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JOSEPHINE RESEARCHER

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EDITORIAL

In this post covid world, we are witnessing a revolution in information and technology. In this age of technological explosion and information over bloom we are trying to bring forth some divergent perspectives through an interdisciplinary approach. It is a humble attempt to express this multifarious voices in the form of an academic journal. Josephine Researcher V volume unifies the vibrant withered souls to contribute their knowledge to the ever expanding world of ideas. The interdisciplinary approach will encourage the readers to look forward for the different vistas in the new methods of knowledge production. On this occasion we are thankful to the contributors for their efforts and patience in compartmentalizing their knowledge arenas. We wish the readers a wonderful experience in reading and enjoying the plethora of innovative ideas and thoughts on the changing times. This volume which affirms quality rather than the quantum of knowledge reiterates the interdisciplinary of research paradigm and spurs further researches.

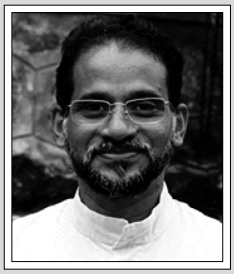
This interdisciplinary research book, which functions as energy pathway, offers dynamic platform for the creative minds to disseminate the distilled knowledge for the inquisitive minds. The treasure trove of knowledge unravels itself before the explorer and demystifies the plurality of knowledge it eludes. On this occasion, we are thankful to the contributors, who are like Alfred Lord Tennyson's Ulysses says, "yet all experience is an arch whereto'/Gleams that untraveled world whose margin fades/Forever and forever when I move". The paramount role of the readers in bridging the energy pathway is appreciated on this context.

We are extremely grateful to our manager **Very Rev. Dr. George Edayadiyil CMI** for his insightful support. We are thankful to **Rev. Dr. Thomas George CMI** (Our Local Manager and Managing Editor). The inspiration and ingenious support of **Dr. Sabukkutty M.G.**, our Principal is to be reckoned on this occasion for infusing life to this resource book. We also express our gratitude to Rev. **Dr. Jomon Kottarathil CMI**, our Bursar.

The present issue (Fifth Volume) includes eight research articles from science, seven from social science and four from literature. We expect that these articles of primary and secondary nature would enable us to have a share in creating a more harmonious world.

For Editorial Team
Dr. Jose James

MASTER BRAINS BEHIND JOSEPHINE RESEARCHER V



Very Rev. Dr. George Edayadiyil CMI

Very Rev. Dr. George Edayadiyil CMI is the Provincial of St. Joseph Province, Kottayam and performed as the manager of our college. He is the guiding inspiration behind this noble venture. He is a well-known educationalist, noted writer, gifted orator and is an effective administrator. He is also working as Professor of Theology, Dhrmaram Vidhya Kshertam, Bangluru.

Rev. Dr. Thomas George Vengaluvakkel CMI

Rev. Dr. Thomas George Vengaluvakkel CMI is our vibrant and efficient local manager and Prior of St. Joseph's Monastery, Arakulam. He is an approved Research guide in Mahatma Gandhi University and worked as HOD in Physical Education Department of our college. He has published more than 25 Research articles in International Journals. He was the founding Director of St. Joseph's Academy of Higher Education and Research, Moolamattom. He co-authored two Malayalam Books and also published one Malayalam Christian Devotional CD.

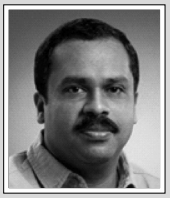
Dr. Sabukutty MG

Dr. Sabukutty MG is the beloved Principal of St. Joseph's College, Moolamattom and has been selflessly serving the institution all along its chronicles of crafting academic repute and laurels for the past twenty six golden years. Spearheading St. Joseph's College to its most cherished and long awaited goal of securing NAAC A grade by being the IQAC coordinator during the tenure 2014-2019, he was assigned the chair of Principal of the institution from 1st May 2021. He became an Associate Professor in 2009 and headed the Department of Mathematics for the term 2015-2021. Besides this, he also dedicates his time in Mathematical Research, and mentoring higher educational institutions across Kerala towards NAAC Accreditation and Ranking.

Rev. Dr. Jomon K Sebastian CMI

Rev. Dr. Jomon K Sebastian CMI is the bursar of our institution. He secured his doctoral degree from Manonmaniam Sundaranar University, Tamilnadu, India on 'Decompositions of Graphs'. Dr. Jomon currently serves as a reviewer of zbMATH and is a member in the panels of referees for 4 international research journals and a life member of 4 professional societies. He has authored 13 research articles in Graph Theory. He is also the author of 15 literary articles in Malayalam. He has attended 32 conferences and presented 16 papers. He also holds post-graduate degrees in Mathematics and Education. He has over 10 years of teaching experience and about 6 years of research experience.

EDITORS



Dr. Jose James

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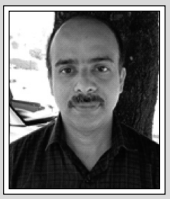
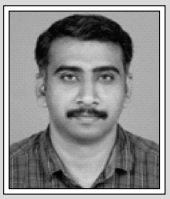


Dr. Praveen Joseph



Dr. Subin Thomas

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Dr. Jose James is serving as the Assistant Professor in the Department of Chemistry since 2011 and is an approved research guide in Mahatma Gandhi University under the faculty of science. In his credit, there are 7 International publications, 2 International edited books, 7 International book chapters, 4 National edited books, 6 National book chapters, 21 International Conference presentations and is serving as a reviewer of number of International Journals. He works in collaboration with Prof. Sabu Thomas, Vice-Chancellor of Mahatma Gandhi University in the domain of Polymer Science and Nanotechnology.

Dr. Sr. Sijo Francis, Assistant Professor and Head of Department in Chemistry, St. Joseph's College, Moolamattom, Idukki, Kerala, India. She earned her PhD from Mahatma Gandhi University, Kottayam. She qualified for the CSIR-UGC examination in Chemical Sciences and had a good score in GATE-2010. She has 12 International peer-reviewed publications, 7 International book chapters and 6 National book chapters. Her research interests include nanomaterials, polymer composites and computational chemistry.

Dr Praveen Joseph is an assistant professor in the department of Physics, St Joseph's College Moolamattom since 2013. He was conferred his PhD degree in Physics from Mangalore University and has 15 years of teaching and research experience. He has published 20 research articles in National and international journals and presented 21 articles in National and international conferences. He is a life member of the academy of Physics teachers, Kerala.

Dr Subin Thomas earned his Ph.D from the Department of Instrumentation, Cochin university of Science and Technology. He later served as a post doctoral fellow at the School of Pureand Applied Physics, Mahatma Gandhi University, where he worked on Surface Enhanced Raman Spectroscopic applications of graphene. Later he moved to Cochin University of Science and Technology as a post doctoral fellow and studied functionalization of graphene for biosensing applications. Dr. Subin Thomas is currently working an assistant professor at the Department of Physics, St. Joseph's college Moolamattom. Dr Subin Thomas has authored 10 papers and conference papers.

Dr Salini LR, has joined the service as Assistant Professor in English, St Joseph College Moolamttom on September 2021. She had completed her MA, MPhil and Phd from Jawaharlal Nehru University, New Delhi. She had worked in many colleges across India as guest lecturer and adhoc faculty in English. She has published a book titled Padayani on 2019. She also had to her credit more than 10 publications in various National journals and had participated in many workshops, seminars and faculty development programs of academic importance.

Ms. Christy Joseph is working as Assistant Professor, in Department of English, St. Joseph's College, Moolamattom. She completed her Post Graduation from Pondicherry University and, M.Phil. from School of Letters, M.G.University. She has published 11 papers in various National and International Journals. She also has four years of teaching experience. Her areas of interest include Postcolonial Literatures and Trauma Studies.

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A. SOCIAL SCIENCE

EFFECT OF TA BATA TRAINING ON ENDURANCE AND SPEED OF COLLEGE LEVEL HANDBALL PLAYERS

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ABSTRACT

The objective of the study was to analyse the benefit of Tabata training on college level handball players. The experimental design of this study was random group design. For this purpose (N=30) thirty college handball players were selected (male), of age group 18 to 21 years from Idukki Handball association, Idukki, Kerala.The subjects were split into two groups of fifteen (n=15) each namely expirimental group (EG) and control group (CG). The expirimental group undervent eight weeks of Tabata training programme on alternte days pre week(Monday, Wednesday and Friday).

The dependent variables selected for the study were speed, and endurance and the independent variable selected for the study was Tabata Programme. The dependent variables selected were tested before and after the training programme for both the groups using standardised tests. After the data collection, the data were statistically examined by applying descriptive statistics, paired't' test and analysis of covariance. All the data were analysed by using statistical package for social sciences (SPSS). The level of significance was fixed at 0.05 level. The result of the study indicated that there was a significant differences in endurance and there was no significant difference in invariable speed.

INTRODUCTION

The Sports training is understood as a process of systematic development of each component, which leads to achieving maximum efficiency within the selected sports discipline. In the broad sense, sport training is the entire process of systematic preparation of athletes for highest levels of athletic performance. Besides, it is the organized process of scientific preparation of athletes for uppermost levels of athletic performance. Performance is understood as an extent to which motor task is accomplished. In the case of the athlete, performance is evaluated following rules of the sports discipline which were set in advance, which is expressed by the merit of the motor activity and is understood as a sports performance. An ability to achieve a given performance repeatedly is referred to as efficiency. Sports'

training is a process of systematic preparation of sportspersons or team to perform well in a sports competition. In this the sportsperson or team gets systematic training which is based on scientific principles. The goal of sports training is to train a sportsperson or team to achieve their full potential and perform optimally in a particular competition. Sportstraining includesphysiological conditioning, psychological training, skill training, and training of game plan or strategy.

TABATA TRANING

The great thing about Tabata training is virtually any exercise, both in the gym and out, from sprinting to weightlifting, can be used in this training style. Although this training method seems to be one of the newest fitness fads, it's actually been around for quite some time (http://www.active.com/fitness/articles/what-is-tabata-training)

Tabata is the name of a particular type of workout program that provides similar health benefits to that of cardio workouts, but Tabata has a bit more spice. Instead of hours upon hours or exercise, Tabata can be completed in 4 minutes. Tabata falls under the category of high intensity interval training (HIIT). (www.active.com/what-is-tabata-training)

Tabata was founded by a Japanese scientist named Izumi Tabata and fellow colleagues at a department of physiology in Japan. Izumi and his fellow scientists decided to conduct a study to compare moderate intensity training with high intensity training. He conducted the tests on 2 groups of athletes; one of the groups used the moderate intensity interval training and the other used high intensity interval training. In group one; the athletes were training in moderate intensity workouts (70% intensity) for five days a week for a total of six weeks with each training session lasting an hour. Group two trained in the high intensity workouts for 4 days a week for a total of 6 weeks with each session lasting 4 minutes, at 20 seconds of intense training (170% intensity) and 10 seconds of rest. Group 1 had a significant increase in the aerobic system (cardiovascular system). However, the anaerobic system (muscles) gained little or no results at all. Group 2 showed much improvement in all their athletes. Their aerobic systems increased much more than group one, and their anaerobic systems increased by 28%. Conclusion, not only did high intensity interval training have more of an impact on the aerobic systems; it had an impact on the anaerobic systems as well. (http://www.active.com/fitness/articles/what-is-tabata-training)

BENEFITS OF TABATA TRANING

Burn Fat

Tabata training will raise one's metabolism and heart rate in no time. Because one is going at such a high level of intensity, one's body has to work much harder to keep up. One's metabolism will stay at a high not only during the workout, but after the workout as well. This means that one's body will be burning fat even when one doesn't do anything. When performing other forms of moderate cardio, one has to wait until one's body gets into the "fat burning zone" in order to really burn fat. As soon as one stops

the cardio, one's body stops burning calories. Tabata training places one's body directly in the fat burning zone within the first round and keeps burning hours after. (http://www.active.com/fitness/articles/what-is-tabata-training)

PROTECTS MUSCLE TISSUE

The last thing that Tabata training does is cut into hard earned muscle tissue. With the short amount of time that it takes to get a good workout, one won't be eating away at any muscle tissue as one might during long durations of cardio. The Tabata method of High Intensity Interval Training (HIIT) places stress on muscle tissue, which tells one's body that more muscle tissue is needed. As a result, the ratio of one's lean body mass to fat goes up, and by choosing exercises that maximize the muscle mass worked, muscle tissue may increase. (http://www.active.com/fitness/articles/what-is-tabata-training)

SHORT ON TIME

No matter how busy one is, all it takes is four to eight minutes of this high intensity workout to get a great workout in. The availability of this workout is time saving in itself, as one does not need to go to a gym to reap the benefits. All one need is one's own body weight or some at home equipment like bands and dumbbells.

