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Editorial Note

Science and People

The journal is entering in 3rd successive year with this issue containing new and more diverse contributions and a new editorial team. The challenges of creating new knowledge in the emerging fields and communicating it to a wide range of experts after adequate authentication and plagiarism check require a very serious input from all the input corners. We are ready to take this challenge in a participatory mode and invite you to join us with due warmness and enthusiasm.

Science as a knowledge, methodology and technology has great potential to improve our life, environment as well as the socio-economic and cultural outlook of the society. Science, technology and society are important for economy, market and industrial growth but more so it is also important to establish a peaceful society with sustainable world order.

Science can do a large for peace, harmony altruism and stability of the emerging need of a progressive world of today and tomorrow. The ancient knowledge has emerged out of people's experiences, innovations and co-operation and the universal facts have figured out through the passages of long time observation and analysis. We need to consider it as our reference point and take a lot of useful out of it for development of modern science and a better society. We wish a great future to science and society with input of all of us.

Rana Pratap

Rana Pratap Singh
Editor-in-Chief

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The journal (International Journal of Science, Technology & Society) which is a peer reviewed research journal is planned to publish the debate, commentary, reviews and original research papers of high quality research and reviews primarily on the issues and knowledge regarding interdisciplinary approach in science and technology and inclusive policies by it can help marginalized sections of the society to become an integral part of main stream. The journal covers new knowledge and new insights in all disciplines of science including its interface with one another and with societies. It is unique in the sense, it makes a bridge between the science, technology and society which is an emerging thrust throughout the world to make an equal, peaceful and sustainable world. There is no page charge and no direct or indirect expenditure involved, but for a meager amount charged, only if the authors intend to buy hard copy of reprints of their paper. The authors will be provided a PDF file of their paper and a copy of the issue in which they have contributed. We invite all the colleagues to contribute their work in this journal in benefit of the science and society.

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GENERAL ARTICLE

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Computational techniques for designing new lead molecules in the process of drug discovery

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ABSTRACT

Computational techniques are important in the field of drug discovery. These techniques are generally categorized in two methods namely 'structure-based' and 'ligand-based' methods. The present review discusses the theory of the most important methods, recent successful applications, pharmacophore modeling and quantitative structure-activity relationship (QSAR) studies. A brief introduction of molecular docking methods and their development and applications in drug discovery process is also included. Basic theories and fundamental techniques including sampling algorithms and scoring functions are discussed.

INTRODUCTION

The design and development of a new drug is a challenging task as timely delivery and managing the expenditures is extremely difficult [1-5]. Although there is a noticeable increase in funding for research and development in the process of drug discovery [6-9], only a small part of the produced drugs (less than 10 percent drugs) pass the clinical trials and only a few drugs reach to market [10-12]. This generates the demand of all pharmaceutical industries and research fields to find alternative ways to increase the efficiency and productivity in the process of drug discovery [13-16]. The computational techniques like docking, molecular dynamics (MD) simulations, QSAR, virtual screening, pharmacophore modeling etc. are helpful for pharmaceutical and biotechnology based companies in designing some new drug like molecules [17-21]. In this mini review, we focus on a brief discussion on various computational techniques to understand their basic details and usefulness in the process of drug discovery [22-25]. This review also reports the impact of computational approaches in drug designing and a few available publications on docking, mapping, homology modeling etc. [26-29].

STRUCTURE-BASED DRUG DESIGN (SBDD)

The molecular modeling of SBDD is a powerful tool to study the structure-activity relationships. It is the design and optimization of a chemical structure with the aim to identify a suitable compound for chemical testing to find some new medications [30]. SBDD is based on the knowledge of 3D structure of the lead molecule. Generally, shape, size and charge of the lead molecule affects its ability to interaction with the biological target and understanding this affect is necessary to for the design and development of new drugs. If the chemical structure of the receptor is not available, it can be predicted by homology modeling techniques [31]. Homology modeling is the modeling of a protein on the basis of known amino acid sequences of a protein and the modeled protein is comparable with similar homologous protein [32].

LIGAND-BASED DRUG DESIGN (LBDD)

The method of LBDD relies on the knowledge of small molecules that bind to the target of interest. Here, the known molecular pattern that bind to a target is used to find molecules with similar patterns [33]. Some popular LBDD approaches are pharmacophore modeling, molecular

similarity approaches, quantitative structure–activity relationship etc. [34]. LBDD is generally used in cases where chemical structure of the receptor cannot be defined [35]. However, this is very useful technique and various efforts have been made to strengthen the LBDD process in last two decades.

QUANTITATIVE STRUCTURE-ACTIVITY RELATIONSHIP (QSAR)

The relationship between the features of the chemical structure of ligands and their biological activity is called QSAR [36-38]. It is among the most practical and widely used tool in analogue/ligand-based drug design process. The principal objective of QSAR is to find a relationship between the biological activity and physiochemical properties for a set of ligands. Various molecular descriptors are used in QSAR to understand the representative molecular properties. 2D descriptors, independent of 3D orientation or conformation of the molecules, have some common property to reflect the structure of molecules [39, 40]. Constitutional descriptors are one of the most important 2D descriptors that reveals the molecular composition of a compound without using molecular geometry [41].

MOLECULAR DOCKING

Molecular docking is the attempt to find the "best" matching between the ligand and the receptor to form a stable complex. It can evaluate different possible conformations of ligand receptor binding, which makes it reliable for understanding the mechanism of interaction [42, 43]. Molecular docking is mainly divided into three types: (i) docking program to identify potential ligands from a library of chemical compounds, (ii) binding mode of potential ligands and (iii) prediction of binding poses [44]. In rigid molecular docking (lock and key model), the internal geometry of the receptor and ligand is fixed during docking. On the other hand, receptor is rigid and ligand is flexible in induced-fit or flexible docking. Docking algorithms can be used to find ligands, multiple proteins and their binding conformations that are close to experimentally determined structures [45]. Different types of algorithms such as molecular dynamics, monte carlo methods, genetic algorithms, fragment-based methods, point complementary methods, distance geometry methods, systematic searches

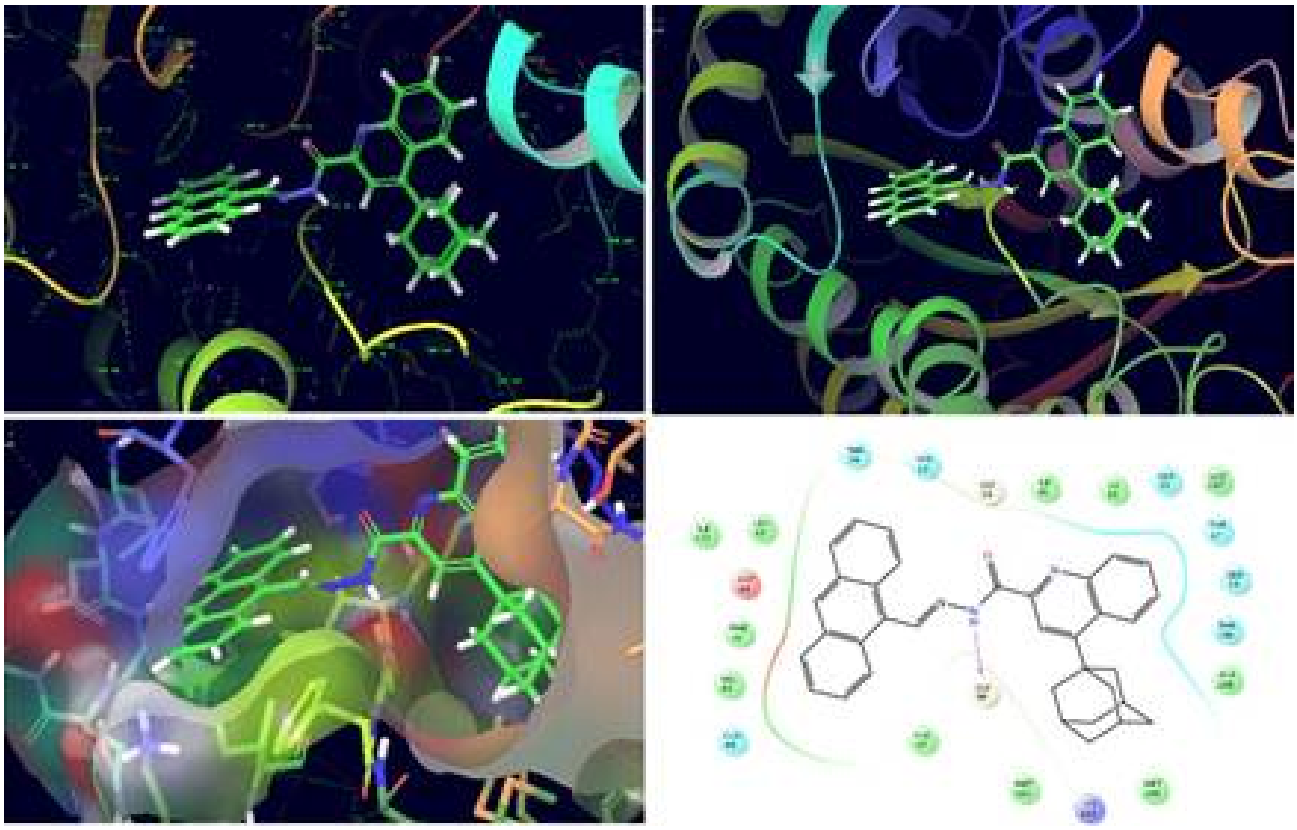

Fig. 1. Images of molecular docking studies

are frequently used for docking calculations. Figure 1 depicts the docked poses of an anti-TB drug molecule with a receptor (PDB-ID 1ZID). The ligand-receptor interaction diagram, showing the important interactions, are also included in this figure. Molecular docking consists of multiple steps as discussed below:

(a) Receptor preparation: The X-ray crystallographic 3D structure of receptor as available on Protein Data Bank (PDB) or any other reliable source is modified with stabilizing charges, filling missing residues, removal of water molecules from the cavity etc.

(b) Ligand preparation: Different conformations of ligands are generated and minimized stepwise for increased activity and selectivity, as well as drug-like properties and used for docking against target biomolecules.

(c) Receptor grid generation: Setting position constraint of the grids used for grid-based scoring in docking.

(d) Docking and scoring: Here ligand is docked with the receptor and the defined grid of receptor interactions are checked. The scoring function generates scores depending on the selected ligand with best fit.

PHARMACOPHORE MODELING

Pharmacophore modeling, as explained by Ehrlich, is a technique that analyzes the important structural features (chemical groups) responsible for the biological activity of a drug molecule. There is a considerable expansion of the concept and application range of a pharmacophore model. According to IUPAC [46], pharmacophore model defines the ensemble of steric and electronic features that are needed to ensure the optimal supramolecular interactions with a specific biological target and trigger the biological response. A pharmacophore model can be either ligand-based or structure-based manner. In ligand-based manner, a set of active molecules are superposed and extract the common chemical features that are responsible for the biological activity [47]. In structure-based manner, the possible interacting points between the biological target and the ligands are summarized. The various steps of pharmacophore modeling are:

(a) Select a training set of ligands: Selection of a set of structurally different molecules having both active and inactive compounds.

(b) Conformational analysis: Production of a set of low energy conformations to contain the bioactive conformation of the selected molecules.

(c) Molecular superimposition: Superimposition of all suitable combinations of low-energy conformations of the molecules.

(d) Abstraction: Transformation of the superimposed molecules into an abstract representation.

(e) Validation: Validation of the model to account the differences in biological activity for a range of molecules.

MOLECULAR DYNAMICS (MD) SIMULATION

Understanding of molecular motions is undoubtedly essential in any successful drug discovery process. MD simulation calculates the accurate binding affinities of ligand-receptor complex, analyzes the binding position and the stability with respect to time [48]. Recently Cavalli and coworkers summarized the role of molecular dynamics and related methods in drug discovery process [49]. This topic is of interest for various researchers in the field of drug discovery [50-53].

QUANTUM MECHANICS/MOLECULAR MECHANICS (QM/MM)

QM/MM is used to study the structural changes and the binding strength upon the formation of ligand-receptor complex. It is an advanced computational technique to perform the geometry optimization, single point energy calculation, Hessian and gradient calculations. It is useful in treating atomic complex system and has the potential to be used as an essential part in drug discovery for the identification of the lead and understand of the ligand receptor interaction in detail [54-59].

Some important terminology:

S. No.	Term	Explanation
1	Ligand	Ligand is an organic substance that forms complex with biomolecule to serve biological purpose. Ligand usually produces a signal for binding to a site on the target biomolecule.
2	Receptor	Target biomolecules act as receptors that bind to signaling ligand and initiate a physiological response. Cell membrane receptors permit signaling ligands to effect the cell function without entering the cell.

S. No.	Term	Explanation
3	Descriptor	Molecular descriptors are set of numerical or binary values representing various molecular properties of a compound. They are classified into two types i.e. 2D and 3D.
4	Active site	Active site is the specific region of an enzyme where a substrate binds and proceed to chemical reaction.
5	Pharmacophore	A pharmacophore modeling refers to the geometrical description of the chemical functionalities of a ligand to interact with the receptor.
6	Affinity	Activity is the relationship between the structure of a ligand and the receptor which suggests the strength of their binding.
7	Dataset	It is the set of biologically active molecules with ascending or descending order of activity values.
8	Training set	It is a set of data to assess the potentially predictive relationships.
9	Test set	Test set is the data set used to evaluate the strength and efficacy of a predictive relationship.

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REVIEW ARTICLE

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Interlinking of Indian Rivers : An Answer to Eco-Sustainability?

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ABSTRACT

Water is the most precious gift of nature to life on earth. India is one of the few countries in the world which has ample quantity of this prized possession. However, the imbalances have thrown up many debatable issues, one of them being the Inter-linking of Rivers (or ILR). The Interlinking of Rivers programme is aimed at linking different surplus rivers of country with deficient ones to probably help in increasing irrigation intensity in the country, increasing water availability for both drinking and industrial purposes, mitigating effects of droughts and floods to a certain extent. The paper focuses of certain factual understanding of the project and its feasibility towards making water a more sustainable resource on planet Earth.

THE INDIAN RIVER SYSTEM

Our rivers play an important role in our lives. They provide potable water, cheap transportation, electricity, and the livelihood for a large number of people across the country. Civilizations have been flourishing on the banks of rivers. The rivers are considered holy and sacred by us, yet, we have added woes to the same! Seven major rivers along with their tributaries make up the river system of India. The largest basin system of the rivers pours their waters into the Bay of Bengal; however, some of the rivers whose courses take them through the western part of the country and towards the east of the state of Himachal Pradesh empty into the Arabian Sea. Parts of Ladakh, northern parts of the Aravalli range and the dry parts of the Thar Desert have inland drainage. All major rivers of India originate from one of the three main watersheds: The Himalaya and the Karakoram ranges, Vindhya and Satpura ranges and Chhotanagpur plateau in Central India, Sahyadri or Western Ghats in Western India. The main Himalayan river systems are the Ganga, the Indus and the Brahmaputra river systems.

The Himalayan Rivers form large basins. Many rivers pass through the Himalayas. These deep valleys with steep rock sides were formed by the down – cutting of the river during the period of the Himalayan uplift. They perform intense erosional activity up the streams and carry huge load of sand and silt. In the plains, they form large meanders, and a variety of depositional features like flood plains, river cliffs and embankments. These rivers are recurrent as they get water from the rainfall as well as the melting of ice. Nearly all of them create huge plains and are navigable over long distances of their course.

The main peninsular river systems include the Narmada, the Tapi, the Godavari, the Krishna, the Cauvery and the Mahanadi river systems. The Peninsular Rivers flow through shallow valleys. A large number of them are seasonal as their flow is dependent on rainfall. The intensity of erosional activities is also comparatively low because of the gentler slope. The hard rock bed and lack of silt and sand does not allow any significant meandering. Many rivers therefore have straight and linear courses.

INTER-LINKING OF INDIAN RIVERS

The Indian Interlinking of Rivers (ILR) is a proposed large-scale project that aims to link Indian rivers by a network of reservoirs and canals and so reduce persistent floods in some parts and water shortages in other parts of India. The project has been split into three parts: a northern Himalayan rivers inter-link component, a southern peninsular

component and an intra-state rivers linking component. The project is being managed by India's National Water Development Agency (NWDA), under the Ministry of Water Resources.

The average rainfall in India is about 4,000 billion cubic meters and most of it comes between June and September. Furthermore, rain spread is not uniform, the east and north gets most of the rain, while the west and south get less. Every year we see monsoons and floods, followed by below average or late monsoons with droughts. Advocates of the rivers inter-linking projects claim the answers to India's water problem is to conserve the abundant monsoon water plenteousness, store it in reservoirs, and deliver this water – using rivers inter-linking project – to areas and over times when water becomes scarce. Beyond 'water security', the project is also seen to offer potential benefits to transport infrastructure through navigation, as well as to broadening income sources in rural areas through fish farming and other marine related activities.

The nation witnesses cycles of drought years and flood years, with large parts of west and south experiencing more deficits and large variations, resulting in immense hardship particularly the poorest farmers and rural populations. Lack of irrigation water regionally leads to crop failures and farmer suicides. Despite abundant rains during July–September, some regions in other seasons see shortages of drinking water. Some years, the problem temporarily becomes too much rainfall, and weeks of havoc from floods. This excess-scarcity regional disparity and flood-drought cycles have created the need for water resources management. Rivers inter-linking is one proposal to address that need.

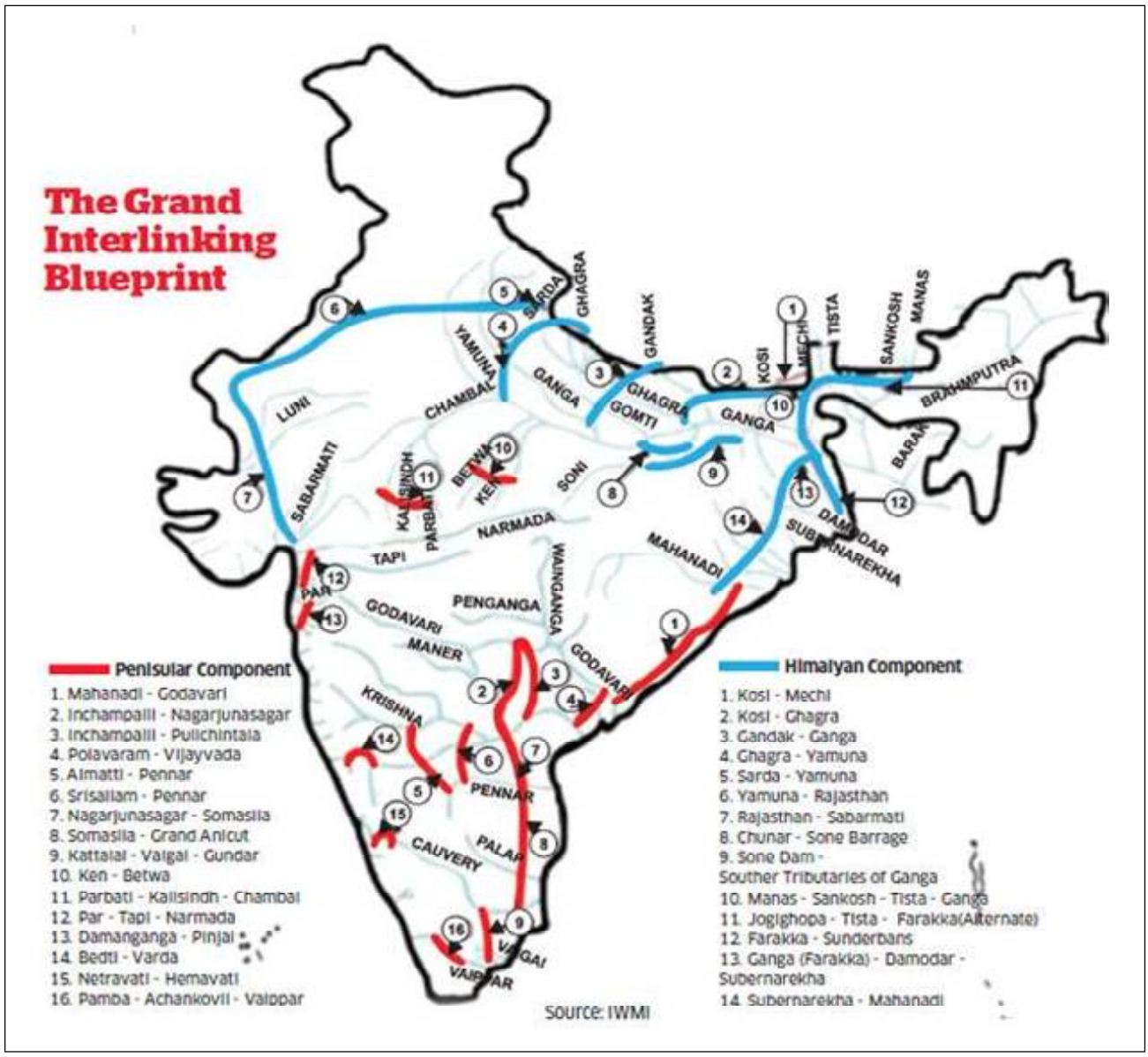
Population increase in India is yet another reason for forced thoughts for river inter-linking. India's population growth rate has been falling, but still continues to increase by about 10 to 15 million people every year. The resulting demand for food must be satisfied with higher yields and better crop security, both of which require adequate irrigation of about 140 million hectares of land. Currently, just a fraction of that land is irrigated, and most irrigation relies on monsoon. River inter-linking is claimed to be a possible means of assured and better irrigation for more farmers, and thus better food security for a growing population.

When sufficient salt export is not taking place from a river basin to the sea in an attempt to harness the river water fully, it leads to river basin closer and the available water in downstream area of the river basin becomes saline and / or alkaline water. Land irrigated with saline or alkaline water becomes gradually in to saline or alkali soils. The water percolation in alkali soils is very poor leading to waterlogging problems. Creation of alkali soils would induce the farmers to cultivate rice or grasses only as the soil productivity is poor with other crops and tree plantations. Cotton is the preferred crop in saline soils compared to many other crops. Interlinking water-surplus rivers with water-deficit rivers is needed for the long term sustainable productivity of the river basins and for mitigating the anthropogenic influences on the rivers by allowing adequate salt export to the sea in the form of environmental flows.

India also needs infrastructure for logistics and freight movement. Using connected rivers as navigation is a cleaner, low carbon footprint form of transport infrastructure, particularly for ores and food grains. India currently stores only 30 days of rainfall, while developed nations strategically store 900 days' worth of water demand in arid areas river basins and reservoirs. India's dam reservoirs store only 200 cubic meters per person. India also relies excessively on groundwater, which accounts for over 50 percent of irrigated area with 20 million tube wells installed. About 15 percent of India's food is being produced using rapidly depleting groundwater. The end of the era of massive expansion in groundwater use is going to demand greater reliance on surface water supply systems. Proponents of the project suggest India's water situation is already critical, and it needs sustainable development and management of surface water and groundwater usage.

India is one of the few countries in the world which is gifted with such considerable water resources, which is surrounded by 3 oceans. being a monsoon country, the land frequently witnesses erratic rainfall causing damages to the political, economic, ecological/ natural and social fabric of the nation .Thus in this regard to overcome from the threat of water scarcity, droughts floods and relating problems in the different part of country and also to reduce the stark differences in water availability in the river basins in our country has thrown up with the idea of interlinking of river programme.

Basically it accounts and seeks to transfer water from the surplus region to the deficit one in our country. The programme instead with the core vision that is to ensure greater equity in the distribution of water by enhancing the availability of water drought prove area and also the excessive rains affected area. The programme is divided into two components – Himalayan Rivers Component (HRC) and Peninsular Rivers Component (PRC) for inter basin transfer of water. Thus, this programme is expected to solve various issues pertaining to drought, floods, unclean



drinking water which leads to a great number of diseases and so thus it could be said that water is the essence of life. It is something that cannot be created by man. Therefore, keeping in regard the future aspects it is the need of hour to sustain such resources for future.

SOME INTERESTING FACTS

1. Per capita Water availability in cubic metre per person per year has gone down from 5177 (1951) to 1820 (2001) to 1545 (2011). By year 2050 it would have gone down to 1140
2. India charges $0.5 per kiloliter for domestic water as compared to $1.5 for the US, $2 for Japan and $3.4 for Brazil
3. India's capacity of water reservoirs is roughly 158 billion cubic metres (BCM), currently they hold around 40 BCM
4. Water Demand expected to climb to 1093 BCM in 2025 and 1447 BCM in 2050, it was 813 BCM in 2010
5. India leads the world in water withdrawals – freshwater and ground water; for 2010 the figure was 760 and 251 BCM respectively for Fresh and Ground water. In China this figure was 627 & 112 while in the US, it was 441 and 112 BCM

6. Thermal Power plants in India use more water per unit of power produced, 4 cubic metre per MWh, in China it is 2.5 and in the US, 2.0
7. 783 million people do not have access to clean and safe water worldwide
8. 1 in 9 people worldwide do not have access to safe and clean drinking water
9. 319 million people in Sub-Saharan Africa are without access to improved reliable drinking water sources
10. Two thirds or about 102 million of the 159 million people still using surface water live in Sub-Saharan Africa
11. 443 million school days are lost each year due to water-related diseases
12. In developing countries, as much as 80% of illnesses are linked to poor water and sanitation conditions
13. Half of the world's hospital beds are filled with people suffering from a water-related disease
14. Women and girls are responsible for water collection in seven out of ten households in 45 developing countries
15. Globally we use 70% of our water sources for agriculture and irrigation, and only 10% on domestic uses

SURVEY OF LITERATURE

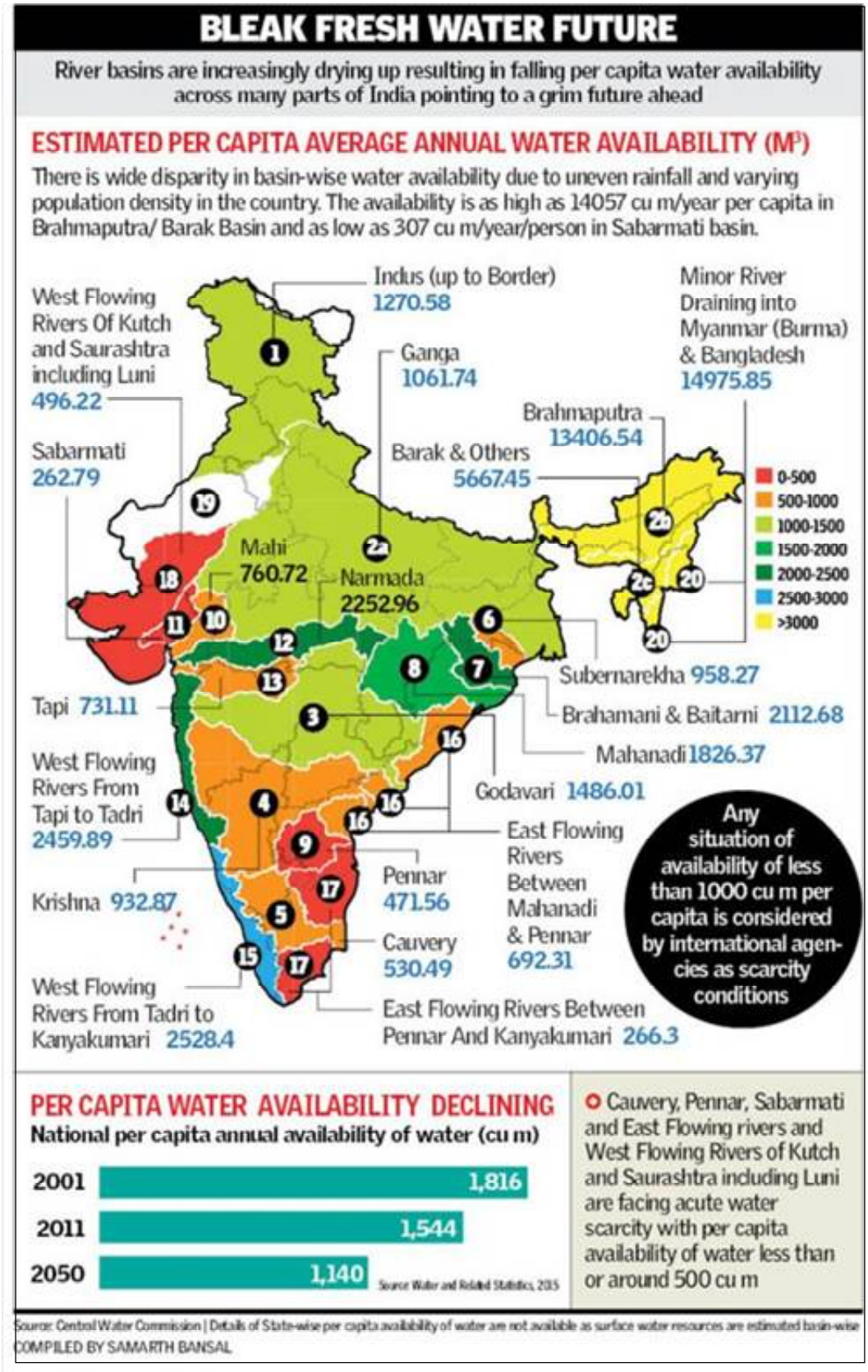
The idea of linking rivers is not new. It was Sir Arthur Cot-ton who had originally proposed the networking of rivers more than a century ago, and Dr. K. L. Rao (Minister of Power and Irrigation in the Cabinet of Smt. Indira Gandhi) re-vived this proposal in 1972. Cotton's prime concern was for inland navigational network and Dr. Rao's concern was for irrigation and power. (Shiva and Jalees, 2003) The then-Ministry of Irrigation (now the Ministry of Water Resources) conceived a plan for "Na-tional Perspectives for Water Development" in August 1980 (Ministry of Water Resources, 1980). This paved the way for the establishment of the National Water Development Agency (NWDA) in 1982 to work out basin-wise surpluses and deficits and explore possibilities of storage, links and transfers, which would connect every major river in the Indian mainland.

Shah and Raju (1986) studied the nature and pattern of the development of water markets across regions of India considering the lift irrigation potential as a major criterion. Even in the international context, supply sharing has been a matter of big versus small, with problems over supply in Ne-pal, Bangladesh, and India. In issues of inter-basin transfers, such diversions do indeed cause the liveliest concerns, often leading to protests and resistance in the exporting region, sparked by the elemental importance of water for life and the economy (Verghese, 1990).

