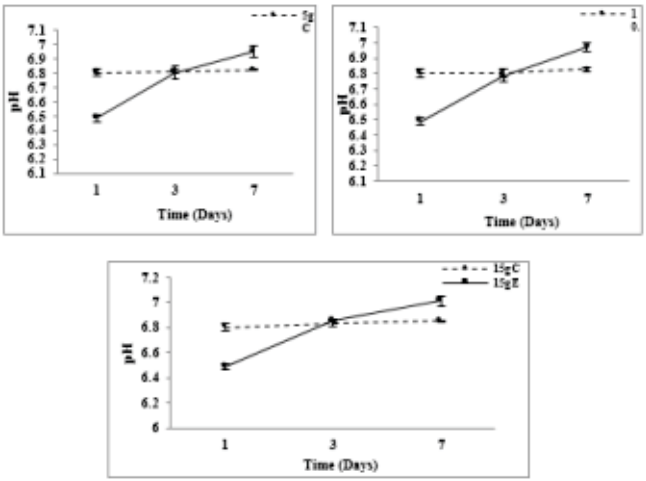
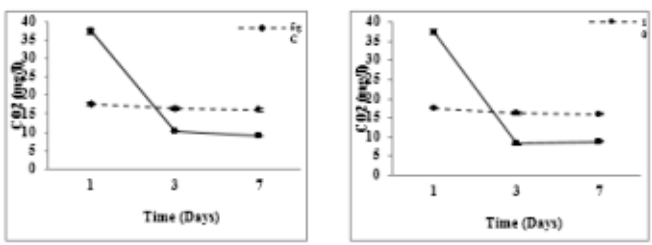


Figure 20: Changes in pH in 5g, 10g and 15g *Spirogyra*

Estimation of free carbon dioxide concentration (mg/L): Results in Figure 21 indicate the changes in free carbon dioxide concentration during the week's study. The lowering of the free carbon dioxide concentration was observed to be more prominent in experiment than in control. Experiment inoculated with 15 g alga significantly lowered the free carbon dioxide concentration (7.3±1.55 mg/L) as compared to inoculation with 5g (8.66±0.02 mg/L) and 10 g (7.79±0.38 mg/L) alga. In case of control, where no exhaust fume gases were introduced, no such significant observations were made. The presence of the introduced carbon dioxide in the experiment resulted in enrichment of the water's condition that helped in more absorption of the carbon dioxide by *Spirogyra* species for photosynthesis and growth. Gao *et al.* (1993) studied the culture of macro algae *Garcilaria* species when aerated with normal air and air enriched with higher concentration of carbon dioxide, and reported higher absorption of carbon dioxide in the enriched air. With respect to these findings, Gao *et al.* (1993) commented that "in their natural habitats, photosynthesis and growth of *Gracilaria* species are likely to be carbon dioxide limited, but, as the air's carbon dioxide content continues to rise, these macro algae should grow ever better in the years ahead." Certain marine algae have also been studied for their ability to absorb and benefited by elevated concentrations of atmospheric carbon dioxide (Riebesell *et al*., 1993; Hein and Sand-Jensen, 1997; Wolf-Gladrow *et al.,* 1999).



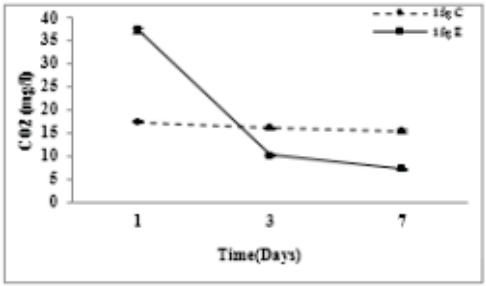


Figure 21: Changes in free carbon dioxide concentration in 5g, 10g and 15g *Spirogyra*

Estimation of nitrate concentration (mg/L): The changes in nitrate concentration are shown in Figure 22. Concentration of nitrate was observed to be the least in experiment with 10g of alga (0.42 mg/L) as compared to experiments with 5 g (1 mg/L) and 15 g (0.55 mg/L) alga. In controls, not much change in nitrate concentration could be observed. It can be attributed that the usage of nitrates in water by the alga species is for its growth and an increased level of nitrate concentration in the water due to introduction of exhaust fumes also led to better absorption in case of experiment, as compared to control. This can also be supported by findings of Ryan *et al.* (1972) and Sikka and Parmer (1968) who have reported that an increase in nitrate level results in greater absorption and also, has a significant effect on algal growth. Ponnuswamy *et al.* (2013) also reported a lowering in the concentration of nitrate, when micro algae *Chlorella vulgaris* was used to treat waste water.