AEROBIC AND ANAEROBIC CAPACITIES INCREASE

The anaerobic capacity, which represents the maximum amount of energy that can be produced by one's body in the absence of oxygen, and the aerobic capacity (the maximum oxygen uptake capacity) are increased. According to recent studies, participants who underwent a Tabata sprint training had their aerobic capacity increased by over 14% and a 28% increase in their body's anaerobic capacity. The outcomesare more energy, stamina and a higher degree of resistance for continuous strain and effort. (http://www.active.com/fitness/articles/what-is-tabata-training)

HIGH INTENSITY TRAINING

The high intensity training (HIT) system embodies a strength training philosophy that focuses on high intensity work, performing quality repetitions to momentary muscular failure (MMF) developing balanced strength throughout each muscle group, and building maximum strength and power in the safest environment possible. The HITstrength system uses the triple progressive overload process, which takes into account not only the number of repetition and the amount of weight but also the amount of time the working muscle is exposed to tension. This progressive overload process translates directly into strength gain and facilitates maximum muscle fiber recruitment to ensure the highest level of strength and power development. (philbin j 2004)

The HIT system strives to achieve specific goals during each repetition of each set for every workout. Athletes must be mentally prepared to concentrate during each exercise and maintain focus through the entire workout. Every time athlete enters the weight room, the HIT system challenges their willingness to push themselves beyond

their current training tolerance for muscle discomfort. Athletes are only as strong as their acquired ability to tolerate muscle discomfort while taping into the deepest inroads of muscle tissue during the last repetition of every set. Most importantly, thousands of athletes will testify to the fact that the HIT system is by far the most intense but rewarding strength system around. (philbin j 2004)

The HIT system uses as many strength resistance modalities as possible including free weights, machines, cables and manuals, to facilitate different muscle requirement patterns. This system can be integrated any athletic strength training programme, regardless of the available equipment, space limitations, or time restrictions-even when there are many athletes in programme (philbin j 2004).

Hypotheses

From the review of literature and the researcher's understanding of the topic following hypotheses are stated:

H1. There may be significant difference in the sprinting ability of college men following eight weeks of Tabata training

H2. There may be significant difference in explosive strength of college level male handball players by the following eight weeks of Tabata training

H3. There may be significant difference in cardiovascular endurance of college level male handball players by the following eight weeks of Tabata training

METHODOLOGY

Selection of subjects

The investigator selectedthirty (N-30) male subjects from Idukki hand ball association, Idukki, Kerala. The subject's age ranged between 18-21 years. Selected subjects randomly divided into two groups namely experimental group (n-15) and control group (n-15. Prior to the administration of test, the investigator held a series of meeting with the subjects and was made clear the objective and purpose of the study. The testing procedure was explainedto them in detail before the test. They were requested to actively participate in the test.

Selection of tests

Table 3.1

Sl. No.	Variables	Tests	Unit of measurements
1	Speed	50 meter dash	In seconds
2	Cardiovascular Endurance	Cooper test	In meters

Collection of data

Data needed for the purpose of the study were collected before and after the 8 weeks of training programme by administrating the appropriate test procedure.

Administration of training programme

The Tabata programme was administrated to the subjects for 3 days in a week alternatively ie. Monday, Wednesday and Friday thirty minutes in the morning 7 am to 7 30 am. Every session started with 10

minutes of general warming up. For the first week there was only one repetition of Tabata work out. From the second to fourth week the repetition of training was increased into two. Starting from the fifth to eight week the training repetition was increased into three.

Analysis of Data

The collected data on selected criterion variables have been analysed and presented. The analysis of the data, results and Tabata training programme on college level male handball players was investigated to derive the effect of two groups, namely experimental group (n=15) and control group.

All the subjects of the two groups were tested on selected variables namely,'Speed' and 'Endurance'before and after the training programme. The effects of Tabata training were determined by computing t test, analysis of co-variance (ANCOVA). The data and interpretations were given below. The level of significance chosen was 0.005 level of confidence throughout the study.

Descriptive Statistics for the selected variables of Experimental and Control Groups

Variable	Test	Group			
		Experimental Group		Control Group	
		Mean	SD	Mean	SD
Speed	Pre-Test	6.557	.504	6.725	.679
	Post-Test	6.553	.497	6.704	.659
Endurance	Pre-Test	2683.333	203.247	2673.333	449.152
	Post-Test	2986.666	250.333	2700.000	412.310

The above table provides a descriptive profile of the data on the selected variables for the total sample for the pre and post test scores of the control group. The table shows variation for the mean and standard deviation of the variables such as Speed and Endurance.

Paired Sample t test for speed of Experimental and Control Groups

Group	Pre-Test Mean	Post-Test Mean	t	Sig
Experimental	6.557	6.553	.214	.834
Control	6.725	6.704	.786	.445

$t_{0.05}(14) = 2.145$

Table 4.9 of paired t test for the pre and post test scores of both experimental and control group on speed indicates t value .214 for the experimental group and it was statistically significant at 0.05 level in the case of control group, the obtained t value was not significant. The graphical representation of the pre and post test scores of speed for experimental and control group is shown in the following figure.

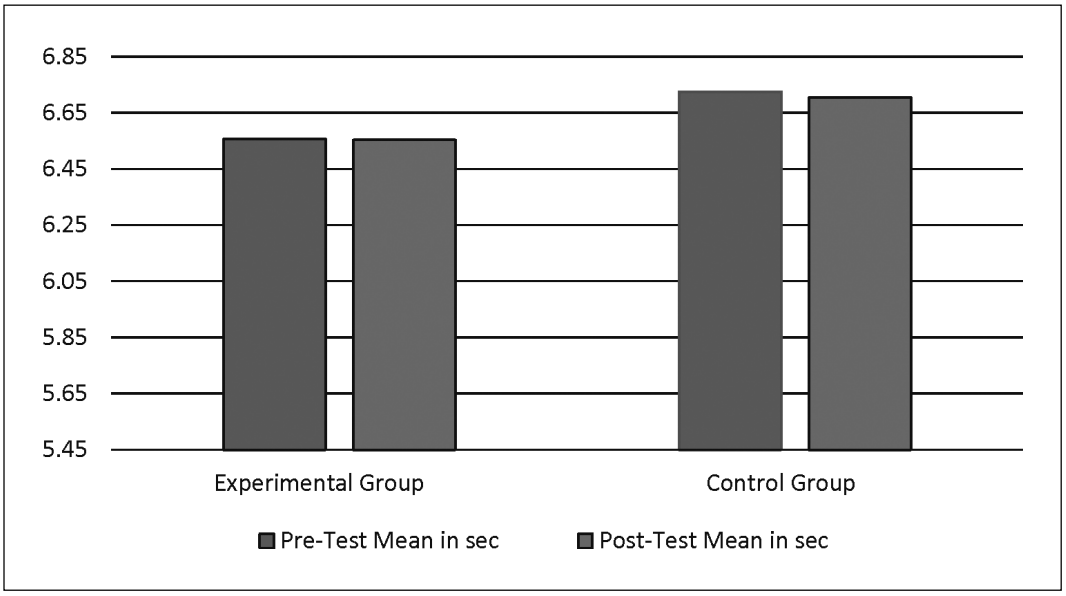


Figure: Adjusted Post Test values of speed Experimental and Control Groups

The t test results show that there is no significant difference in the pre and post test score of speed. To know the effect of independent variable on speed, we have to consider the pre-test scores as covariate. For this ANCOVA was used. The result of the analysis of co variance for the experimental and control group after the Tabata training on speed is presented in the following table

Analysis of Covariance for Post Test Scores of speed for the Experimental and Control Group

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Speed-Pre	9.346	1	9.346	1219.587	.000
Treatment	.001	1	.001	.114	.738
Error.207	27	.008			
Corrected Total9.725	29				

The effect of Tabata training on post adjusted mean of speed was examined by using ANCOVA with pre-test score used as covariate. As seen from table 4.10, significant F ratio of .114 was obtained for group there by indicating significant difference in post adjusted values for speed between the experimental and control groups.

Paired Sample t test for endurance of Experimental and Control Groups

Group	Pre-Test Mean	Post-Test Mean	t	Significance
Experimental	2683.333	2986.666	-10.294	.001
Control	2673.333	2700.000	-.544	.595
$t_{0.05}$ (14) = 2.145				

Table 4.11 of paired t test for the pre and post test scores of both experimental and control group on endurance indicates t value -10.294 for the experimental group and it was statistically significant at 0.05 level in the case of control group and the obtained t value was not significant.

The graphical representation of the pre and post test scores of endurance for experimental and control group is shown figure 6.

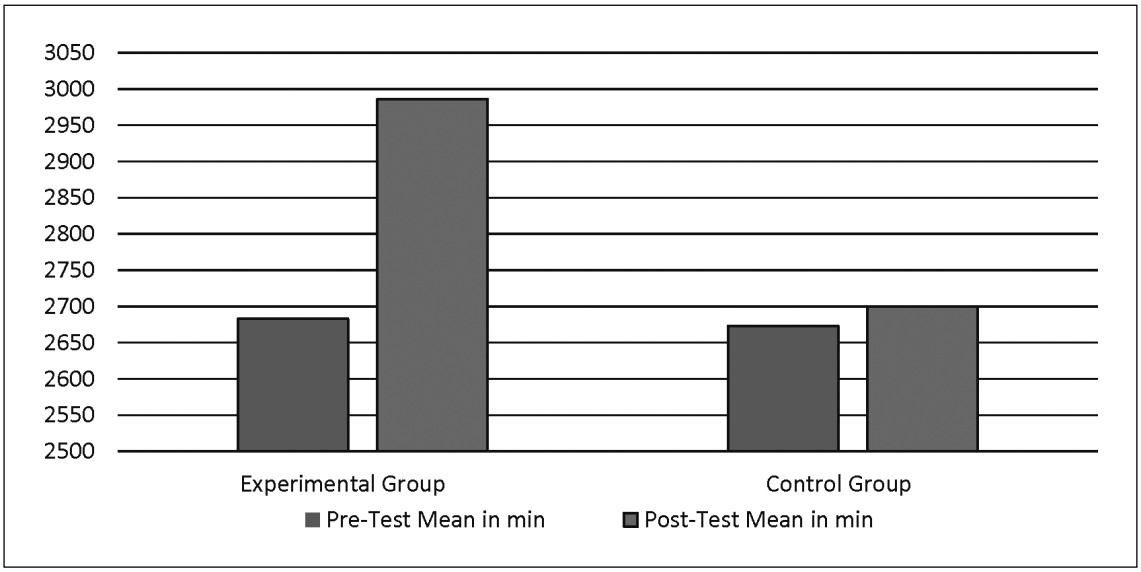


Figure 6 Adjusted Post Test values of endurance Experimental and Control Groups

The t test results show significant difference in the pre and post test score of endurance. To know the effect of independent variable on endurance, we have to consider the pre-test scores as covariate. For this ANCOVA was used. The result of the analysis of covariance for the experimental and control group after the Tabata training on enduranceis presented in table 4.12.

Analysis of Covariance for Post Test Scores of endurance for the Experimental and Control Group

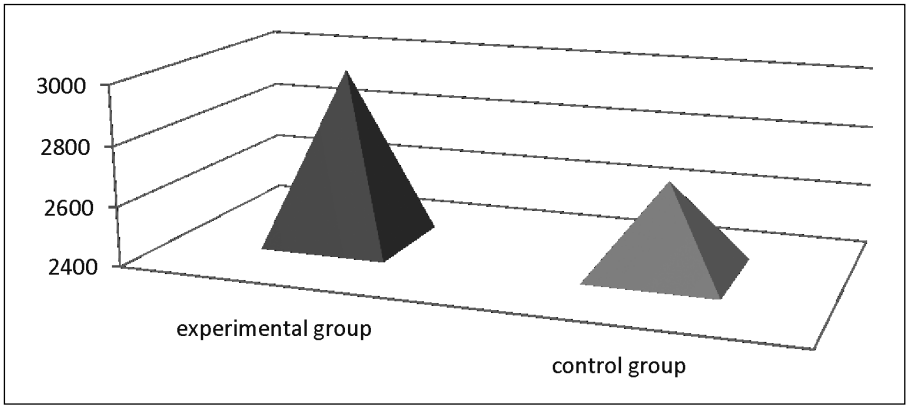
Source	Type III Sum of Squares	df	Mean Square	F	Significance
Endurance–Pre	2621525.601	1	2621525.601	111.325*	.000
Treatment	579040.582	1	579040.582	24.589*	.000
Error	635807.732	27	23548.435		
Corrected Total	3873666.667	29			

The effect of Tabata training on post adjusted mean of endurance was examined by using ANCOVA with pre-test score used as covariate. As seen from table 4.12, significant F ratio of 24.589 were obtained for group there by indicating significant difference in post adjusted values for endurance between the experimental and control groups.

Experimental Group	Control Group	Mean Difference	Standard Error	Significance
2986.66	2700	277.889*	56.040	.000

*Mean difference significant at 0.05 level

The above table of comparison of post adjusted group means for the experimental and control group for endurance indicates significance difference between the experimental and control groups. The experimental group showed significant increase in endurance from pre-test to post-test values following Tabata training as compared to control group. Since the t ratio was significant Bonferroni post hoc test was used.



The graphical representation of the post adjusted group means for endurance of the experimental and control group is shown in the figure given below.

Figure 7 post adjusted group means for endurance of the experimental and control group

4.2 Discussions of Findings

The purpose of the study was to investigate the effect of Tabata training on Speedand Endurance of college level male handball players. The study was investigated by the effect of eight-week Tabata training on selected psychological variables.

The result of the study indicatedthat significant increase in endurance (12 minutes run or walk) after the eight weeks of Tabata training. Tabata training programmes were helpful to improve the cardio vascular endurance of the handball players.The Tabata training programme is a high intensity interval training which lasts for some time. Every session of the Tabata training programme lasts for five to fifteen minutes with the maximum intensity of the handball players. So, the vigorous exercises in the Tabata training programme helped to improve the endurance.

The result indicated that there is no significant improvement on speed after the eight weeks of Tabata training. Tabata is a high intensity interval training. Speed only improved through regular specific training. This Tabata work out plan doesn't include specific seed training so the result indicated there is no significant increase from pre to post test for speed.