On governance, Ramaswamy Iyer (2002, 2003) writes that the most visible manifestation of water politics has been in inter-State river-water disputes. The dispute over the shar-ing of Cauvery waters has assumed enormous importance in the politics of Tamil Nadu and Karnataka. Similarly, the disputes over Ravi-Beas waters have occupied Punjab and Haryana. Verghese (2003), one of its few champions outside the government, suggests it should be viewed as a 50-100 year project. Verghese (2003) found ILR variously described as "frighteningly grandiose", a "misapplied vision", "extrava-gantly stupid", a case of putting the "cart before the horse", a "sub-continental fiasco", "a flood of nonsense", a "dangerous delusion" or a case of "hydrohubris". According to Iyer (2003) "It amounts to nothing less than the redrawing of the geog-raphy of the country."

According to Bandyopadhyaya and Praveen (2003), the proposal claims to package an uncertain and questionable idea as a desirable one. Rath (2003) called the ILR a 'pie in the sky' because he, like many others, is skeptical of the govern-ment's capacity to mobilize the kind of investable funds ILR demands. Shukla and Asthana (2005) reveal the challenges inherent in the government's policy decision to interlink riv-ers as envisaged by the bureaucratic agency of state power, a culture of scientific expertise, a perceived need to mobilize global capital, and the opposition to such plans engendered by the agency of civil society in a bid to examine how dif-ferent actors conceptualize the project through a discursive approach. It is expected that the water demand of nonfood grain crops will further accelerate with changing consump-tion patterns (Amarasinghe *et al*, 2007).

Krueger *et al* (2007) highlight that properly planned wa-ter resource development and management has the ability to alleviate poverty, improve the quality of life, and reduce re-gional disparities and to maintain the integrity of the natural environment. Shah *et al* (2007) put seven reasons why re-visiting the river linking issue is a good idea. Reddy (2008), in his most comprehensive review of water pricing as a demand management option, concludes that the ability of water pric-ing to influence water use in India is severely constrained both by the nature and level of water rates as well as by the lack of effective institutional and technical conditions. Shilp *et al* (2008) show that the existing pattern of inter-state virtual water trade is exacerbating scarcities in already water scarce states and that rather than being dictated by water endowments, virtual water flows are


BLEAK FRESH WATER FUTURE
River basins are increasingly drying up resulting in falling per capita water availability across many parts of India pointing to a grim future ahead
ESTIMATED PER CAPITA AVERAGE ANNUAL WATER AVAILABILITY (M³)
There is wide disparity in basin-wise water availability due to uneven rainfall and varying population density in the country. The availability is as high as 14057 cu m/year per capita in Brahmaputra/ Barak Basin and as low as 307 cu m/year/person in Sabarmati basin.
Indus (up to Border) 1270.58
Ganga 1061.74
Brahmaputra 13406.54
Barak & Others 5667.45
Minor River Draining into Myanmar (Burma) & Bangladesh 14975.85
West Flowing Rivers Of Kutch and Saurashtra including Luni 496.22
Sabarmati 262.79
Mahi 760.72
Narmada 2252.96
Subernarekha 958.27
Brahamani & Baitarni 2112.68
Mahanadi 1826.37
Godavari 1486.01
Tapi 731.11
West Flowing Rivers From Tapi to Tadri 2459.89
Krishna 932.87
Penner 471.56
Cauvery 530.49
East Flowing Rivers Between Mahanadi & Pennar 692.31
West Flowing Rivers From Tadri to Kanyakumari 2528.4
East Flowing Rivers Between Pennar And Kanyakumari 266.3
0-500
500-1000
1000-1500
1500-2000
2000-2500
2500-3000
>3000
Any situation of availability of less than 1000 cu m per capita is considered by international agencies as scarcity conditions
PER CAPITA WATER AVAILABILITY DECLINING
National per capita annual availability of water (cu m)
2001 1,816
2011 1,544
2050 1,140
Source: Water and Related Statistics, 2015
Cauvery, Pennar, Sabarmati and East Flowing rivers and West Flowing Rivers of Kutch and Saurashtra including Luni are facing acute water scarcity with per capita availability of water less than or around 500 cu m
Source: Central Water Commission | Details of State-wise per capita availability of water are not available as surface water resources are estimated basin-wise
COMPILED BY SAMARTH BANSAL

influenced by other factors such as per capita gross cropped area" and ac-cess to secured markets".

CHALLENGES AHEAD

Hyped as the world's largest irrigation infrastructure project, the ILR programme proposes 30 river links. ILR will see the excavation of 15,000 km of new canals to relocate 174 cubic km of water-enough to annually supply over 100 mega-metropolises the size of Delhi or Mumbai. The National Water Development Agency (NWDA), which has designed the projects – 14 for Himalayan rivers and 16 in peninsular India-as part of the National Perspective Plan (NPP) for Water Resources Development since 1982 is already listing the benefits. According to NWDA, the ILR will double India's current 42,200 megawatt hydropower generation (from medium and major projects), adding 34 additional GW to the capacity. Also designed to irrigate 35 million monsoon-dependent hectares, ILR is the only realistic means to raise the country's irrigation potential from 140 million to 175 million hectares by 2050, when the population is projected to touch 1.6 billion.

But 'unofficial' estimates published by the Delhi-based South Asia Network on Dams, Rivers and People (SANDRP) say the project will displace nearly 15 lakh people from their homes. This caused by the submergence of at least 27.66 lakh hectares of land needed for the storage structures and the network of planned canals. And it's not just the human cost. The overall land area going under includes 104,000 hectares currently under natural forest cover, including reserves and sanctuaries. It will also be an astronomically expensive adventure. Initially pegged at Rs 5.6 lakh crore at 2002-03 prices, Union water resources, river development and Ganga rejuvenation minister Uma Bharti says ILR cost would be over Rs 11 lakh crore. This includes cost of land acquisition, compensation and construction. However, final cost outlays for individual links will only be known after the detailed project reports (DPRs) have been techno-economically approved in each case.

After a full decade of considered scorn under UPA-I and UPA-II, during which then environment minister Jairam Ramesh described the proposal as disastrous, the ILR programme has got a strong second wind under NDA-II. The Centre's confidence flowed from a Supreme Court judgment in 2012, wherein the programme was said to be in the national interest. The judges ordered the creation of a special committee for inter-linking of rivers. Enthusiastically, Narendra Modi's administration constituted a special committee under the water resources ministry on September 23, 2014. An independent task force too was established in April 2015 to identify means of fast-tracking projects and to bring on board many of the reluctant states. The first among five "priority links" is Ken-Betwa through which the payoffs expected are irrigation to 6.35 lakh hectares across Chhatarpur, Tikamgarh and Panna in MP, and Mahoba, Jhansi and Banda in UP; domestic drinking water for 13.42 lakh people in both states and 78 MW of power from two hydropower stations.

Another question posed by experts is that there is simply no scientific evidence to justify what the government wants to attempt. A simplistic identification of 'water surplus' and 'water deficit' river basins is premised on flimsy and dubious scientific data, it is argued. The water balance studies (for 137 basins and sub-basins) have been deliberately manipulated, while most feasibility reports since 1982 are outdated because water use patterns since then have far outstripped availability in almost all basins. Further, it could have been deliberately overlooked examining the complete water resource management options before commanding a particular river basin as 'surplus' or 'deficit', say the experts. For instance, Water balance studies, their basis for showing the Ken surplus and the Betwa dry, are prejudiced. Outside the dense teak forests too, the farmlands are decidedly dried. The scores of distressed small farmers and farm workers have migrated in search of work. The Ken catchment has witnessed many monsoons of alternating flood and drought. Water activists point to associated floods and droughts in both Ken and Betwa basins to challenge the NWDA's assertions of the Ken as a surplus river.

The forest advisory committee (FAC), an expert body that advises the government on approval or rejection of major projects involving diversion of forest land has recently recommended the Ken-Betwa river link project (phase 1) in Madhya Pradesh for forest clearance. But the panel has several reservations with the project. About 4141 ha of the total area to be submerged falls within the core Panna Tiger Reserve (PTR). FAC has observed that if there is no other option and the present proposal is the best possible option available with the government in light of the demand of water in this area and for human welfare, the proposal for diversion of forest land from PTR may be considered. FAC refers to an earlier report filed by a subcommittee of the FAC, and states that the construction of the proposed Dhaudhan dam inside the reserve is not the best option in the light of conservation of the pristine forest and its ecosystem. The panel also observes that it is not possible to compensate the loss because the submergence area falls in a riverine habitat which is unique and cannot be replicated

elsewhere.

FAC has recommended that the loss of forest land has to be compensated by purchasing revenue or other non-forest land. The project proponents and the government should compensate the loss of forestland and tiger habitat through purchase and transfer to PTR equivalent revenue and private land. The panel also recommended that the height of Dhaudan dam be re-examined to conserve a part of the tiger reserve. FAC suggested the height of the dam may be reduced by 10 meters if not at least 5 meters as a trade-off between conservation and development. FAC's subcommittee had examined the cost-benefit analysis made by the government. In the cost benefit ratio the capital cost was about Rs 13744 Crore and annual benefit was assessed to be Rs 2829 Crore. The committee had noted that the cost benefit analysis had not paid attention to eco system services lost due to diversion of unique riverine eco system. FAC has recommended a cost benefit analysis should be done considering the ecological cost of diversion of PTR.

The irrigation projects/big dams account for 16 million hectares which is about a fourth of the total irrigated area (66-68 million hectares) in the country. The maximum coverage ever achieved (17.7 million hectares) from such projects was in 1991-92 pointing to the largely ignored fact that over 60 per cent of India's current irrigation needs are met from groundwater and small irrigation projects. And this is going up with every passing year. A report by the World Commission on Dams concluded that a mere 10-12 per cent of India's food grain production comes from big dams. But it is groundwater that has been India's real lifeline! It is estimated to be 70 per cent more productive than canal irrigation; it needs to be sustained by protecting traditional recharge systems. If implemented, the ILR programme, would seriously endanger the very resource that sustains India's food security.

The ILR's critics say the programme entails environmental tinkering on an epic scale-destruction of natural rivers, aquatic and terrestrial biodiversity, salinity ingress and a significant increase in methane emissions from storage reservoirs. Few say that the cumulative devastation from the ILR projects could be irreversible. The ILR may deeply compromise the very integrity of the monsoon cycle. Inflows from rivers help maintain high sea-surface temperatures in the Bay of Bengal, critical for creating low-pressure areas and intensification of the monsoon. Plummeting the flow of river waters into the sea could bear serious long-term consequences for climate and rainfall in the subcontinent. NDA Government minister Maneka Gandhi, a former environment minister herself, openly criticised river-linking projects while speaking on India's role in climate change and global warming and she has declared linking two rivers was extremely dangerous.

In yet another view, the proposal is based on the serious ecological myth that river waters which drain into the sea, are going 'waste'. When rivers wind through forested, cultivated, and settled lands, they carry with them large amounts of silt. This silt is deposited along the way, enhancing the productivity of the surrounding lands, and finally of the coastal waters. This is the basis of the rich agriculture of the plains of India, and of the rich fisheries off our coasts. The river also pushes out the sea, which would otherwise invade deep into the land, and erode the coast.

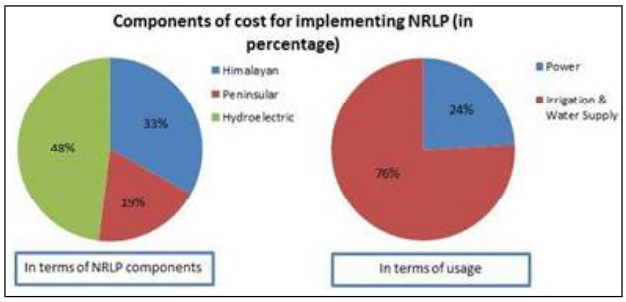
Climate modelling once predicted that India's dry areas will become drier and its wet areas wetter, but this is no longer the case. A team of scientists from the Indian Institute of Technology in Bombay and Madras found a significant decrease in the monsoon rainfall over major water surplus river basins in India. The team's computer simulations showed that the water yield in surplus river basins is decreasing but it is increasing in deficit basins. What may appear as water deficient today may become water surplus in the future due to climate change, so how do we justify inter-linking?

Geologists are concerned, too. Over the millennia India's landscape has gradually evolved with the natural flow of water. Most rivers are fed by monsoon rains and have built large floodplains and deltas over the years, pushing rivers around through ILR disrupts the supply of sediments and nutrients downstream thereby affecting agriculture, as farmlands have been built over centuries in floodplains and near river deltas. Rivers recharge aquifers near farmlands are critical to freshwater biodiversity, including fish, and carry nutrients to marine life.

The ILR scheme ignores the very real value of flooding. For one thing, it carries huge volumes of silt that can reduce coastal erosion. A river is not just a natural pipe through which water flows, it carries deposits and sediments. Dams trap sediments that are critical to habitats downstream. Natural flooding also helps recharge supplies of freshwater below India's floodplains and deltas. Without that sporadic influx from floods, salt water gradually intrudes into groundwater supplies in land. Desiccation and desertification follow. Decreased sedimentation also leads to coastal erosion. The presence of excess fresh water in the Bay of Bengal delta is especially crucial, as it helps create and maintain a layer of low salinity in the bay, which is one of the several complex, interlinked factors that

influence the onset of the Indian summer monsoon. Artificially manipulating the natural system could disrupt the monsoon rainfall in the region. The huge amount of water in dams would increase the water pressure in the cracks and push on crust below, possibly increasing the risk of earthquakes in the already quake-prone Himalayas.

Many states have opposed the ILR programme questioning the NWDA's water balance assessments. Odisha turned down a proposal on the ambitious Mahanadi-Godavari link project. Responding to concerns over extensive submergence from the big dam at Manibhadra, the Navalawala task force is drafting alternative strategies. The Mahanadi-Godavari link is critical to the construction of eight other downstream river links!



CONCLUSION

'India is a land of diversity', this statement is not only a famous description of our country but also a real feel of the complexities emerging out of situations on the economic, political and the ecological fronts. The country is endowed with rich water resources and there is no second opinion to it. We are very poor managers of water as a resource; this is also a notable fact! Ecological decisions by the apex bodies in our country do have political overtures to certain extent, and the ILR is no different!

Long ago our then Prime Minister Shri Atal Bihari Vajpayee along with the then President Late Dr. APJ Abdul Kalam presented this concept to the nation. Researchers, as they should be, propounded conflicting views on the issue and it gained momentum when serious water trouble brewed in many pockets in India, Latur got highlighted through the water train, Bundelkand too after the then existing Government turned down Centre's offer to send another train there, then the Tamil Nadu-Karnataka row on water sharing and then the floods and draughts in many parts of the country and this even forced the IPL matches to be out to some other place from the already decided venues!

Since then, the ILR is a major issue to be 'discussed' at forums with eminent environmentalists, water scientists, politicians, economists and social scientists along with management professionals but nothing concrete seems to have developed except for a new Ministry of water Resources in the 'strong' Modi-led Central Government. Reasons have been many, few of them have been discussed at large here but the major one as we feel is 'mismanagement' and absence of a sense of 'sustainability' in the long run. It is really hard for anyone to imagine that we worship our rivers in the morning and by evening we use it as a dump yard! Our basic societal understanding of eco issues is miniscule, thanks to our education system.

Both pros and cons exist regarding this ILR, it is good on various fronts but bad too on many. Whatever may be the case, our decisions should be concurrent to nature. Only then sustainability can be attained, be it body, mind or ecological balance. The answer to the theme of this paper is very difficult to comprehend as issues are multiplying with increasing timeline. The best solution is we should do something that does not harm nature or disbalances it. Our children, the next generation will not forgive us for our misdeeds, if any, and that too irreversible!

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RESEARCH ARTICLE

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Investigation and Performance Evaluation of Organic Filter for Removal of Tar and SPM

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ABSTRACT

Producer gas obtained from biomass gasification contains organic impurities (Tar), inorganic impurities and suspended particulate matter in addition to the main components. Tar, which is in sticky nature, can cause severe operational problems such as fouling and blocking of the pipes and equipment. Most applications of Producer gas require a low Tar content (less than 50 mg/Nm^3 for motive power application, less than 5 mg/Nm^3 for turbine application, and even less than 1 mg/Nm^3 for fuel cell). Therefore, these contaminants must be removed before the producer gas is used for motive power application and/or fuel cells and methanol synthesis. Several technologies are available for Tar removal. Here an organic filter are used for Tar removal due to easily available, cheaper than other technologies and creates less impact on environment. The producer gas passing through different organic filter components (such as gram straw, coconut husk and egg shell) could clean the impurity present with them. This paper provides the performance evaluation and saturation time of different organic filter components for removal of Tar. The saturation time of organic filter was found in the range of 9-10 hours and percentage of tar removal was between 65 to 70%. Hence, overall Tar removal efficiency of the entire system including modified air heat exchanger was found to be 74.84%.

INTRODUCTION

Producer gas obtained from biomass gasification contains organic impurities (Tar), inorganic impurities and suspended particulate matter in addition to the main components (Laurence, 2011; Reed, 1988).

The Producer gas is a mixture of carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), hydrogen (H_2), nitrogen (N_2) and water vapour (Chiranjeevaraoseela, 2015). If tar not removed, it can cause severe operational problems. Tar can cause blocking of the pipelines, filter elements and gas turbines, gas engine suction channels, etc. due to its condensable characteristics at temperature below 150ÚC (Asha,2017).

For fixed bed gasifier with IC engine applications, high concentrations of particulates and tars can damage the engine or lead to an unacceptable level of maintenance which results in decrease of efficiency and increases the cost of the process (Kim, 2008). Producer gas cleaning is therefore a fundamental step in integrated biomass gasification systems.

The raw producer gas of the investigated counter current (Up-draft) gasifier exhibit a particle level in the range 100 mg/Nm^3 to 3000 mg/Nm^3, whereas the concentration of the high boiling tar components ranges from 10,000mg/Nm^3 to 150000 mg/Nm^3 (Hasler, 1999). Several technologies are available for Tar removal however, they are neither environmental friendly nor economical.

In this experiment small scale (10 kg of biomass feed capacity) fixed bed counter-current (up-draft) gasifier was used, in which tar content was very high, depending upon the type of biomass feed in gasifier. The main emphasis is given to removal of tar from organic filter and its saturation time. Here basic idea for using of organic filter is having zero waste. Once organic filter is saturated, it could be dried and reused for gasification (Singh 2007).

METHOD AND MATERIALS

Experimental setup (Fig.1) consists of air heat exchanger and organic filters (gram straw, coconut husk, egg shell). Producer gas coming out from gasifier first passes through air heat exchanger later to organic filters. Passing of producer gas through air heat exchanger reduces the gas temperature drastically which, eliminate the requirement of water cooling of producer gas.

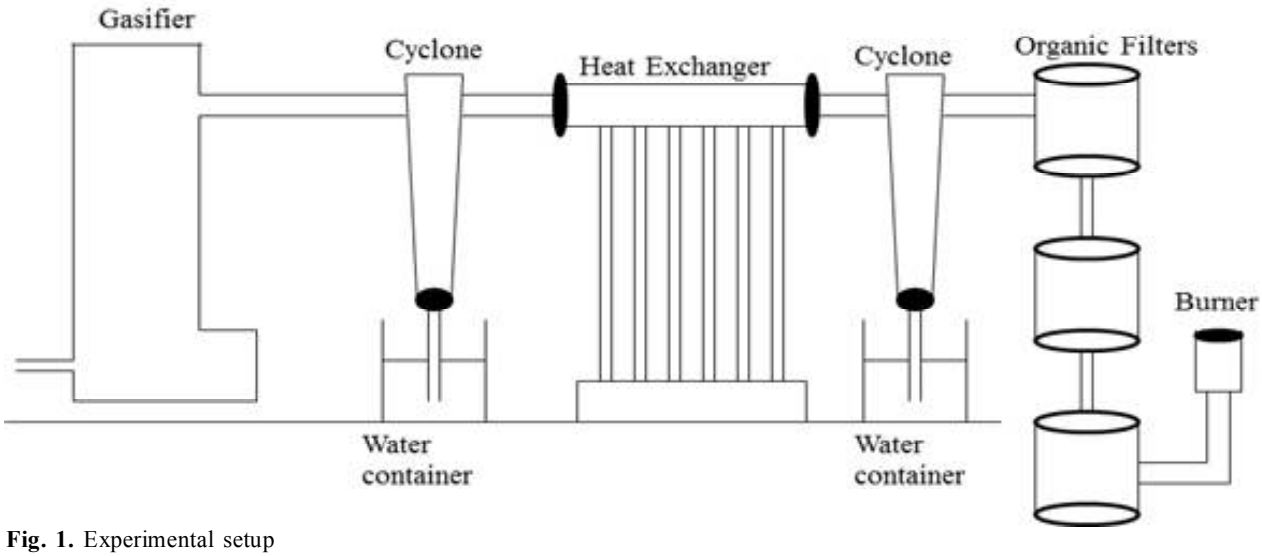

Fig. 1. Experimental setup

Organic filter components

The three different filters arranged in series are used for study. Theses filters contain gram Straw, coconut husk and egg shell respectively. Eggshell is made almost entirely of calcium carbonate ($CaCO_3$) crystals. Calcium carbonate is also used in flue gas desulfurization applications eliminating harmful SO_2 and NO_2 emissions from coal and other fossil fuels burnt in large fossil fuel power stations (https://www.exploratorium.edu/cooking/eggs/eggcomposition.html)**.**

Keeping that in mind egg shell was utilized as one of the component of organic filter. The filters were arranged on the basis of filter component porosity, i.e. from higher porosity (gram straw) to lower porosity (Egg shell) filter component (Fig. 2).

Design of Organic Filter

Organic filter available at School of Energy and Environmental Studies (SEES) was used for study. Filter was fabricated with concentric cylinders of different diameters in which outer cylinder is of 381 mm(15") diameter, whereas inner cylinder is of 190 mm (7.5").The flow of producer gas was from inner cylinder and passes through the gap between two concentric cylinders (Fig. 3).

Producer Gas Sampling and Analysis

Sampling of producer gas was carried out at different cumulative operating hours across each filter. Gas was collected in gas sampling bottle (250 ml capacity) from each outlet of the filter. Later samples were analysis for Tar and SPM. For this purpose sampling bottles was left overnight in deep freezer maintaining 5-6^{o}C temperature.

At this temperature Tar and SPM (suspended particulate matter) were deposited at inner surface of the gas sampling bottle. Later bottle was removed from the deep freezer; gas was released in the atmosphere. Bottle was

Egg shell Coconut huskhuhusk Gram Straw

Fig. 2. Pictorial view of organic filters component

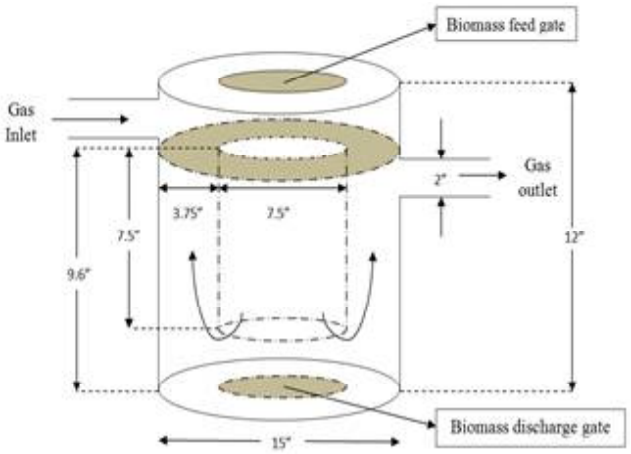

Fig. 3. Dimension of organic filter

washed using acetone and poured on known weight of cotton. Cotton was kept in hot air oven (110 °C) to evaporate the acetone as well as moisture. Left out material divided by volume of producer gas measures the quantity of Tar and SPM present in the producer gas.

RESULTS AND DISCUSSION

Figure 4 shows the condition of organic waste used for cleaning of the producer gas.

Tar Removal Efficiency of Organic Filters

Raw and clean producer gas samples was analysis using the procedure as discussed in sub heading 2.3 of this paper and data is recorded and presented graphically in Fig. 5.

The graph (Fig.5) shows the percentage removal of Tar& SPM from gram straw with cumulative hours of use. Critical analysis of Fig. 5 indicate the gradual increment of percentage of tar removal, which starts from 26% and reach to the highest point of 58%, later started decline. This curve also depicts the nature of the organic filter component, which change due to moisture accumulation and porosity variation. The saturation time of gram straw filter was about 10 hours.

Performance of coconut husk based organic filter is shown in Fig 6. Coconut husk organic filter was able to

Fig. 4. Photographic view of gram straw, coconut husk and Egg shell before and after test

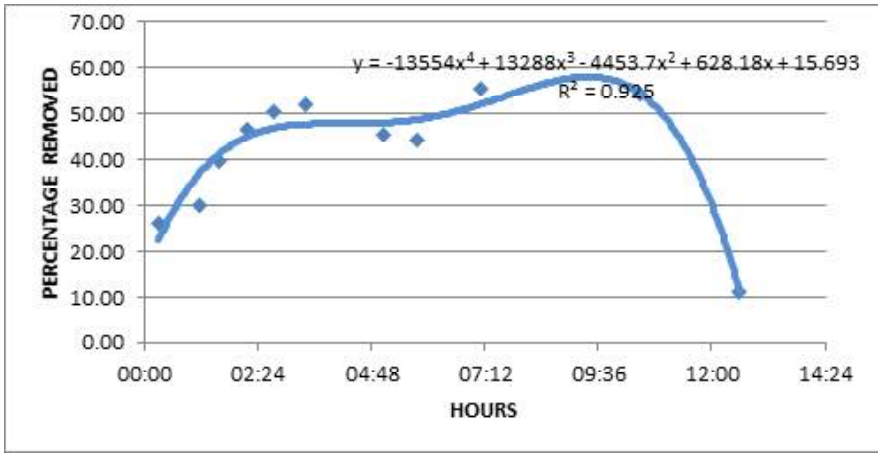

Fig.5. Percentage removal of Tar & SPM from gram straw with respect to time

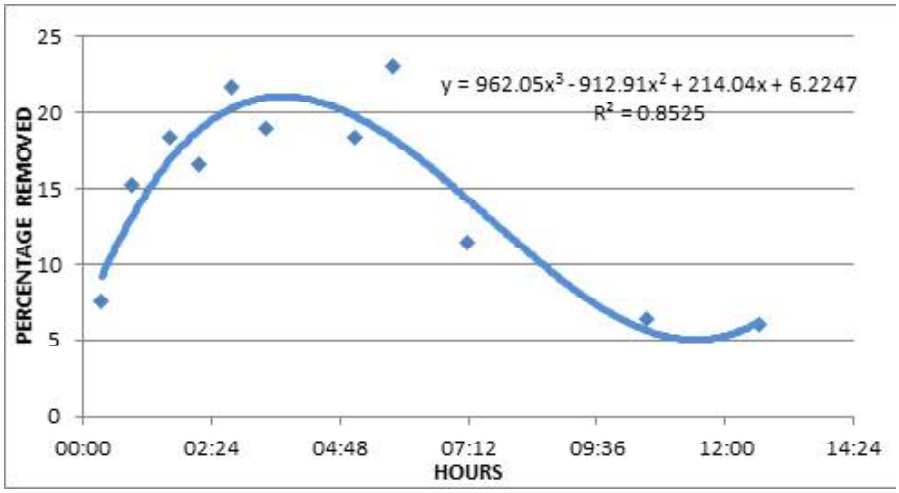

Fig.6. Percentage removal of Tar & SPM from coconut husk with respect to time

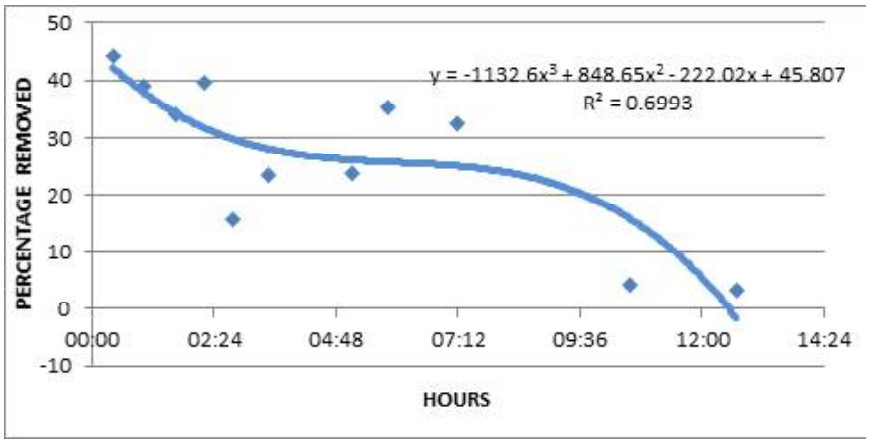

Fig.7. Percentage removal of Tar & SPM from egg shell with respect to time

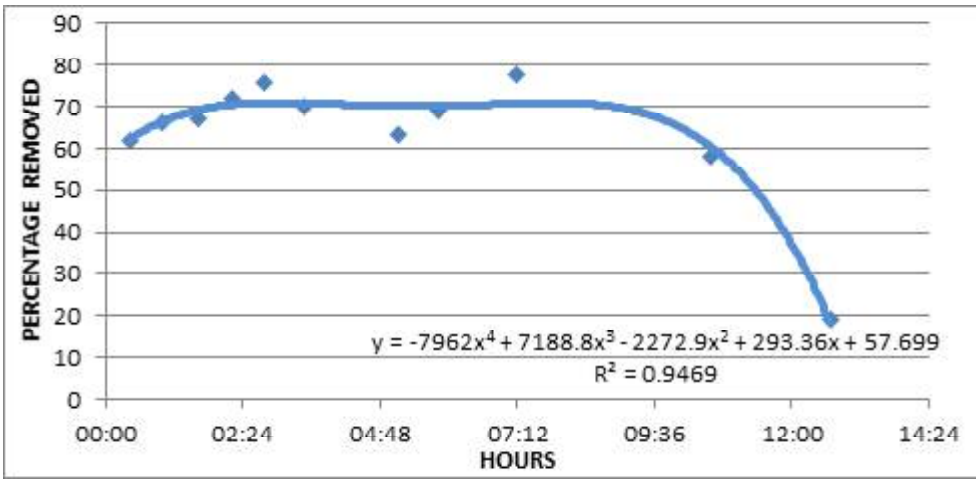

Fig. 8. Over all percentage removal of Tar & SPM from the organic filters

remove low percentage of Tar & SPM as compared to other organic filter components. It was capable to remove up to 20% Tar & SPM left after gram husk filter. Apart from this saturation time of this filter was also less (only 4 hours). Lower percentage of tar removal was may be due to low compression of coconut husk in filter cylinder.

Figure 7 shows the percentage removal of Tar & SPM remains after gram straw filter and coconut husk filter respectively. Critical analysis of Fig.7 indicate that egg shell filter, removes high percentage of Tar & SPM at the beginning (44%) and later sustain up to 26% for a saturation time of around 7 hours. Due to high initial tar removal capacity egg shell filter can be utilized to compensate initial tar removal capacity of other filter components (gram straw and coconut husk) which is generally less.