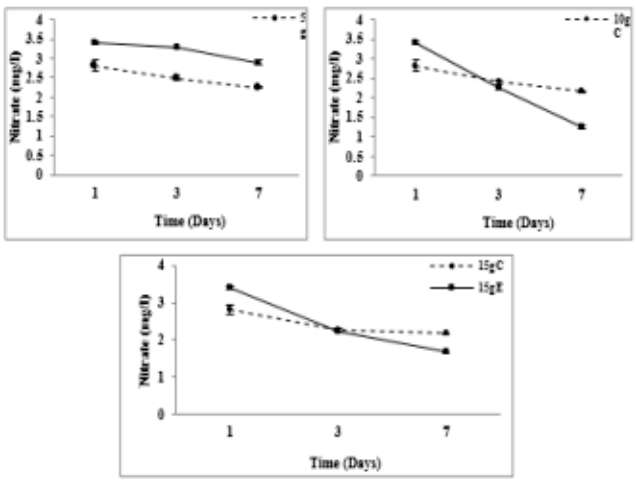


Figure 22: Changes in nitrate concentration in 5g, 10g and 15g *Spirogyra.*

Estimation of sulphate concentration: The findings of sulphate concentration within the 7 days period are shown in Figure 23. In case of sulphate

concentration, lower levels in control were reported in inoculations with 15g alga (75 mg/L) and in experiment, in inoculations with 10g and 15g alga (76 mg/L each). The findings show that the alga *Spirogyra* did not cause any significant changes in the sulphate concentration. However, in contrast to our findings Ponnuswamy *et al.* (2013) reported an increase in the concentration of sulphate when *Chorella vulgaris* was used for wastewater treatment.

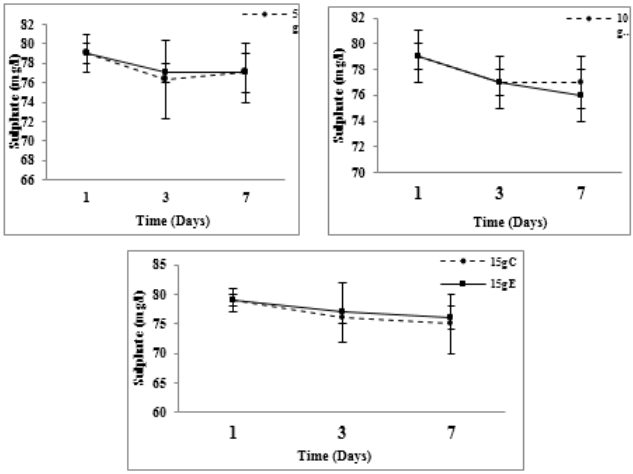


Figure 23: Changes in sulphate concentration in 5g, 10g and 15g *Spirogyra*.

Conclusion

Algae are emerging as a potential and promising option for carbon dioxide sequestration studies. Algae are of particular interest in the development of future renewable energy and to diminish carbon dioxide overload. *Spirogyra* can be regarded as a potential alga species for carbon dioxide and nitrate removal studies. Though large extent of work has not been done using the *Spirogyra* species for such mitigation processes, yet, it can have great prospects for such possibilities in future. *Spirogyra* is one such species which is easily available in fresh water conditions and use of this species can generate positive results in the long run. The present findings indicate that *Spirogyra* species can be utilized for carbon dioxide sequestration and also can be used for sequestration of exhaust fume gases.

REFERENCES

de Morais, M. G., & Costa, J. A. V. (2007). Carbon dioxide fixation by Chlorella kessleri, C. vulgaris, Scenedesmus obliquus and Spirulina sp. cultivated in flasks and vertical tubular photobioreactors. *Biotechnology Letters, 29*,1349–1352.

Dutta, A. C. (1996). *Botany*. For Degree Students. Oxford University Press. Calcutta.

Gao, K., Aruga, Y., & Asada, K. (1993). Influence of enhanced CO2 on growth and photosynthesis of the red algae Gracilaria sp. and G. chilensis. *Journal of Applied Phycology, 5,* 563-571.