4.3 Tenability of Hypothesis

The results of the study have led to the following decisions for the formulation of hypothesis:

- Hypothesis 1was also accepted because there is significant difference in the cardiovascular endurance of college men following eight weeks of Tabata training. So, the hypothesis is accepted at 0.05 level of significance.
- The other hypothesis was rejected because there is not any significant improvement on the other variable speed of college level handball players.

CONCLUSIONS

The present study was an experimental study on the effect of "Tabata training on college level handball players". The experimental design of this study was random group design. For this purpose thirty (N=30) college level handball players (male), of age 18 to 21 from Idukki handball association, Idukki, Kerala were selected. The subjects were divided into two groups of fifteen (n=15) each namely experimental and control group. The experimental group underwent eight weeks of Tabata training programme on alternate dates per week (Monday, Wednesday and Friday).

The dependent variables selected for the study were selected psychological variables namely endurance and speed and independent variables selected for the study were Tabata training programme. The dependent variables selected were tested prior to and after the training programme for both using standardised tests.

After the data collection the data were statically examined by applying descriptive statistics, paired't' test and analysis of covariance. Since, both experimental and control groups were selected from the same population, there is a possibility of affecting the post-test mean. For eliminating any possible influence of covariates the adjusted post-test mean of experimental and control groups were tested for significance by using analysis of covariance (ANCOVA). All the data were analysed using statistical package for social sciences (SPSS). The level of significance was fixed at 0.05 level.

The result indicated that there was significant difference in endurance and there were no significant differences in the variables of speed. Within the delimitations and limitations of the present study and on the basis of the obtained result, the following conclusions were drawn.

Participation in the eight weeks of Tabata training programme results in significant increase in enduranceof handball players aftereight weeks of Tabata training.There is no significant increase in speed by the effect of Tabata training.

RECOMMENDATIONS

In the light of the conclusion drawn, following recommendations are made:

- The result of the study will be helpful to frame new training plans for the eliteplayers as a supplementary to traditional high intensity training programmes.
- Tabata training is very useful for improving endurance among sports persons. So, it can be used to include in the training programme for improving endurance.
- Similar study will be conducted to improve the cardiovascular endurance.
- Similar study can be conducted to other specific game players.
- The Tabata training programme may help to improve better physical capacity of athletes quickly. This will help the coaches in preparing the athletes.

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A CASE STUDY ON VODAFONE INDIA MERGER WITH IDEA CELLULAR

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ABSTRACT

The case discusses the merger between India's third largest mobile telephony company Idea Cellular and the second largest mobile operator in the country, Vodafone India Limited. The deal announced in March 2017 was valued at around US$ 23 billion. The merger came in the aftermath of an unprecedented change that the Indian telecom landscape had undergone after launch of Reliance Jio Infocom Ltd. in September 2016. The leading players in the industry who were already facing financial challenges due to huge infrastructure costs and a high debt burden, faced more problems with the exodus of customers to Jio. To face the onslaught from Jio, the telecom operators went into consolidation mode, acquiring spectrum, small players, infrastructures, etc. With Jio growing stronger by the day with offers like free mobile headsets, and another competitor Airtel also looking at consolidation through acquisitions, Idea-Vodafone faced a tough road ahead. It remains to be seen whether the biggest ever merger in the history of Indian telecom would prove to be a game changer in the world's second largest telecom market.

Keywords: *Merger, debt, consolidation*

History

On 20 March 2017, Idea and Vodafone India announced that their respective Boards had approved a merger of the two companies. The merger got approval from Department of Telecommunication in July 2018. On August 30, 2018, National Company Law Tribunal gave the final nod to the Vodafone-Idea merger. The merger was completed on 31 August 2018 and the newly merged entity s named Vodafone Idea Limited. The merger created largest telecom company in India by subscribers and by revenue. Under the terms of the deal, the Vodafone group holds a 45.2% stake in the combined entity, the Aditya Birla Group holds 26% and the remaining shares held by the public.

Idea previously brought Spice Communications Ltd, operating as Spice Telecom, for over Rs. 2,700 crores. Idea Cellular Limited was an Indian mobile network operator based at Mumbai, Vodafone Group is a British multinational telecommunication com-

pany. Its registered office and headquarters are in Newbury, Berkshire, England. It predominantly operates services in Asia, Africa, Europe and Oceania.

Vodafone India

Vodafone India was the Indian subsidiary of UK-based Vodafone Group and was a provider of Telecommunications services in India with its operational head office in Mumbai. Since 2011, Vodafone launched 3G network using 900MHz and 2100MHz. The first city to receive 3G service was Luck now in UP.

M-pesa was launched in India as a close partnership with HDFC bank in November 2011.On 28 June 2012, Vodafone launched a new international roaming package under which the users shall have not to pay multiple rentals in the countries they are visiting.

On 19 May 2015, TRAI announced that Vodafone had been awarded spectrum in 9 circles for 3G coverage, bidding around Rs 11617.86 million for the spectrum.

On 8 December 2015, Vodafone announced the roll out of its 4G LTE coverage in India on 1.8 GHz and 2.1 GHz brands starting from Kochi. The service become available in Indian nationally in 2017, with plans of further expansion. Vodafone now starts 2100MHz and 2500MHz for 4G by which customer will get superior 4G speed than previous.

Idea Cellular

Idea cellular were incorporated as Birla communications limited on march 1995 and granted a certificate of commencement of business on August 11, 1995. The name was changed to Birla AT&T Communications Ltd. on May 30, 1996 following the execution of a joint venture agreement dated December 5, 1995 between AT&T Corporation and Grasim Industries Limited pursuant to which Aditya Birla Group held 51% of our equity share capital and AWS group held 49% of equity share capital.

The introduction of idea brand their name was changed to Idea cellular limited on May 1, 2002. The AWS group exited from the company on September 28, 2005 by selling 371,780,740 equity share of the company, which constituted 50% of the holding of AT&T Cellular private limited.

The TATA Group ceased to be a shareholder of the company on June 20, 2006 when TATA industries Limited and Apex Investments Holding Private Limited sold all their shares in the company to Aditya Birla Group.

Highlights

- Creation of India's largest telecommunications company
- Equal partnership between Aditya Birla Group and Vodafone Group
- Strategic fit and complementary assets
- Significant synergies

The merger will give a higher stake to the promoters of Idea as compared to Vodafone India so that in the long run both the companies are able to gain access to equal hold.

The first step for AB Group would be the acquisition of 4.9 percent of shares from

Vodafone. This would amount to a total of **Rs. 3874 crores wherein each share worth Rs. 108.** This would be helpful in increasing the shareholding capacity of Idea to 26 percent.

While **Vodafone holds 45.1 percent of the shares in the merger**, Idea would be allowed to buy another 9.6 percent but at a cost of Rs. 130 per share in the period spread over next four years. However, if Idea is unable to come up equal to the shareholding percentage of Vodafone, it can go forward and buy the number of shares required further but at the price prevailing in the market.

Principles of partnership

Equal Partnership

- Idea promoters and Vodafone Group will be joint promoters of the combined entity
- Equal affirmative rights to both promoters on key matters

Board Composition

- 12 member Board with 6 independent directors
- Equal representation from Aditya Birla Group and Vodafone Group
- Chairman: Mr Kumar Mangalam Birla

Key Management

- CEO & COO – "Best person for the job" – joint appointment
- CFO – Vodafone to appoint

Shareholding Equalisation

- Aditya Birla Group has the right to acquire up to 9.5% additional share holding from Vodafone Group
- If equalization is not achieved, Vodafone Group to sell excess stake
- Till equalisation, voting on excess stake held by Vodafone to be restricted and exercised jointly as per the agreement

Vodafone-Idea Limited Content Partnerships

In 2019, Vodafone Idea limited empowered it's customer service with varied content partnerships to encourage on their mobile apathy first partnership was between Vodafone Idea Limited and Sun TV Network for its OTT platforms, Sun NXT, which will now be accessible to Vodafone Idea users. Sun NXT caters to Tamil, Telugu, Kannada and Malayalam audiences having over 50,000 hours of content. The partnership offers Vodafone and Idea's customers 'access to Sun NXT's exclusive digital content for free.

Post to this, Vodafone Idea Limited announced a partnership with Shemaroo and Zee5 or similar cost effective content viewing options for their customers. There was an additional partnership created between Idea and Amazon prime for Idea's Nirvana post-paid users.

Highlights of combination

Largest Telecom Operator

- Creating India's largest telecommunications company.
- Combined Subscriber base of nearly 400 million.

- Combined RMS of 40.7% and CMS of 35.1%.
- Leadership position (#1 / #2 rank) 2 in 21 (out of 22) telecom circles.

Complementary Footprint

- Largest existing Mobile Voice population coverage of 1.1 billion Indians.
- Pan India Broadband currently covering approximately 650 million Indians; committed to reach 1.1billion.
- Strong brand appeal across metro, urban, rural & deep interior markets.
- New leadership positions in 7 markets.

Wide Scale Network

- Deepest Pan India GSM network infrastructure of 273,000 GSM sites.
- Rapidly expanding existing Mobile Broadband network spread of over 189,000 sites.
- Release of overlapping equipment for expansion of mobile broadband services to uncovered geographies.

Largest Spectrum Portfolio

- Substantial overall spectrum holding of 1,850 MHz across multiple bands.
- Auction acquired liberalised spectrum quantum of 1,645 MHz.
- Large broadband (3G/4G) spectrum portfolio of 1,429 MHz.
- Premium 900 MHz band in 17 circles.

Highest Broadband capacity

- 163 mobile broadband carriers; highest amongst all operators.
- 3G - Pan India 344 carriers with 2 carriers in 11 leadership telecom markets.
- 4G - Pan India 1294 carriers & capability to offer up to 250 Mbps in 12 markets.
- Large fibre network of approximately 2, 50,000 kms.
- Ability to build large broadband capacity on existing spectrum.

Extensive Distribution Channel

- Widest pre-paid reach through over 2 million retailers.
- Post-paid reach to Enterprise & Retail through 30,000 *Field Sales Team*.
- Brand strategy will be developed in due course and will leverage customers' affinity for both existing brands, built up over the past decade.

Unparalleled Service Infrastructure

- Service footprint of 19,000 company branded stores.
- More than 28,000 contact centre agents to serve 400mn customers.
- Managing daily volume of 2.3 million consumer calls.

Significant Synergies

- Rationalisation of operating expenses including Network Infrastructure & IT Services, Channel & Service partner, brand efficiencies, etc.
- Reduced Network capex due to redeployment of overlapping equipment, deduplication of fresh equipment & spectrum consolidation.

- Estimated NPV of net synergies of approximately INR 670 billion.

Business Expansion

- Higher participation in evolving Digital Services including content.
- Larger canvas for Payment Bank Services to 400 million existing mobile users.
- Scale up presence in Fixed Line segment including FTTH, MPLS etc.
- Deeper penetration in the Enterprise – MNC, National, Regional & SMEs.

Operations

Vodafone Idea Limited competes with other major mobile operators including Airtel, BSNI, MTNI and Reliance Jio. Tata DoCoMo-with whom Vodafone Idea Limited competed is now in the process of merging their businesses with Airtel. Vodafone Idea Limited has gone far ahead of the rest of this competitors with a Revenue Market Share of over 32.2%.

On 19 May 2010, in the 3G spectrum auction Vodafone Idea Limited paid Rs 57.68 billion [US$ 830 million] for spectrum in 11 circles. Vodafone Idea Limited launched its first 3G services in 2011.

As of September 2018, Vodafone Idea Limited offers 4G LTE services on its own spectrum in all the telecom circles.

Merger Pattern

Vodafone Idea Limited is India's largest telecom operator with its headquarters based in Mumbai, Maharashtra. Vodafone idea was a pan-India integrated GSM operator offering 2G, 3G & 4G[LTE] mobile services under two brands named Vodafone and idea. Vodafone idea also provides services including Mobile payments, advanced enterprise offerings and entertainment, accessible via both digital channels as well as on-ground touch points, centres across the country. The company's vision is 'to create world class digital experience to connect and inspire every Indian to build a better tomorrow. As of December 2018, Vodafone Idea has 35.61% market share in India with 418.745 million subscribers, making it the largest mobile telecommunications network in India and world. Vodafone Idea-Vodafone has a broad band network of 340,000 sites, distribution reach of 1.7 million retail outlets.

On 31 August 2018, Vodafone India merged with Idea Cellular, and was renamed as Vodafone Idea Limited. However, the merger entity continues using both the Vodafone Idea brands. Currently, the Vodafone Group holds a 45.1% stake in the combined entity, the Aditya Birla Group holds 26% and remaining shares will be held by the public. Kumara Mangalam Birla heads the merger company as the Chairman, with Balesh Sharma as the CEO.

On 20 March 2017, Idea and Vodafone India announced that their respective boards had approved a merger of the two companies. The merger got approval from Department of Telecommunications in July 2018. On August 30, 2018, National company Law tribunal gave the final nod to the Vodafone-Idea merger the merger was completed on 31 August 2018, and the newly merged en-

tity is named Vodafone Idea Limited. The merger created the largest telecom company in India by subscribers and by revenue. Under the terms of the deal, the Vodafone Group holds a 45.2% stake in the combined entity, the Aditya Birla group holds 26% and the remaining shares will be held by the public. Idea previously brought Spice Communications Ltd, operating as Spice Telecom, for over 2,700 crore.

Challenges

The industry barely has three players left thanks to Jio's blitzkrieg of 2016. Discounted rates can be affordable for a new player like Jio because of its cash-rich parent Reliance. But the same can't be said about others.