Figure 8, shows the combine effect of all three organic filters connected in series with each other. Critical analysis of Fig.8 reveals that combination of organic filters (gram straw, coconut husk and egg shell) could remove maximum 70% of Tar & SPM from the producer gas and can sustain about 9 hours. Latter efficiency started decreasing drastically due to saturation of the used organic components. Although used organic filter are not able to remove tar level for the application of motive power. However, major portion of the Tar & SPM is being removed with the help of organic filter. Most of even thermal application also needs to remove Tar and SPM to maintain the quality of their product. For them these types of filters would be very cheap as well as environmental friendly. As, once the organic filter materials saturated, it can be reused in the gasifier after drying. Hence create zero waste in the environment.

Overall Tar Removal Efficiency Including Modified Air Heat Exchanger

To increase the efficiency of air heat exchanger modification was done on it by applying fins on the surface of the heat exchanger tubes (Fig. 9). Due to which, heat transfer from the surface increases and producer gas get cool rapidly. Since the condensation of tar starts at temperatures below 150 C, so lower the temperature higher will be tar condensation. By introducing the fins on air heat exchanger cleaning efficiency of producer gas was increased about 5%. Hence over all percentage removal of Tar & SPM becomes about 74.84%, which was earlier only 70%. Author believes that over all percentage removal of Tar & SPM could be further increased, if circular pipe is used instead of square pipe for heat exchanger tubes.

Fig. 9. Pictorial view of modified heat exchanger with fins

CONCLUSION

From the above study following conclusions could be drawn:

Developed organic filters worked satisfactory and the tar and particulates removal efficiency was in the range of 65-70%. Overall saturation time of organic filter was around 9 hours. By introducing the fins on air heat exchanger tubes cleaning efficiency of producer gas was increased about 5%. Hence over all percentage of Tar & SPM removal becomes about 74.84%. Over all percentage removal of Tar & SPM could be further increased, if circular pipe is used instead of square pipe for heat exchanger tubes.

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RESEARCH ARTICLE

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Study of absorption spectra of organic light emitting materials (triphenyl derivatives of amine): A quantum mechanical study

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ABSTRACT

Density Functional theory (DFT) is used to study the effect of substituents on the electronic and optical property of organic light emitting material 1,3,5-tris(4'-(1''- phenyl-benzimidazol-2''-yl)phenyl) amine (TPBB) and its derivatives (MeO-TPBB, Br-TPBB and Bu-TPBB). TD – DFT has been used to study the absorption spectra of these molecules. This study suggests that each derivative of TPBB shows a UV – VIS spectra at slightly different frequency.

INTRODUCTION

Organic molecules are generally considered to be insulators but the discovery of conducting polymers in 1970s brought about a new era in the field of organic opto – electronics. Since then organic luminescent materials have received an increased attention due to their potential application as organic light – emitting devices (OLEDs) (Minaev et al. 2014; Xio et al. 2011). Tang and VanSlyke (Tang et al. 1987) in 1987 found the emission from a semiconducting organic molecule under the application of an electric field. In the year 1990, Conjugated organic polymers were also found to emit yellow green light under an electric field (Brroughes et al. 1990). At present organic light emitting devices have already been commercialized. In order to make these devices more practical, devices based on new mechanisms such as thermally activated delayed fluorescence (TADF) (Adachi et al. 2014) are being looked into. The phenomenon of electroluminescence in OLED is either fluorescence or phosphorescence, further a high efficiency and long life time can be achieved by these organic materials if they are stacked in a proper manner (Karzai et al. 2001, 2003; Kukarni et al. 2004; Hung et al. 2002). An OLED emits light when it is provided a proper external voltage (less than 5eV). The low operating voltage leads to less power consumption (Peumans et al. 2003; Karzazi et al. 2014; Blochwitz et al. 1998; Miyata et al. 1997). The photo – physical and electronic properties of organic materials depends on the nature of substituent (Detert et al. 2000; Park et al. 2008). These properties of luminescent molecules can be altered by the presence of substituent, therefore several derivatives of these molecules have been synthesized, for e.g. by Huang *et al*. (Xia et al. 2000). The effect of the nature of substituent, i.e. electron donating or withdrawing, has also been investigated by Urch *et al. 2001*.

Computational techniques such as DFT and TD – DFT (Runge et al. 1984) have enabled systematic calculations and study of the properties and structure of OLED materials both in ground and excited states providing valuable knowledge for photo absorption, emission and charge carrier mobility (Hwang et al. 2011). It is known that the optical and electronic properties of organic luminescent materials depend on the nature of substituents. The present work reports electronic structures of four TPBB derivatives and their excited state absorption spectra in UV-visible range. These materials were observed to have very useful emission properties (Kim et al. 2010). Theoretical study of TPBB and its derivatives (with different substituents) using Time dependant – Density Function Theory (TD – DFT) with singlet excitation method is done to calculate the absorption spectra of TPBB and its derivatives.

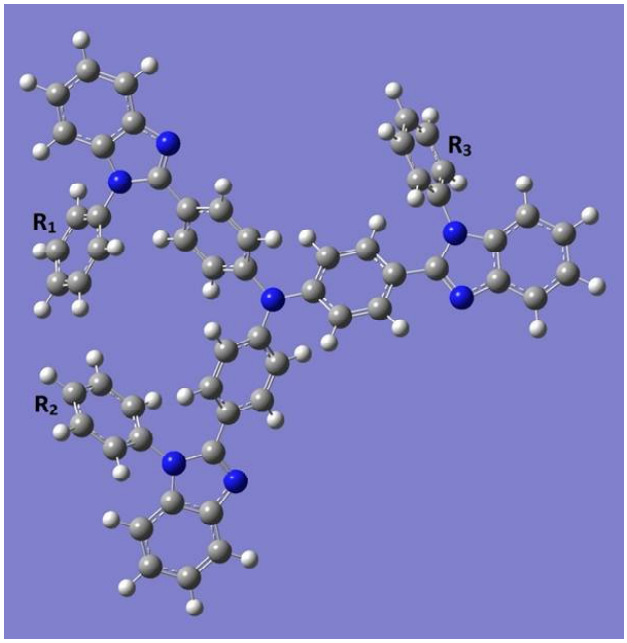

Fig. 1. Optimized Geometry of TPBB

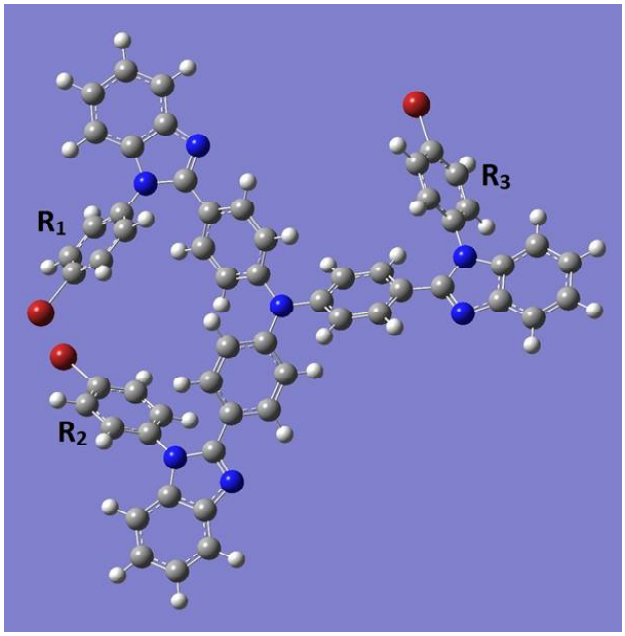

Fig. 3. Optimized Geometry of Br-TPBB

Theoretical methodology

DFT calculations for TPBB and its derivatives were performed. A uniform strategy is adopted for the study of these molecules. After generating the molecular structure using Gauss view, geometry optimization has been carried out without any constraints and checked for imaginary frequencies using M06 (Zhao yet al. 2008) method with 6-31G** (Hay et al. 1985) basis set (i.e. split valence –shell augmented by d polarization function on hydrogen atom as well as diffuse function for both hydrogen and heavy atom was used) (Ku et al. 2009; Hwang et al. 2009; Hehre et al. 1972; Kim et al. 2003). The above basis set has been

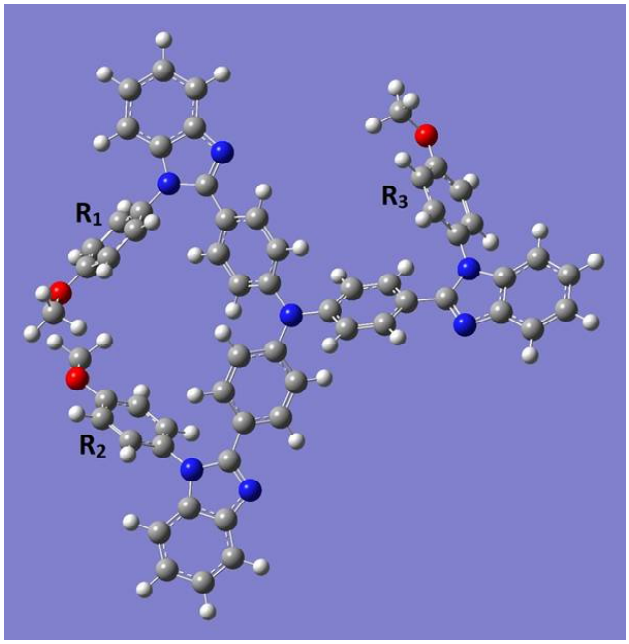

Fig. 2. Optimized Geometry of MeO-TPBB

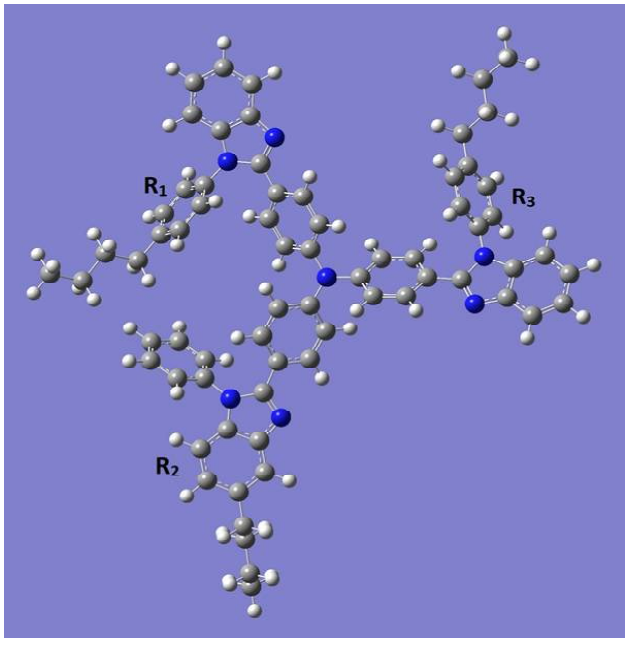

Fig. 4. Optimized Geometry of Bu-TPBB

Table 1. Optimized Geometry parameters of TPBB and its derivatives

Derivative	substituent group	bond length between substituent group and benzene rings (Å)		Mullikan charge on substituent group
		Ring	Bond Length	
TPBB	**H**	R1	1.088	0.114086
		R2	1.088	0.113276
		R3	1.087	0.130698
Bu - TPBB	**Bu**	R1	1.500	-0.021456
		R2	1.503	-0.011708
		R3	1.500	-0.035824
Br - TPBB	**Br**	R1	1.892	-0.137
		R2	1.893	-0.138
		R3	1.891	-0.127
MeO -TPBB	**Meo**	R1	1.352	-0.237875
		R2	1.352	-0.241268
		R3	1.351	-0.233352

R1, R2, R3 are the rings as shown in figures.

employed on Gaussian 09 package (Frisch et al. 2010) for this purpose and TD – DFT calculation was also done using the same method.

RESULT AND DISCUSSION

The Figures 1-4 present optimized geometry of TPBB, MeO-TPBB, Br-TPBB, and Bu-TPBB. From figures it is clear that in case Bu-TPBB, because of long alkyl chain there is a rotation in benzene ring and all three Butyl group are away from each other. In all other cases two substituent groups are interacting with each other non-covalently. The geometry parameters after optimization are listed in Table 1. The parameters include the Mullikan charge on the substituent group present in each molecule along with the bond length between the substituent and the benzene rings R_1 , R_2 , R_3 as shown in figures 1 – 4.

The molecular orbital analysis of (HOMO and LUMO) of molecules 1-4 provides a reasonable qualitative indication of the excitation properties and the electron transport because of the relative order of these orbitals. The HOMO and LUMO energy of TPBB and its derivatives computed using the TD-DFT/6-31G** method, are shown in Table 2. The calculated HOMO-LUMO gap is usually considered as representation of the emission characteristics of the molecule. The TPBB derivatives showed almost the same HOMO and LUMO energy values without reference to the substituent.

The computed results in Table 2 suggest that there is not much effect on HOMO – LUMO gap and in vertical excitation with substitution. Table 3 gives the prominent excitations in these molecules along with their oscillator strengths and absorption wavelengths. Figures 5 – 8 give the UV – VIS spectra of TPBB and its derivatives.

CONCLUSION

The M06/6-31G** method is good for the analysis of structural and electronic properties of TPBB and its derivatives. The TPBB derivatives with substituent Br, Bu and MeO group show improvement in light absorption. The Br, Bu, and MeO substituent could hardly alter the energy levels of TPBB although they have different electron donating ability. The slight variations in the absorption wavelengths can be attributed to the variations of conjugation present in these molecule due to different

Table 2. HOMO and LUMO values for TPBB and its derivatives

Derivative	HOMO (eV)	LUMO (eV)	LUMO + 1 (eV)
TPBB	-5.308290312	-1.269112304	-1.170933587
Bu-TPBB	-5.254983187	-1.153572716	-1.131776388
Br-TPBB	-5.472130128	-1.340895967	-1.099394827
MeO - TPBB	-5.275201254	-1.148701876	-1.282636368

Table 3. Details of major transitions in TPBB and its Derivatives

Derivative	Major Transition	Absorption Wavelength (λ_{abs})	Oscillator Strength (f)
TPBB	HOMO → LUMO	377.91 nm	0.6586
	HOMO → LUMO + 1	367.55 nm	1.1684
Bu-TPBB	HOMO → LUMO	372.61 nm	1.0049
	HOMO → LUMO + 1	369.70 nm	0.8519
Br-TPBB	HOMO → LUMO	369.23 nm	0.8908
	HOMO → LUMO + 1	364.62 nm	0.7630
MeO-TPBB	HOMO → LUMO	370.02 nm	0.8112
	HOMO → LUMO + 1	365.34 nm	0.9538

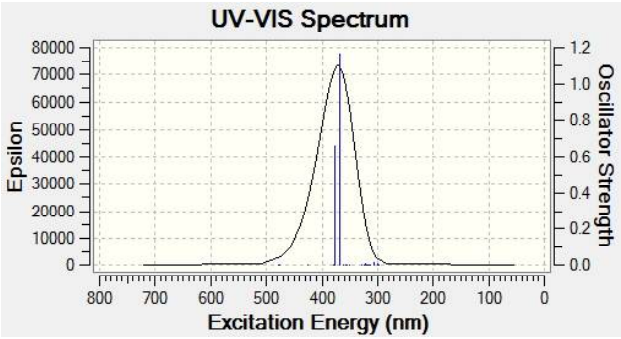

Fig. 5. Absorption Spectra for TPBB.

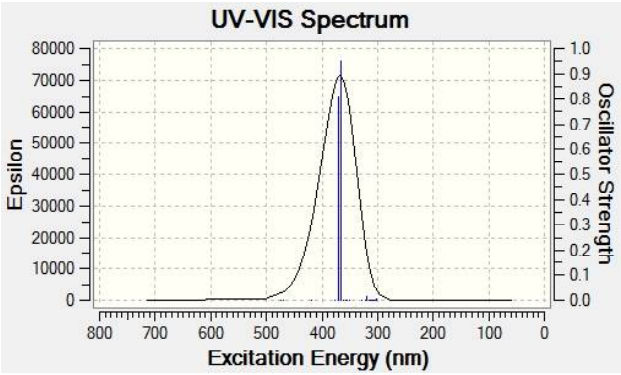

Fig. 6. Absorption Spectra for MeO-TPBB

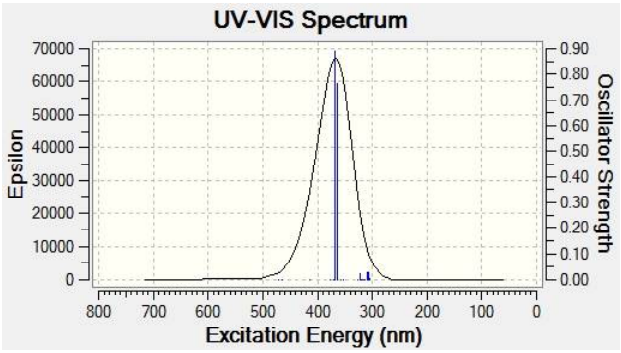

Fig. 7. Absorption Spectra for Br-TPBB

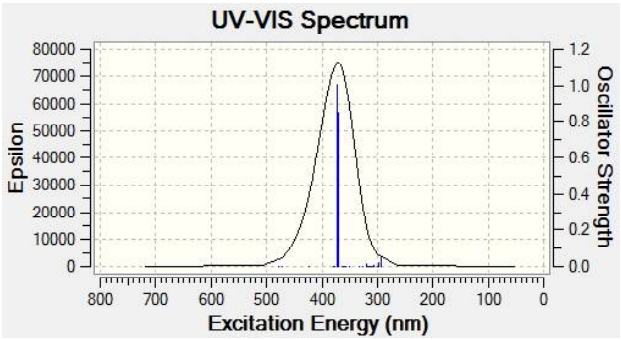

Fig. 8. Absorption Spectra for Bu-TPBB.

substituents. This result suggests that derivatives of TBPP can also be effectively used for fabrication of a practical OLED.

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RESEARCH ARTICLE

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Study of heat transfer in a nanofluid layer using homotopy analysis method

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ABSTRACT

In this paper, we perform a weak nonlinear stability analysis to study the heat transfer in a horizontal nanofluid layer. We consider a set of new boundary conditions for the nanoparticle fraction, which is physically more realistic. The new boundary condition is based on the assumption that the nanoparticle fraction adjusts itself so that the nanoparticle flux is zero on the boundaries. The governing equations for this problem are reduced to Ginzburg–Landau equation and solved by using homotopy analysis method (HAM). Obtained results are valid for the whole solution domain with high accuracy. Nusselt number and Nanoparticle Nusselt number are calculated for different values of parameters. The results have been depicted graphically.

INTRODUCTION

Enhancement of heat transfer in conventional fluid by using nanoparticles is one of the rapidly growing research area in fluid dynamics. It is well known that by using nanoparticles the heat transfer in conventional fluid increases considerably, and suits many applications where rapid heat transportation is required. Growing technology demands high class energy efficient devices which needs rapid heat exchangers, where nanofluids can be used as a coolant. Saidur et al. (2011) enlightened some of the special features of nanofluids from the application point of view. The documented works on convective heat transfer based on the experimental and theoretical results, which ensures the efficiency of nanofluids to enhance the heat transfer, are provided by Wen et al. (2009), Eastman et al. (2001), Wang and Mujumdar (2007), Daungthongsuk and Wongwises (2007), Trisaksria and Wongwises (2007), Godson et al. (2010), Kakaç and Pramuanjaroenkij (2009), Robert et al. (2013).

Natural convection in a horizontal fluid layer attracts considerable interest due to its applications in many engineering branches, in atmospheric sciences, and in geophysical problems. The buoyancy induced convection arises due to temperature gradient in a nanofluid layer finds its application in solar collector, nuclear reactors etc. Kim et al. (2004) studied the buoyancy driven instability of nanofluids using Buongiorno model. Buongiorno (2006) developed the equations for nanofluid convection and found that only Brownian diffusion and thermophoresis are important slip mechanisms in nanofluid convection. Tzou (2008a, 2008b) studied the nanofluid instability caused by natural convection and found that the critical Rayleigh number is significantly low by one to two orders of magnitude as compared to that for regular fluids. Nield and Kuznetsov (2010) studied the onset of convection and predicted that oscillatory convection is possible with bottom heavy nanoparticles fluid layer. Abu-Nada (2011) studied the effect of variable thermal conductivity and variable viscosity of nanofluids on heat transfer in natural convection using CuO-water nanofluids. Agarwal and Bhadauria (2015) studied the thermal instability of nanofluid layer under local thermal non-equilibrium. Recently, Nield and Kuznetsov (2014) considered a physically more realistic model for thermal instability by taking a new set of boundary conditions which is based on the assumption that the normal

component of the nanoparticle flux on boundaries is zero. Therefore, in this paper, we have also made an attempt to study the heat transfer in a nanofluid layer with new set of boundary conditions.

Homotopy analysis method (HAM) is used to solve the problem, which is a powerful method to solve the nonlinear differential equations. This method was introduced by Liao in 1992. This innovative technique has been used by several authors in a field of science and engineering to solve different types of governing differential equations. HAM offers highly accurate successive approximations of the solution. Some relevant studies are referred in following references [see. Liao (2004), Hayat et. al. (2004), Domairry and Nadim (2008)]

GOVERNING EQUATION

We consider an infinitely extended horizontal fluid layer nanofluid, confined between the planes and $z=0$ and $z=d$. We choose a Cartesian frame of reference with origin at the lower boundary and the z-axis in vertically upward direction. The gravitational force is acting in vertically downward direction. T_h and T_c are the lower and upper plate temperature respectively with the condition that $T_h > T_c$, T_c, is taken as reference temperature. Moreover, it is assumed that there is no nanoparticle flux at the boundaries and that the particle fraction value there adjusts accordingly. Further, the density variation is considered under Boussinesq approximation. Then using the approximated buoyancy term, the governing equations under the above considerations incorporating the Brownian diffusion and thermophoresis are as follows:

$$\nabla.\mathbf{q} = 0\,, \tag{1}$$

$$\rho_f\left(\frac{\partial \mathbf{q}}{\partial \tau} + \mathbf{q}.\nabla\mathbf{q}\right) = -\nabla \mathbf{p} + \mu\nabla^2\mathbf{q} + \left(\phi\rho_p + (1-\phi)\rho_f\left[1-\beta\left(T-T_c\right)\right]\right)\mathbf{g} \tag{2}$$

$$(\rho c)_f\left(\frac{\partial T}{\partial \tau} + \mathbf{q}.\nabla T\right) = \kappa\nabla^2 T + (\rho c)_p \times \left[D_B\nabla\phi.\nabla T + \left(\frac{D_T}{T_c}\right)\nabla T.\nabla T\right] \tag{3}$$

$$\frac{\partial \phi}{\partial \tau} + \mathbf{q}.\nabla\phi = D_B\nabla^2\phi + \left(\frac{D_T}{T_c}\right)\nabla^2 T, \tag{4}$$

where $q=(u,v,w)$. It is assumed that the boundaries are held at constant temperature and the nanoparticle flux is zero on the boundaries therefore, the boundary conditions are taken as follows:

$$w = 0, T = T_h, D_B\frac{\partial\phi}{\partial z} + \frac{D_T}{T_c}\frac{\partial T}{\partial z} = 0 \text{ at } z = 0, \tag{5}$$

$$w = 0, T = T_c, D_B\frac{\partial\phi}{\partial z} + \frac{D_T}{T_c}\frac{\partial T}{\partial z} = 0 \text{ at } z = d. \tag{6}$$

We introduce the dimensionless variable by using the following transformations:

$$\begin{aligned} &\left(x^*, y^*, z^*\right) = \left(x, y, z\right)/d,\ \tau^* = \tau\frac{\alpha_f}{d^2},\\ &\left(u^*, v^*, w^*\right) = \left(u, v, w\right)d/\alpha_f,\ \mathbf{p}^* = \mathbf{p}\frac{d^2}{\mu\alpha_f},\\ &\phi^* = \frac{\phi-\phi_0}{\phi_0} \text{ and } \mathrm{T}^* = \frac{T-T_c}{T_h-T_c}, \end{aligned} \tag{7}$$

$$\text{where } \alpha_f = \frac{\kappa}{(\rho c)_f}$$

where ϕ_0 is a reference scale for the nanoparticle fraction.

The nondimensionlized equations (after dropping the asterisks for simplicity) are:

$$\nabla.\mathbf{q} = 0, \tag{8}$$

$$\frac{1}{Pr}\left(\frac{\partial \mathbf{q}}{\partial \tau} + \mathbf{q}.\nabla\mathbf{q}\right) = -\nabla\mathbf{p} + \nabla^2\mathbf{q} - Rmk\hat{} + RaTk\hat{} - Rn\phi k\hat{}, \tag{9}$$

$$\frac{\partial T}{\partial \tau} + \mathbf{q}.\nabla T = \nabla^2 T + \left[\frac{N_B}{Le}\nabla\phi.\nabla T + \frac{N_A N_B}{Le}\nabla T.\nabla T\right], \tag{10}$$

$$\frac{\partial \phi}{\partial \tau} + \mathbf{q}.\nabla\phi = \frac{1}{Le}\nabla^2\phi + \frac{N_A}{Le}\nabla^2 T \tag{11}$$

$$w=0, T=1, \frac{\partial \phi}{\partial z}+N_A \frac{\partial T}{\partial z}=0 \text{ at } z=0 \quad (12)$$

$$w=0, T=0, \frac{\partial \phi}{\partial z}+N_A \frac{\partial T}{\partial z}=0 \text{ at } z=1. \quad (13)$$

The nondimensional parameters, which appeared in the above equations are defined as follows:

$Pr=\frac{\mu}{\rho \alpha_f}$ is the Prandtl number, $Le=\frac{\alpha_f}{D_B}$ is the Lewis number, is the Rayleigh number, $Ra=\frac{\rho_f g \beta d^3 \left(T_h-T_c\right)}{\mu \alpha_f}$ is the basic-density Rayleigh number, $Rm=\frac{\left[\rho_p \phi_0+\rho_f\left(1-\phi_0\right)\right] g d^3}{\mu \alpha_f}$ is the $Rn=\frac{\left(\rho_p-\rho_f\right) \phi_0 g d^3}{\mu \alpha_f}$ concentration Rayleigh number, $N_A=\frac{D_T\left(T_h-T_c\right)}{D_B T_c \phi_0}$ is the modified diffusivity ratio, is the modified particle density increment.

BASIC STATE SOLUTION

The basic state of the nanofluid is assumed to be quiescent thus, temperature field and nanoparticle volume fraction vary in the *z*-direction only. This gives the solution of the form

$$u=v=w=0,\ T=T_b(z),\ \phi=\phi_b(z), \quad (14)$$

which satisfy the following equations

$$\frac{d^2 T_b}{dz^2}+\frac{N_B}{Le}\frac{d\phi_b}{dz}\frac{dT_b}{dz}+\frac{N_A N_B}{Le}\left(\frac{dT_b}{dz}\right)^2=0, \quad (15)$$

$$\frac{d^2 \phi_b}{dz^2}+N_A \frac{d^2 T_b}{dz^2}=0 \quad (16)$$

Using the boundary conditions (Eq. 12-13), Eq. (16) may be integrated to give

$$\frac{d\phi_b}{dz}+N_A \frac{dT_b}{dz}=0. \quad (17)$$

Using Eq. (17) in the Eq. (15), we get

$$\frac{d^2 T_b}{dz^2}=0. \quad (18)$$

The solution of the Eq. (18), subject to the boundary conditions (Eq. 12-13), is given by

$$T_b=1-z, \quad (19)$$

also the Eq. (16) has been solved subjected to the boundary conditions (Eq. 12-13) using (19), we get

$$\phi_b=\phi_0+N_A z. \quad (20)$$

PERTURBATION STATE

Introducing the stream function ψ, eliminating the pressure term and then imposing finite amplitude perturbations on the basic quiescent state as

$$\psi=\Psi,\ T=1-z+\Theta \text{ and } \phi=\phi_0+N_A z+\Phi, \quad (21)$$

we get the following set of equations:

$$\frac{1}{Pr}\left(\frac{\partial}{\partial \tau}\nabla^2-\nabla^4\right)\Psi+Ra\frac{\partial \Theta}{\partial x}-Rn\frac{\partial \Phi}{\partial x}=\frac{1}{Pr}\frac{\partial\left(\Psi,\nabla^2\Psi\right)}{\partial(x,z)}, \quad (22)$$

$$\frac{\partial \Psi}{\partial x}+\left(\frac{\partial}{\partial \tau}-\nabla^2+\frac{N_A N_B}{Le}\frac{\partial}{\partial z}\right)\Theta+\frac{N_B}{Le}\frac{\partial \Phi}{\partial z}=\frac{\partial(\Psi,\Theta)}{\partial(x,z)}+\left[\frac{N_B}{Le}\nabla\Phi.\nabla\Theta+\frac{N_A N_B}{Le}\nabla\Theta.\nabla\Theta\right], \quad (23)$$

$$-N_A\frac{\partial \Psi}{\partial x}-\frac{N_A}{Le}\nabla^2\Theta+\left(\frac{\partial}{\partial \tau}-\frac{1}{Le}\nabla^2\right)\Phi=\frac{\partial(\Psi,\Phi)}{\partial(x,z)}. \quad (24)$$

Boundary conditions to solve Eqs. (22-24) are

$$\Psi=0,\ \Theta=0, \frac{\partial \Phi}{\partial z}+N_A\frac{\partial \Theta}{\partial z}=0 \text{ at } z=0,1. \quad (25)$$

We now introduce the following asymptotic expansion

$$Ra = Ra_{0,c} + \chi^2 Ra_2 + \chi^4 Ra_4 + ..., \quad (26)$$

$$\Psi = \chi\Psi_1 + \chi^2\Psi_2 + \chi^3\Psi_3 + ..., \quad (27)$$

$$\Theta = \chi\Theta_1 + \chi^2\Theta_2 + \chi^3\Theta_3 + ..., \quad (28)$$

$$\Phi = \chi\Phi_1 + \chi^2\Phi_2 + \chi^3\Phi_3 + ..., \quad (29)$$

where $Ra_{0,c}$ is the critical value of the Rayleigh number at which the onset of convection takes place.

We assume the variation of time only at the slow time scale $t = \chi^2\tau$ and arranging the systems at different order of χ.

At the lowest order, we have

$$\begin{pmatrix} -\nabla^4 & Ra_{0;c}\frac{\partial}{\partial x} & -Rn\frac{\partial}{\partial x} \\ \frac{\partial}{\partial x} & \left(-\nabla^2 + \frac{N_A N_B}{Le}\frac{\partial}{\partial z}\right) & \frac{N_B}{Le}\frac{\partial}{\partial z}\nabla^2 \\ -N_A\frac{\partial}{\partial x} & -\frac{N_A}{Le}\nabla^2 & -\frac{1}{Le}\nabla^2 \end{pmatrix} \begin{pmatrix} \Psi_1 \\ \Theta_1 \\ \Phi_1 \end{pmatrix} = 0. \quad (30)$$

Solution at the lowest order subject to the boundary conditions (25), are assumed to be

$$\Psi_1 = A[t]\psi_F, \ \ \Theta_1 = B[t]\theta_F, \ \Phi_1 = C[t]\phi_F \quad (31)$$

where

$$\psi_F = Sin(k_c x)Sin(\pi z), \quad \theta_F = Cos(k_c x)Sin(\pi z), \quad \phi_F = -N_A Cos(k_c x)Sin(\pi z). \quad (32)$$

where $\delta^2 = k_c^2 + \pi^2$ and k_c is the critical wave number.