Goldman, J. C., Oswald, W. J., & Jenkins, D. (1974). The kinetics of inorganic carbon limited algal growth. *Journal of the Water Pollution Control Federation, 46*, 1359-1366.

Hein, M., & Sand-Jensen, K. (1997). CO2 increases oceanic primary production. *Nature, 388*, 988-990.

King, D. L. (1970). The role of carbon in eutrophication. *Journal of the Water Pollution Control Federation, 42*, 2035-2051.

Kurano, N., & Miyachi, S. (2005). Selection of microalgal growth model foe describing specific growth rate-light response using extended information criterion. *Journal of Bioscience and Bioengineering, 100,* 403-408.

Lawton, R. J., de Nys, R., Skinner, S., & Paul, N. A. (2014). Isolation and Identification of Oedogonium Species and Strains for Biomass Applications. *PLoS ONE, 9*(3), e90223. doi:10.1371/journal.pone.0090223.

Maeda, K., Owada, M., Kimura, N., Omata, K., & Karube, I. (1995). CO2 fixation from the flue gas on coal-fired thermal power plant by microalgae. *Energy Conversion and Management, 36*(6-9), 717-720.

Masakazu, M., & Masahiro, I. (1997). The Biological CO2 Fixation and Utilization Project by Rite (2)-screening and Breeding of Microalgae with High Capability in Fixing CO2. *Energy Conversion and Management, 38*, 493–497.

Michael. P. (1986). *Ecological Methods for Field and Laboratory Investigations*. Tata McGraw-Hill Publishing Company Limited. New Delhi.

Naoto, U., & Mashiro, I. (1997). The Biological CO2 Fixation and Utilization Project by Rite (1)-highly Effective Photobioreactor System. *Energy Conversion and Management*, *38*, 487–492.

Ponnuswamy, I., Madhavan, S., & Shabudeen, S. (2013). Isolation and Characterization of Green Microalgae for Carbon Sequestration, Waste Water Treatment and Bio-fuel Production. *International Journal of Bio-Science and Bio-Technology, 5*(2).

Ramaraj, R., Tsai, D. D., & Chen, P. H. (2015). Biomass of algae growth on natural water medium. *Journal of Photochemistry and Photobiology B: Biology, 142*, 124–128.

Razzak, S. A., Hossain, M. M., Lucky, R. A., & Bassi, A. S. (2013). Integrated CO2 Capture, Wastewater Treatment and Biofuel Production by Microalgae Culturing-A Review. *Renewable & Sustainable Energy Reviews, 27*, 622– 653.

Riebesell, U., Wolf-Gladrow, D. A., & Smetacek, V. '(1993).' Carbon dioxide limitation of marine phytoplankton growth rates. *Nature, 361*, 249-251.

Ryan, J. B., Riemer, D. N., & Toth, S. J.'(1972).'Effects of Fertilization on Aquatic Plants, Water, and Bottom Sediments. *Weed Science, 20* (5), 482-486.

Sakai, N., Sakamoto, Y., Kishimoto, N., Chihara, M., & Karube, I. (1995). Chlorella strains from hot springs tolerant to high temperature and high CO2. *Energy Conversion and Management, 36*, 693-696.

Sikka, H. C., & Parmer, D. (1968). Physiological effects of fluometuron on some unicellular algae. *Weed Science, 16*, 296-299.

Stewart, C., & Hessami, M. A. (2005). A study of methods of carbon dioxide capture strains from hot springs tolerant to high temperature and high CO2. *Energy Conversion and Management, 36*, 693-696.

Sung, K. D., Lee, J. S., Shin, C. S., & Park, S. C. (1999). Isolation of a new highly CO2 tolerant fresh water Microalga Chlorella sp. KR-1. *Renewable Energy, 16*(1-4), 1019-1022.

Wolf-Gladrow, D. A., Riebesell, U., Burkhardt, S., & Bijma, J. (1999). Direct effects of CO2 concentration on growth and isotopic composition of marine plankton. *Tellus, 51B*, 461-476.

Zhao, B., & Su, Y. (2014). Process Effect of Microalgal-Carbon Dioxide Fixation and Biomass Production: A Review. *Renewable Sustainable Energy Reviews, 31*, 121– 132.

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