Jio is now India's largest telecom operator with more than 330 million users. It acquired all of these customers within a short span of three years. While it added a huge chunk of users from rural regions, a huge proportion of these users ported in from other operators.

The current average rate for 1 GB of 4G data is $ 0.26, while it costs $ 12.37 in the US, $6.66 in the UK, and a global average of $ 8.53. Adding to this, India's airwaves (spectrum) are among the costliest in the world. In 2015, the government raised a record revenue of at least Rs 1 trillion ($14 billion) that will be paid over the coming years.

However, the market did not respond well to the merger. After the announcement, Ideas price range began to decline. The share price dropped from Rs. 97.70 on March 20, 2017 to Rs. 81.80 on September 06, 2017. Analysts were of the opinion that this would be similar to a three –legged race with Usain Bolt. In other words, the feeling of competing with two leading brand [Airtel and Jio] for two different brand could be a daunting task.

Sky-high operating costs

Investors who bought shares in the company's rights issue at a seemingly low price of Rs. 12.50 just five months ago have lost nearly 50 percent of their investment. In a bid to take on the juggernaut called Jio, Vodafone India merged with Idea Cellular to form India's largest operator with more than 400 million subscribers last year. The merger took a year to complete and was expected to provide more firepower against the other two players.

However, subscribers left Vodafone-Idea in hordes. The company lost 14 million subscribers in the June quarter, taking the losses in the past year to about 115 million users. The month of June ended with Vodafone-Idea having just 320 million users.

4G transition

The merger failed to solve both the company's existing issues. Total debt now stands at more than Rs. 1 lakh crore and their ARPU (Average Revenue Per User) is lowest in the world at Rs. 108, while Jio and Airtel are at Rs. 124 and Rs. 129, respectively. Vodafone-Idea has been in the industry for decades and has sufficient experience in deploying new technology. But with the 4G transition, both were stormed by Jio's

instantly available 4G infrastructure. The carrier relies on conventional technology for voice calls while Jio had deployed Volte (voice over LTE) since the beginning. This gave Jio a huge lead in terms of call quality and operating expenses. Adding to this, Jio was the first operator in India to make phone calls completely free because they came bundled with the 4G data pack. Vodafone-India couldn't immediately offer this without taking a hit on operating expenses.

Integration of Vodafone India and Idea's network hasn't been a smooth journey as well. There have been multiple outages and customer complains about frequent call drops, slow data transfers and poor coverage. A decade back, Vodafone India was known for its solid reach and superior offering, but the same can't be said now.

In comparison, Airtel has shifted focus and wants to improve its ARPU instead of adding subscribers. According to open signal, Airtel leads the charts with an average download speed of 8.7 Mbps, followed by Jio at 6.3 Mbps. Vodafone and Idea (as separate entities) were at 5.9 and 5.4 Mbps, respectively.

On an analyst angle, the company hinted that it'll be conservative with the expense since their shares have been on a free-fall for months. Any more expenditure will inch the company close to a crisis. But curbs on investment hurt customer experience and lead to subscriber churn.

It can be concluded that the merger was short-sighted and lacked direction. Instead of solving each other's problems, they ended up consolidating them. Right now, winning hearts of loyal customers should be a priority to prevent an exodus, but the company is busy concentrating on network integration. They are also running two huge brands under one umbrella. These factors actually increase operating costs and efficiency is nowhere to be found.

The way ahead

Vodafone-Idea planned the sale of its 11.15 percent stake in Indus which could yield an estimated Rs. 6,000 crores. The board of directors cleared the planned Rs. 25,000 crore rights issue at a price of Rs. 12.50 per equity share. But, these sources shall only last for a few quarters. In the longer game, Vodafone-Idea will require more capital to go up against the might of Jio and Airtel.

Vodafone (UK) has a 45.1 percent stake in the combined company. This is after transferring a 4.9 percent stake at Rs. 110 per share to Aditya Birla Group for Rs. 3,900 crore in cash. Aditya Birla Group now owns 26 percent of the combined company. The remaining 28.9 percent is owned by Idea shareholders. In this structure, no party is interested in investing further. There could be some relief if the government decides to save the distressed Telco by extending the moratorium on spectrum-related payments. After all, a majority of the company's debt is owed to the government for spectrum.

1. Firstly, there can be initiatives based on the **renewal of price discipline** for the disruptive entry by Jio has caused some serious misbalance

2. Secondly, the poor financial health of the telecom sector can be observed and through such mergers there will be infusion of health and life since **India is the fastest growing market in terms of the subscriber base.**
3. Through the merger, Vodafone and Idea will **overcome their debts** and large sum of credit will be infused in the system
4. The deal has also **saved both the telecom companies from selling off their business**, as was being planned by them initially and this would directly impact the quality of services being provided by different players in the industry

The merger will surely boost the pace of the telecom sector. It has also been found that the savings, synergies and also the spectrum will have substantial impact on the escalating growth. There will be **saving of over 60 percent of the operations cost** and this will aid in improving the quality and performance of the service through investments from the saved money. **Enhancement in network infrastructure will be observed** while the operational efficiencies have a chance to reach excellence. Moreover, the **revenue market share is expected to rise** for all the locations and the spectrum of the entity would exceed the initial caps.

Dirt-cheap tariffs

Vodafone-Idea has sought a two-year moratorium on its annual spectrum payment citing debt and stress on the balance sheet. India is already facing a credit crisis and major financial institutions such as DHFL, IndiaBulls and Yes Bank have been affected. Sinking of a two-decade-old telecom operator because of a tariff war and expensive spectrum won't be encouraging for foreign investors. In the best-case scenario, Vodafone-Idea will operate as a regional carrier. On the contrary, public-sector units like BSNL and MTNL will get Rs. 74,000 crore bailout. BSNL is one of the country's biggest loss-making PSUs, while MTNL is the third-highest loss-making PSU. Disinvestment in these units will not have any takers and shutting them down may cost up to Rs. 1.2 lakh crore.

Conclusion

The merger between Idea and Vodafone will make them a top player. For the benefit of corporate management. It will also bring credit for the sale of Towers Assets to a consolidated business. The concept of consolidation seems to save costs and financial opportunities that aid financial performance. And whether the company will be able to monetize the remaining spectrum must be seen. Aditya Birla Group's promoters are smart enough to integrate with Vodafone in this price war and at the same time they have the rights to measure the pole in stages. So far, there is no benefit for public shareholders and they will hope to benefit from the long-term merger.

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NAAC & ACADEMIC LIBRARY PERFORMANCE INDICATORS

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ABSTRACT

National Assessment and Accreditation Council (NAAC) was established in 1994 as an autonomous institution of the University Grants Commission (UGC) with its Head Quarter in Bengaluru. Every 5 years, NAAC assesses the quality of the institution through a well-structured format. Annual Quality Assurance Report – (AQAR) is a yearly report, which should be submitted to NAAC every year by all Accredited Institutions as per the format prescribed online. Changes in society and education demand, the restructuring of performance indicators for academic libraries. COVID 19 pandemic situation, the new Education Policy, changes in technologies, and the mode of learning have redefined the role of the Libraries. It's high time to develop a new framework for assessing the performance of academic libraries.

Keywords: NAAC, UGC, AQAR, Covid 19, Academic Library

Introduction

National Assessment and Accreditation Council (NAAC) is the only Assessment procedure for assessing the quality of academic institutions in India. The NATIONAL ASSESSMENT AND ACCREDITATION COUNCIL (NAAC) conducts assessment and accreditation of Higher Educational Institutions (HEI) such as colleges, universities or other recognized institutions to derive an understanding of the 'Quality Status' of the institution. NAAC evaluates the institutions for its conformance to the standards of quality in terms of its performance related to the educational processes and outcomes, curriculum coverage, teaching-learning processes, faculty, research, infrastructure, learning resources, organization, governance, financial well being and student services. (http://naac.gov.in/index.php/en/about-us#vision)

Every 5 years, NAAC evaluates each HEI's through a well structured format that is, SELF STUDY REPORT (SSR), which was divided in to 7 criteria. Every year NAAC collects the data through AQAR (Annual Quality Assurance Report). For both, the criteria's are the same. They are,

Criterion I	Curricular aspects
Criterion II	Teaching- Learning and Evaluation
Criterion III	Research, Innovations and Extension
Criterion IV	Infrastructure and Learning resources
Criterion V	Student Support and Progression
Criterion VI	Governance, Leadership and Management
Criterion VII	Institutional Values and Best Practices

These Criteria evaluation leads to quality of the Higher Education Institution. In this, tried to explain more about Academic Library Indicators, which came under Criteria IV Infrastructure and Learning Resources.

Academic Library & Performance Indicators

Libraries across all sectors serve as a particular purpose and set out to achieve the goals and objectives of the library's stakeholders. These objectives will differ according to the nature and strategic function of the library and the expectations of its user community. Librarians are faced with measuring total expenditure for library, expenditure for books and journals, expenditure for e books and e-journals, usage, quality of service, strategic performance, and usage statistics, the number of students who attended induction sessions in an academic year or how many books were issued or how many electronic articles both books and journals) were downloaded. These types of statistics are simply measures of usage only.

There are some factors which will affect the efficient and smooth functioning of the Library. They are,

1. Efficient and reliable Suppliers
2. Technically expert staff
3. Good IT infrastructure

Outcome of Library usage varies according to the type of the Library. According to father of library science, Dr SR Ranganathan, academic library is the beating heart of the institution, where it is attached. In this context, Performance indicators are to be redefined. Existing evaluation methods and performance indicators developed for the academic libraries do not match with the real scenario. No or minimal participation of library professionals in the development of existing performance and evaluation methods.

These 3, Information Literacy, Student attainment / academic success and research impact are the outcome of an academic Library. We can define a student community as information literate, if there an increase in percentage of users who are confident in searching and find out information, confident in navigating electronic resources, decrease in number of inquiries, percentage increase in using interlibrary loan facility, number of outreach activities, increase in number of external memberships, increase in Institution repository, and increase in number of citations.

Key features of an Academic Library

Performance Indicators must include,

1. Nonfinancial Measures
2. Frequent measuring System
3. They clearly indicate what action needs to be taken to remedy the situation if negative or adverse performance is indicated.
4. Significant role in achieving goals and outcomes.

Conclusion

Librarians have always been professional and meticulous when collecting statistics, data and metrics, and this should continue to be the case, as it ensures rich data and information about the services, quality and performance. Academic library performance tool is so powerful including measuring top-level performance against a library's strategic outcomes. Library stakeholders and use community expect to receive high-quality service, and libraries now exist in a culture of striving to achieve excellence and deliver continual high-service performance.

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SIGNIFICANCE OF COMMUNITY BASED REHABILITATION (CBR) STRATEGIES IN HOLISTIC DEVELOPMENT OF PEOPLE WITH DISABILITIES

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Introduction

The World report on disability (WRD) is the first document to give an extensive global picture of the situation of people with disabilities, their needs, and the barriers they face to participating fully in their societies. The report states that more than 1 billion persons in the world have some form of disability. This corresponds to about 15% of the world's population. Between 110-190 million people have very significant difficulties in functioning. People with disabilities are more likely to be unemployed than non-disabled people. In Organisation for Economic Co-operation and Development countries, the employment rate of people with disabilities (44%) is slightly over half that for people without disabilities (75%). People with disabilities often do not receive needed health care. Half of disabled people cannot afford health care, compared to a third of non-disabled people. People with disabilities are more than twice as likely to find health-care providers' skills inadequate; nearly three times more likely to be denied health care; and four times more likely to report being treated badly than non-disabled people (WHO 2010).

Children with disabilities are less likely to attend school than non-disabled children. Education completion gaps are found across all age groups in all settings, with the pattern more pronounced in poorer countries. Even in countries where most non-disabled children go to school, many children with disabilities do not go to school. For example in Bolivia about 98% of non-disabled children go to school, but fewer than 40% of disabled children attend school. In Indonesia, over 80% of non-disabled children go to school, but less than 25% of children with disabilities go to school. People with disabilities experience increased dependency and restricted participation in their societies. Even in high-income countries, 20-40% of people with disabilities lack the help they require to engage in everyday activities. In the United States of America, 70% of adults with disabilities rely on family and friends for assistance with daily activities (WHO 2011).

Being the largest among the vulnerable and disadvantaged section of the society, these disabled individuals are exposed to numerous challenges such as accessibility to health care institutions; poor infrastructure support; pessimistic attitude of health care providers; minimal educational / vocational opportunities; lack of self-belief; financial constraints; and minimal support to the family members, especially in developing countries. Furthermore, owing to the overburdened status of the public health care delivery system, ensuring rehabilitation of the disabled individuals, especially in the community-settings, is of significant public health concern (Shrivastava et al. 2014).

Community Based Rehabilitation

When the idea of Community-based Rehabilitation (CBR) was launched in the early 1980s, it was seen as an approach to answer the needs of persons with disabilities in rural and isolated areas of countries which had limited access to rehabilitation services. The first manual on CBR, published by WHO in 1989, indicated that CBR could be useful for different groups of persons with disabilities (World Health Organisation, 1989). The preamble to the United Nations Convention on Rights of Persons with Disabilities (United Nations, 2007) recognises the diversity of persons with disabilities. CRPD touches upon different life-domains including education, health, work and employment, social protection and participation (Articles 24 -30), recognising these as key aspects of life. These same life-domains are also part of the CBR Matrix in the CBR Guidelines (WHO, UNESCO, ILO and IDDC, 2010). CBR activities are designed to improve the quality of life and meet the basic needs of people with disabilities, reduce poverty, and enable access to health, education, livelihood and social opportunities – all these activities support the aims of the CRPD (IDDC, 2012).