The expression for thermal Rayleigh number is given by

$$Ra = \frac{\delta^6}{a^2} - N_A Rn(Le+1), \quad (33)$$

where α is the wave number.

The critical value of the Rayleigh number and the corresponding wave number for the onset of stationary convection is calculated numerically, the expression for critical Rayleigh number is given by

$$Ra_{0,c} = \frac{\delta^6}{k_c^2} - N_A Rn(Le+1), \quad (34)$$

and the critical wave number is $k_c = \frac{\pi}{\sqrt{2}}$

AMPLITUDE EQUATION

At the second order, we have

$$\begin{pmatrix} -\nabla^4 & Ra_{0;c}\frac{\partial}{\partial x} & -Rn\frac{\partial}{\partial x} \\ \frac{\partial}{\partial x} & \left(-\nabla^2 + \frac{N_A N_B}{Le}\frac{\partial}{\partial z}\right) & \frac{N_B}{Le}\frac{\partial}{\partial z}\nabla^2 \\ -N_A\frac{\partial}{\partial x} & -\frac{N_A}{Le}\nabla^2 & -\frac{1}{Le}\nabla^2 \end{pmatrix} \begin{pmatrix} \Psi_2 \\ \Theta_2 \\ \Phi_2 \end{pmatrix} = \begin{pmatrix} R_{21} \\ R_{22} \\ R_{23} \end{pmatrix}. \quad (35)$$

where

$$R_{21} = 0, \quad (36)$$

$$R_{22} = \frac{k_c^2\pi}{2\delta^2}A[t]^2 Sin(2\pi z) - \frac{\pi k_c^2 N_A N_B}{2\delta^4}(k_c^2 Sin^2(k_c x) Sin^2(\pi z) + \pi^2 \mathrm{Cos}^2(k_c x)\mathrm{Cos}^2(\pi z))A[t]^2 \quad (37)$$

$$R_{23} = \frac{\pi k_c^2 N_A}{2\delta^2}(Le+1)A[t]^2 Sin(2\pi z). \quad (38)$$

The second order solution subject to the boundary conditions (25), are assumed to be

$$\Psi_2 = 0, \ \Theta_2 = B_S[t]\theta_S, \ \Phi_2 = C_S[t]\phi_S \quad (39)$$

where

$$\theta_S = Sin(2\pi z), \ \phi_S = -N_A Sin(2\pi z). \quad (40)$$

The horizontally averaged Nusselt number and Sherwood number, *Nu* and Nu_Φ, for stationary mode of convection (the mode considered in this problem) is given by:

$$Nu[t]=\frac{\left[\frac{k_c}{2\pi}\int_0^{\frac{2\pi}{k_c}}\left(1-z+\Theta_2\right)_z\,dx\right]_{z=0}}{\left[\frac{k_c}{2\pi}\int_0^{\frac{2\pi}{k_c}}\left(1-z\right)_z\,dx\right]_{z=0}}, \tag{41}$$

$$Nu_{\Phi}[t]=\frac{\left[\frac{k_c}{2\pi}\int_0^{\frac{2\pi}{k_c}}\left(\phi_0+N_A z+\phi_2\right)_z\,dx\right]_{z=0}}{\left[\frac{k_c}{2\pi}\int_0^{\frac{2\pi}{k_c}}\left(\phi_0+N_A z\right)_z\,dx\right]_{z=0}}, \tag{42}$$

Substituting expressions of Θ_2 and Φ_2 in the above Eqs. (41 and 42) and simplifying, we get

$$Nu[t]=1+\frac{k_c^2}{4\delta^2}(A[t])^2, \tag{43}$$

$$Nu_{\Phi}[t]=1+\left(\frac{k_c^{\,2}Le}{4\delta^2}\left((Le+1)+\frac{1}{Le}\right)\right)(A[t]).^2 \tag{44}$$

At the third order, we have

$$\begin{pmatrix} -\nabla^4 & Ra_{0;c}\frac{\partial}{\partial x} & -Rn\frac{\partial}{\partial x} \\ \frac{\partial}{\partial x} & \left(-\nabla^2+\frac{N_A N_B}{Le}\frac{\partial}{\partial z}\right) & \frac{N_B}{Le}\frac{\partial}{\partial z}\nabla^2 \\ -N_A\frac{\partial}{\partial x} & -\frac{N_A}{Le}\nabla^2 & -\frac{1}{Le}\nabla^2 \end{pmatrix}\begin{pmatrix}\Psi_3\\ \Theta_3\\ \Phi_3\end{pmatrix}=\begin{pmatrix}R_{31}\\ R_{32}\\ R_{33}\end{pmatrix}. \tag{45}$$

where

$$R_{31}=-\frac{1}{Pr}\frac{\partial}{\partial t}\left(\nabla^2\Psi_1\right)-Ra_2\frac{\partial\Theta_1}{\partial x}, \tag{46}$$

$$R_{32}=\frac{\partial\Psi_1}{\partial x}\frac{\partial\Theta_2}{\partial z}+\frac{N_B}{Le}\left\{\frac{\partial\Phi_1}{\partial z}\frac{\partial\Theta_2}{\partial z}+\frac{\partial\Phi_2}{\partial z}\frac{\partial\Theta_1}{\partial z}\right\}+2\frac{N_A N_B}{Le}\left\{\frac{\partial\Phi_1}{\partial z}\right\}\frac{\partial\Theta_2}{\partial z}-\frac{\partial\Theta_1}{\partial t}, \tag{47}$$

$$R_{33}=\left\{\frac{\partial\Psi_1}{\partial x}\frac{\partial\Phi_2}{\partial z}\right\}-\frac{\partial\Phi_1}{\partial t}, \tag{48}$$

Substituting the value of $\Psi_1,\ \Theta_1,\ \Theta_2,\ \Phi_1$ and Φ_2 in the above equations to get the expressions of $R_{31},\ R_{32},\ R_{33}$.

Applying the solvability condition for the existence of third order solution, we get the non-autonomous Ginzburg-Landau equation with time periodic coefficients in the form

$$a_1\frac{dA[t]}{dt}+a_2A[t]+a_3(A[t])^3=0 \tag{49}$$

where

$$a_1=\frac{\delta^2}{Pr}+\frac{k_c^{\,2}}{\delta^4}\left(Ra_{0,c}+RnN_A\right)+\frac{k_c^{\,2}}{\delta^4}LeRnN_A(Le+1),$$

$$a_2=-\frac{k_c^{\,2}}{\delta^2}Ra_2$$

$$a_3=\frac{k_c^{\,4}}{8\delta^4}\left(Ra_{0,c}+RnN_A\right)+\left(\frac{k_c^{\,4}N_A Le}{8\delta^4}\right)\times LeRn\left((Le+1)+\frac{1}{Le}\right)$$

The Ginzburg-Landau (GL) equation given by (49) is a Bernoulli equation and to obtained its solution HAM method has been employed, subject to the initial condition $A[0]=a_0$, where a_o is the chosen initial amplitude of convection. In our calculations, we may assume $Ra_2=Ra_{0,c}$ to keep the parameters to the minimum.

METHOD DESCRIPTION

Let us assume the following nonlinear differential equation in the form of

$$N\left[A(t)\right]=0 \tag{50}$$

where *N* is a nonlinear operator, *t* is an independent variable and *A(t)* is the solution of the equation. We define the function, $\varphi(t,p)$ as follows:

$$lim_{p\to 0}\varphi(t,p) = A_0(t) \tag{51}$$

where, $p:[0,1]$ and $A_0(t)$ is the initial guess which satisfies the initial or boundary conditions and

$$lim_{p\to 1}\varphi(t,p) = A(t) \tag{52}$$

By using the generalized homotopy method, Liao's so-called zero-order deformation (Eq. (50)) is

$$(1-p)L\left[\varphi(t,p) - A_0(t)\right] = phN\left[\varphi(t,p)\right], \tag{53}$$

where *h* is the auxiliary parameter which helps us to increase the convergence results, *L* is the linear operator. It should be noted that there is a great freedom to choose the auxiliary parameter *h*, the initial guess $A_0(t)$ and the auxiliary linear operator *L*. This freedom plays an important role in establishing the keystone of validity and flexibility of HAM as shown in this paper. Thus, when *p* increases from 0 to 1, the solution $\varphi(t,p)$ changes between the initial guess $A_0(t)$ and the solution $A(t)$. The Taylor series expansion of with respect to *p* is

$$\varphi(t,p) = A_0(t) + \sum_{m=1}^{+\infty} A_m(t)\,p^m \tag{54}$$

and

$$A_0^{[m]}(t) = \frac{\partial^m \varphi(t,p)}{\partial p^m}|_{p=0} \tag{55}$$

where $A_0^{[m]}(t)$ for briefly is called the mth-order of deformation derivation which reads

$$A_m(t) = \frac{A_0^{[m]}(t)}{m!} = \frac{1}{m!}\frac{\partial^m \varphi(t,p)}{\partial p^m}|_{p=0}. \tag{56}$$

Now, we define the vector of

$$\vec{A}_m = \{\vec{A}_1, \vec{A}_2, \vec{A}_3, ..., \vec{A}_n\}. \tag{57}$$

According to the definition in Eq. (56), the governing equation and corresponding initial conditions of $A_m(t)$ can be deduced from zero-order deformation (Eq. (50)). Differentiating Eq. (50) *m* times with respect to the embedding parameter *p* and setting *p=0* and finally dividing by $m!$, we will have the so called m[th]-order deformation equation in the form:

$$L\left[A_m(t) - \chi_m A_{m-1}(t)\right] = hR\left(A_{m-1}\right) \tag{58}$$

where

$$R\left(A_{m-1}\right) = \frac{1}{(m-1)!}\frac{\partial^{m-1} N[\varphi(t,p)]}{\partial p^{m-1}}|_{p=0}$$

and

$$\chi_m = \begin{cases} 0 & m \le 1 \\ 1 & m > 1 \end{cases}$$

So by applying inverse linear operator to both sides of the linear equation Eq. (50), we can easily solve the equation and compute the generation constant by applying the boundary condition.

APPLICATION

We have

$$\frac{dA[t]}{dt} = Q_1 A(t) - Q_2 A(t)^3 \tag{59}$$

where $Q_1 = -\frac{a_2}{a_1}$ and $Q_2 = \frac{a_3}{a_1}$. According to the nature of the GL equation, the initial solution may be taken in the form:

$$A_0(t) = c_1 + (a_0 - c_1)e^{\gamma t} \tag{60}$$

where $c_1 = \sqrt{\frac{Q_1}{Q_2}}$ and γ is yet to be specified. The determination of γ can and will be dealt with at the time of seeking a series solution of the GL equation with a time-periodic coefficient. Quite obviously $A_0(t)$ has been so chosen that it satisfies the conditions $A_0(\infty) = c_1$ and $A_0(0) = a_0$. The choice of the form of $A_0(t)$ is most important in obtaining a convergent series solution by the HAM. Now, we introduce two notations to obtain the series solution of GL equation by HAM.

$$L[A(t)]= \frac{dA[t]}{dt} + \gamma A(t) \quad (61)$$

$$N[A(t)] = \frac{dA[t]}{dt} - Q_1 A(t) + Q_2 A(t)^3. \quad (62)$$

The required equation for $\varphi(t,p)$ can be constructed using *L[A(t)]* and *N[A(t)]*, and we also remind ourselves at this point that $\varphi(t,p)$ varies from $A_0(t)$ to $A_{NL}(t)$ as *p* varies from 0 to 1. The required equation is as follows:

$$(1-p)L[\varphi(t,p) - A_0(t)] = phN[\varphi(t,p)] \quad (63)$$

where *h* is a convergence-control parameter. Eq. (63) and $\varphi(t,0) = a_0$ are called the zeroth-order deformation equations. Now, in order to obtain the *p*-derivatives of $\varphi(t,p)$, we differentiate m-times the zeroth-order deformation equations with respect to *p*. To make use of the notation $A_m(t)$ defined in Eq. (56), we set *p=0* in the resulting equations and also divide by m!. The above procedure results in the following infinite system of linear equations:

$$L[A_m(t) - \chi_m A_{m-1}(t)] = hR_m\left(\tilde{A}_m(t)\right) \quad (64)$$

subject to the initial conditions

$$A_m(0) = 0, (m = 1,2,3....) \quad (65)$$

$$\tilde{A}_m(t) = \left(A_0(t), A_1(t), A_2(t), A_3(t), ..., A_{m-1}(t)\right), \quad m \geq 0 \quad (66)$$

and

$$R\left[\tilde{A}_{m-1}(t)\right] = A'_{m-1}(t) - Q_1 A_{m-1}(t) + Q_2 \sum_{k=0}^{m-1} A_{m-1-k}(t) \times \sum_{j=0}^{k} A_{k-j}(t) A_j(t), \quad (m = 1,2,3....) \quad (67)$$

After some simplification, we get recurrence relation

$$A_m(t) = \chi_m A_{m-1}(t) + he^{-\gamma t} \int_0^t e^{\gamma t} R\left[\tilde{A}_{m-1}(t)\right] dt \quad (68)$$

Some iterative solution is as follows:

$$A_1(t) = \frac{1}{2\gamma} e^{-3\gamma t} h\left\{-(a_0 - c_1)^3 Q_2 - 6(a_0 - c_1)^2 c_1 e^{\gamma t} Q_2 + 2c_1 e^{3\gamma t}\left(-Q_1 + c_1^2 Q_2\right) + e^{2\gamma t}\left(2c_1 Q_1 + a_0^3 Q_2 + 3c_1 \times \left(a_0^2 - 3a_0 c_1 + c_1^2\right) Q_2 - 2(a_0 - c_1)\gamma\left(\gamma + Q_1 - 3c\right)_1^2 Q_2\right) t\right\} \quad (69)$$

Other iterative solution is too long to be mentioned here, therefore, we demonstrate our results graphically.

To determine an appropriate *h*, we define a residual error in the form:

$$E_R(h) = \frac{1}{t_0} \int_0^{t_0} \left[\frac{dA[t]}{dt} - Q_1 A(t) + Q_2 A(t)^3\right]^2 dt \quad (70)$$

where t_o is time domain in which we want to capture the error. We have to choose the value of *h* in such a way that the error $E_R(h)$ is going to minimum. Here it is noticed that *h* is a helpful parameter that influences the rate of convergence of HAM solution but the convergent solution is independent of the choice of h, as proved by Liao (2009) Further, m[th]-order HAM solution can be written in the following form

$$A_{NL}^m(t) = \sum_{i=0}^{m} A_m(t), \quad m = 1,2,3..... \quad (71)$$

RESULTS AND DISCUSION

We performed a weak nonlinear stability analysis to study the heat transfer in a horizontal nanofluid layer, and calculated the effect of Lewis number, modified thermophoresis to Brownian-motion diffusivity ratio, concentration Rayleigh number and Prandtl number on the heat transport. Using power series expansion in terms of perturbation parameter, which is assumed to be small, the problem is reduced to a Ginzburg-Landau amplitude equation. Obtained Ginzburg-Landau equation is then solved using homotopy analysis metohod considering fifteen terms. From the expression of *Rn*, it is observed that *Rn* is defined as a typical nanofluid fraction instead of the difference of two fractions, therefore, cannot be negative, the modified diffusion ratio N_A is positive, moreover it is not

necessary to take large values of *Le*. As there is no longer two opposing agencies which affects the instability therefore, the oscillatory instability is not possible. One can observe that the solution of first order, second order and the Ginzburg-Landau equation is independent of modified particle-density increment N_B, therefore heat transfer remains unaffected by modified particle-density increment N_B, this happens due to orthogonality of the solution of the trial functions.

If one wants to quantify heat and mass transfer, which linear stability analysis is unable to do, a nonlinear stability analysis has to be performed, thus the need for nonlinear stability analysis is justified. It is difficult to control the nanoparticle fraction at the boundaries, therefore, we consider new set of boundary conditions by assuming that the normal component of the nanoparticle flux on boundaries is zero, such an assumption can be taken as more realistic and suits the real world problem. It is important to study the effect of nanoparticle concentration and modified diffusion ratio in nanofluid convection in fluid layer. The objective of this article is to consider nanoparticle concentration and modified diffusion ratio for either enhancing or inhibiting convective heat transport as is required by the real application.

At the critical wave number the Eq. (34) can be expressed as

$$Ra_{0,c} + N_A Rn(Le+1) = \frac{27\pi^4}{4}. \qquad (73)$$

The Eq. (73) can be taken as an useful upper bound for the value of critical Rayleigh number in case of stationary convection.

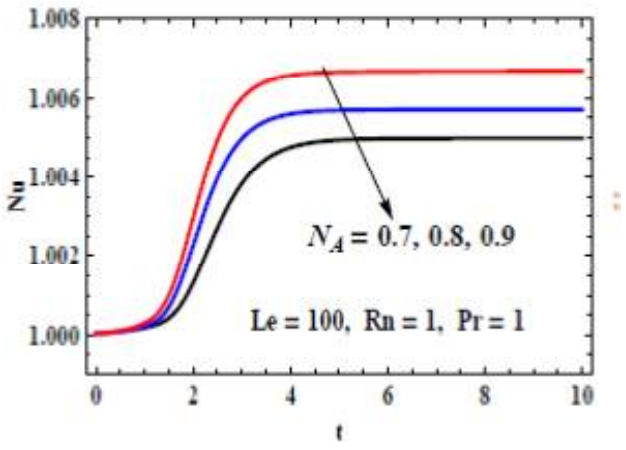

Fig. 1 : *Nu* versus *t* for different values of N_A

Figs. (1-4) show the effect of parameters on heat transport. Initially the value of Nusselt number is one, which shows that the heat transfer is by conduction alone. As time increases the value of Nusselt number increases, showing that the heat transport is being affected by convection. Further, after reaching a fixed value there is no change in the magnitude of Nusselt number with respect to time, shows the saturation state for heat transfer. Figs. (1-4) show the effect of parameters on the heat transport, while Figs. (5-8) show the effect of parameters on the nanoparticles mass transport. We keep our parameters to the fixed value of *Pr=1, Rn=1,* $N_A = 0.7$ and *Le=100,* except for the varying one.

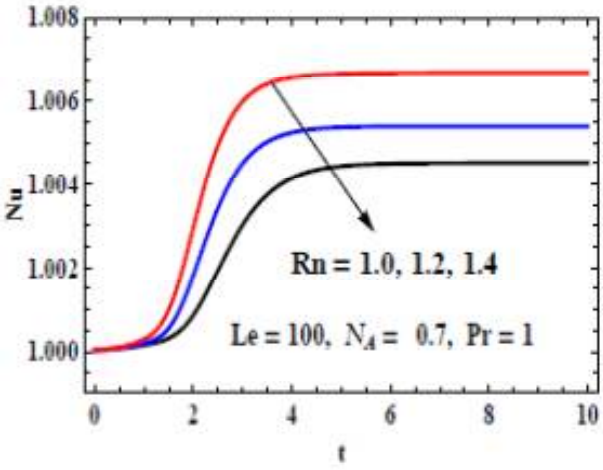

Fig. 2 : *Nu* versus *t* for different values of *Rn*

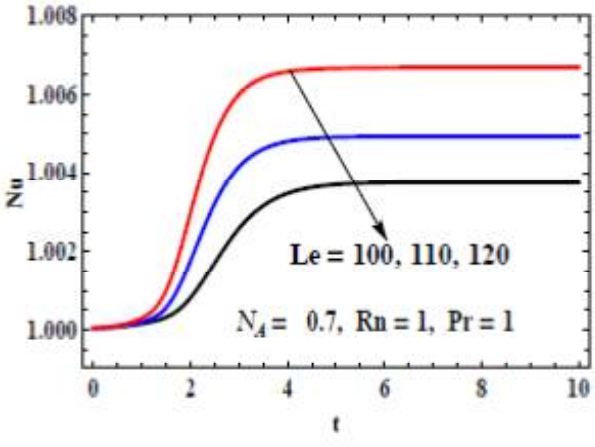

Fig. 3 : *Nu* versus *t* for different values of *Le*

Following results have been found from the Figs. 1-4 for the heat transport

1. $[Nu]_{N_A=0.9} < [Nu]_{N_A=0.8} < [Nu]_{N_A=0.7}$
2. $[Nu]_{Rn=1.2} < [Nu]_{Rn=1.1} < [Nu]_{Rn=1}$
3. $[Nu]_{Le=120} < [Nu]_{Le=110} < [Nu]_{Le=100}$
4. $[Nu]_{Pr=0.1} < [Nu]_{Pr=0.2} < [Nu]_{Pr=0.3}$

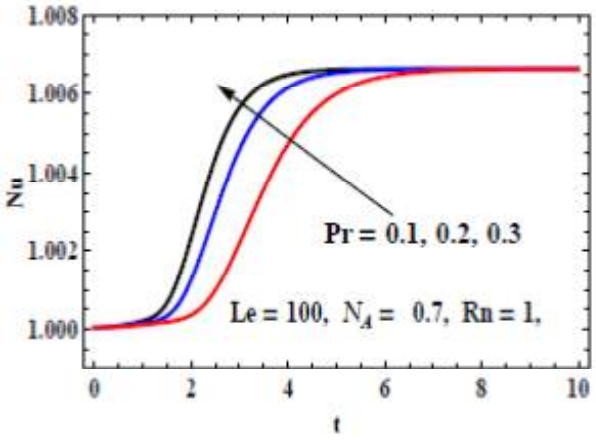

Fig. 4 : *Nu* versus *t* for different values of *Pr*

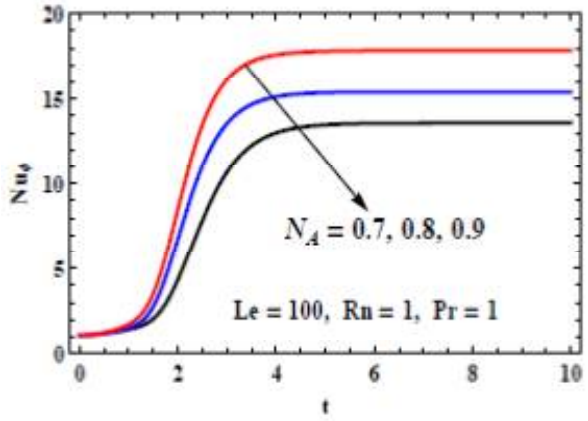

Fig. 5 : Nu_e versus *t* for different values of N_A

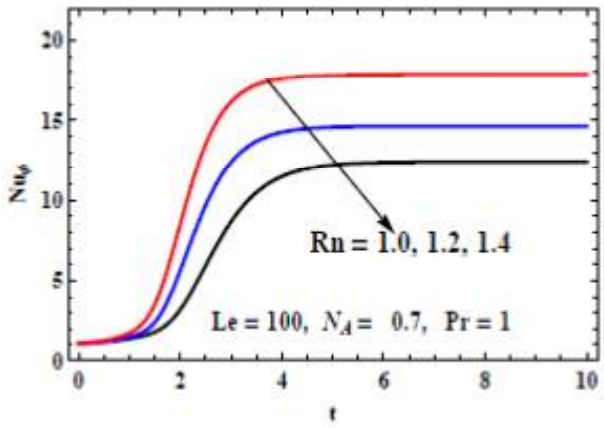

Fig. 6 : Nu_ϕ versus *t* for different values of *Rn*

The above results can be interpreted as: Fig.1 shows the effect of modified thermophoresis to Brownian-motion diffusivity ratio. It is observed from the figure that for increasing its values heat transfer decreases. From Fig. 2 we observe that for the increasing values of concentration Rayleigh number heat transfer decreases. The effect of Lewis number is shown in Fig.3 and for the increasing value of Lewis number heat transfer decreases. Further, from Fig.4, we observe that the effect of *Pr* on *Nu[t]* on heat transport is felt only for a short time.

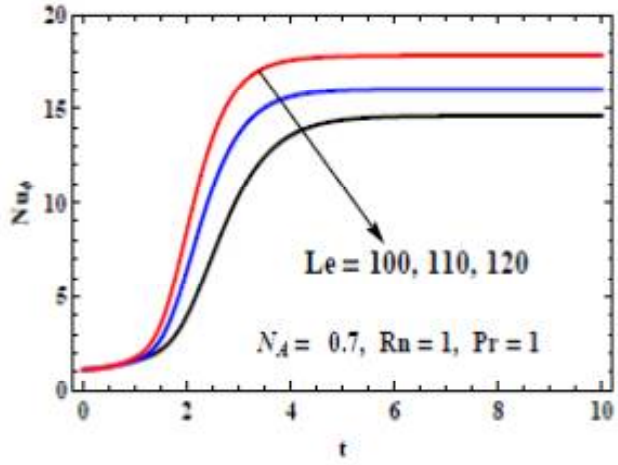

Fig. 7: Nu_ϕ versus *t* for different values of *Le*

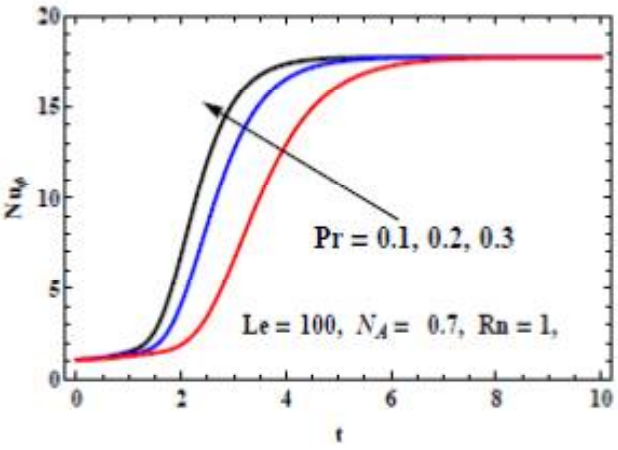

Fig. 8: Nu_ϕ versus t for different values of Pr

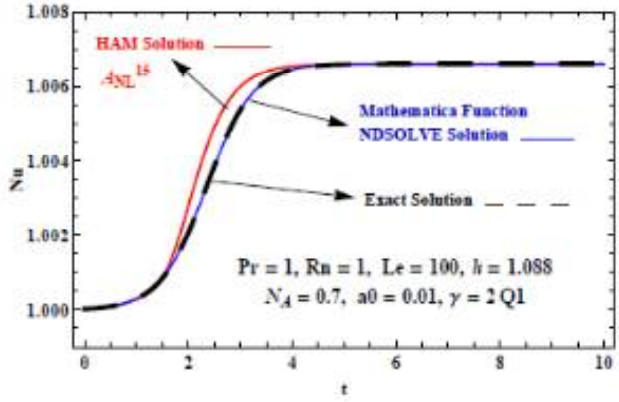

Fig. 9 : Comparison between various solutions for Nu verses t

Following results have been found in Figs.(5-8) for the nanoparticles mass transport:

1. $[Nu_\Phi]_{N_A=0.9} < [Nu_\Phi]_{N_A=0.8} < [Nu_\Phi]_{N_A=0.7}$
2. $[Nu_\Phi]_{Rn=1.2} < [Nu_\Phi]_{Rn=1.1} < [Nu_\Phi]_{Rn=1}$
3. $[Nu_\Phi]_{Le=120} < [Nu_\Phi]_{Le=110} < [Nu_\Phi]_{Le=100}$
4. $[Nu_\Phi]_{Pr=0.1} < [Nu_\Phi]_{Pr=0.2} < [Nu_\Phi]_{Pr=0.3}$

The above results are same as obtained in Figs. (1-4). Comparison of the exact solution and MATHEMATICA solution with the fifteen-order HAM solution is depicted in Fig.9 and Fig.10 for heat and mass transport respectively. Fig.9 exhibits the plot of Nu verses t, on the other hand Fig. 10 shows the plot of Nu_ϕ verses t. In both these figures, the HAM results are found to be very close to the results obtained by MATHEMATICA and the exact solution for $h=1.088$.

When $h = -2.5$, increasing the order of HAM results in increasing the residual error, thus the series is divergent. Besides, choosing any a value of h in the region $-2.5 < h < -2.3$ results in divergent series. However, choosing any value of h in the region $-1.3 < h < 0$ results in convergent series. Obviously, there exists such a region $h_B \le h < 0$ where h_B is a constant, that is choosing any value of h in this region $-1.3 < h < 0$ results in convergent HAM series. It is unnecessary to determine the exact value h_E of the boundary. For example, from Fig.11 it is obvious that the HAM series converges by choosing any a value of h in the region $-1.3 < h < 0$. Besides, as proved by Liao (2009), all of these convergent HAM series converge to the same result for given physical parameters, although the convergence rate is dependent upon the choosen value of h.

Variation of stream lines, isotherms, isoconcentrations at different instant of time are depicted in Fig.12, Fig.13, and Fig.14 respectively. The magnitudes of stream lines increases as time increases, it is evident from Fig.12. Fig.13 shows the variation of isotherms at different instant of time, it is found that initially the isotherms are flat and parallel shows the heat transport is only by conduction alone, and as time increases isotherms start oscillating, showing convective regime is in place. Fig.14 shows that initially the isoconcentrations are flat and parallel, thus heat transport is by conduction only, and as time increases isoconcentrations start oscillation and form contours which shows that the convective regime has become stronger. Moreover, it is clear from the Figs.12-14 that after some time there is no change in stream lines, isotherms, isoconcentrations for the further elapses of time, thus steady state has been achieved.

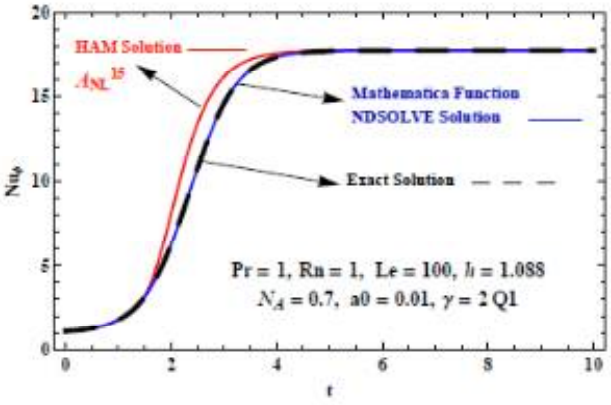

Fig. 10 : Comparison between various solutions for Nu_ϕ verses t

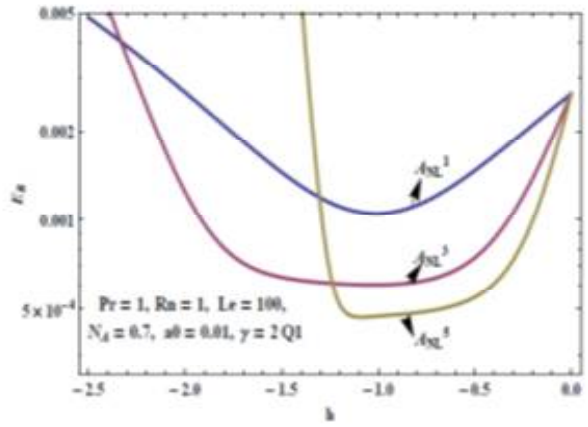

Fig. 11:Curve of residual error E_R versus convergence controlling parameter h

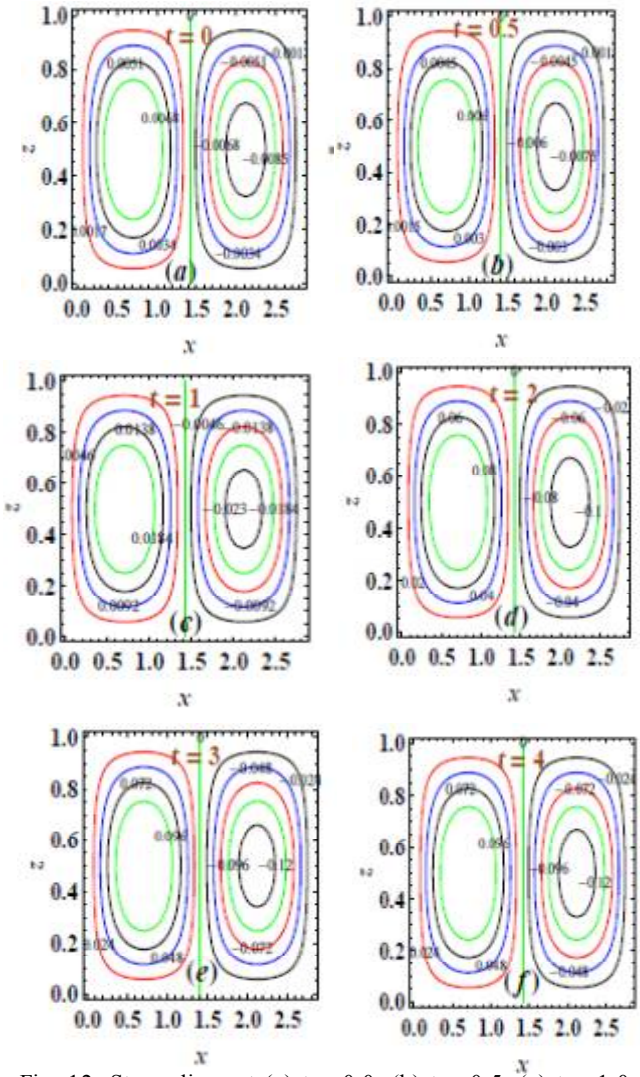

Fig. 12: Streamlines at (a) t = 0.0, (b) t = 0.5, (c) t = 1.0, (d) t = 2.0, (e) t = 3.0, (f) t = 4.0

CONCLUSIONS

We investigated the weak nonlinear effect on nanofluid convection using Ginzburg-Landau equation in an infinite horizontal fluid layer which is heated from below. We study the effect of concentration Rayleigh number, modified thermophoresis to Brownian-motion diffusivity ratio, Lewis number and Prandtl number on the heat and mass transfer for the stationary mode of convection. The following conclusions have been drawn from our analysis for increasing values of parameters:

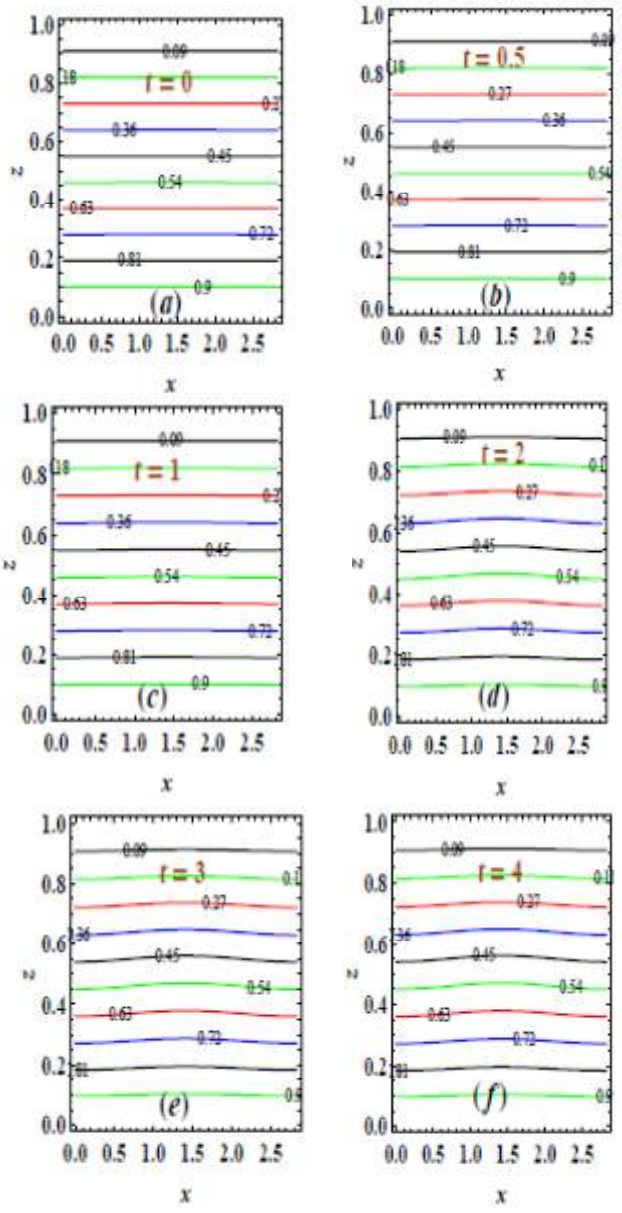

Fig. 13 : Isotherms at (a) t = 0.0, (b) t = 0.5, (c) t = 1.0, (d) t = 2.0, (e) t = 3.0, (f) t = 4.0

1. Prandtl number *Pr*: effect of heat and mass transport only for short time.
2. Concentration Rayleigh number parameter *Rn*: heat and nanoparticles mass transports decrease.
3. Lewis number *Le*: heat and nanoparticles mass transports decrease.
4. Modified thermophoresis to Brownian-motion diffusivity ratio N_A: heat and nanoparticles mass transports decrease.

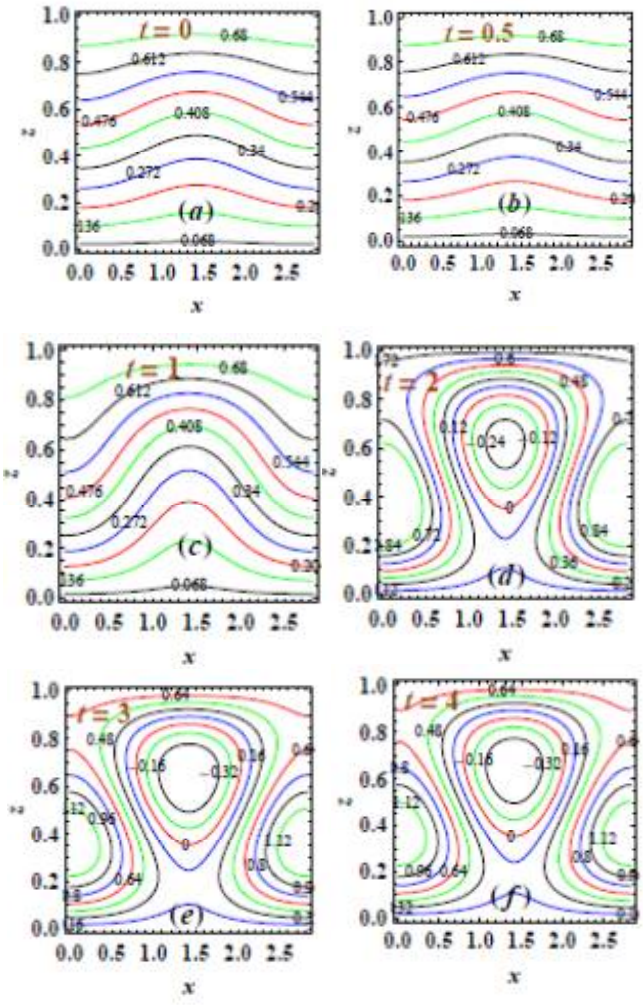

Fig. 14: Isohalines at (a) t = 0.0, (b) t = 0.5, (c) t = 1.0, (d) t = 2.0, (e) t = 3.0, (f) t = 4.0.

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RESEARCH ARTICLE

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Convection in an Anisotropic Porous Medium with Temperature Dependent Viscosity and Throughflow under G-jitter

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ABSTRACT

In the present article, we study the combined effect of variable viscosity and throughflow in an anisotropic porous media under gravity modulation by reducing the model equations into Ginzgburg-Landau equation. A weakly non-linear stability analysis has been performed by adopting power series expansion in terms of the amplitude (assumed to be small) of gravity modulation. The Nusselt number is obtained in terms of the amplitude for the stationary mode of convection. Heat transfer mechanism is done by Nusselt number by taking different parameters, and depicted it graphically. Further, it is found that on increasing the value of thermo-rheological parameter, heat transport is more in the system. An increment in the amplitude (frequency) of gravity modulation enhances (diminishes) the heat transport. The behavior of Vadasz number, anisotropic parameters, and Peclet number are also studied.

INTRODUCTION

Anisotropy in porous medium comes from asymmetric geometry of porous matrix or fibres. Studies of thermal instability in an anisotropic porous media plays very significant roles in many research fields; such as in petroleum industry, chemical engineering, sedimentation and compaction, etc. Some of the convection problems with anisotropic porous medium are; Epherre (1977), Kvernvold and Tyvand (1979), Nisen and Storesletten (1990), Tyvand and Storesletten (1991), Degan et al. (1995), Nield and Kuznetsov (2003, 2007), Govender (2006, 2007), Malashetty and Heera (2006), Malashetty and Swamy (2007), Simmons et al. (2010) and Altawallbeh et al. (2013). Recently Alok et al. (2013) Bhadauria and Kiran (2013a), gave the model for anisotropic porous medium with variable viscosity. When the fluid viscosity changes with temperature, the top and bottom structures of fluid layer differ from each other, this is known as non-Boussinesq effect. For instance, in coal slurries, the viscosity of the fluid varies with temperature. A number of research articles where dynamic viscosity of fluid considered as function of temperature are available in the literature. Richardson and Straughan (1993) studied the problem of convection in porous medium when the viscosity depends on temperature for vanishingly small initial data thresholds. Payne et al. (1999) derived unconditional nonlinear stability for temperature-sensitive fluid in porous media. Nield (1996), Holzbecher (1998), Rees et al. (2002), Siddheshwar and Chan (2004) and Siddheshwar and Vanishree (2010) studied the effects of variable viscosity on convection problems in a porous medium. Recently, Bhadauria and Kiran (2013b) studied the variable viscosity in a fluid layer.

The concept of throughflow is used to control the convective mechanism in engineering sciences, industries, geophysics etc. The basic state temperature profile of throughflow changes from linear to non-linear with layer height, which affects the stability of the system. The effect of throughflow on the onset of convection in a horizontal porous layer has been studied by Wooding (1960), Sutton (1970), Homsy and Sherwood (1976), Jones and Persichetti (1986). Nield (1987) and Shivakumara (1997) showed that a small amount of throughflow can have a destabilizing effect.

Khalili and Shivakumara (1998) have investigated the effect of throughflow and internal heat generation on the onset of convection in a porous medium. The authors found that throughflow destabilizes the system even when the boundaries are identical. The non-Darcian effects on convective instability in a porous medium with throughflow has been studied in order to account for inertia and boundary effects by Shivakumara (1999). Shivakumara and Nanjundappa (2006) investigated analytically, the effects of quadratic drag and vertical throughflow on double diffusive convection in a horizontal porous medium using the Forchheimer extended Darcy equation. It is found that irrespective of the nature of boundaries, a small amount of throughflow in either of its direction destabilizes the system. Shivakumara and Sureshkumar (2007) have studied convective instability in non-Newtonian fluid saturated porous medium in the presence of vertical throughflow and found that throughflow has stabilizing or destabilizing effect depending on the boundaries and the directions of the flow. Brevdo (2009) investigated three-dimensional absolute and convective instabilities at the onset of convection in a porous medium with inclined temperature gradient and vertical throughflow. Barletta et al. (2010) analyzed the convective roll instabilities of vertical through flow with viscous dissipation in a horizontal porous medium. Reza and Gupta (2012) investigated the effect of through flow on the onset of convection in a horizontal layer of electrically conducting fluid, confined between two rigid permeable boundaries, and heated from below in the presence of a uniform vertical magnetic field. They found that magnetic field inhabits the onset of steady convection, and a positive throughflow is more stabilizing than negative throughflow. Recently, Nield and Kuznetsov (2010), Bhadauria and kiran (2015) studied the effect of throughflow in porous medium for different model.

External regulation of convection is important either for enhancing or diminishing heat transfer in a physical system. These types of regulations (e.g. thermal, gravity, rotation and magnetic field modulation) are used effectively to control convective phenomenon. First of all, Gresho and Sani (1970) studied the thermal instability under gravity modulation, in their model they observed that the gravity modulation enables the system to get control on its instability either by suitably adjusting the values of frequency or the amplitude of modulation. The related studies of gravity modulation are given in Malashetty and Padmavathi (1997), Malashetty and Swamy (2011), Bhadauria and Kiran (2014a, b).

In this paper, our aim is to study convection in an anisotropic porous medium with temperature dependent viscosity and throughflow under gravity modulation. The heat transfer rate is examined by computing the Nusselt number in terms of the amplitude of convection by solving the Ginzburg-Landau equation and presented graphically. It is observed that modulation and throughflow has tendency to control the convective phenomenon. The influence of other convective parameters on the system is also studied.

MATHEMATICAL STRUCTURE

An infinitely extended horizontal anisotropic porous layer of depth d, confined between two parallel planes; the lower plane at $z=0$ while the upper plane at $z=d$. A Cartesian frame of reference is adopted in such a way that the origin lies on the lower plane and z axis is vertically upward. The porous layer is heated from below and cooled from the above. The physical configuration of the model is depicted in Fig. 1. The Darcy law and Oberbeck-Boussinesq approximation is adopted to solve the model equations. The non-dimensionlized system of the model equations is obtain according to Alok et al (2013), Bhadauria and Kiran (2015) as

$$\frac{1}{V_a}\frac{\partial}{\partial t}(\nabla^2\psi) = -\bar{\mu}(T)\nabla^2_{\xi}\psi - \frac{1}{\xi}\frac{\partial\bar{\mu}(T)}{\partial z}\frac{\partial\psi}{\partial z} - R_a(1+\varepsilon^2\delta cos(\Omega t))\frac{\partial T}{\partial x}, \tag{1}$$

$$-\frac{\partial\psi}{\partial x}\frac{\partial T_b}{\partial z} - \left(\nabla^2_{\eta} - P_e\frac{\partial}{\partial z}\right)T = -\frac{\partial T}{\partial t} + \frac{\partial(\psi,T)}{\partial(x,z)}, \tag{2}$$

where $V_a = \frac{\phi\nu d^2}{K_z\kappa_{Tz}}$ Vadasz number, $R_a = \frac{\alpha_T g_0 \Delta T d K_z}{\nu\kappa_{Tz}}$ thermal Rayleigh number, $\bar{\mu}(T) = \frac{1}{1+\varepsilon^2 V\ T}$ the weak viscosity variation since is small quantity, $V = \delta_0\Delta T$ variable viscosity parameter, $P_e = \frac{w_0 d}{\kappa_{Tz}}$ Peclet number and other variables have their usual meanings.

The externally imposed thermal boundary conditions are given by

$$T = \begin{cases} T_0 + \Delta T, & \text{at } z = 0, \\ T_0 & \text{at } z = d. \end{cases} \tag{3}$$

The basic state temperature present in Eq. (2) is obtained by using the above boundary condition Eqs. (3) as

$$T_b = T_0 + \left(\frac{e^{Pe\, z} - e^{P_e}}{1 - e^{P_e}} \right) \Delta T. \tag{4}$$

Here we consider small variation of time, and re-scaling it as $\tau = \varepsilon^2 t$. Further, we solve Eq. (1) and Eq. (2) by using $\overline{\mu}(T) = \overline{\mu}(T_b)$ (Nield, 1996) and adopting impermeable boundary conditions as given below

ψ =0 and T=0 at z=0,

ψ =0 and T=0 at z=1. (5)

FORMULATION OF GINZBURG-LANDAU EQUATION

In Eq. (1) and (2) we, introduce a small perturbation parameter ε, which shows a deviation from the critical state of onset of convection. The variables for a weak non-linear state may be expanded in power series of ε, as in Malkus (1958) and Venezian (1969), are

$$\begin{aligned} R_a &= R_0 + \varepsilon^2 R_2 + \varepsilon^4 R_4 + \cdots \\ \psi &= \varepsilon\psi_1 + \varepsilon^2\psi_2 + \varepsilon^3\psi_3 + \cdots \\ T &= \varepsilon T_1 + \varepsilon^2 T_2 + \varepsilon^3 T_3 + \cdots, \end{aligned} \tag{6}$$

where denotes the critical value of the Rayleigh number at which the onset of convection takes place in the absence of gravity modulation. Now we compare the coefficients of different powers of perturbation parameter.

For the first order, the matrix operator is obtain similar to linear case as

$$\begin{bmatrix} \nabla_\xi^2 & R_0 \dfrac{\partial}{\partial x} \\ -\dfrac{\partial}{\partial x}\dfrac{\partial T_b}{\partial z} & -\left(\nabla_\eta^2 - P_e \dfrac{\partial}{\partial z} \right) \end{bmatrix} \begin{bmatrix} \psi_1 \\ T_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}. \tag{7}$$

The solution of the first order system subject to the boundary conditions Eq. (5), is assumed to be

$$\psi_1 = A(\tau) \sin ax \ \sin \pi z, \tag{8}$$

$$T_1 = -\frac{4a\pi^2}{(P_e^2 + 4\pi^2)(\eta a^2 + \pi^2)} A(\tau) \cos ax \ \sin \pi z. \tag{9}$$

The values of the critical Rayleigh number and the corresponding wave number of the system for the stationary mode of convection are as given below:

$$R_{0c} = \frac{(\eta a^2 + \pi^2)(a^2 + \frac{\pi^2}{\xi})(P_e^2 + 4\pi^2)}{4\pi^2 a^2}, \tag{10}$$

$$a_c = \frac{\pi}{(\xi\eta)^{1/4}}. \tag{11}$$

In particular, for ξ =1 and η =1 (isotropic), we have

$$R_{0c} = \frac{(a^2 + \pi^2)^2 (P_e^2 + 4\pi^2)}{4\pi^2 a^2}, \tag{12}$$

$$a_c = \pi, \tag{13}$$

which are the results obtained by Bhadauria and Kiran (2015) recently.

Now at second order, we have

$$\begin{bmatrix} \nabla_\xi^2 & R_0 \dfrac{\partial}{\partial x} \\ -\dfrac{\partial}{\partial x}\dfrac{\partial T_b}{\partial z} & -\left(\nabla_\eta^2 - P_e \dfrac{\partial}{\partial z} \right) \end{bmatrix} \begin{bmatrix} \psi_2 \\ T_2 \end{bmatrix} = \begin{bmatrix} R_{21} \\ R_{22} \end{bmatrix}, \tag{14}$$

where

$$R_{21} = 0, \tag{15}$$

$$R_{22} = \frac{\partial \psi_1}{\partial x}\frac{\partial T_1}{\partial z} - \frac{\partial \psi_1}{\partial z}\frac{\partial T_1}{\partial x}. \tag{16}$$

The second order solution subject to the boundary condition (5) is given by

$$\psi_2 = 0, \tag{17}$$

$$T_2 = -\frac{2a^2\pi^3}{(\eta a^2 + \pi^2)(P_e^2 + 4\pi^2)^2} A^2(\tau) sin(2\pi z). \tag{18}$$

The horizontally averaged Nusselt number $N_u(\tau)$, for the stationary mode of convection is given by

$$N_u(\tau) = 1 + \left[\left(\frac{\partial T_2}{\partial z} \right)_{z=0} / \left(\frac{dT_b}{dz} \right)_{z=0} \right]. \tag{19}$$

By using Eq. (4) and (18), we can simplify Eq. (19) as

$$N_u(\tau) = 1 + \frac{4\pi^4 a^2 (e^{P_e} - 1)}{P_e(\eta a^2 + \pi^2)(P_e^2 + 4\pi^2)^2} A^2(\tau). \quad (20)$$

It is clear that the gravity modulation is effective at third order and affects $N_u(\tau)$ through which is evaluated at third order. At the third order, we have

$$\begin{bmatrix} \nabla_\xi^2 & R_0 \frac{\partial}{\partial x} \\ -\frac{\partial}{\partial x}\frac{\partial T_b}{\partial z} & -\left(\nabla_\eta^2 - P_e \frac{\partial}{\partial z}\right) \end{bmatrix} \begin{bmatrix} \psi_3 \\ T_3 \end{bmatrix} = \begin{bmatrix} R_{31} \\ R_{32} \end{bmatrix}, \quad (21)$$

where

$$R_{31} = -(1-e^{Pe})^2 \frac{1}{V_a}\frac{\partial}{\partial \tau}\left(\nabla^2 \psi_1\right) - V(e^{Pez} - e^{Pe})(1-e^{Pe})\left(\nabla_\xi^2 \psi_1\right)$$

$$+(1-e^{Pe})\frac{V}{\xi} e^{Pez} Pe \frac{\partial \psi_1}{\partial z} - [R_0 (2V(e^{P_e z} - e^{P_e})(1-e^{P_e})$$

$$+\delta \cos(\Omega\tau)(1-e^{P_e})^2) + R_2 (1-e^{P_e})^2] \frac{\partial T_1}{\partial x}, \quad (22)$$

$$R_{32} = \frac{\partial \psi_1}{\partial x}\frac{\partial T_2}{\partial z} - \frac{\partial T_1}{\partial \tau}. \quad (23)$$

Using first/second order solutions, the expressions of R_{31} and R_{32} are determined. Now, under the solvability condition for the existence of third order solution, one may derive the Ginzburg-Landau equation for finite amplitude convection as

$$A_1 \frac{dA(\tau)}{d\tau} + A_2 A(\tau) + A_3 A(\tau)^3 = 0, \quad (24)$$

where

$$A_1 = \frac{c}{V_a}(1-e^{P_e})^2 + \frac{4\pi^2 a^2 R_0 (1-e^{P_e})^2}{(\eta a^2 + \pi^2)^2 (P_e^2 + 4\pi^2)},$$

$$A_2 = V(1-e^{Pe})\left(a^2 + \frac{\pi^2}{\xi}\right)\left(\frac{4\pi^2 + e^{Pe}(Pe^3 + 4(Pe-1)\pi^2)}{Pe(Pe^2 + 4\pi^2)}\right) + 2(1-e^{Pe})^2 \frac{V}{\xi}\pi^2 \left(\frac{Pe}{Pe^2 + 4\pi^2}\right)$$
$$- \frac{4\pi^2 a^2 R_0 (1-e^{Pe})^2 (1+\delta\cos(\Omega\tau))}{(\eta a^2 + \pi^2)(Pe^2 + 4\pi^2)},$$

$$A_3 = \frac{2\pi^4 a^4 R_0 (1-e^{P_e})^2}{(\eta a^2 + \pi^2)^2 (P_e^2 + 4\pi^2)^2}.$$

The Eq. (24) (Ginzburg-Landau equation) is solved numerically using the function NDSolve of Mathematica, subject to the suitable initial condition $A(0) = a_0$, where a_0 is chosen as initial amplitude of convection. In our computation, we assume to keep the parameters to the minimum.

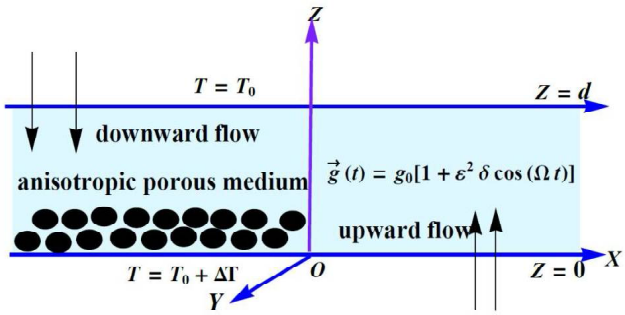

Fig. 1. Physical configuration of the problem

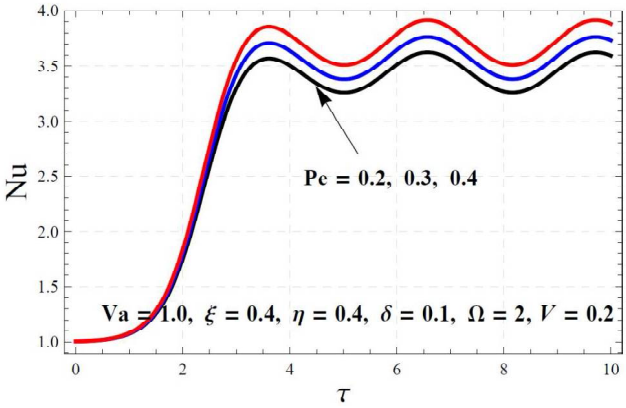

Fig. 2. Effect of Pe on Nu

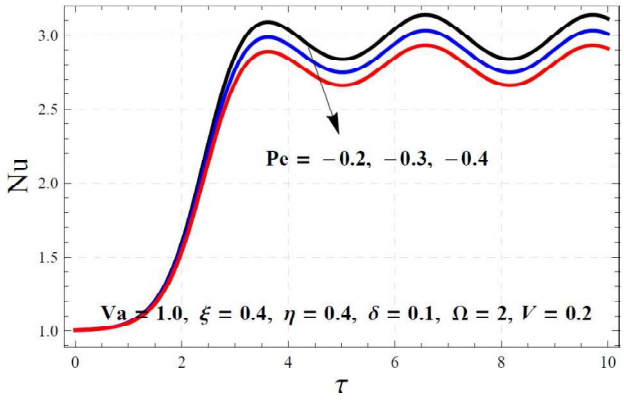

Fig. 3. Effect of Pe on Nu

RESULTS AND DISCUSSION

The present article deals with the study of convective

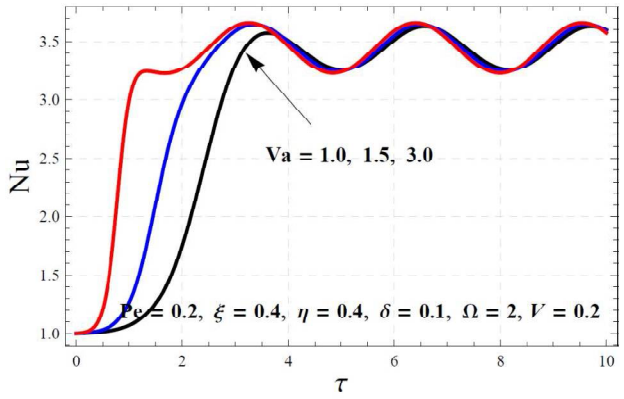

Fig. 4. Effect of Va on Nu

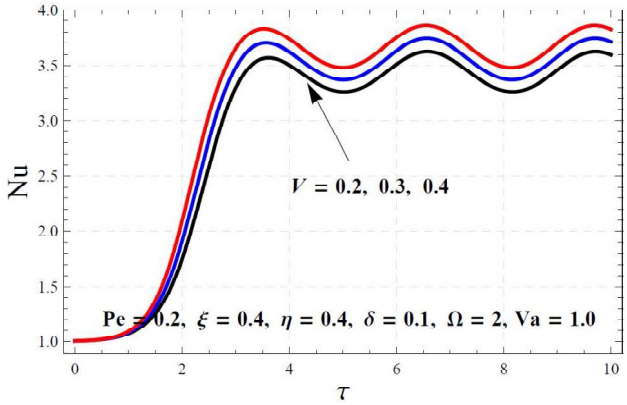

Fig. 5. Effect of V on Nu

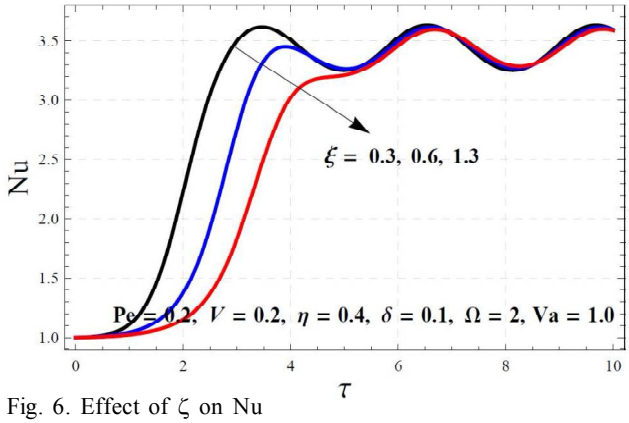

Fig. 6. Effect of ζ on Nu

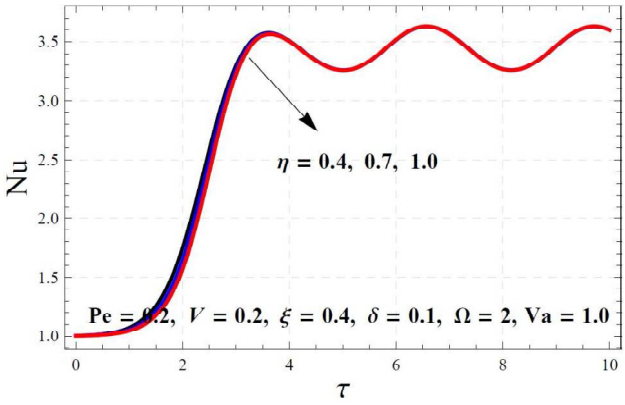

Fig. 7. Effect of η on Nu

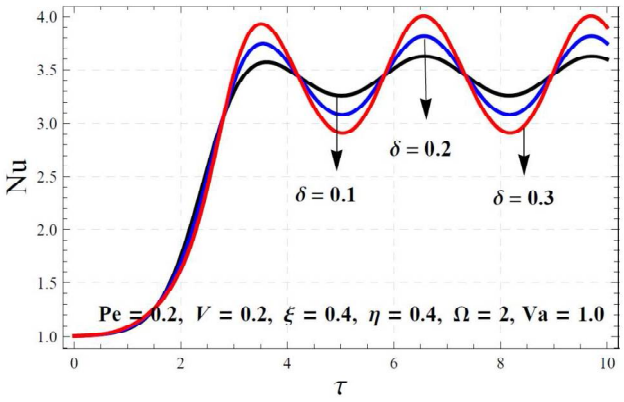

Fig. 8. Effect of δ on Nu

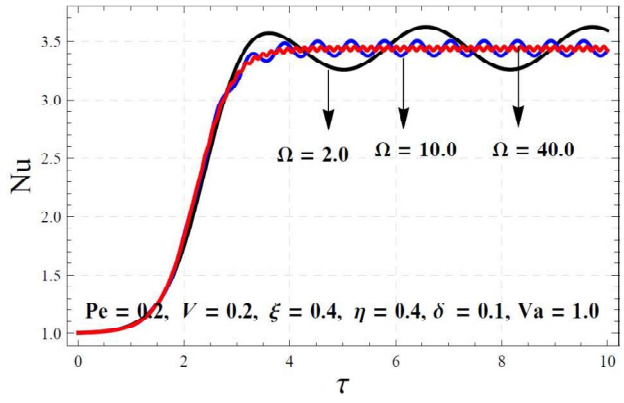

Fig. 9. Effect of Ω on Nu

flow under the effect of throughflow and variable viscosity in an anisotropic porous medium subject to gravity modulation. A weakly non-linear stability analysis has been performed by adopting power series expansion in terms of the amplitude (assumed to be small) of gravity modulation. The Nusselt number is obtained (numerically) in terms of the amplitude for the stationary mode of convection by using Ginzburg-Landu equation. The work of Nield (1996) has been used for the thermo-rheological relationship of temperature-dependent viscosity of the fluid. Here, we consider the value of V_a as one due to vadasz (1998). Heat transfer mechanism of the system is done in terms of Nusselt

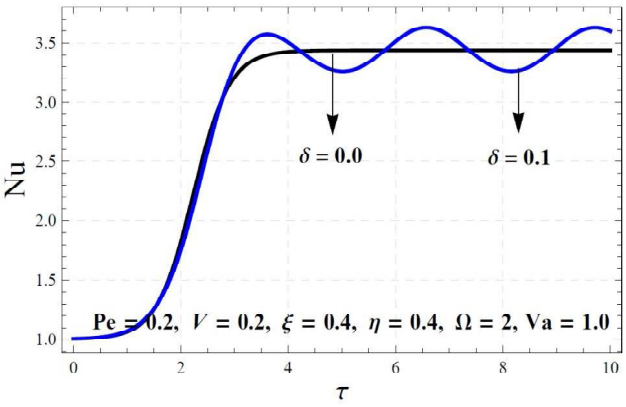

Fig. 10. Comparison of system

number by taking different parameters, and depicted graphically in Figs. (2-10). For isotropic porous media and constant viscosity under temperature modulation this model reduces in to Bhadauria and Kiran (2016) model.