Rehabilitation is defined as the process of combined and coordinated use of medical / vocational/ social / psychological measures for enabling individuals to attain the highest possible level of positive health and thus achieve social integration (Park 2009). The notion of community-based rehabilitation (CBR) emerged in 1978 with an aim to improve the accessibility of disabled people to rehabilitation services, especially in developing countries, by ensuring optimal use of locally available resources(WHO – 2010). Thus, CBR encompasses different strategies that are implemented in collaboration with multiple sectors to empower disabled people/ their family members /community members regardless of any parameter by creating awareness, eliminating stigma, promoting social inclusion, meeting basic needs and facilitating access to health, education and vocational opportunities (Park 2009, Diaz et. al. 2012).

CBR: Scope, Benefit and Significance

Community-based rehabilitation (CBR) programs support people with disabilities by providing health services at their doorsteps, and thus establish a strong linkage between people with disabilities and the health-care system (WHO 2010) . The key activities of the CBR program comprise of organizing training sessions for the welfare of family

and community members on disability; providing educational assistance and improving physical access; setting-up referral services; providing assistance (viz. financial support, assistive devices); arranging employment opportunities; and extending social & recreational support (Park 2009). Findings of multiple studies have revealed that CBR activities are not only cost-effective, but have delivered encouraging results in increasing independence; enhancing mobility, improving communication skills; augmenting educational/vocational opportunities; influencing community attitudes positively; and in facilitating social inclusion, of disabled people (Diaz 2012, Mannan et al. 2007, Velema et. al. 2008).

Challenges in the field of CBR

In the face of the availability of evidence indicating remarkable benefits of CBR in different domains, the appraisal studies have revealed a wide range of challenges in the execution of CBR such as ambiguity surrounding the concept; uncertainty about the methods by which its implementation can be fostered in community (Kendall et al. 2009); implementation of similar CBR framework without customizing it to the local settings; absence of any inbuilt mechanism to ensure evaluation of the strategy (Chung et al. 2011); limited availability of resources (Hartley et al. 2010); minimal participation of community owing to culturally- insensitive nature of the programs (Pollard et. al. 2008); shortage of health care workers to exercise CBR (Mannan et. al. 2012); untrained CBR workers (Mannan et. al. 2012); non-employment of multi-disciplinary teams (Hartley et. al. 2010); and poor coordination among health care providers and systems of delivery (La Cour K 2013). These challenges have significantly threatened the implementation and the sustainability of CBR programs.

Recommended strategies to counter the barriers

In order to negate the identified barriers, there is a need to have a strong leadership to facilitate the translation of theory into practice (Kendall et. al. 2009). Furthermore, adequate collaboration is required among different stakeholders (viz. policy makers, medical practitioners, health care professionals, community, and representatives from non-governmental organization) to support this intervention (WHO 2010). In addition, other interventions such as setting clear and unambiguous goals and objectives (WHO 2010); building a comprehensive CBR evaluation framework (conducted in close collaboration with the local community, including people with disabilities) and testing the same for relevance and appropriateness in the local settings (Chung EY 2011); adopting combination of qualitative and quantitative methodologies to better capture the effectiveness of this strategy (Hartley S 2010); fostering use of management information systems and monitoring; ensuring active community participation by designing context-specific and culture-sensitive programs (Pollard N 2008); enrolling workers from allied sectors who are skilled and willing to work for the welfare of disabled; organizing training sessions for CBR workers; ensuring availability of adequate

resources & establishing referral services; employing multi-disciplinary teams to ensure successful delivery of services in the community; organizing formal and informal meetings between members of the team to enhance their coordination and coherence; and building mechanism to monitor their performance and impact on health indicators (Mannan H 2012).

Conclusion

Community based rehabilitation strategy plays vigorous role in the development for rehabilitation, equalisation of opportunities and social inclusion of people with disabilities. The CBR activities are carried out through the combined efforts of people with disabilities themselves and by other professionals, their families, organisations, communities and multidisciplinary team. The relevant governmental and non-governmental health, education, vocational, social and other services are offered through community based rehabilitation measures to ensure the sustainability and strengthen the people with disabilities. The CBR can play a role in the setting up and strengthening of people with disabilities and this is considered as one way of strengthening the implementation of the UN Convention on Rights of People with Disabilities.

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CREATIVITY AMONG RURAL ADULTS

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ABSTRACT

Creativity studied in various dimensions, but a few studies were conducted among rural population. Present study focused the creativity of rural young adults. The size of the sample was 100 (N=100) selected by using convenient sampling method from Idukki district. The creativity style scale of Kumar & Holman (1997) was used to collect the data. Data was analysed by using SPSS. The study reveled rural adult had higher level of creativity. Further, it revealed that young adults having lower level education had higher level of creativity than their counter part.

Key Words: Creativity, Rural adults, Rural area

Introduction

Creativity is arguably our most uniquely human trait. It enables us to escape the present, reconstruct the past, and fantasize about the future, to visualize something that does not exist and change the world with it. Defining creativity presents difficulties; for example, not all creative works are useful, and not all are aesthetically pleasing. Both usefulness and aesthetic value capture, in some sense, what creativity is about. Nevertheless, psychologists have almost universally converged on the definition originally proposed by Guilford over sixty years ago (Liane Gabora, 2013). Creativity is a topic of interest across numerous disciplines and areas of study.

Numerous studies and interventions exist on the topic of creativity in the domains of education, work, art, science, and in society in general (Artola et al., 2012, Garaigordobil & Pérez, 2004). This thriving development exists side by side with an open debate on how to measure, apply, and develop creativity (Garaigordobil, 2003).

While it has been shown that creativity is a basic human trait (Artola et al., 2012), research has allowed us to understand that it does not depend exclusively on stable characteristics (Averill, 2004), but that it is the result of individual, cognitive, affective, behavioral, and contextual processes (Amabile et al., 2005, Csikszentmihalyi, 2011, Sternberg & Lubart, 1995). Creativity may be understood as a human resource to deal with the challenges of life, supporting psychological and social adaptation (Artola et al., 2012, da Costa & Páez, 2015). The relationship between creativity and intelligence has been widely debated, and while there is agreement that very creative people are also intelligent, a high IQ it is not a necessary nor a sufficient precondition for high creativity (Garaigordobil, 2003, Gardner, 2010). Those studying creativity agree that there are two principal aspects that define creativity: a) novelty – creative work has to be original and different in some way from previous work (Amabile, 1996, Feldman et al., 1994, Runco, 2014), quality – the new product must be deemed suitable, even useful, by a reference group with respect to a problem or situation (Sternberg & Kaufman, 2010). Creativity can be analyzed as a personal attribute, a process, a product, and as the context which enables it (Baer, 2010). Sternberg and Lubart (1995) propose that personality, intelligence, knowledge, thinking style, motivation, and environment are factors associated with creativity. While the first five are individual factors corresponding to the creative person, we also need to consider given characteristics such as age and gender, acquired characteristics such as education, and other individual attributes such as attitude, affect, and emotional intelligence (Garaigordobil, 2003). Creativity is closely related with gender. The study of Baer and Kaufman, (2008) is an example. According to Stoltzfus, Nibbelink, Vredenburg, and Thyrum, (2011) people with feminine quality were more creative. Creativity related with age, it, peaking between 30 and 40 year of age and declining after 40. Regarding acquired characteristics like education, it has been suggested that the level of education is associated with creativity, although it is not a determining factor beyond a certain level (Artola et al., 2012). Personality traits such as extraversion, agreeableness, neuroticism, and conscientiousness were not strongly related, but trait openness to experience clearly associated with creativity (Hülsheger et al, 2009). Thinking styles and attitudes associated specifically with creativity, such as field independence, tolerance of ambiguity, perseverance in the face of frustration, relative disinterest in social approval, and a pro-risk attitude (Feist, 1998). In addition to intelligence, personality traits, attitudes, and cognitive styles, motivation is a further individual factor which is important in creativity. It has been claimed that there is a positive relation between creativity, intrinsic motivation, and self-efficacy (Artola et al., 2012, Guilford, 1968, Runco, 2014). It is expected that people are more likely to be creative when they are intrinsically motivated, i.e., by interest, pleasure, satisfaction, and the challenge of the task itself, more than by external pressure and reward (Amabile, 1996). Self-efficacy refers to the perception

that one has the capacity to behave in a way required to attain a goal and the beliefs about one's personal competences to be proactive in the generation of new ideas and the application of innovations. It is expected that high self-efficacy is associated with greater creativity (Hülsheger et al., 2009a, Ma, 2009). The relation between extrinsic motivation and creativity is not clear, although some authors suggest a negative link (Ma, 2009)

Finally, emotions and affectivity are individual factors relevant to creativity. In terms of the relation between affectivity and creativity, it is thought that emotions can change thinking and that knowing them can help one use them to process information in a better way, thus allowing emotional intelligence to further creativity (Mayer & Salovey, 2007). In addition to the above factors, positive affect facilitates creativity (Amabile et al., 2005). There is also evidence to suggest a link between negative affect and psychopatholgy, given the fact that the percentage of disorders is high among some creative groups such as artists, although this association has also been questioned (Ma, 2009).

Characteristics of Rural Area

Rural area is sparsely populated because many people leaves rural areas and settles in the urban areas for more facilities. These society has homogeneity. in its profession that is their only source of earning is agriculture and this is transmitted from generation to generation. There is homogeneity in dress, language and customs. It means all these remain same because their culture is same they belong to the same area. These areas have got slow means of communication. Rural areas have very slow rate of change because of lack of education and modern technology. These settlements have got simple culture transmitted from generation to generation. Rural areas have got informal social life that is they spent their life in a. simple way. Rural communities have got strong relationships and interactions of the people. It means that they help each other in distress and shares the happiness. In such areas there is less rate of pollution because there are no factories and mills and the number of automobiles is less. In such areas people shows great hospitality to their guests and treat them as a member of a family.

The village communities are smaller in area than the urban communities. As the village communities are small, the population is also low. Density of population is low, the people have intimate relationships and face-to-face contacts with each other. Agriculture is the fundamental occupation of the rural people and forms the basis of the rural economy. A farmer has to perform various agricultural activities for which he needs the cooperation of other members. Thus, the members of the entire family share agricultural activities. The rural people are in close contact with nature as most of their daily activities revolve around the natural environment. The village communities are homogenous in nature. Most of their inhabitants are connected with agriculture and its allied occupations, though there are people belonging to different castes, religions, and classes. In rural society, social stratification is a traditional characteristic, based on caste.

The rural society is divided into various strata on the basis of caste. The social interaction in rural areas is comparatively lower than in urban areas. However, the interaction level possesses more stability and continuity. The relationships and interactions in the primary groups are intimate. The family fulfills the needs of the members and exercises control over them. In rural areas, mobility is rigid as all the occupations are based on caste. Shifting from one occupation to another is difficult as caste is determined by birth. Thus, caste hierarchy determines the social status of the rural people. The degree of social solidarity is greater in villages as compared to urban areas. Common experience, purposes, customs, and traditions form the basis of unity in the villages. Another feature of rural society is the joint family system. The family controls the behaviour of the individuals. Generally, the father is the head of the family and is also responsible for maintaining the discipline among members (Faridi, 2021).

In Kerala, Idukki is a remote hilly rural area. Idukki is the second largest district in kerala. The district has total geographical area of 4358 sq km of which 45 per cent is covered by forests. About 81 percentage per cent of the total land holdings are of size less than one hectare and the size of average land holding is 0.56 ha (PLP report Idukki 2013-2017). The grater part of the residents in the district is marginalized and belongs to socially vulnerable class. Most of the people are migrates from neighbouring states and different parts of kerala in search of a living and engage in daily work on planation and in other agriculture fields for very small wages. Agriculture and animal husbandry are the main occupation and most of the families depend upon related seasonal jobs for survival. Often their daily ernings from agriculture hardly contribute 60 percentage to their daily living expences and this led them to promote allied activities like dairy, goat, rabbit, and pig rearing (Justin, Manu, Kiran, Mathew & Lijo, 2020)

In their study, Justin, Manu, Mathew, Lijo and Ajo, (2020) found that residents of Idukki had lower level of coping resoureces, while confronting monsoon disasters. But the scenario was changed among the residents of Idukki. New generation adults take a deviation from conventional income generation resoureces and most of them got better positions in public as well as private sectors. Some of them went to abroad as the part of building their career. Under the above circumstances it is essential to identify the creativity among rural adults and the study is entitled as 'creativity among young adults'.

Objectives

To find out whether there is a any significant difference in creativity style of rural adults on the basis of their educational qualification.

To find out whether there is any significant difference in creativity style of rural adults on the basis of their place of residence.

Hypotheses

There will be significant difference in creativity style of rural adults on the basis of their educational qualification.

There will be significant difference in creativity style of rural adults on the basis of their place of residence.

Method

The researcher used descriptive research design. The sample consisted of 100 adults aged in between 20-30 years, from Idukki district. The data were collected through questionnaire method and collected data were analysed by using SPSS.