Further, we have plotted N_u with respect to the slow time τ in Figs. (2-10) and see the influence of various parameters on the system. From Figs. 2-3, one can see that the effect of throughflow P_e on the system is destabilizing (stabilizing), as N_u increasing (decreasing) for $P_e > 0$ ($P_e < 0$). This agrees with the results due to Kiran and Bhadauria (2016). Hence, throughflow can be used as a tool to control the convective phenomenon. In Fig. 4, as V_a increases, there is an increment in the heat transfer, compatible with the results obtained by Alok et al. (2013), thus the Vadasz number has a tendency to destabilize the system. Fig. 5 indicates the effect of variable viscosity parameter V on thermal instability as to destabilize the system since heat transport increases on increasing the value of V. Further, the effect of ζ is found to stabilize the system as the heat transfer decreases on increasing ζ, given in Fig. 6. There is not much effect on the system on increasing the value of η, as depicted in Fig. 7. Hence, it is noticed that η is a dummy variable in our study, which is compatible with the results obtained by Bhadauria and Kiran (2013a). The effects of the amplitude of modulation δ and frequency of modulation Ω on heat transport are given in Figs. 8-9 respectively. In Fig. 8, one can see that an increment in amplitude of modulation increases the magnitude of N_u, thus enhances the heat transfer and advancing the convection. An opposite effect is obtained in the case of frequency of modulation Ω as given in Fig. 9. Hence, we found that the effect of gravity modulation decreases as the frequency of modulation increases. In the last, we compared the results of modulated and unmodulated systems and presented them in Fig. 10. It is found that in modulated system heat transfer is more than the unmodulated system.

CONCLUSIONS

In the present paper, we study thermal instability under the combined effects of variable viscosity and throughflow in an anisotropic porous media subject to gravity modulation, and perform a weakly non-linear stability analysis by using the Ginzburg-Landau equation. The following conclusions are drawn:

a) The system shows destabilizing or stabilizing effect according as $P_e > 0$ or $P_e < 0$.

b) Vadasz number V_a and thermo-rheological parameter V have destabilizing effect on the system.

c) The anisotropic parameter ζ has stabilizing effect on the system as heat transport decreases on increasing the value of ζ.

d) Effect of η on the system is negligible.

e) An increment in the amplitude of modulation δ is to advance the convection and heat transfer.

f) The frequency of modulation Ω is to decrease the heat transfer.

g) Heat transfer is more in the present case than in the absence of modulation.

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RESEARCH ARTICLE

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Weak nonlinear rotating Bénard convection with modulation using Ginzburg-Landau model

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ABSTRACT

This article theoretically investigates the effect of modulated rotation speed on rotating Rayleigh-Bénard convection. The Rayleigh-Bénard momentum equation with Coriolis term has been used to describe the fluid flow in the medium. The system is consider to rotate about vertical axis with non-uniform rotational speed consisting of steady and time dependent parts. In particular, we assume that the rotation speed i.e time dependent part is varying sinusoidally with time. A nonlinear stability analysis has been performed to find the effect of modulation on heat transport. The heat transfer quotient, Nusselt number obtained in terms of amplitude and frequency of modulation, and depicted graphically with respect to slow time, showing the effect of various parameters of the system on heat transport. It is found that the effect of rotation speed modulation is to stabilize or destabilize the system depending on the amplitude and frequency of modulation. The corresponding streamlines and isotherms are presented at different states of slow time τ.

INTRODUCTION

The classical Bénard convection due to bottom heating is widely known and is a highly explored phenomenon given in two excellent books Chandrasekhar [1] and Drazin and Reid [2]. Over decades many researchers have investigated how to control the convective phenomena in a horizontal fluid layer by imposing external physical constraints like modulation which includes temperature, gravity, magnetic field and rotation etc. Venezian [3] was the first to perform a linear stability analysis of Rayleigh-Bénard convection under temperature modulation considering free-free boundaries. While deriving the shift in the critical Rayleigh number as a function of frequency of modulation, he found that it is possible to delay or advance the onset of convection by time modulation on wall temperature. The same problem considering different physical models under temperature modulation was studied by [4-18].

A brief study of the combined effect of thermal modulation and rotation on the onset of convection in a rotating fluid layer was made by Rauscher and Kelly [19]. Liu and Ecke [20] analyzed heat transport of turbulent Rayleigh-Bénard convection under rotational effect. Malashetty and Swamy [21] investigated thermal instability of a heated fluid layer subject to both, rotation and temperature modulation. Kloosterziel and Carnevale [22] investigated the effect of rotation on the stability of thermally modulated system. Malashetty and Swamy [23] studied the effect of rotation on the stability of thermally modulated system. Bhadauria [24] investigated rotational influence on Darcy convection and found that both rotation and permeability suppress the onset of thermal instability. Bhadauria et al. [25] investigated the nonlinear thermal instability in a rotating viscous fluid layer under temperature/gravity modulation using Ginzburg-Landau model. They found that rotation has stabilizing effect and it reduces heat transfer in the system for both modulations. The effect of rotational speed modulation and internal heating on Rayleigh Bénard convection investigated By Bhadauria and Kiran [26]. They found that rotation reduces and internal heating increases heat transfer in the system. The effect of gravity modulation on electrically conducting fluid layer is studied by Bhadauria and Kiran [27]. They found that gravity modulation can be used to regulate heat transfer in the system, and magnetic field is to decrease the heat transfer in the system. The patterns of streamlines and isotherms

are drawn and explained their nature. Other related studies for modulation either for temperature or gravity modulation the reader may refer the studies of [28-33]. We also see other models in which heat transfer related studies have been discussed. Shooshtari and Razavi [35] investigated nonlinear free and forced vibration of a transversely isotropic rectangular magneto-electro-elastic thin plate with supported boundary conditions and closed circuit electro-magnetic boundary conditions at top and bottom surfaces of the plate is studied for the first time based on the thin plate theory along with the von Karmans nonlinear strains. Kumar and Devi [35] studied a global nonlinear stability analysis is performed for a couple-stress fluid layer heated from below saturating a porous medium with temperature-pressure dependent viscosity for different conducting boundary systems. The effect of magnetic field on an incompressible viscoelastic rotating fluid heated from below in porous medium is analyzed by Kumar et al.[37]. They found that magnetic field and permeability have both stabilizing and destabilizing effect on the thermal convection under some conditions whereas rotation has a stabilizing effect on the thermal convection. Arani et al [38] an experimental and numerical results of heat transfer from a heated rotating disk in still air are presented over a large range of inclination angles and a dimensionless correlation is developed for forced, natural and mixed convection. Tamim and Abbassi [39] investigated the problem of unsteady mixed convection while considering boundary layer flow of a viscous incompressible fluid near the stagnation-point on a vertical permeable plate with both cases of prescribed wall temperature and prescribed wall heat flux is investigated numerically. Sheikhzadeh et al.[40] the natural convection heat transfer of Al_2 O_2-EG-water nanofluid in a rectangular cavity which is heated from the bottom and is cooled from the top has been investigated numerically. Their focused on the effects of variable thermophysical properties of nanofluid on the heat transfer in natural convection. The transient MHD laminar free convection flow of nano-fluid past a vertical surface is investigated by Freidoonimehr et al.[41] Concerning natural convection heat transfer of nanofluid in a two-dimensional square cavity containing several pairs of heater and coolers was investigated by Garoosi et al.[42]. Using differential transform method (DTM) the combined free and forced (mixed) convection about inclined surfaces in a saturated porous medium is investigated by Rashidi et al. [43] while considering both aiding and opposing flows. The other physical models which investigates convective heat transfers are [44-46].

Actually, the study of Venezian [3] was motivated by the experiment of Donnelly [47], in which, he investigated the effect of rotation speed modulation on the onset of instability in fluid flow between two concentric cylinders. However, the rotation speed modulation was the originating idea of the temperature as well as gravity modulation, but the available literature in this field is scarce. For Rayleigh-Bénard convection the temperature modulation is supposed to stabilise the conduction state. However, complications set in, since the temperature modulation breaks the reflection symmetry about the mid-plane and hexagons, rather than cylinders, constitute the convection plan-form immediately above the threshold. For the Rayleigh-Bénard problem with rotation, the above problem can be avoided if the rotation speed is modulated. This leads to a cleaner problem for the study of the effect of modulation on the threshold. When we study the rotation effect then one more parameter, in the form of rotation speed, exists which can affect the stability of convective flow. Amongst the available studies, the study due to Bhattacharjee [48] is of great importance, in which he studied the effect of rotation speed modulation on Rayleigh-Bénard convection in ordinary fluid layer, and found stabilizing effect due to modulation. Bhadauria and Suthar [49] investigated the effect of the rotation speed modulation on the onset of free convection in a rotating porous layer placed farther away from the axis of rotation. Further. Om et al. [50] investigated the effect of the rotation speed modulation on the onset of free convection in a rotating porous layer, rotating about vertical axis.

From the above literature it is clear that most of the studies considered only linear theories which do not supportive to quantify heat transfer results. To the best of authors' knowledge, there is no nonlinear study available in the literature in which effect of rotation speed modulation has been considered. This motivated us to study nonlinear thermal convection under rotation speed modulation using Ginzbur-Landau model.

MATHEMATICAL FORMULATION

We consider an infinitely extended horizontal, viscous incompressible fluid layer, confined between two parallel planes which are at $z = 0$, lower plane and $z = d$, upper plane.

The lower surface is heated and upper surface is cooled to maintain an adverse temperature gradient across the fluid layer. We assume that the system is rotating with variable rotation speed , about the z-axis as shown in Fig.1. The effect of rotation is restricted to Coriolis term, and thus we neglect the centrifugal force term. The effect of density

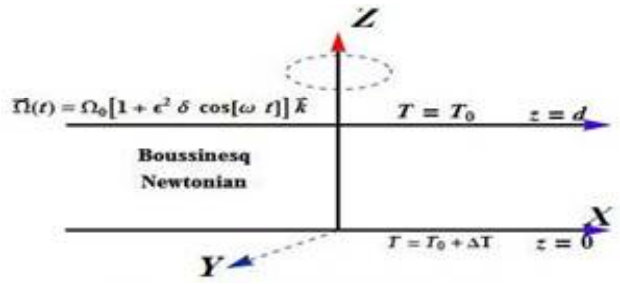

Fig.1 : Physical configuration of the problem

variation is considered by Boussinesq approximation. With these assumptions, the basic governing equations are (given by [25]):

$$\nabla \cdot \vec{q} = 0, \tag{1}$$

$$\frac{\partial \vec{q}}{\partial t} + (\vec{q}\cdot\nabla)\vec{q} + 2(\vec{\Omega}\times\vec{q}) = -\frac{1}{\rho_0}\nabla p + \frac{\rho}{\rho_0}\vec{g} + \nu\nabla^2\vec{q}, \tag{2}$$

$$\frac{\partial T}{\partial t} + (\vec{q}\cdot\nabla)T = \kappa_T\nabla^2 T, \tag{3}$$

$$\rho = \rho_0[1 - \alpha_T(T - T_0)], \tag{4}$$

The rotation speed is assumed to vary sinusoidally with respect to tim and it is given by [26,47]:

$$\vec{\Omega} = \Omega_0(1 + \varepsilon^2\delta\cos(\omega t))\hat{k}, \tag{5}$$

where the variables in the above equations are given in nomenclature, and , are the small amplitude and frequency of modulation, is a quantity that indicates the smallness in order of magnitude of modulation and *t* is the time. The considered thermal boundary conditions are.

$$T = T_0 + \Delta T \quad \text{at z=0, } T = T_0 \quad \text{at z=d} \tag{6}$$

The basic state is assumed to be quiescent i.e . The other quantities of the basic state are:

$$\vec{q} = q_b(z) \qquad \rho=\rho_b(z) \qquad T=T_b(z) \tag{7}$$

Substituting Eq.(7) into Eqs.(1)-(4), we get the following relations which help us to de ne basic state pressure and temperature:

$$\frac{dp_b}{dz} = -\rho_b g, \tag{8}$$

$$\kappa_T\frac{d^2(T_b - T_0)}{dz} = 0, \tag{9}$$

$$\rho_b = \rho_0[1 - \alpha_T(T_b - T_0)]. \tag{10}$$

The Eq.(9) is solved for $T_b(z)$ subject to the boundary condition Eq.(6), we get:

$$T_b = T_0 + \Delta T\left(1 - \frac{z}{d}\right), \tag{11}$$

The finite amplitude perturbations on the basic state are superposed in the form:

$$\vec{q} = q_b + \vec{q}', \quad \rho=\rho_b+\rho', \quad p=p_b+p', \quad T=T_b+T'. \tag{12}$$

Substituting Eq.(12) in Eqs.(1)-(4), and using the basic state solutions we obtain:

$$\nabla\cdot q' = 0, \tag{13}$$

$$\frac{\partial q'}{\partial t} + (q'\cdot\nabla)q' + 2(\vec{\Omega}\times q') = -\frac{\nabla p'}{\rho_0} + \alpha_T g T' + \nu\nabla^2 q', \tag{14}$$

$$\frac{\partial T'}{\partial t} + W'\frac{\partial T_b}{\partial z} + (q'\cdot\nabla)\,T' = \kappa_T\nabla^2 T'. \tag{15}$$

Since our study restricted to two dimensional convection we introduce stream function ψ as $u' = \frac{\partial\psi}{\partial z}$ & $w' = -\frac{\partial\psi}{\partial x}$. Also the non-dimensional physical variables resealed as

$$(x, y, z) = d(x^*, y^*, z^*), \; t = \frac{d^2}{\kappa_T}t^* \; q' = \frac{\kappa_T}{d}q^* \; \psi = \kappa_T\psi^* \quad T = \Delta T T^*$$

& $\omega^* = \frac{\kappa_T}{d^2}\omega$. Finally using the above dimensionless quantities into Eqs.(13-15), eliminating the pressure term from momentum equation (dropping the asterisk for simplicity) we obtain the non-dimensional governing system as:

$$\frac{1}{\Pr}\frac{\partial}{\partial t}(\nabla^2\psi) - \frac{1}{\Pr}\frac{\partial(\psi,\nabla^2\psi)}{(x,z)} = -Ra_T\frac{\partial T}{\partial x} + \nabla^4\psi + \sqrt{Ta}(1 + \varepsilon^2\delta\cos(\omega t))\frac{\partial V}{\partial z}, \tag{16}$$

$$-\frac{\partial\psi}{\partial x}\frac{\partial T_b}{\partial z} + \nabla^2 T = -\frac{\partial T}{\partial t} + \frac{\partial(\psi, T)}{\partial(x, z)}, \tag{17}$$

Also from Eq.(16), we may write the following equation for V:

$$\frac{1}{\Pr}\frac{\partial V}{\partial t} - \nabla^2 V = -\sqrt{Ta}(1 + \varepsilon^2\delta\cos(\omega t))\frac{\partial\psi}{\partial z} + \frac{1}{\Pr}\frac{\partial(\psi, V)}{\partial(x, z)} \tag{18}$$

The non-dimensionless parameters in the above equations are given in nomenclature. We assume small variations of time and re-scaling it as $\tau=\varepsilon^2 \tau$, to study the stationary convection of the system. It is to be noted that in our study we are not considering overstable solutions of the system. We write the nonlinear Eqs.(16-18) in the matrix form as given bellow

$$\begin{bmatrix} \frac{\varepsilon^2}{\mathrm{Pr}}\frac{\partial}{\partial\tau}\nabla^2-\nabla^4 & Ra_T\frac{\partial}{\partial x} & -\sqrt{Ta}\frac{\partial}{\partial z} \\ \frac{\partial}{\partial x} & -\varepsilon^2\frac{\partial}{\partial\tau}-\nabla^2 & 0 \\ \sqrt{Ta}\frac{\partial}{\partial z} & 0 & -\frac{\varepsilon^2}{\mathrm{Pr}}\frac{\partial}{\partial\tau}-\nabla^2 \end{bmatrix} \begin{bmatrix} \psi \\ T \\ V \end{bmatrix} = \begin{bmatrix} \frac{1}{\mathrm{Pr}}\frac{\partial(\psi,\nabla^2\psi)}{(x,z)}+\sqrt{Ta}\varepsilon^2\delta\cos(\omega\tau)\frac{\partial V}{\partial z} \\ \frac{\partial(\psi,T)}{\partial(x,z)} \\ \frac{1}{\mathrm{Pr}}\frac{\partial(\psi,V)}{\partial(x,z)}-\sqrt{Ta}\varepsilon^2\delta\cos(\omega\tau)\frac{\partial\psi}{\partial z} \end{bmatrix} \quad (19)$$

We considering stress free and isothermal boundary (for these free surfaces, no tangential stresses act) conditions as given bellow (given by Bhadauria et [25,26]):

$$\psi=\frac{\partial^2\psi}{\partial z^2}=\frac{\partial V}{\partial z}=T=0 \text{ at z=0 and z=1.} \quad (20)$$

HEAT TRANSPORT FOR STATIONARY INSTABILITY

In order to solve the above nonlinear system we introduce the following asymptotic expansions in Eqs.(19-20), as earlier used by Malkus and Veronis [34] for finite amplitude convection:

$$\begin{aligned} \psi &= \varepsilon\psi_1+\varepsilon^2\psi_2+\varepsilon^3\psi_2+.. \\ T &= \varepsilon T_1+\varepsilon^2 T_2+\varepsilon^3 T_3+.. \\ V &= \varepsilon V_1+\varepsilon^2 V_2+\varepsilon^3 V_3+.. \end{aligned} \quad (21)$$

where R_{oc} is the critical value of the Rayleigh number at which the onset of convection takes place in the absence of modulation. It is required that expressions Eq.(22) satisfy the above nonlinear system for all the values of ε less than some maximum ε. The coefficients of each power of generated while

substituting the expressions in Eq.(22) into the nonlinear system must vanish individually and the resulting series for each of the variables must converge if relations Eq.(22) are to represent a satisfactory solution to the problem. Now we solve the system for different orders of ε.

At the lowest order, we have:

$$\begin{bmatrix} -\nabla^4 & R_{0c}\frac{\partial}{\partial x} & -\sqrt{Ta}\frac{\partial}{\partial z} \\ \frac{\partial}{\partial x} & -\nabla^2 & 0 \\ \sqrt{Ta}\frac{\partial}{\partial z} & 0 & -\nabla^2 \end{bmatrix} \begin{bmatrix} \psi_1 \\ T_1 \\ V_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \quad (22)$$

The solution of the lowest order system subject to the boundary conditions Eq.(20), is

$$\psi_1 = A(\tau)\sin(\mathrm{k}_c\mathrm{x})\sin(\pi z) \quad (23)$$

$$T_1 = -\frac{k_c}{\beta^2}A(\tau)\cos(k_c x)\sin(\pi z) \quad (24)$$

$$V_1 = -\frac{\pi\sqrt{Ta}}{\beta^2}A(\tau)\sin(k_c x)\cos(\pi z), \quad (25)$$

whereThe critical value of the Rayleigh number for the onset of stationary convection is calculated numerically, and the expression is given by:

$$R_{0c}=\frac{(\beta^6+\pi^2 Ta)}{k_c^2}. \quad (26)$$

For the system without rotation (Ta = 0) we get: $R_{0c}=\frac{\beta^6}{k_c^2}$, and the corresponding wavenumber: $k_c=\frac{\pi}{\sqrt{2}}$, which are the classical results obtained by Chandrasekhar [1].

At the second order, we have

$$\begin{bmatrix} -\nabla^4 & R_{0c}\frac{\partial}{\partial x} & -\sqrt{Ta}\frac{\partial}{\partial z} \\ \frac{\partial}{\partial x} & -\nabla^2 & 0 \\ \sqrt{Ta}\frac{\partial}{\partial z} & 0 & -\nabla^2 \end{bmatrix} \begin{bmatrix} \psi_2 \\ T_2 \\ V_2 \end{bmatrix} = \begin{bmatrix} R_{21} \\ R_{22} \\ R_{23} \end{bmatrix} \quad (27)$$

$$R_{21}=0, \quad (28)$$

$$R_{22}=\frac{\partial\psi_1}{\partial x}\frac{\partial T_1}{\partial z}-\frac{\partial\psi_1}{\partial z}\frac{\partial T_1}{\partial x}, \quad (29)$$

$$R_{23}=\frac{\partial\psi_1}{\partial x}\frac{\partial V_1}{\partial z}-\frac{\partial\psi_1}{\partial z}\frac{\partial V_1}{\partial x}. \quad (30)$$

The second order solutions subject to the boundary conditions given by Eq.(20) is obtained as: (at this stage the second order solutions fully depending on first order solutions):

$$\psi_2 = 0, \tag{31}$$

$$T_2 = -\frac{k_c^2}{8\beta^2\pi} A^2(\tau)\sin(2\pi z), \tag{32}$$

$$V_2 = -\frac{\pi^2\sqrt{Ta}}{8k_c\,\mathrm{Pr}\,\beta^2} A^2(\tau)\sin(2k_c x). \tag{33}$$

The horizontally averaged Nusselt number Nu, for the stationary mode of convection, is

$$Nu(\tau) = 1 + \frac{\left[\dfrac{\mathrm{k}_c}{2\pi}\displaystyle\int_0^{\frac{2\pi}{\mathrm{k}_c}} \frac{\partial T_2}{\partial z}\,dx\right]_{z=0}}{\left[\dfrac{\mathrm{k}_c}{2\pi}\displaystyle\int_0^{\frac{2\pi}{\mathrm{k}_c}} \frac{\partial T_b}{\partial z}\,dx\right]_{z=0}} \tag{34}$$

Substituting the expression of T_2 and in Eq.(34) and simplifying, we get:

$$Nu(\tau) = 1 + \frac{\mathrm{k}_c^2}{4\beta^2} A^2(\tau) \tag{35}$$

At the third order, we have

$$\begin{bmatrix} -\nabla^4 & R_{0c}\dfrac{\partial}{\partial x} & -\sqrt{Ta}\dfrac{\partial}{\partial z} \\ \dfrac{\partial}{\partial x} & -\nabla^2 & 0 \\ \sqrt{Ta}\dfrac{\partial}{\partial z} & 0 & -\nabla^2 \end{bmatrix} \begin{bmatrix} \psi_3 \\ T_3 \\ V_3 \end{bmatrix} = \begin{bmatrix} R_{31} \\ R_{32} \\ R_{33} \end{bmatrix} \tag{36}$$

where

$$R_{31} = -\frac{1}{\mathrm{Pr}}\frac{\partial}{\partial\tau}\nabla^2\psi_1 + \sqrt{Ta}\delta\cos(\omega\tau)\frac{\partial V_1}{\partial z} - R_2\frac{\partial T_1}{\partial x}, \tag{37}$$

$$R_{32} = -\frac{\partial T_1}{\partial\tau} + \frac{\partial T_2}{\partial z}\frac{\partial\psi_1}{\partial x}, \tag{38}$$

$$R_{33} = -\frac{1}{\mathrm{Pr}}\frac{\partial V_1}{\partial\tau} - \frac{1}{\mathrm{Pr}}\frac{\partial\psi_1}{\partial z}\frac{\partial V_2}{\partial x} - \sqrt{Ta}\delta\cos(\omega\tau)\frac{\partial\psi_1}{\partial z}, \tag{39}$$

The terms in right hand side of the above equation is difficult to resolve so substituting first and second order solutions into Eqs.(37-(49) we obtain expressions for R_{31}, R_{32} and R_{33} easily. Now by applying the solvability condition for the existence of third order solution, we get the Ginzburg-Landau equation for stationary mode of convection with time-periodic coefficients in the form

$$A_1\frac{dA(\tau)}{d\tau} - A_2 A(\tau) + A_3 A(\tau)^3 = 0, \tag{40}$$

where the qoefficients are defined by:

$$A_1 = \left(\frac{\beta^2}{\mathrm{Pr}} + \frac{R_{0c}k_c^2}{\beta^4} - \frac{Ta\pi^2}{\mathrm{Pr}\,\beta^4}\right),\ A_2 = \left(\frac{R_2 k_c^2}{\beta^2} - \frac{2\pi^2 Ta}{\beta^2}\delta\cos(\omega\tau)\right),$$

$$A_2 = \left(\frac{R_{0c}k_c^4}{8\beta^4} + \frac{\pi^4 Ta}{8\,\mathrm{Pr}^2\,\beta^4}\right).$$

The Ginzburg-Landau amplitude equations given by Eq.(40) is a Bernoulli equation and obtaining its analytical solution is difficult, due to its non-autonomous nature. Therefore, it has been solved numerically using the in-built function NDSolve of Mathematica 8, subjected to the initial condition $A(0)=a_0$, where a_0 is the chosen initial amplitude of convection. In our calculations we may use $R_2=R_{0c}$ to keep the parameters to the minimum. This condition indicates that we are studying thermal instability near to the onset critical Rayleigh number.

RESULTS AND DISCUSSIONS

The present problem address a non-linear realm of Rayleigh-Bénard convection with rotation speed modulation. Here we have presented a weakly nonlinear stability analysis to investigate the effect of rotation speed modulation on heat transport. The modulation on Rayleigh-Bénard system has been assumed to be of order $O(\varepsilon^2)$ which shows that, only small amplitude of modulation is considered. This assumption will help us in obtaining an amplitude equation of simple manner and easier than the Lorenz model. Before presenting the discussion of the results, we mention some features of the following aspects of the problem.

1. The importance and need for non-linear stability analysis.
2. The relation of the problem to real application.
3. The selection of all dimensionless parameters utilized

in computations.

4. Consideration of numerical values for different parameters.

As mentioned in the introduction that it is important to study a nonlinear theory, if one wants to quantify heat transport in the system. As it is well known fact that the linea theory will not give an analysis of amplitude convection, therefore consideration of nonlinear theory is a fundamental technique where the coupling of momentum and energy flow takes place. When there is interaction between stream flow and thermal diffusion due to energy transmission the disturbances grow in strength of finite amplitude. In order to measure the strength of the finite amplitude one needs to account the nonlinearity in the system. Another additional thing is that modulation, external regulation of convection is important for controlling thermal instability, due to this rotation speed modulation is considered. Further, we obtain the effect of rotation speed modulation for either enhancing or inhibiting the convective heat transport as is required by a real application. The parameters that arise in the problem are *Pr, Ta, δ, ω* and these parameters influence the convective heat transport. The first parameter relate to the fluid layer and the next three parameters concern the external mechanism of controlling convection. The fluid layer is not considered to be highly viscous, therefore only moderate values of *Pr* are taken for calculations. Because of small amplitude of modulation, the values of δ are considered around 0.5. Further, the rotation speed modulation is assumed to be of low frequency, as at low range of frequencies, the effect of frequencies on the onset of convection is maximum**.**

In Figures (2-6), we have presented results for heat transfer Nusselt number *Nu(τ)* with respect to time ô for the case of rotation speed modulation. From the figures, we find that for lower values of time τ, the value of $Nu(\tau)$ does not alter and remains almost constant, then it increases on increasing τ, and finally becomes oscillatory on further increasing the time τ. It is clear from the figures that *Nu* starts with one, showing the conduction state, initially. From the Figure 2, we find that the Nusselt number *Nu* increases on increasing the Prandtl number *Pr*, for fixed values of other parameters. This may happen due to the dominating role of thermal diffusivity over kinematic viscosity. As Prandtl number *Pr* increases, then for no change in kinematic viscosity, probably there is a large decrement in thermal diffusivity, and this makes sudden increase in the temperature gradient. So convection takes place early, and there is an enhancement in heat transfer. Thus, the effect of an increment in Prandtl number *Pr* is to advance the

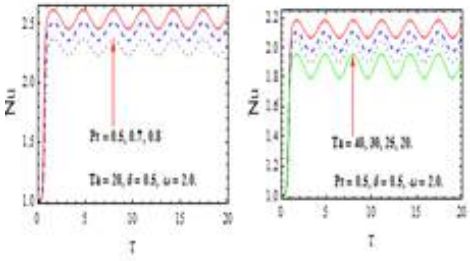

Fig .2 : Nu verses τ for different values of Pr Fig .3 : Nu verses τ for different values of Ta

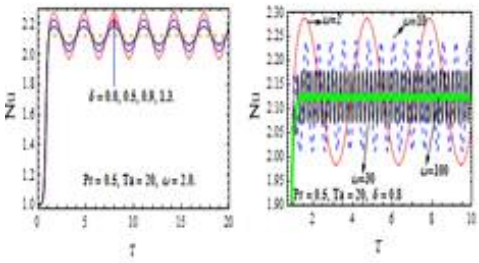

Fig .4 : Nu verses τ for different values of δ Fig .5 : Nu verses τ for different values of ω

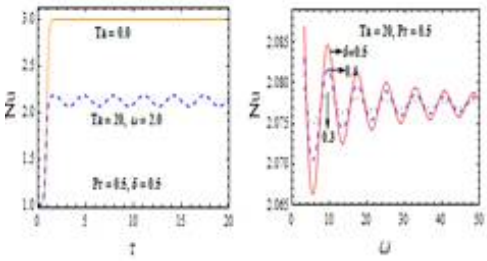

Fig .6 : Nu versus τ for different values of Ta and ω Fig .7 : Effect of amplitude on heat transport

convection, reader may also see the article [29]. We have the following this is the case of general implication of results for *Pr*.

In the Figure 3, we depict the effect of Taylor number *Ta* on *Nu* for fixed values of other parameters. An increment in Ta, increases the value of critical Rayleigh number R_{0c}, so delays the onset of convection [50], hence heat transport decreases. This is natural phenomenon for rotating fluid layer, where rotation always stabilize the system but, except for oscillatory case of nonlinear convection. Also, we observe from the figure that as Taylor number *Ta* increases the amplitude of modulation is also increasing so the effect of *Ta* is reflecting on amplitude of modulation. From the Eq.(40), it is clear that Taylor number *Ta* is multiple of amplitude of rotation speed modulation, which means the amplitude of rotation speed modulation is dependent of

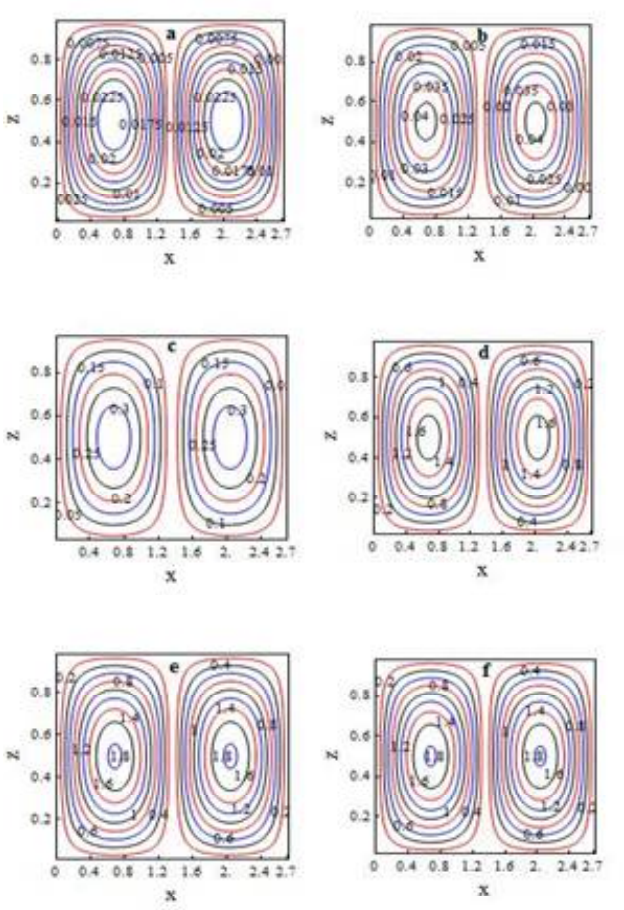

Fig .8: Streamlines at (a) τ = 0.0 (b) τ = 0.1 (c) τ = 0.5 (d) τ = 1.0 (e) τ = 1.5 (f) τ = 2.0

rotation. Generally, if there is no rotation i.e. (Ta=0), it is meaningless to talk about rotation speed modulation. In general have $Nu_{Ta=40} < Nu_{Ta=30} < Nu_{Ta=25} < Nu_{Ta=20}$.

In Figure 4 we show the effect of amplitude of modulation for moderate values of Ta, and for fixed values of other parameters. We find that increasing the value of δ is to increase Nu, hence advancing the convection so the heat transport. However, when δ=0, we obtain the results of unmodulated case. For amplitude effect one may have:

$$Nu_{\delta=0.5} < Nu_{\delta=0.9} < Nu_{\delta=1.3}$$

In Figure 5 we consider the effect of frequency of modulation on heat transport of the system. We found that heat transport is more at low modulation frequency ω, however, as ω increases, the effect of rotation speed modulation on Nu decreases, and also it shortens the wavelength of oscillations. As the modulation frequency increases from 2 to 100, the magnitude of Nu decreases, and so the effect of modulation on heat transport diminishes. On further increasing the value of ω, the effect of modulation on thermal instability disappears altogether, this conforms the results of [25,26.49.50]. Hence the effect of ω is to stabilize the system, one may have:

$$Nu_{\omega=100} < Nu_{\omega=30} < Nu_{\omega=10} < Nu_{\omega=2}$$

The Figure 6 shows that, the heat transport is more when there is no rotation Ta=0 (which means no modulation) than in the presence of rotation and modulation. Hence rotation and modulation together strongly stabilize the system and reduces heat transfer. The reader may note that, the study of Bhadauria and Kiran [26] gives a similar study, where they have considered the rotation speed modulation with internal heating and temperature dependent viscosity effects. The heat transfer results can be preserved from the studies of [26-33].

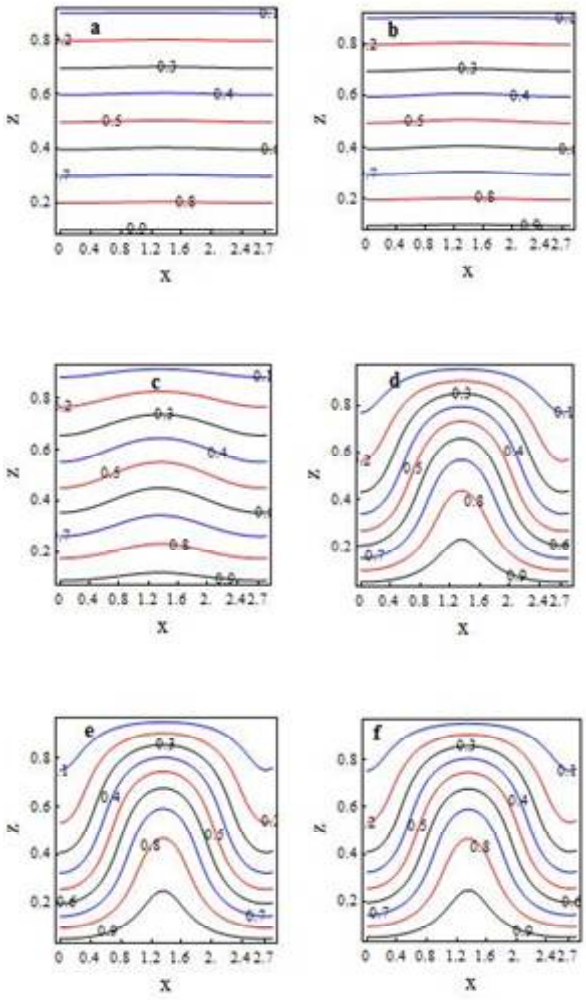

Fig .9: Isotherms at (a) τ = 0.0 (b) τ = 0.1 (c) τ = 0.5 (d) τ = 1.0 (e) τ = 1.5 (f) τ = 2.0

In order to observe clearly the effect of modulation on *Nu*, Figure 7 has been included. This figures show *Nu* as a function of modulation frequency, as amplitude increases there is increment in *Nu*, also as ω increases modulation effect decreases and finally disappears. In Figures 8 and 9, the stream lines and the corresponding isotherms are depicted, respectively at τ= 0.0,0.1,0.5,1.0,1.5 and 2.0 for *Pr*=0.5, *Ta*=20.0, δ=0.5 and and ω=2.0. From the figures we found that initially for lower values of time, the magnitude of streamlines is also small (Figures 8a,b) and isotherms are straight that is the system is in conduction state (Figures 9a,b). However, as time increases, the magnitude of streamlines increases and the isotherms loses their evenness. This shows that the convection is taking place in the system. Convection becomes faster on further increasing the value of time. However, the system achieves the study state beyond τ=1.0 as there is no change in the streamlines and isotherms (Figures 8-9d,e,f).

CONCLUSION

The effect of rotation speed modulation on Rayleigh-Bénard convection in a rotating horizontal fluid layer has been studied by employing non-linear stability analysis and using Ginzburg-Landau model. The results have been obtained in terms of the Nusselt number, and the effect of various parameters have been obtained and depicted graphically. We have the following observations

1. The effect of increasing Prandtl number *Pr* is to increase the heat transfer.
2. The effect of an increment in Taylor number is to delay the onset of convection and hence heat transfer.
3. An increment of modulation amplitude increases heat transfer.
4. On increasing the modulation frequency diminishes the heat transfer 5. At high modulation frequency, the effect of rotation speed modulation disappears altogether.
6. As time τ increases, the magnitude of streamlines increases, and isotherms loses their evenness, showing that convection is taking place. At τ=1.0 the system achieves steady state.

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RESEARCH ARTICLE

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Impact of Drudgery Reducing Technologies among Farmwomen of Gorakhpur and Deoria districts of U. P.

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ABSTRACT

The present study investigates awareness & adoption towards improved farm tools and implements by the women farmers in Gorakhpur & Deoria districts of Uttar Pradesh. Data were gathered from 200 women farmers through a well-structured questionnaire, focused group discussion and personal interview. Findings revealed that women farmers use traditional tools and implements since a long time but most of the women farmers felt immense drudgery in their use. It was also found that most of the farmers were unaware of improved farm tools and implements, which reduce drudgery. The results also suggested that the respondents were willing to accept the information and subsequent use the improved tools and implements. This study can provide scope for promotion of technology in gender perspective towards the challenges of farmwomen would help in reducing drudgery and occupational health problems of women workers in agriculture.

INTRODUCTION

Agriculture is a primary unorganized sector in which women farm workers perform the majority of the drudgery prone work (Rani, 2007; Nag and Nag, 2004; Mukherjee 2004). Women as farmer or farm workers, participate in several activities such as seeding, transplanting, weeding, fertilizer & manures application, plant protection, thinning, harvesting, processing, selling, winnowing, storing, etc. (Sudharani and Raju, 1991Verma and Sinha, 1991; Sudharani and Raju, 1991; Begam, 2000; Oberoi and Singh, 2001; Rani, 2007; Mukherjee, 2014). These works which lead to "drudgery" is conceived as physical and mental strain, agony, monotony and hardship experienced by human beings while all of the women in the is regard is alarming as they continue to be constrained by illiteracy, malnutrition, and unemployment (Armstrong, 1983; Nag and Nag, 2004) . Many believe that women's involvement in agricultural tasks and large is a source of heavy burden of drudgery on them (Verma and Sinha, 1991). The farmwomen perform agricultural tasks with the age-old traditional tools since gender friendly appropriate tools are either not available or insufficient in number or unawareness. Unsafe, hazardous, unhealthy and long hours of work with age-old traditional and cumbersome tools accelerate health related problems, especially among women farmers (Nag and Nag, 2004). Farmers/ farmwomen are not always aware of the improvements they could make by using scientific and technological knowledge. Thus, the attention of farmwomen was directed towards the women friendly improved farm tools (Gite and Singh, 2005; Nag and, 2004; AICRP, 2009; Anon, 2010; Patel et al., 2015). Farmwomen from the unorganized sector are vulnerable as new and improved technologies are inaccessible for them. It is imperative that they are exposed to these technologies and motivated to adopt the new technologies, which would help them to improve their quality of life (NRCWA, 2006).

Women are the backbone of agricultural work force because they perform more than 79% of farm activities. Farmwomen often lack education and information on the health hazards and habitually view pain as a normal part of work and seek care only when the condition becomes severe or disabling. Usually, they do not understand the association of a health problem with its source. Further, Women being over burdened with so much workload both on farm and at home; they usually neglect their health (Menon and Sheshadri, 2004). Some of the reasons responsible for health

hazards are labour intensive field operations, excessive reliance on human power, low level of adoption of drudgery r (Pandey et al. 2014Patel et al. 2015educing implement, low productivity of human labour, difficult nature of work and decrease in the labour available for agriculture. Other factors might be poverty, inadequate training and lack of awareness, which delay to deal with the occupational related health problems.

The health of farmwomen is one of the important resources for agricultural development. Therefore, drudgery reduction measures needs to be initiated to avoid occurrence of health hazards among farmwomen. Hence, an urgent need to make women aware about latest drudgery reducing tools, implements and other technologies and motivate them to adopt the same was felt. If appropriate drudgery reduction technologies are made available to the farmwomen at home and farm, it would definitely contribute in reducing their drudgery, increasing their working capability, increasing farm production resulting in improved quality of life. Several types of drudgery reducing technologies are available in market (Sutjana, 2000; Singh et al, 2008Singh and Gite, 2007; Singh et al. 1999; Singh et al. 2006; Kumar et al. 2015; Sharma et al. 2015) but to what extent these are being used by farmwomen and whether farmwomen are aware about these technologies or not are the questions of investigation.

MATERIALS & METHODS

A number of tools and implements known to reduce drudgery (Anon. 2010) were procured (Table 1) from Central Institute of Agricultural Engineering (CIAE), Bhopal. Awasthi and Singh, 2014) has assessed the part of body parts of a women which are stressed during farm work, especially in rice cultivation. These implements were placed at Agricultural Implements Unit (AIU) located in the five project villages. The Self Help Groups (SHG) stored the implements and coordinated the activities**.** Individual users hired these implements by paying a small maintenance cost. The money so raised was deposited in the SHG account. Baseline data of all the 1,000 beneficiaries was collected. The present study investigates awareness towards improved farm tools and implements by the women farmers in the Gorakhpur & Deoria districts of Uttar Pradesh. Data were gathered from 200 women out 1,000 beneficiary farmers through a well-structured questionnaire, focused group discussion and personal interview. An interview schedule was developed, validity of, which was checked by jury of experts. In the study, various types of primary as well secondary data have been analyzed. The main objective of the study was to assess the awareness about drudgery reducing tools and implements and preparedness of the community to accept the intervention regarding improved tools.

Table 1. Drudgery reducing tool and implement introduced from CIE, Bhopal

S. N.	Tool / Implement	Number units	of Units placed at each AIU
1	Single & Double Wheel barrow	34	6 - 7
2	Manual Naveen Dibbler	10	2
3	Improved Sickle	100	20
4	Groundnut Decorticator	5	1
5	Tubular Maize Sheller	100	20
6	Four-row Paddy Drum Seeder	5	1
7	Cono Weeder	5	1
8	Paddy Winnower	5	1
9	Zero- till Seed Drill	5	1
10	Hand Ridger	10	2
11	Rice mill	5	1
12	Weed Hand Hoe	10	2
13	Bhindi Plucker	25	5
14	Knap Sack Sprayer	17	3 - 4
	Total	**341**	**68**

RESULTS & DISCUSSION

Baseline survey data on the social and economic status of 1,000 women beneficiaries was collected and upon analysis, several important observations came in. Information on first 200 women who are involved in using the drudgery reducing tools and implements are discussed here.

Personal and social variables of farm women

Majority (59%) of farmwomen belonged to middle age group (Table 2). Only 16 percent were of young age group. Majority (55%) of farmwomen were illiterate, only some (13.5%) had secondary school education. High Majority (79%) of farmwomen had nuclear family. Little more than half (62.5%) of respondents had medium size family and maximum (55%) of them belonged to SC/ST caste category (Table 2). It can be inferred from the findings that majority of the farm women who were involved in farming were of middle age group. No farmwoman was educated above

Table 2. Distribution of respondents according to the personal and social profile – (N=200)

Personal and Social Variables	Frequency	Percent
Age:		
Young (18-30 years)	32	16
Middle (30-50 years)	118	59
Old (Above 50 years)	50	25
Education:		
Illiterate	110	55
Primary school education (up to 8th standard)	63	31.5
Secondary school education (9th to 10th standard)	27	13.5
Type of Family:		
Joint family	42	21
Nuclear family	158	79
Size of family:		
Small (up to 5 members)	54	27
Medium (6 to 9 members)	125	62.5
Large (Above 9 members)	21	10.5
Caste:		
General	04	2
OBC	80	40
SC / ST	110	55
Minority	06	3

secondary level. Trend of nuclear type and medium size family was prevalent.

Economic Variables of Farm Women:

Over-helming high majority (73.5%) of farmwomen had relatively low level of annual family income (Table 3). Only some (7.5%) farmwomen had relatively high level of annual family income. Majority (80.5%) of the farmwomen family had marginal size of land holding only few (1.5 %) were medium farmers. Majority (74%) of the farmwomen had medium size of herds. Majority (72.5%) of the farmwomen had the semi pucca type of houses. The finding leads to conclude that only some farmwomen had relatively high level of annual income and were from big farmer families. A little more than one-third farmwomen had large size of herds and only some (9.5%) had completely pucca house (Table 4).

Table 3. Distribution of respondents according to economic variables (N=200)

S.N.	Economic Variables	Frequency	Percent
1	**Annual family income (INR):**		
	Low (< 1,00,000)	147	73.5
	Medium (1,00,000 to 3,00,000)	38	19
	High (> 3,00,000)	15	7.5
2	**Type of farmers:**		
	Marginal farmer (< 1.00 ha)	161	80.5
	Small farmer (= 1.00 to 2 ha)	36	18
	Medium farmer (> 2.00 ha)	03	1.5
3	**Herd size:**		
	Small (< 5)	23	11.5
	Medium(5 to 10)	148	74
	Large (> 10)	29	14.5
4	**Type of house:**		
	Kuchcha	36	18
	Semi Pucca	145	72.5
	Pucca	19	9.5

Communication variables of farm women:

Table 4 shows that high majority (78%) of the farm women had low level of mass media exposure. Only some (3.5%) farmwomen had high level of mass media exposure. Similarly, majority of (81%) of the respondents had low level of contact with extension personnel's, only some women farmers (4.5%) of the respondents had high level of contact with extension personnel's. Majority (79.5%) of the respondents had low level of contact with extension institutions, only few women farmers (3%) had high level of contact with extension institutions. It can be inferred that majority of the farm women had low level of mass media exposure, low contact with extension personnel's as well as extension institutions.

Drudgery Level Perceived by Farm Women in Performance of Farming

These women had perceived mostly the weeding as drudgery prone operation (83.5%) followed by manual harvesting (86%) and threshing (79%). Farming activities,

Table 4. Distribution of respondents with according to the communication profile (N = 200)

S.N.	Communication Variables	Frequency	Percent
1	**Mass media exposure level:**		
	Low exposure (< 08)	156	78
	Medium exposure (08 to 13)	37	18.5
	High exposure (> 13)	07	3.5
2	**Contact with extension personnel's/agents:**		
	Low contact (< 05)	162	81
	Medium contact (05 to 10)	29	14.5
	High contact (> 10)	09	4.5
3	**Contact level with extension Institutes:**		
	Low contact (< 05)	159	79.5
	Medium contact (05 to 10)	35	17.5
	High contact (> 10)	6	3

which were perceived as moderately drudgery prone by majority (80%) of farmwomen, were cleaning of farm produce by winnowing. 45% of farmwomen perceived storage of farm produce as moderately drudgery prone activity. Whereas least drudgery prone activity perceived were winnowing, drying of farm produce, and storage of farm produce at least drudgery prone activity (Table 5).

It can be inferred that among the farming activities carry dung and produce from one place to another, sowing, weeding, manual harvesting, threshing, groundnut decorticating, and maize shelling are the most drudgery causing operations.

Awareness and Adoption Level among Farm Women of Drudgery Reducing Tools and Implement

Table 6. Distribution of the respondents according to awareness level regarding Drudgery reducing tools and implement (N = 200)

S. N.	Awareness level	Frequency	Percent
1.	Low (< 50)	131	65.5
2.	Medium (50 to 65)	60	30
3.	High (> 65)	09	4.5
	Total	**200**	**100**

It is revealed from data presented in Table 6 that a majority (65.5%) of farmwomen had low level of awareness about drudgery reducing tools and implement followed by medium level (30%). Only some (4.5%) farmwomen were highly aware about drudgery reducing tools and implement. It can be concluded from findings that about 66 percent farmwomen had low level of awareness about improved drudgery reducing tools and implement.

Table 5. Drudgery level perceived by farmwomen during farming activities (N = 200)

Farm activities	Level of drudgery					
	Most drudgery Prone		Moderately drudgery prone		Least drudgery prone	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Ploughing	-	-	52	26	12	6
Carry dung and produce	78	39	24	12	-	-
Sowing	47	23.5	72	36	-	-
Cleaning premises	-	-	25	12.5	34	17
Weeding	167	83.5	33	16.5	-	-
Manual Harvesting	172	86	28	14	-	-
Threshing	158	79	42	21	-	-
Groundnut decorticating	40	20	160	80	-	-
Winnowing	-	-	45	22.5	155	77.5
Maize shelling	90	45	110	55	-	-

Table 7. Distribution of the respondents according to adoption level of drudgery reducing tools and implement (N = 200)

S. N.	Adoption level	Frequency	Percent
1.	Low (< 50)	20	10.0
2.	Medium (50 to 65)	53	26.5
3.	High (> 65)	127	63.5
	Total	**200**	**100**

Majority (63.5%) of farmwomen had high level of adoption of drudgery reducing tools and implements. Only 26.5% of respondents had medium level of adoption of drudgery reducing implement (Table 7). It can be inferred from above findings that majority of farm women had very low level of adoption of drudgery reducing tools and implement.

Verma and Sinha (1991) reported heavy burden on farmwomen when they work on farm also. Kumar et al. (2011) reported drudgery of farmwomen when they work by bending, long hours and in the scorching sun. They should use appropriate drudgery reducing tools and implements for the work where stress is severe (Mrunalini and Snehlata, 2010; Sudharani and Raju, 1991; Rani, 2007; Patel et al. 2015). Use of inappropriate tools by farmwomen was reported by Aggarwal et al. (2013) to result into acute and sub-acute cumulative trauma of wrist and forearm. Singh et al. (2014) reported higher working efficiency while harvesting with serrated sickle. These observations and recommendations rhyme well with our findings during the last 4 years in the project. The interventions are now bearing the fruits in which now 1,000 farmwomen participate.

CONCLUSION

- Drudgery of farmwomen is a reality although they do not express it and suffer silently.
- Among farming activities most drudgery prone activities perceived by high majority of farmwomen were transport of animal dung and farm produce, weeding, harvesting, groundnut decorticator, maize shelling, and threshing.
- Tools and implements are available in the country, which can reduce these drudgeries. These are affordable .
- Self Help Groups can provide avenues where these tools and implements can be procured and stored for use by the individuals. This will provide a cheap module as every implement need not to be procured by every individual.
- Low level of awareness and low level of adoption of drudgery reducing tools and implement was found among majority of farmwomen. Communication is an issue of concern.
- Once available, farmwomen adopt these tools and implements very well.

V. SUGGESTION:

- Women-friendly drudgery reducing tools and implements need to be popularized primarily related to most drudgery prone faming activities.
- Farmwomen must be motivated to adopt drudgery reducing tools and implement.
- Training must be organized for farmwomen about operation and handling of drudgery reducing tools and implement and about safety measures to prevent different kinds of occupational health hazards.
- Since every household can't afford to keep all the implements, these may be aggregated and kept at on centre from where they can hire. This will assure availability of all types of implements and generate income for the village group. This saved time they can use for relaxing, caring for themselves and children. By the saved time and energy, they will improve their health.
- With improved health, they will save on their medical bill and money to be used for other purposes. Women are the centre of family and thus nurture a cheerful and healthy one.
- Most drudgery reducing implements also provide efficiency and thereby save energy and time of farmwomen.

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RESEARCH ARTICLE

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Medical Negligence: Experiences of Doctors in Hospital Settings

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ABSTRACT

Medical profession which is a noble profession has now becoming a business. Medical professionals often forget their responsibilities towards their patients and conduct their professional work without observing the code of ethics and thereby violate the rights of the patients. Growing incidences of malpractice and medical negligence keep the patient resulting into the poor health or sometime in medical complications. Every now and then people slap or become aggressive if their patient dies in the hospital setting. They directly blame doctor for medical negligence.

On the other hand doctors feel that medical profession is becoming very tough and patient and their relatives are no more passive recipient of the treatment. This paper explores the doctors' experiences about the medical negligence.

It is very difficult to understand the concept of medical negligence particularly by the lay man who is not aware of the complexity of medical treatment. It is highly technical and scientific area of investigation, but for patient simply it is related with the betterment of their health. The receiver of treatment does not distinguish between the complexity of medical treatment and its outcome.

So to understand the dynamics of medical profession, one can not only take the views of doctors, but it is equally important to understand the patient's views regarding medical negligence and what causes they attribute for medical negligence.

The medical profession is often held to represent the professional ideal in modern society. It ranks high in social prestige and financial remuneration and it performs essential services within the community backed by specialized and effective knowledge and expertise. Doctors occupy a higher social status in the society not only because of high professionalization but also because they deal with health and life of human beings (Elliot: 1972).

It has often been claimed that our society, as perhaps most, is more enamoured with medical intervention to correct health problems than it is with preventing the health problems in the first place. This ready acceptance or desire for curative intervention rather than preventive maintenance has been fuelled by a long list of biomedical and scientific breakthroughs that have contributed to the belief that, regardless of the problem, medical science can be counted on to produce a quick fix, such as a vaccine or a cure.

The recognition that an individual's behaviour can contribute significantly to the risk of premature morbidity or mortality has led to numerous admonitions, on the one hand, for individuals to be more responsible for their own health and discussions, on the other hand, of the right of the state to develop policies that coerce individuals to lead more healthy or risk-reducing lives (Knowles: 1977).

In an ethical analysis of the responsibility of the state and the right of the individual concerning health, Wikler (1978) has examined three ethical; justifications for state-initiated programs in health promotion that may not correspond to individual preference profiles regarding behaviours or life-styles. The first justification is based on the notion that health is a valued good. It may not be a terminal or ultimate value in most individual's lives, but clearly many normal and routine life events cannot be experienced without a modicum of health. Accordingly, Wikler argues that state initiated health promotion programs could be justified ethically on the basis of the principle of beneficence, or doing well. In pointing this out, Wikler also notes that health promotion programs run into problems of possible charges of paternalism, that is forcing individuals to do something that, while it may be in the individuals long-term health interest, is something the individual may

not want to do in the short run. Potential infringement on individual liberty is a major ethical dilemma in virtually any health promotion program that goes beyond the simple provision of information. A second ethical premise examined to justify state-based health promotion initiatives rests on the argument that it is unfair for some individuals to act as they please when such action leads to significant burdens on society. A third principle Wikler identifies is that of promoting the general societal welfare. The argument here is that the state has a right to promote the general welfare, because this leads to improved societal productivity, a better economy and so forth. The latter are goods that can benefit a majority of individuals in a society. Such benefits may be used to justify curtailment of individual life-style of those persons who engage in high-risk behaviours.

In one of his study related to "Rural Elderly: Health Status and Available Health Services", Kumar (1996) described that much of the disability and ill health of old people is the result of medical negligence. Now that the mathematical chance of surviving to the old age has increased, a more positive approach to the incurable diseases of this period to avert the personal frustrations and community problems that accompany physical disability and mental health. The medical profession is beginning to realize that old people do respond to treatment and can recover to function to a surprising degree. It is observed that though majority of the elderly need medical aid for longer period from government hospitals, they are not able to visit the hospitals on account of long distance and poor transportation facilities, and lack of personal help. Poverty is also one of the important factors, preventing the elderly to avail proper medical aid. Like children, the aged too need health and personal care and hence there is need to establish separate geriatric wards in the hospitals with geriatric professionals. Thus, quality of life plays a major and particularly obvious role in the treatment and control of hypertension. In its mild to moderate from this disease is virtually symptoms, but the medications can produce many side effects, affecting quality of life and leading to noncompliance. These problems can perhaps best be addressed in clinical practice if proper inquiries are made by medical personnel and treatment is adjusted according and as needed.

Certain types of people, such as students and others who are relatively mobile, are very likely to receive medical information from several doctors about the same condition, without these doctors necessarily knowing that the person has already received advice elsewhere. If the patient is referred for an opinion, the specialists reply is sent in a letter to the first doctor and will rarely be seen by the patient. However, the specialist may be willing, or may unwittingly, divulge information that the general practitioner has not disclosed to the patient. The way he is examined, or the questions that are asked, may also help 'to give the game away' to the patient. Doctors appear to feel the need to guard against patients 'devious' way of gaining access to information. Very often the patient strategy may be met by a counter-strategy. Balint warns doctors of some patients 'ability to play off" one doctor against another and suggests ways of combating this- by improving communications and history-taking on the part of the medical staff to prevent the patient from taking advantage of the loop-holes in the system (Balint:1971).

The issue about the "patient's voice" does not, however, go away. This is due to changes in how people think about their health, about living with serious illness and about professional expertise. This is a continuation of the relationship of medicine to society, one that goes back to the end of the 18th century. The introduction of the new clinical techniques changed "being a patient" from a question of how to die with contrition to one of how to survive with medical help, and ultimately how to live. In the last half century the development of new procedures such as endoscopy, of new drug therapies and recently the promise of genetic engineering not only enable survival but provoke questions of how to live when cure is not possible. The emergence of an ethics of illness means that the voice of the patient is no longer framed solely within the consulting room or the clinic. It is not something to be heard only in response to the ministrations of the doctor, but is an active part of people's use of medical help in a world where they wish to determine their own way of life (Herzlich and Pierret: 1987).

Auxiliaries, known also as dispensers, health aides and medical assistants, have been employed in some developing countries for many years but, as Djukanovic and Mach (1975) pointed out, they have been used very ineffectively in the past. Many have been underutilized, undertaking only the simplest tasks. This is partly because of opposition from the medical profession, which has claimed that it is both unethical and dangerous to entrust the care of sick people to these workers, and in several developing countries where training centres for auxiliaries existed before independence they were closed after medical schools were established. In many cases, they have been sent to the rural areas without adequate support, drugs and other resources; dissatisfaction has been reported because of low salaries, poor promotion prospects, inadequate

transport and unsatisfactory living conditions. Some have been accused of treating those who pay private fees in addition to government charges and in some cases auxiliaries have left government service to establish private practices or to work for physicians in urban areas. Thus in the present paper we are trying to understand the process of medical negligence in terms of its nature and form. Further, we are also focusing doctors' views for the medical negligence.