Instruments

1. Demographic data sheet: it is prepared by the researcher to collect personal details of respondents.
2. Creativity style Questionnaire developed by Kumar and Holman (1997) comprises 78 of items evaluated on a scale from 1 "strongly agree to 5 strongly disagree and it contains seven scales. The purpose of this questionnaire is to see how people go about accomplishing the creative act. For the purpose of finding out the reliability of the scale; it contains seven scales. Each scale has between 2 and 18 items which are divided to the total number of items of the scale: a. Belief in unconscious processes (17 items; á = .70; "I typically wait for a flash of inspiration before I begin working."); b. Use of techniques (18 items; á = .81; "I keep a pen/notepad/tape recorder handy to record new ideas as they occur"); c. Use of other people (9 items; á = .74; "When I have a new idea, I tend to discuss it with someone to determine its potential for success"); d. Final product orientation (7 items; á = .45; "I work most creatively when I have deadlines"; e. Environmental control/behavioral self-regulation (18 items; á = .70; "I have a particular place (or places) for creative work."); f. Superstition (2 items; á = .72; "I have a favourite tool (a certain pen/easel/thinking cap etc.) without I would find it hard to concentrate when I am engaged in creative work."); g. Use of senses (5 items; á = .76; "I tend to use my sense of touch a lot in my creative work.").The questionnaire was translated and used with the approval of its main author, K. Kumar from West Chester University.

Results and Discussions

Table No. 1

ANOVA of creativity style of rural adults with respect to their qualification.

Variable		Sum of squares	Df	Mean of squares	F
Creativity style total	Between groups	7735.151	2	3867.575	4.387*
	Within groups	85518.239	97	881.631	
	Total	93253.390	99		

*Significant at 0.05 level

The table revealed that the calculated F value of creativity total is 4.387 which is greater than the table value and it is statistically significant at 0.05 level.

The result of group mean analysis given below:

Table No: . 2

Post hoc table creativity style total with respect to qualification.

		Subset of alpha=0.05
	N	1
UG	46	244.20
PG	48	261.42
Plus two	6	264.67
Sig.		.084

The group mean analysis revealed that creativity is higher among plus two students. UG and PG two shows less creativity compared to plus two. As per above table the group difference was not statistically significant. But the F value is statistically significant. Various researches showed that creativity directly or indircetly influenced by education. Present finding contradicted to the study of Artola et al. (2012). In their study they were suggested that the level of education is associated with creativity, although it is not a determining factor beyond a certain level. It is clear that individuals having plus two level education found their own ways and engaged in their interested income generating careers creatively. Individuals having graduation obtained low score in creativity. It may due to the higher level maturity and ability to compiling situational factors of graduated students. Over confidence and desire for white collar job may pushback their creativity level. A dominating thought of to got a job or 'became an employ' thinking may cut short their entrepreneurial spirit.

Table No. 3

ANOVA of creativity style of rural adults with respect to their Place of Residence

Variable		Sum of squares	Df	Mean of squares	F
Creativity style total	Between groups	7411.034	2	3705.517	4.187*
	Within groups	85842.356	97	884.973	
	Total	93253.390	99		

*Significant at 0.05 level

The above table shows that the calculated F value of creativity style which is greater than the table value and it is statistically significant at 0.01 level.

The group mean analysis given below:

Table No. 4

Post hoc table of creativity style with respect of place of residence.

	N	Subset of alpha=0.05	
		1	2
Rural	51	245.57	
Semi Urban	33	259.82	259.82
Urban	16		266.94
Sig.		.083	.394

As per above table creativity was significantly varied among urban and rural people. People living in urban area obtained a higher score in creativity than rural adults. People belonging to semi urban did not differed with any other groups. Urban people enjoyed plenty of opportunities to interact with various amenities. Urbanization brought numerous opportunities and options for urban people. In rural areas, mobility is rigid as all the occupations are based on caste. Shifting from one occupation to another is difficult as caste is determined by birth. Most of the rural people engaged in agricultural and allied activities, they have higher rate of social solidarity and family control in every activities than urban people (Faridi, 2021).

Conclusion

Creativity of individuals deviated largely from its normal paths in this pandemic ira. Electronic gargets and online facilities widely been accepted and promoted. Individuals from the all the age groups enjoying various types of online services in urban areas as well as rural. Eventhough, creativity is comparatively low among people living in rural area than urbans.

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MENOPAUSE AND RURAL WOMEN

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ABSTRACT

Menopause triggers familial, economical and career related discomforts among middle aged women. Present study focused on middle aged rural women. Because they were marginalised and side-lined with their problems. The study was conducted on a sample of 120 rural women aged in between 44 to 55. Results showed that menopause problems spouse support and type of family did not influence menopause problems of rural women. Further it revealed that types of occupation did not make any influence upon menopause and related problems. The mean cores of each group were slightly differed, but the difference is not statistically significant.

Key words**:** *Menopause, rural women, spouse support.*

Introduction

When a women's spring's ends, the other side prepares for her another time. She enters into another effective and illusory lifestyle. A woman's cultural and family circumstances, her education and her work affect her and her menopause. When her body, which is compatible with menstruation is slowly saying goodbye to it, she suffers from many kinds of hardships, both physically and mentally. According to Singh (2014) most prevalent symptoms identified include sleep disturbances, muscle or joint pain, hot shes and night sweats. Menopause also ıncreases the risk for certain conditions such as osteopenia, osteoporosis, decreased lung capacity and cardiovascular problems etc.

Menopausal women confront with various difficulties. Despite menopause being a natural part of the ageing process, there is a general lack of awareness of its symptoms and effects, often resulting in menopausal women experiencing a lack of support, as well as discrimination and harassment. The effects of menopause are most likely to manifest in sickness absence and perfor-

mance issues. The link to menopause may not always be easy to spot, especially as many menopausal women will be reluctant to share this information and sick notes may not refer explicitly to menopause. As awareness increases in society generally, menopausal women perhaps feel more prepared and empowered to speak up, and the number of cases likely rises, employers will need to be alive to the issues, be well equipped to provide adequate support at work and remain mindful of any obligations towards staff (particularly where they may be disabled but also generally) (Ashmore and Heaton 2021). Symptoms associated with menopause may cause difficulties for working women, especially if untreated, yet employers are practically silent on this potentially costly issue (Jack, 2016). Vasomotor (and associated) symptoms have a negative impact on women's productivity, capacity to work and work experience, this is not a uniform finding. Psychological and other somatic symptoms associated with menopause can have a relatively greater negative influence. Physical (e.g., workplace temperature and design) and psychosocial (e.g., work stress, perceptions of control/autonomy) workplace factors have been found to influence the relationship between symptoms and work. According to the Department of Work and Pensions (2015), the proportion of women between 50 and 64 who are in work is at its highest level ever. Thus, many women go through the menopause while working full-time or part-time. Menopausal symptoms such as hot flushes, changes to periods, mood swings and poor memory are often at odds with the self-confident professional image which women want to convey.

The most rural women have only primary education. As everyone knows, rural women generally work hard, engage in both skilled and unskilled labour in hinterland. Superstitiousness and partial knowledge of menopause and its scientific aspects contribute dangerous effects on the working conditions of these people and tend to have unreasonable sufferings both physical and psychological.

Women living in rural communities described a need to understand fully the intensity of menopause related symptoms, including changes to their physical and mental well-being. Menopause is a difficult process especially for rural women. The mean age at menopause of the women is plus or minus 4.2 years. Menopausal symptoms were prevalent and bone and joint pain were the most prevalent symptoms. Knowledge and use of hormones replacement therapy were poor. Most of the women considered the menopause to be beneficial, rural women described the menopause experience as having a significant impact on their personal relationships and identified social support and humour as their primary coping strategies. The symptoms related to menopause can made it a considerable struggle for these already dealing with their hectic lives. Woman's ability to cope with the stresses of menopause can be enhanced through education and social support (Anolue,2012).

Apart from the biological discomforts, certain psychological as well as emotional disturbances also be present in different

stages of menopause. Carter (2001) explained that some women experiencing psychological symptoms during perimenopauses. Mood and cognitive disturbances common during perimenopause including mood swings, irritability, fatigue, a subjective sense of loss of memory, difficulty with word retrieval and decreased libido. These emotional imbalances may affect women in their family, occupational and personal life. According to the study of Afridi (2017), the psychological factors such as personal psychological vulnerability, life stressors, interpersonal relationships etc. have its own contributions. Various personal factors of an individual may affect her menopausal experiences and the life stressors such as lack of social support, unemployment, surgical menopause, poor overall health status etc. may affect negatively. A major social support in a woman's life and help her in life with influential effects on psychological health. They may include relationship with partner, relationship with children, relationship with society and friends.

Thornton (2015) the menopausal transition, a time characterized by hormonal, physiological and social changes. Menopausal symptoms and sexual dysfunction can negatively impact quality of life for women. Women more likely to engage in partnered, intimate sexual activities tend to be of younger age, lower body mass index, married, and have better emotional well-being. This raises the possibility that aging women affected by obesity or single status may be at high risk for experiencing an overall decrease in quality of life. Despite their decrease in desire and arousal, the majority of women still reported that sex was moderately to extremely important to them. Menopausal women with some college or graduate school education have better physical and mental parameters of health that are related to quality of life compared to those with a high school education or less. This demonstrates that multiple socioeconomic factors impact sexual functioning and quality of life for menopausal women. Women affected by socioeconomic stressors may benefit from increased social support.

Attitude towards menopause was of major influence on the degree of specific symptoms (depression, misery, headache etc.), women who had a negative attitude towards the menopause suffered much more from such symptoms than women who had a positive one. Moreover, women who were satisfied with their physical appearance experienced fewer troublesome symptoms (Bloch,2002). They found a significant association between high self-esteem and fewer menopausal symptoms. The higher the self-esteem, the lower the symptoms.

The rural women especially those who are living in hilly area may have variations in such situations. The estate working women's life style, family and socio- economic status are relatively lower than others. These all factors among menopausal women may affect in different ways. The menopausal symptoms may negatively impact their health. They may have experienced lower level of mental health and emotional well -being, self -esteem, educational qualifications, occupational status and social functioning. As mentioned above the

menopause affect the professional life and productivity. The study of Jack (2016), Department of Work and Pension (2015) etc. are examples for various studies conducted among working women and their productivity, but a few studies were taking place among rural women. Many of the times rural backward women and their hard shift become side-lined. Present study is an attempt to explore the impact of menopause and related problems among rural women.

Objectives

1. To find out significant differences in menopause problems among women categories on the basis of spouse support.
2. To find out significant differences in menopause problems among women categories on the basis of belonging to nuclear or joint family.
3. To find out significant differences in menopause problems among women categories on the basis of occupation.

On the basis of these objectives, the following hypotheses were formed.

Hypothesis

1. There will be significant differences in menopause problems among women categorised on the basis of spouse support.
2. There will be significant differences in menopause problem among women categorised on the basis of type of family.
3. There will be significant differences in menopause problems among women categorised on the basis of their occupation.

Method

Descriptive research design was used in this study. Questionnaires were used to collect data. A number of 120 rural women selected by using snow ball sampling technique. The age of the respondent in between 44 to 55.

Instruments

1. Demographic data sheet prepared by the researcher includes respondents age, religion, education, occupation, marital status, type of family and various demographic characteristics.
2. Menopause problem scale developed by Tiwari and Sahoo developed menopausal scale. As the dimensions is the physical problem (11 items) emotional problems (10 items) personality problems (3 items) sexual problems (7 items) urinary problem (9 items) total (40 items). The scoring system was decided on the Lickert pattern 5 points viz none (0), mild (1), moderate (2), severe (3), very severe (4).

Validity and Reliability

The validation of questionnaires was based on five-point rating scale-highly suitable, suitable, somewhat suitable, unsuitable and not at all suitable. A score 5 was sought for highly suitable, 4 for suitable, 3 for somewhat suitable, 2 for suitable and 1 for not at all suitable. For quality ranking of questionnaire on the basis of technical assessment mean scores were computed for selected parameters. Consequently, mean score 5-4.3

was found for highly suitable, 4.2-3 for suitable, 3.4-2.7 for somewhat suitable, 2.6-1.9 for unsuitable and 1.8-1 for not at all suitable ranking of questionnaire. The calculated mean score was obtained as 4.76 which shows that the questionnaire was highly suitable for assessing menopausal problems.

The reliability of the scale was determined by split half method on the score sheets of 300 samples group. The items were divided into two groups, odd items & event items. The coefficient of correlation got between these two groups was is 0.89, which is significant at.01 level of significance.

Results and discussions

Table 1

Mean, SD and corresponding 't' value obtained by women in menopausal problems on the basis of spouse support.

Variable	Mean of having no support (N=101)	SD	Mean of having support (N=19)	SD	't' value
Menopausal problems	168.4851	29.95951	190.3158	20.88075	3.035*

As per the result, in the case of spouse support menopause problems significantly varied. Women getting spouse support obtained high mean scores than women having no spouse support. It may be due to the result of mutual support and caring. The spouse accepts their partners discomforts and help them to overcome such a situation. Women got relief from her spouse through those sharing and inclined with the partner. In some cases, it may create adverse effects. But in the case of women have not receive any spouse support, manage their difficulties independently and try to manage emotional, personal, sexual and other related matters of menopause. In many cases, spouses were not aware about the related problems of menopause. Present findings supported the study of Idiana, Hussain, Sulaiman and Kadir (2020). They emphasised the relevance of education programme regarding menopausal problems. In their study, most of the women did not received support from their spouse. In rural area, women as well as men had not been aware about such problems and they may ignore the related issues of menopause and trying hard to meet both the ends.

Hence hypothesis here will be a significant difference in menopause problem among women based on their spouse support is rejected.

Table 2

Mean, SD and corresponding 't' values obtained by women belonged to nuclear and joint family.

Variable	Mean of nuclear family (N=103)	SD	Mean of joint family (N=17)	SD	't' value
Menopausal problems	170. 25	30.73	182.17	20.71	.541

As per the above table, menopausal problems high among women belonged to joint family than women from nuclear family. But the difference is not statistically significant. An active support system may be functioning in the joint family system and they may share responsibilities and become relaxed, and ironically the burden become heightened. In joint family, several women had become increasingly responsible for the well-being of older parents and in-laws. As the mother of two teenage boys put it, 'Menstrual mother, teenage boys, just are not a healthy mix'(Healthtalk.org, 2022). But in the case of nuclear family system, they were fully engaged and duty bounded. In rural setting, women also take an equal role to lead her family with the spouse. They may together engage in income generating activities too. Their busy daily life schedule caused for the ignorance of related problems of menopause.

Table 3

ANOVA with respect to occupation

Variable		Sum of squares	Df	Mean of squares	F
Menopausal problems	Between groups	7364.691	4	1841.173	2.164
	Within groups	97861.901	115	850.973	
	Total	105226.592	199		

Menopause problems of women varied in accordance with their occupation. But the difference is not statistically significant. Which means that employment or occupation engaged by women did not influence seriously in menopausal problems. The researcher selected samples from different occupational groups such as; wage holders, homemakers, self-employed women, private and government employees. According to Thorne, Griffiths and Hunter (2018), work outcomes were not associated with menopausal status but were significantly associated with job stress and aspects of the work

environment, such as demand, control and support.

The study could light upon how spouse support, type of family and occupation status influence on menopausal problems. The study will obviously be a solace and reference to climacteric women, doctors, psychologists, social workers and students of various sectors.

Conclusion

The years leading up to menopause and the transition itself can bring changes to human body. But they can also have an effect on mind, specifically mental health. Four out of every five women will experience symptoms relating to the menopause. One in four women will experience severe symptoms. Many women will also experience psychological symptoms which can include low mood, depression, anxiety and stress.

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A CASE STUDY ON PETROLEUM PRICE HIKE IN INDIA

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ABSTRACT

Petrol and diesel prices have been rising to record high levels recently in India. The government ended the practice of changing petrol and diesel prices, allowing oil marketing companies to revise fuel rates daily. Crude oil prices crashed in 2020 during the seventh phase of the covid-19 pandemic. But the petroleum prices did not come down in India. Petrol products are not brought under GST and it is an unfair practice from part of the government.

The reasons given by government about the price hike are covid-19 pandemic and reduced fuel production in international market. Fluctuation in the price of petroleum impacts the production and transportation costs of essential and various items.

The prices of petroleum would come down under the ambit of GST. Finance minister told that, it's a call that the GST Council has to take. If Council decides to bring petroleum under the ambit of GST, it will have to ensure that governments continue to earn the kind of money through petroleum taxes that they have been in the past. Another solution is that switching to electric vehicles. These vehicles offer better running realization. The demand and price of petroleum will be decreased by the increased use of alternatives.

Key words: *Price hike, GST Council, Electric vehicle*

Petroleum

Petroleum or mineral oil is India's next biggest source of energy after coal. It supplies heat and lighting power, machinery lubricants and raw materials for a variety of manufacturing industries. Petroleum refineries for synthetic textiles, fertilizers and numerous chemical industries act as a "nodal industry". Most of India's petroleum occurrences are associated with anticlines and fault traps in tertiary age rock formations. It occurs in folding regions, anticlines, or domes, where oil is trapped in the unfold crest.

In the petroleum industry, petroleum companies are divided into upstream, midstream and downstream. This refers to oil and gas Company's position in the supply

chain. Upstream oil and gas companies identify, extracts, or produces raw materials. Downstream oil companies engage in business related to the post- production of crude oil and natural gas. Midstream oil and gas companies connect downstream and upstream companies, typically by participating in the storage and transportation of oil and other refined products.

Ancient cultures used crude oil as a substance for binding materials and as a sealant for waterproofing various surfaces. Petroleum can occur in liquid, gaseous or solid forms. Natural gas is a liquid form of petroleum. The word "Petroleum" was first used by a German mineralogist in 1556.

Petroleum price hike in India

Petroleum is one among the commodities which provide largest amount of tax revenue to the government. Highest rate of petrol has gone up above Rs.100. The Prime Minister blamed the previous government for this unabated price hike. Over two third of the price we pay for fuel comprises of taxes and other levies. As a result, less than a third of the retail petrol price in India is affected by a movement in crude oil price, which essentially means no matter whatever changes with crude oil only 30% of Indian retail prices will be impacted. As much as 70% of the local prices will remain unaffected. More precisely when price is on fire, it's the excise tax levied by the Central and State government that is to blame. Under the head, in last three years, a whopping of 14 lakh crore has been mopped up by the Central and State governments combined.

Determination of petrol price in India

Petroleum is a commodity in India that has been kept out of the purview of the GST. The retail selling price of petrol is based on a crude oil OMC margin, transportation cost, freight costs, Central & State government taxes, excise duty and other taxes.

Crude oil: - Crude oil is required for processing petrol; oil manufacturing companies in India pay overseas crude oil companies additional charges along with the freight and insurance charges to obtain the oil.

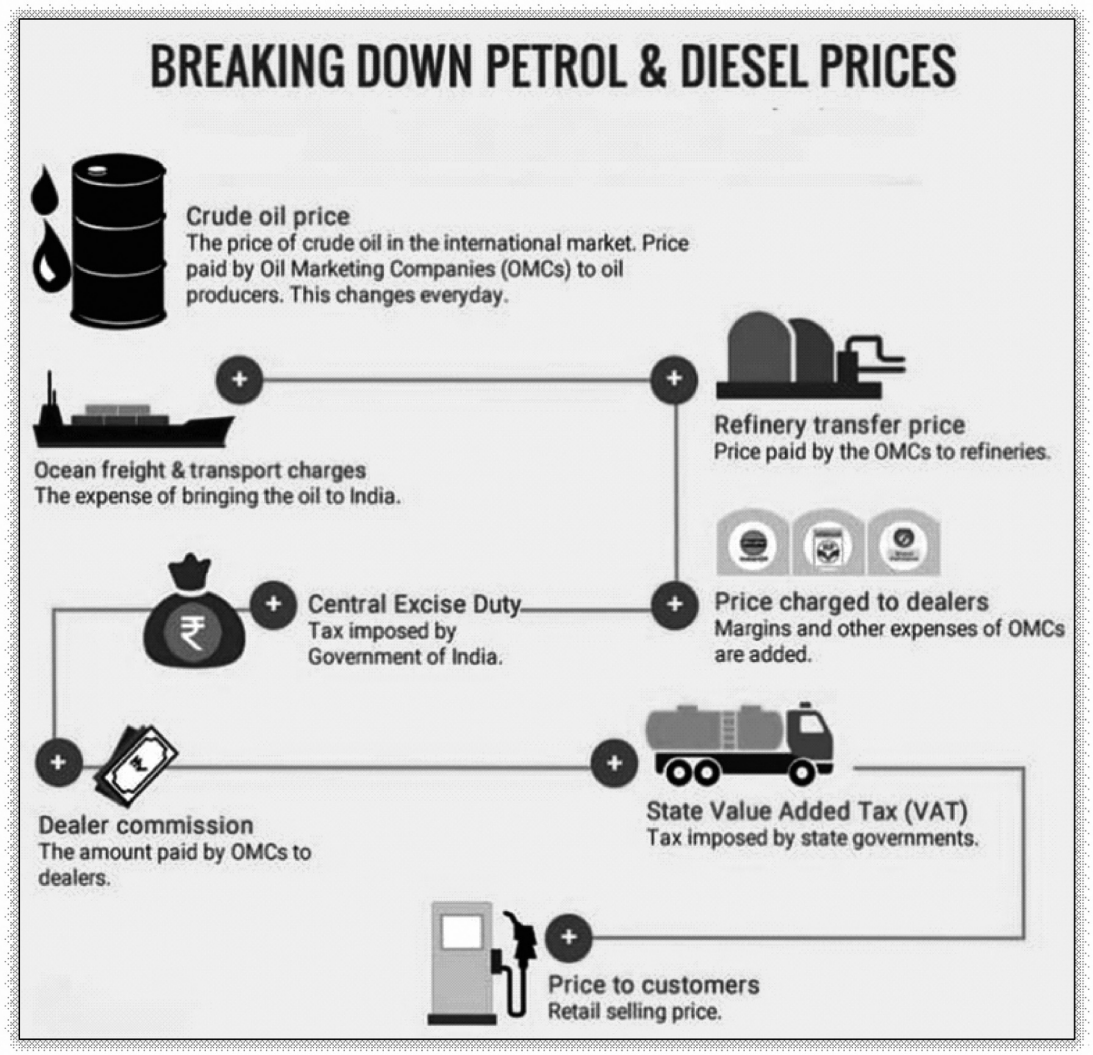
OMC costs: - Oil marketing companies refine crude oil into petrol and sell it to dealers, which include transportation cost, operation cost, refinery processing cost and others.

VAT: - The value added tax on petrol varies from State to State. So petrol price differs across various States & Cities in India.

Central & State Taxes: - The excise duty on petroleum is same across the nation. Currently excise duty levied on petroleum by Indian government is 27.90 per litre.

Impact of petroleum price hike in India

Petrol has become an indispensable part of our day to day life and we can't imagine our life without it. But the petroleum price is skyrocketing. It is eventually affecting everything in our day to day life. Poor people are already working hard to earn square meal a day and this hike definitely going to paralyze these already burdened people. The price of petroleum has reached in its all-time records. It is nothing but adding fuel to fire.



Petroleum hike directly or indirectly affects all the major sectors like transportation, textiles, automobile industry, FMCG, etc… for manufacturing & transportation. This affects the prices of daily essential commodities which are transported on a daily basis. Banking sector is also expected to suffer due to high inflation level.

Increase in fuel prices will result in an increase in the rate of food price. This will make a more severe impact on poor people, because poor house-hold spent more than half of their income on food and only spent a very small portion less than 10% of their income on fuel. Petroleum price hike is considered as a chain reaction once started will affect all.

Increase in petrol price will increase the transportation cost, increase in transportation cost will increase in the price of goods

and other commodities and it will let the people suffer more intensely and so on like this, the chain will further propagate. These ups and downs push more people into poverty and leading to a more pathetic situation of those already poor. This has obviously sent shock waves to the common man who is trying hard to make both ends meet. Price hike affects only the low wages or fixed salaried families of the middleclass as compared to higher salaried family class.

The existing middleclass is squeezed and many of those striving to attain the middleclass standard find it persistently out of remit. This will bring no negative impact on government employees as their dearness allowance will be increased. Accordingly, rich and corrupted people are least bothered of it. People like taxi drivers, auto rickshaw drivers shall transfer the burden to the common people. Common people if doing business shall also transfer the burden to customers and the chain reaction continues. The community that suffers the most is common people.

Comparison of petroleum price of India with its neighbouring countries

Most of the countries neighboring to India are either developing or underdeveloped countries, but the price of petroleum products there is almost half of the price of petroleum in India. In Asia, the country with highest rate of petroleum products is in India. In comparison to India petroleum is cheaper in Pakistan, Nepal, Sri Lanka, Bangladesh and Bhutan.

Country	Petrol Price (Rs.) approx.
India	100.00
Bangladesh	76.41
Nepal	68.98
Sri lanka	60.26
Pakistan	51.14
Bhutan	49.56

In INR, petrol price in Pakistan is Rs 51.14 per litre. In Bhutan, petrol is available at Rs. 49.56 per litre and it is the cheapest at Rs 49.56; whereas in Sri Lanka the petrol price is Rs 60.26. In Bangladesh petrol price is Rs 76.41, in Nepal it is Rs 68.98. The price of petrol is increasing daily in India. Constantly rising inflation is also putting economic burden on the people. The cheapest petrol is sold in Venezuela where the price of petrol is at Rs 1.45 per litre whereas petrol is sold in India at Rs 100 and above per litre.

Ways to reduce petroleum price

Some of the probable solutions which aids to reduce petroleum price are as follows:

- **GST (Goods & Service Tax)**

GST is an indirect tax which is a comprehensive multistage destination based tax; comprehensive because it has subsumed almost all the indirect taxes except a few state taxes, but petroleum products are still not brought under this GST. If it is brought under GST, we could be able to access petroleum at much lesser price.

- ***An Era of Electric Vehicles***

The government is able to increase the

tax rate of petroleum produced in an unjustifiable manner because people haven't got any alternative source for transportation vehicles. If electric vehicles take the role, the monopolistic nature of petroleum produced splits and thereby leads to a decrease in petroleum demand and so as the price will also come down.

Solution 1: To bring petroleum under GST

The clamour for bringing petroleum products under the ambit of GST has suddenly risen in the backdrop of a recent surge in prices of petrol and diesel.

Why petroleum is not brought under GST

Prime Minister told the house, "it is not possible to bring petrol and diesel under the GST regime in the next 8 to 10 years" because States would not be ready for an annual revenue loss of 2 lakh crore (collectively by all States). He also said that Central and State together earn 5 lakh crore from tax on petroleum products. So if petrol or diesel if brought under the Goods and Services Tax (GST) regime then how would the loss of Rs.2 lakh crore revenue to States recovered. He explained that if petroleum products are brought under GST, 28% of tax would be collected on them as that are the highest slab in the tax regime. Presently 60% tax is being collected on petroleum products; this would result in short fall of Rs.2 lakh crores to Rs. 2.5 lakh crores to both Central and State. If we collect 28% tax on petroleum products then only Rs.14 will be collected (per litre) against Rs. 60 at present, he pointed out.