SAMPLE METHOD

The purpose of our study is to understand the Medical Negligence; therefore hospital institutions are taken into account. Hospitals are comprised of doctors, patients and other para-medical staff. Out of the 21 districts, we randomly selected Bhiwani district, which is one of the largest districts in the state of Haryana. To select the hospitals for the study purpose, we decided to study both government and private hospitals in Bhiwani city of Haryana. Bhiwani has one big government hospital and approximately 700-800 patients visit in a day in the Out Door Department (OPD) and 80-90 (per day) patients in indoor. It has 22 doctors. On the other hand, there are 46 well established private clinics/ nursing homes/hospitals.

Among 46 private hospitals, we selected the hospital which is oldest in terms of year of its establishment and simultaneously has highest number of indoor patients and it has 9 doctors. *We interviewed 13 doctors from government hospital and 9 doctors from private Chugh hospital. Thus, in total we interviewed 22 doctors. On the basis of several visits made to these intuitions, it became evident that there is profound difference between institutions in terms of the clinical and other facilities.*

MEDICAL NEGLIGENCE

Before discussing medical negligence, it would be desirable to understand the concept of negligence as such. Negligence may be defined as the "breach of a duty caused by the omission to do something which a reasonable man, guided by those considerations which ordinarily regulate the conduct of human affairs would do, or doing something which a prudent and reasonable man would not do". A shorter definition is that "negligence as a tort is the breach of legal duty to take care which results in damage, undesired by the defendant to the plaintiff" (In the leading case Bolam v. Friern Hospital Management Committee (1957) 2 All ER). The definition involves three constituents of negligence: (1) A legal duty to exercise the due care on the part of the party complained of towards the party complaining the former's conduct within the scope of the duty; (2) breach of the said duty; (3) consequential damage.

For a doctor negligence means failure to act in accordance with the standards of reasonably competent medical men at the time. This is a perfectly accurate statement, as long as it is remembered that there may be one or more perfectly proper standards; and if a medical man conforms to one of those proper standards then he is not negligent. A doctor is not guilty of negligence if he has acted in accordance with a practice accepted as proper by a responsible body of medical men skilled in that particular art. Putting it the other way round, a doctor is not negligent, if he is acting in accordance with such a practice, merely because there is a body of opinion that takes a contrary view. At the same time, that does not mean that a medical man can obstinately and pig-headedly carry on with some old technique if it has been proved to be contrary to what is really substantially the whole of informed medical opinion.

NATURE AND FORMS OF MEDICAL NEGLIGENCE

As many as 436 people died last year due to Serious Adverse Events (SAE) during clinical trials. Investigations are now on to ascertain how many of the deaths were caused by drugs administered to the trial subjects. In 2011, 438 cases of SAE were reported, of which 16 were found to be due to clinical trials. The previous year, 668 cases of SAE were reported, of which 22 were caused due to trials. The Union Health Ministry says there were alleged irregularities in nine cases of clinical trials during the last three years. Sources said that most of the clinical trials involving patients who died 'due to clinical trial' involved global pharmaceutical giants testing drugs for different types of cancer and antibiotics. The Supreme Court had recently pulled up the Centre for its insensitivity to scores of deaths and serious adverse effects to thousands during clinical trial of new drugs. "We have taken steps like mandatory registration of clinical trial in ICMR (Indian Council of Medical Research) registry to ensure that safety, rights and well-being of clinical trial subjects are protected," said the health minister. The Health Ministry data shows the number of trials being approved has also gone down: from 529 permissions granted in 2010 to 283 in 2011 and 253 in 2012 (The Times of India: 2013 A).

A R Madhukumar, the assistant superintendent of the Central Prison, Viyyur, has approached the Kerala Human Rights Commission alleging that his wife had died due to the medical negligence at the Thrissur Medical College Hospital (TMCH). According to Madhukumar, he had taken his wife P Vasantha to the TMCH on this August 1, with the test report indicating high levels of creatinine, and had met

the duty doctor in the urology department on that day. The doctor had directed blood, urine and kidney tests of Vastantha to be conducted then, and did not admit her even though she was unwell and very weak, he alleged. The doctor had also prescribed some medicines even before the results came, Madhukumar said. He said he got the tests done immediately at the hospital, but the doctor had gone by the time he came back to OP with the results. According to him, Vasantha had started shivering after she consumed the medicine prescribed by the doctor and she was admitted to the casualty in the evening. She was shifted to the ICU after some time and she died after another few hours. Madhukumar alleged that the TMCH authorities were not giving him the results of the blood and urine tests conducted on his wife, despite his repeated requests. The commission member K Mohankumar had issued notices to the TMCH superintendent and the director of medical education directing them to submit reports (The Times of India: 2016 A).

As many as 2,644 people, called subjects, died during the clinical trials of 475 new drugs on human beings in last seven years and only 17 of the medicines were approved for marketing in India, the Centre has informed the Supreme Court. Union Health and Family Welfare Ministry said of the 57,303 enrolled subjects, 39,022 completed the clinical trials. "Serious adverse events of deaths during the clinical trials during the mention period were 2,644, out of which 80 deaths were found to be attributable to the clinical trials (Times of India: 2013 C).

An eminent cardiologist Dr. D Seshagiri Rao, head, department of cardiology, Nizam's Insititute of Medicine, Hyderabad was caught red-handed while accepting a bribe of Rs 1.6 lakh from a stent supplier. Stents, the scaffolding devices inserted into blood vessels to keep them open, are used if the patient has more than 70% block of an artery. But doctors confide that stents are used even when the block is less than 30%. This not only inflates the bill, but increases the risk of a heart attack, say cardiologists. In fact, a study by National Heart and Lung Institute in the US found that 1-2 per cent of people who have stented arteries develop a blood clot at the stent site which can cause a heart attack or stroke. "When stenting was introduced, it was hailed as a medical breakthrough, but patients are now being advised to go through the procedure even when the clot can be treated through aggressive medical intervention or through a bypass," says Dr B Soma Raju, chairman of CARE Hospitals, Hyderabad, and a pioneer in this treatment. Dr Sai Satish, an International cardiologist at Apollo Hospitals, calls the trend "criminal." "Last year I received at least four patients who were advised to go in for angioplasty when the problem could have been remedied through medication. We need a system to check this," he says (Times of India: 2013 B).

INCIDENCE OF MEDICAL NEGLIGENCE

Table 1. Incidence of Medical Negligence Reported by Doctors

Level of Education of Doctors	Government Hospital		Private Hospital	
	Yes, Incidence of Medical Negligence	No Incidence of Medical Negligence	Yes, Incidence of Medical Negligence	No Incidence of Medical Negligence
BDS	-	2 (9.09)	-	-
BAMS	-	-	1 (4.54)	4 (18.18)
MBBS	2 (9.09)	5 (22.73)	-	-
MD/MS	3 (13.64)	1 (4.54)	1 (4.54)	3 (13.64)
Total	5 (22.73)	8 (36.36)	2 (9.09)	7 (31.82)

(Figures in the bracket represent percentage)
*Multiple Responses

We asked doctors to state that weather there are occurrence of cases of medical negligence in hospital. Out of twenty two doctors, almost one third of the doctors admit that, there are cases of medical negligence in the medical facilities. However, 15 (68.18 per cent) have totally refused that there are no cases of medical negligence in the hospital. Contrary, to this in the private hospital setting doctors are not ready to accept that they have the cases of medical negligence that is why only 2 (9.09 per cent) doctors admitted that they do have cases of medical negligence.

Table 2. Nature of Medical Negligence

Nature of Medical Negligence	Government Hospital	Private Hospital	Total Response*
New drug given to patient for trial	6 (40)	3 (20)	9 (60)
Use of devices like stent etc. not needed to patients	6 (40)	5 (33.33)	11 (73.33)

(Figures in the bracket represent percentage)
*Multiple Responses

Out of the doctors who report that there are cases of medical negligence in the medical facility, sixty per cent of opine that many times new drugs are given to patient on trial basis. This may be due to kick backs from the pharmaceutical companies or may be from the medical representative of the company who are visiting the doctors for the promotion of their medicines. Another 11 (73.33 per cent) doctors feel that there is rampant use of medical devices like stent etc. which are in reality not needed to the patients. Thus, the medical negligence is viewed in terms of drug administration to patients and also unnecessary use of medical devices which are not needed by the patients.

Banerji (1982) points out in his study that doctors do not behave in the same manner towards all patients for medical check-ups. Patients with resistance and those who need the new drug regimen the most may not get it. This denies the right of individuals to quality treatment.

Table 3. Forms of Medical Negligence

Forms of Medical Negligence	Government Hospital	Private Hospital	Total Response*
Wrong treatment	10 (45.45)	5 (22.73)	15 (68.18)
Delay in treatment	12 (54.54)	4 (18.18)	16 (72.73)
Takeout patient's organs without his/her consent	12 (54.54)	7 (31.82)	19 (86.36)
Over doses of medicine	9 (40.91)	5 (22.73)	14 (63.64)

(Figures in the bracket represent percentage)

*Multiple Responses

To ascertain doctors' information regarding the forms of medical negligence, 19 (86.36 per cent) mention that taking out of patients' organs without his/her consent is the most severe form of medical negligence. Nearly seventy three per cent reports that delay in treatment of the patient is also a form of medical negligence. Fifteen (68.18 per cent) feel that wrong treatment is also medical negligence. Over dose of medicine is another form of medical negligence which has been mentioned by 14 (63.64 per cent).

A patient was brought to the hospital with fever. Family alleged that doctors at the emergency wing turned away the patient without any treatment. They claimed that they insisted the patient be admitted. But doctors sent them back home saying that the patient did not need treatment for fever. Back home the patient's condition got deteriorated and he was brought back to the hospital once more. They alleged that this time too the patient was kept in front of the emergency without any treatment for minutes. Patient died before getting any medical attention.

Hell broke loose soon after. A mob gathered and vandalizing the hospital.

Hospital sources however denied the negligence charges. They said that the patient was brought dead in the emergency wing. "Since it was brought dead case a post mortem was required. But the patient would not allow post mortem and prevented police from removing the body to the morgue. The trouble started from here," said principal RG Kar Medical College and Hospital. The hospital authority said that it will also probe whether there was any negligence in dealing with the patient when he was brought for the first time (The Times of India: 2016 B).

The process of consultation is very complex and the patient has to be taken into account if one wants to understand how treatment decisions are made. The patient has ways of influencing what treatment the doctor will give. His self-presentation is a strategy to influence the outcome of the consultation. In this sense, then, the outcome of the consultation is negotiable, even if the level of interaction is little overt bargaining over what the treatment will be (Stimson: 1975).

Table 4. Causes of Doctors' Medical Negligence

Causes of Medical Negligence	Government Hospital	Private Hospital	Total Response*
Do not scrutinize the patients properly	4 (54.14)	1 (14.28)	5 (71.43)
Busy schedule	1 (14.28)	2 (28.57)	3 (42.86)
No proper consultation with other senior doctors about the illness	1 (14.28)	-	1 (14.28)
Due to apathy between doctor and patient	4 (54.14)	2 (28.57)	6 (85.71)
Economic consideration	4 (54.14)	2 (28.57)	6 (85.71)

(Figures in the bracket represent percentage)

*Multiple Responses

It is equally important to look into the causes of medical negligence reported by doctors'. When we tried to gather information about the causes of medical negligence from the patient, we received several responses. We sorted out some of the common responses. 6 (85.71 per cent) Doctors think that due to apathy of doctors to serve the patients or loss of feeling of mankind and economic consideration are most important causes of medical negligence. Almost seventy per cent of the doctors state that before treatment, doctors do not scrutinize patients' medical history etc. Some doctors feel that over-burdened doctors and avoidance of consultation with other doctors also pushes them towards incidences of medical negligence.

In India, the private sector consists of a small but powerful corporate sector, a rapidly proliferating set of nursing homes, and a vast body of private practitioners ranging from specialists to untrained individuals. The professionals view the latter with contempt and their practice is in the process of being banned, even though they are often the only healers available for the poor. The schemes set in place to upgrade and train these practitioners have been severely criticised by professional doctors. Similarly, the nursing homes are a mixed bag of doubtful quality providers, as revealed by the qualifications of their personnel and the quality of their infrastructure (Baru: 1998).

Deputy Commissioner Dr M Lokesh, when he visits to the community health centre (CHC) at Holaur and primary health centre (PHC) at Aladahalli. He was shocked to see the sorry state of affairs in terms of poor medical services and lack of interest on part of the authorities in maintaining health centres. Acting on complaints by the public about the poor facilities in the health centres the DC expressed his concern and directed the CMO to issue notices to medical officers of the two establishments for their careless attitude. And also checked the medical stores, attendance registers, and services available at the centres, cleanliness, emergency services and availability of essential medicines (The Times of India: 2016 C).

CONCLUSION

Out of twenty two doctors, almost one third of the doctors admit that there are cases of medical negligence in the medical facilities. However, approximately seventy per cent doctors have totally refused about the no cases of medical negligence in the hospital.

The doctors who report that there are cases of medical negligence in the medical facility, sixty per cent of doctors opine that many times new medicines are given to patient on the trial basis. This may be due to kick backs from the pharmaceutical companies or may be from the medical representative of the company who are visiting the doctors for the promotion of their medicines. Another seventy four per cent of the doctors feel that there is rampant use of medical devices like stent etc. which are in reality not needed to the patients. Thus, the medical negligence is viewed in terms of drug administration to patients and also unnecessary use of medical devices which are not needed to the patients.

To ascertain doctors' information regarding the forms of medical negligence, eighty seven per cent mention that taking out of patients' organs without his/her consent is the severe form of medical negligence. Nearly, seventy three per cent reports that delay in treatment of the patient is also a form of medical negligence. Nearly, seventy per cent feel that wrong treatment is also medical negligence. Over dose of medicine is another form of medical negligence which has been mentioned by sixty four per cent.

It is equally important to look into the causes of medical negligence at doctors' level. When we try to gather information about the causes of medical negligence from the patient, we received several responses. Doctors think that due to apathy of doctors to serve the patients or loss of feeling of mankind and economic consideration are most important causes of medical negligence. Almost doctors stated that before treatment, doctors do not scrutinize patients' medical history etc. Some doctors feel that over burdened doctors and avoidance of consultation with other doctors also push them toward incidences of medical negligence.

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RESEARCH ARTICLE

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Doctor -Patient Relationship: An Empirical Analysis in Hospital

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ABSTRACT

Patients are hardly communicated for their pattern of treatment, unless and until one shows anxiety to know about it. Informed choice for the treatment is conspicuous by its absence, as patients are hardly informed and in turn patients also think that it is the doctor who is the most competent person to look after the treatment. Treatment process cannot be viewed without the patient involvement in the process of interaction. Patient should occupy the centre stage. The serious issues of treatment should not by pass the patient but it should be a matter of available choices.

The interaction between doctors and patients becomes cardinal not only in the process of medical care, but also within the institution of medicine. It is through this interaction that the basic components of medical care like diagnosis, prognosis, and therapeutics get accomplished. Additionally, this interaction can be seen as part of the whole process of medical care where both the actors are influenced by the changing medical knowledge. The doctors' responsibility in terms of medical ethics and patients' right to receive health care is also understood through the process of interaction.

Advani in his book *Doctor-patient Relation in Indian Hospitals* points out that the patients were not given sufficient attention, as the major role attributed to them was to help the physician in their maximum possible capacity in the collection of information about illness for rendering better care. Moreover, from a professional perspective, another stream of studies examined the temperament, attitude and behaviour of doctors and patients and tried to link them to the socio-economic class of the respective actors, thereby showing conflict between them (Advani: 1980).

Hasan (1979) in his study *Medical Sociology of Rural India* finds out that doctor treated the villagers with sympathy, talked to them very mildly, paid enough attention to each patient, made queries from the patient or his relative and examined his body with hand or stethoscope. Among the qualities which the people attributed to the doctor, was his quality of paying equal attention to all without any discrimination. Doctor was devoid of casteism or communalism, made no distinction between men, women or children and did not show any favor to the rich. He paid more attention to the poor and did not charge any fees for home visits from them and sometimes he himself brought costly medicines to the poor patients and did not charge even the actual cost.

Regarding 'structural' and 'processual' analysis of the medical professionals in the hospital settings and the nature and pattern of clientele developed with the patient, Nagla (1988) mentioned that the medical practitioner enjoys a respectable position in community or society. However, because of lack of facilities in the rural areas, urban orientation, living styles, etc., the medical professionals continues to work in urban areas. In order to get medical care, people from villages have to look towards medical professionals in urban areas. In view of this, hospitals provide a good setting to study the doctor-patient relationship in the context of recruitment, socialization process of the doctors and that of expectations and satisfaction level of the patients from the doctors with whom they develop clientele for a short or long period depending upon nature of disease and severity of illness.

Social scientists like Parsons (1951), Friedson (1961)

and Bloom (1963) have viewed that the mutual relationship between physician and patient as crucial in healthcare seeking behaviour. One dimension of this relationship, as argued by Larsen and Rootman (1976), that is of interest to both researchers and health professionals is level of patient's satisfaction with medical services. This is crucial because patient satisfaction is an important factor in healthcare as it influences whether a patient seeks medical help, whether he/she compiles with a therapeutic regimen, and maintains a counting relationship with a physician. It is generally assumed that a patient's general level of satisfaction is influenced by a physician's role performance. Role consists of a set of behavioural expectations, which contain a normative component. In medical situation, both the patient and physician hold different expectations.

SAMPLE METHOD

The purpose of our study is to understand the patients' satisfaction by treatment and doctor-patient communication, therefore hospital situation is taken into account. We randomly selected the Bhiwani district, which is one of the largest districts in the state of Haryana. To select the hospitals for the study purpose, we decided to study both government and private hospitals in Bhiwani city. Bhiwani city is purposively selected because of presence of enough number of private hospitals where large number of patients seeks their treatment. City of Bhiwani has one big government hospital with the 22 doctors. It was established in 1976 and approximately 700-800 patients visits in a day in the Out Door Department (OPD) and 80-90 (per day) patients in indoor. On the other hand, there are 46 well established private clinics/nursing homes/hospitals.

General Hospital is selected for the study purpose in the government hospital category. One private hospital is selected on the basis of date of establishment and its large size in terms of indoor facility for patients. It also has the larger number of patients in indoor facility i.e. 10-12 patients per day in ward.

Purposively we interviewed 120 patients, 60 each from government and private hospital. We interviewed 13 doctors from government hospital and 9 doctors from private hospital. Thus, in total we interviewed 22 doctors. On the basis of several visits made to these intuitions, it became evident that there is profound difference between institutions in terms of the clinical and other facilities.

DOCTOR-PATIENT RELATIONSHIP

The initial attitudes of doctors towards patients depict not only diagnosis and prognosis of the disease but also reflects doctor's feelings towards the patient as a professional, as a human-being and as a service-oriented person.

Table 1. Relationships of Doctor-Patient in Treatment Process

Relationship in Treatment process	Government Hospital	Private Hospital	Total
Good relationship with patient	8 (36.36)	5 (22.73)	13 (59.09)
Not good relationship with patient	5 (22.73)	4 (18.18)	9 (40.91)
Total	13 (59.09)	9 (40.91)	22 (100)

(Figures in the bracket represent percentage)

In our study, when we ask our doctors that what do they think about the relationship between doctor and patient. It is interesting to note that nearly sixty per cent of the doctors feel that there exists a good relationship between doctor and patient and in term it helps in the treatment process. Conversely, 9 (40.91 per cent) doctor reported that there is no good relationship with the patients in the treatment process.

Table 2. Content of the Relationship between Doctor-patient viewed by Doctor

Content of the Relationship	Government Hospital	Private Hospital	Total Response*
To clear doubts of patients regarding diseases	7 (53.85)	4 (30.77)	11 (84.61)
To understand each other in better way	3 (23.08)	3 (23.08)	6 (46.5)
Social responsibility	5 (38.46)	4 (30.77)	9 (69.23)
To diverted patient's mind from tensions	4 (30.77)	1 (7.69)	5 (38.46)
Interaction is a part of professional ethics	3 (23.08)	2 (15.38)	5 (38.46)

(Figures in the bracket represent percentage)
*Multiple Responses

Further regarding the content of the relationship between doctors and patients, nearly eighty five per cent of doctors mention that while interacting with the doctor they want to clear the doubts of patients in terms of disease and process of treatment. Ultimately the clarity of doubts helps in the treatment process. 9 (69.23 per cent) doctors view that social interaction with the patient is their social responsibility to maintain interaction for the healing process. Five of them feel that by having social interaction with the patient, the mental tension is diverted and they also act according to professional ethics.

Table 3. Behaviour with the Patients viewed by Doctors

Behaviors with Patients viewed by Doctors	Government Hospital	Private Hospital	Total Response*
Cooperative	6 (27.27)	5 (22.73)	11 (50)
Normal	11 (50)	2 (9.09)	13 (59.09)
Emotional	1 (4.54)	2 (9.09)	3 (13.64)
Friendly	2 (9.09)	3 (13.64)	5 (22.73)

(Figures in the bracket represent percentage)
*Multiple Responses

Table- 3 provides the behaviour of the doctors with the patients. Nearly sixty per cent of the doctor mention that they have normal behaviour with their patients, whereas fifty per cent of the doctor that they are cooperative with their patients. Five (22.73 per cent) are friendly with their patients and another 3 (13.64 per cent) are emotive with their patients.

SATISFACTION/DISSATISFACTION OF PATIENTS FROM TREATMENT

Whether people are satisfied or dissatisfied with the treatment and with their doctor is an important issue in doctor-patient relationship. Satisfaction and dissatisfaction are concepts, like expectations and performance which are difficult to operationalize in research. Abrams (1968) has argued that this is a matter of the refinement of questioning techniques. We would suggest that it is because of the fluctuating nature of people's feelings about their encounters with doctors. What may be seen as satisfactory in one context may be seen as unsatisfactory in another. For example, one person describe his/her doctor as being good with children and explained that he/she was always happy with his treatment of his/her son, only to criticize that same concern over his/her child's health when the doctor made an unrequested home visit that he/she considered to be unnecessary.

Table 4. Patient's Response about Satisfaction from Treatment

Satisfaction from Treatment	Government Hospital	Private Hospital	Total
Yes	38 (31.67)	43 (35.83)	81 (67.5)
No	22 (18.33)	17 (14.17)	39 (32.5)
Total	60 (50)	60 (50)	120 (100)

(Figures in the bracket represent percentage)

Satisfaction from the treatment not only helps in the healing process but also provide good interaction and relationship between doctors and patients. To know the satisfaction from the treatment, we asked our respondents that are they satisfied with the treatment they are receiving from the hospital. Majority of them i.e. 81 (67.5 per cent) reported that they are satisfied with the treatment they are receiving from the hospital. There is variation in terms of satisfaction in government and private hospital. More number of patients in private hospital are satisfied with the treatment as compared to government hospital. Only 39 (32.5 per cent) are not satisfied with the treatment.

Table 5. Patients Satisfaction with Doctor's Behaviour

Satisfaction with Behavior of Doctors	Government Hospital	Private Hospital	Total
Yes	39 (32.5)	49 (40.83)	88 (73.33)
No	21 (17.5)	11 (9.17)	32 (26.67)
Total	60 (50)	60 (50)	120 (100)

(Figures in the bracket represent percentage)

Nearly seventy per cent of patients are satisfied with doctor's behaviour. However, 32 (26.67 per cent) are not satisfied with doctors behaviour. The patients who are not satisfied with doctors' behaviour are more from government hospital.

It has been the traditional responsibility of the health care provider to integrate all the sources of medical information and convey to the patient at the time of the consultation. Traditionally, the relationship between the physician and the patient was asymmetrical; that is to say, doctors had significantly more information about medical

conditions than their patients. Increasingly however this traditional sole professional filter is being bypassed by the patients who now have access to both external means of procuring health information as also to their health records. The locus of power in health care is shifting: instead of the doctor acting as sole manager of patient care (i.e., "the captain of the ship"), a consumerist model has emerged in which patients and their doctors are partners in managing the patient's care. These changes are already finding resistance from the provider community (Reents: 1999).

Table 6. Patients Dissatisfaction with the Behaviour of Doctors

Causes of Dissatisfaction	Government Hospital	Private Hospital	Total Responses*
Not paying equal attention to all	16 (50)	3 (9.37)	19 (59.37)
Rude behaviour	11 (34.37)	10 (31.25)	21 (65.62)
Do not share line of treatment	9 (28.12)	1 (3.12)	10 (31.25)

(Figures in the bracket represent percentage)
*Multiple Responses

Further, the dissatisfaction from the behaviour of doctors is reported in terms of their rude behaviour, discrimination in treatment, further doctors do not share the line of treatment with patients. Majority of patients i.e. 19 (59.37) feel that doctors do not pay equal attention to all. They are biased towards their own kin, caste, relatives etc.

Patients are regarded as particularly sensitive to and observant of the non-verbal communications conveyed by their doctors, because illness usually involves emotions such as fear, anxiety and emotional uncertainty. Patients therefore often look for clues to assess the situation. By maintaining eye contact, looking attentive, nodding encouragingly and using other gestures, the doctor can provide positive feedback to the patient and facilitate his or her participation. By contrast, continued riffling through notes, twiddling with a pen or failing to look directly at the patient convey disinterest and result in patients failing to describe their problems or to seek information and explanation. Similarly, the patient's body language and eye contact can convey whether he or she is feeling tense, anxious, angry or upset (Lloyd & Bor: 1996).

Similarly, we also asked about their satisfaction from the treatment process.

Table 7. Patients Satisfaction from Treatment

Causes of Satisfaction	Government Hospital	Private Hospital	Total Responses*
Proper care	11 (13.58)	30 (37.03)	41 (50.62)
All tests available	7 (8.64)	27 (33.33)	34 (41.97)
Test report on time	4 (4.93)	21 (25.93)	25 (30.86)
Nominal charges	18 (22.22)	16 (19.75)	34 (41.97)

(Figures in the bracket represent percentage)
*Multiple Responses

Equal number of patients i.e. 34 (41.97 per cent) reported that they are getting proper care in the hospital with the nominal charges. However, the level of proper care in terms of satisfaction is high in private hospital as compared to government hospital. The satisfaction in terms of diagnostic tests and timely reports of tests are viewed in case of private hospitals as compared to government hospitals.

The assumption that private services offer superior quality of services is not adequately supported by any hard evidence. While some private sector facilities offer good quality services, this cannot be generalised because of the heterogeneity of facilities, personnel and their practices. Evidence from micro studies is revealing. Private care practitioners along with public care practitioners, for example, in Delhi, are more skilled and knowledgeable in the wealthier areas in comparison to the poorer area (Das and Hammer: 2007).

Overall dissatisfaction with the facility of health care in government and private hospital is reported by the patients in terms of their multiple responses. They vary from shortage of doctors, beds, nurses, and paramedical staff. Another important causes of dissatisfaction comes from the poor hygiene in hospital, beds sheets are dirty. Most of the diagnostic tests are delayed or machines are not in order and some time they are faulty also. That's why patient have doubt on the diagnostic tests done by the hospital staff. Some of them also reported doctor's biasness in treatment. The patients are not treated with dignity and respect.

Interaction in the consultation and the information and explanations provided by doctors has been shown to reflect their assumptions of the interests of different patient groups (Street: 1991). For example, there is some evidence that doctors volunteer more explanations to some groups

Table 8. Patients Dissatisfaction from Hospital Services

Causes of Dissatisfaction	Government Hospital	Private Hospital	Total Responses*
Due to shortage of Doctors	22 (56.41)	-	22 (56.41)
No proper care by doctors	19 (48.72)	7 (17.95)	26 (66.67)
Due to shortage of ward staff	18 (46.15)	10 (25.64)	28 (71.79)
Due to shortage of Beds for the patients	16 (41.02)	-	16 (41.02)
Not having proper medical knowledge	13 (33.33)	7 (17.95)	20 (51.28)
Insufficient para-medical staff	20 (51.28)	16 (41.02)	36 (92.31)
High cost of treatment	-	17 (43.59)	17 (43.59)
Delay in diagnostic tests	21 (53.85)	3 (7.69)	24 (61.54)
Doubt on diagnostic tests done by hospital	11 (28.20)	7 (17.95)	18 (46.15)
Due to shortage of diagnostic tools	5 (12.82)	3 (7.69)	8 (20.51)
Discrimination in care	22 (56.41)	8 (20.51)	30 (76.92)
Failing to treat the patient with dignity or respect	22 (56.41)	5 (12.82)	27 (69.23)
Dirty Bed sheets	21 (53.85)	9 (23.08)	30 (76.92)
Poor sanitation and hygiene	19 (48.72)	12 (30.77)	31 (79.49)

(Figures in the bracket represent percentage)
*Multiple Responses

of patients, including more educated patients and male patients, even when the explanation is not explicitly requested by the patient. Some patients can therefore be doubly disadvantaged; because of both their passive communication styles and the doctor's (mis-) perceptions of their informational needs and desires.

Common complaints against public care cited in the recent NSSO (2006) and NFHS (1998-99 and 2005-06) include: "Not satisfied with medical treatment", "lack of availability of services", "long waiting times", "poor quality of care", and poor interpersonal interactions. Additionally, assessment of the public sectors underscore poor technical competence, poor accessibility to services, inadequacy of drugs and supplies, poor staff availability, and poor quality and amenities (Rao et al: 2005).

CONCLUSION

It is interesting to note that sixty per cent of the doctors feel that there exists a good relationship between doctor and patient and in term it helps in the treatment process. Regarding the content of the relationship between doctors and patients, majority of doctors mention that while interacting with the doctor they want to clear the doubts of patients in terms of disease and process of treatment. Doctors mention that they have normal behaviour with their patients. Some doctors are friendly as well as emotive with their patients. Satisfaction from the treatment not only helps in the healing process but also provide good interaction and relationship between doctors and patients. Sixty seven per cent patients reported that they are satisfied with the treatment which they are receiving from the hospital. There is some difference in terms of satisfaction in government and private hospital. More numbers of patients in private hospital are satisfied with the treatment as compared to government hospital. Most of the patients are satisfied with doctor's behaviour. The patients who are not satisfied with doctors' behaviour are more from government hospital. The level of satisfaction from proper care is high in private hospital as compared to government hospital.

The important cause of dissatisfaction with the facility of health care comes from the poor hygiene in hospital, dirty beds sheets. Most of the diagnostic tests are delayed or machines are not in order and some time they are faulty also. That's why patient have doubt on the diagnostic tests done by the hospital staff. Some of them also reported doctor's biasness in treatment. The patients are not treated with dignity and respect. Majority of the doctors feel that good relationship between doctor and patient helps in the treatment process.

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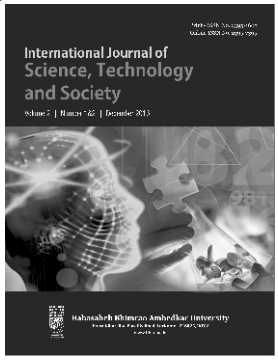

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