GST - Tax Slab Rate

Tax Rate	Indicative items
0%	50% of the consumer price basket including food grains
5%	Mass consumption items like spices and mustard oil
12%	Procured foods
18%	Soaps, oil, toothpaste, refrigerator, Smart phones
28%	White goods, cars
28%	Luxury cars, panmasala, tobacco

What if, petroleum brought under the slab rate of GST?

GST is an indirect tax which sub consumes almost every taxes existing in the country where GST is not brought on petroleum products. If GST comes on petroleum products including petrol and diesel the state and central tax duties will get integrated. GST has a maximum slab rate of 28% of price of a product.

If that GST comes on petrol, its price will be as follows:

- If petroleum comes under GST the tax will be a maximum of 28%.
- If so, the petrol sales price will be price * 28÷100

Solution 2: Switching to electric vehicles

An era of electric vehicles

In the era of burning price of petrol and diesel, it's the perfect time to switch to a much cleaner and economical alternative for

travelling- The Era of electric vehicles. The price of petrol has reached Rs.100 and diesel is being sold above Rs.90 per litre. 60% of money we spend on petrol is tax. The government is able to initiate such an unfair rate of tax on petrol, it is because of the monopolistic behavior of petroleum and no other alternatives are sufficient enough to break the demand of petroleum. By the use of electricity as a fuel for running vehicles the demand for the petroleum products will get split and there by the price of petroleum can be brought down.

Cost of running per km with various fuels

Now a day's filling up of a full tank of petrol is fast becomes a pipe dream for many, the alternatives as well as futuristic electric powered vehicles seems to offer better running price realization. The calculation takes into account that the recent rise in petrol prices is a fact, which has reached Rs.100 per litre while diesel is being sold at over 90 per litre.

Consequently, the running cost of EVs comes to Rs 1 per km, Rs 9 per km for petrol, Rs 6 for diesel and about Rs 2.5 per km for vehicles being run on CNG. Under the bare minimum conditions, the calculation becomes even clearer.

Cost of running an EV = Unit price × Battery size

Notably a home based 7 kWh charger takes about 6-8 hours for fully charging a vehicle with a battery size of over 40kWh. The time period comes down as the battery size decreases. In terms of cost special permissions plus wiring is required to install such a system at home or even in flats. Once the infrastructure is in place, the cost will come down to unit price.

A 40kWh battery installed in leading EVs like Hyundai Kona electric) can provide range from 350-400 km on a full charge. The running cost of the size of vehicle in a home charger infrastructure will be less than Rs 1 per km. Mahindra eVerito uses just 16kWh battery that would go up to 180km in one charge. In home charging connection it would need less than four hours to charge fully. Planning for any contingencies the companies have to cover the risk by developing mobile carrier charging units in major cities. Still on a competitive basis, EVs thump petrol on both cost and environment friendly scales.

Electric cars in India

At present automobile companies such as Tata Motors, Mahindra, MG Motors and Hyundai have come out with pure electric variants and standalone mode in India.

Models	Price in Rs.
Hyundai Krona	23.75
M G Zsev	20.99
Tata Nexon EV	13.99
Mahindra Everito	10.15

Advantages of Electric vehicles

- They are easier for the environment: - Electric vehicles are better for environment, EVs doesn't even have an exhaust system meaning that they have zero emission.

- Maintenance is less frequent & less expensive: - since electric vehicles are electric and they don't run on oil and therefore not necessary for oil charges.
- The beads on electric vehicles typically don't wear as quickly as those on conventional vehicles which mean even more savings.
- They are very quiet: - Conventional vehicles can be very noisy. EVs on the other hand are very silent.
- Easy to drive and manage: - Since electric vehicles don't have gear shifts, it is very easy to drive when compact with conventional vehicles.

Disadvantages of Electric vehicles

- Some EVs have short range for driving: - Long distance travelling is a problem for considering electric vehicles both range as well as the availability of changing station is a problem for electric vehicles during long rides.
- Charging can take a lot of time: - Petrol vehicles can make their refueling within a matter of minute while the electric vehicles would take 4 to 8 hours for getting full charged.
- Initial investment is steep: - Initial investment required for purchasing an electric vehicle is very high when compared with other vehicles.
- Reconditioning is tedious: - Once the vehicles get absolute damage the reconditioning requires the complete replacement of parts, seems to be more expensive.
- Impact of natural calamity: - Any impact of natural calamity which interrupts power supply will completely interrupt the transportation of EVs.

Conclusion

Petroleum has been selling at record high levels in India but this hike in oil prices does not seem to worry the government. About 60% of retail price of petroleum is Central and State taxes, so that the fluctuation in the price of crude oil does not affect the retail price of petroleum in India. The middleclass and the lower class of the society are the most vulnerable communities suffering petroleum price hike. They struggle to meet the two ends.

To bring petroleum under GST is the easiest method so that petroleum price can be brought under control. Electricity can be used an alternative to petroleum in various areas like transportation. Switching to electric vehicles provides benefits like ecofriendly environment, less noise and air pollutions, less maintenances for vehicles etc. The demand for the petroleum products will decline when the use of electricity increases. Across the nation we can see lot of protest activities, campaigns, strikes against the petroleum price hike. A proper support from the government can only change the recent situation in the country.

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B. SCIENCE

MORE ON CHARACTERISTIC POLYNOMIALS OF CHEMICAL TREES

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ABSTRACT

The characteristic polynomials of graphs obtained from the structural diagrams of alkanes play a vital role in the study of their physical / chemical properties [2, 3, 7, 8, 11, 12, 15, 16]. The roots of these polynomials form their spectrum and the indices derived from these polynomials and the spectrum are found to be well correlated with their properties. In this paper we discuss some methods for an easy computation of the characteristic polynomials of chemical trees.

1. Introduction

Let G be a simple graph with vertices $v_1, v_2, \ldots, v_n$. The adjacency matrix [6] of G in the $n \times n$ matrix $A(G) = \begin{cases} 0 \; if \; i = j \\ 1 \; if \; i \neq j \; and \; v_i \; and \; v_j \; are \; adjacent \\ 0 \; if \; v_i \; and \; v_j \; are \; not \; adjacent \end{cases}$

A single numerical value characteristic of a graph is described as a topological index [6]. Topological indices are extremely useful in drug designing that saves time, money and lives of living beings contrary to the traditional trial and error method, many of these indices are constructed using the characteristic polynomials of graphs representing a chemical molecule. These indices are systematically tried out in the investigation of drugs in the treatment of COVID-19 [5]. Here we consider some methods which help in an easy computation of such polynomials.

We denote a path of length 'n' by P_n and its characteristic polynomial by L_n. The kenograms (hydrogen depleted diagram) of alkanes are trees (also called chemical trees) and we denote them by 'T'. For any chemical tree, the characteristic polynomial is given by $\varphi(T, \lambda) = |\lambda I - A|$ where 'λ' is an indeterminate and 'I' is the identity matrix of the order of 'A' [14].

The eigen values of the characteristic equation $\varphi(T, \lambda) = 0$ have significant roles in determining the Quantitative Structure Property Relationships (QSPR) / Quantitative Structure Activity Relationships (QSAR) / Quantitative Structure Toxicity Relationships (QSTR) of chemical molecules.

2. Preliminary Results

Theorem 1 [6] : The characteristic polynomial $\phi(P_n, \lambda)$ or L_n of a path P_n on 'n' vertices is, ${}^{n}C_0\lambda^n - {}^{n-1}C_1\,\lambda^{n-2} + {}^{n-2}C_2\,\lambda^{n-4} - {}^{n-3}C_3\lambda^{n-6} + \ldots + (-1)^r\,{}^{n-r}C_r\,\lambda^{n-2r} + \ldots$

where $0 \le r \le \lfloor n/2 \rfloor$ where $[x]$ is the greatest integer less than or equal to x.

The characteristic polynomials of chemical trees other than paths can be computed using the following theorem due to Heilbronner and Edgar Heilbronner.

Theorem 2 [6]: If 'G' is a forest and if 'v' is a leaf with a neighbor 'u', the characteristic polynomial of 'G' satisfies the following recurrences:

(i) $\phi(G, \lambda) = \lambda\,\phi(G - v, \lambda) - \phi(G - v - u, \lambda)$

(ii) $\phi(G, \lambda) = \phi(G - uv, \lambda) - \phi(G - u - v, \lambda)$ where uv is an edge of G.

To get the maximum benefit of these results, select edges / vertices in the above formulae so that their deletion results in a graph whose components are either paths or trees whose characteristic polynomials could easily be determined.

By a linear combination of the characteristic polynomials $L_n, L_{n-1}, L_{n-2}, \ldots, L_{n-i}$ we mean a relation of the form $a_0 L_n + a_1 L_{n-1} + a_2 L_{n-2} + .. + a_i L_{n-I}$ where $a_0, a_1, a_2, \ldots, a_i$ are real constants.

The following theorem facilitates the computation of the characteristic polynomials of graphs, especially trees.

Theorem 3: Let $P_{n+1} = v_1\, v_2 \ldots v_{n-1}\, v_n\, v_{n+1}$ be a path in a tree 'T' such that $d(v_i) \le 2$, for all $1 \le i \le n$. If $T - P_n$ be the graph obtained by deleting the vertices $v_1, v_2, \ldots, v_n$ the following result holds:

$$\phi(T, \lambda) = \phi(P_n, \lambda)\,\phi(T - P_n, \lambda) - \phi(P_{n-1}, \lambda)\,\phi(T - P_{n+1}, \lambda)$$

Theorem 4 : $L_n + L_{n-2} + L_{n-4} + \ldots + L_{n-2i}$

$$= L_i\, L_{n-i},\ 0 \le i \le \lfloor n/2 \rfloor$$

Construction 5 : Let $P_n(i)$ be the caterpillar obtained by adjoining a vertex to the i^{th} vertex of a path P_n. The procedure of naming of alkanes permit us to speak of $P_n(i)$ for $2 \le i \le \left\lfloor \frac{n+1}{2} \right\rfloor$ only.

Theorem 6 : The characteristic polynomial of $P_n(i)$ is given by,

$$\phi(P_n(i), \lambda) = L_{n+1} - L_{n-3} - L_{n-5} \ . \ . \ . - L_{n-(2i-1)}$$

Now we prove an important theorem, for the existence of the characteristic polynomials of chemical trees in the form of linear combination of characteristic polynomial of paths.

Theorem 7: The characteristic polynomial of any tree T on 'n' vertices ($n \ge 4$) can be written as a linear combination of the characteristic polynomials of paths of lengths n, n - 4, n - 6, n - 8, . . . as follows:

$$\phi(T, \lambda) = L_n - a_1 L_{n-4} - a_2 L_{n-6} - a_3 L_{n-8} \ . \ . \ . - a_r L_{n-2(r+1)}.$$

where $r = \frac{n}{2} - 1$ if 'n' is even and $r = \frac{n-3}{2}$ if 'n' is odd. Further, this expression is unique.

Proof: The proof is by induction on 'n', the number of vertices. When n = 4, the possibility is the tree T of 2-Methyl Propane (i.e., 2MC3) [1], the characteristic polynomial of which is $\phi(T, \lambda) = \phi(P_3(2), \lambda) = L_4 - L_0$ (by Theorem 6).

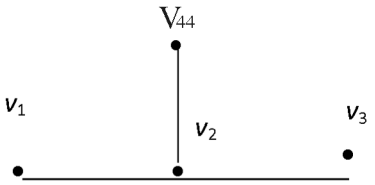

Figure 1

Therefore the result is true for n = 4. We assume that the result is true for every graph with fewer than 'n' vertices.

Let T be a tree on 'n' vertices. Let $v_{n-1}v_n$ be an edge of T where v_n is a leaf. Deleting the leaf v_n and the edge $v_{n-1}v_n$ from T we can get two subgraphs $T_1 = T - v_n$ and $T_2 = T - v_{n-1}v_n$ of T with $n-1$ and $n-2$ vertices respectively. Applying part (i) of Theorem 2 on vertex deletions (deleting v_n), we have,

$$\phi(T, \lambda) = \lambda\phi(T_1, \lambda) - \phi(T_2, \lambda) \qquad (1)$$

Since T_1 and T_2 are trees with fewer than 'n' vertices, by induction hypothesis, their characteristic polynomials can be expressed as linear combinations of paths in the following forms.

$\phi(T_1, \lambda) = L_{n-1} - a_1L_{n-5} - a_2L_{n-7} \ldots$ and

$\phi(T_2, \lambda) = L_{n-2} - b_1L_{n-6} - b_2L_{n-8} \ldots$, where $a_1, a_2, \ldots, b_1, b_2, \ldots$ are real constants. Further $\lambda = L_1$.

Therefore, equation (1) becomes,

$$\phi(T, \lambda) = L_1[L_{n-1} - a_1L_{n-5} - a_2L_{n-7} \ldots] - [L_{n-2} - b_1L_{n-6} - b_2L_{n-8} \ldots]$$

$$= L_1L_{n-1} - a_1L_1L_{n-5} - a_2L_1L_{n-7} \ldots - L_{n-2} + b_1L_{n-6} + b_2L_{n-8} \ldots$$

Using Theorem 4, we get

$$\phi(T, \lambda) = [L_n + L_{n-2}] - a_1[L_{n-4} + L_{n-6}] - a_2[L_{n-6} + L_{n-8}] \ldots$$

$$- L_{n-2} + b_1L_{n-6} + b_2L_{n-8} + \ldots$$

$$= L_n - a_1L_{n-4} - (a_1 + a_2 - b_1)L_{n-6} - (a_2 + a_3 - b_2)L_{n-8} \ldots,$$

which is a linear combination of $L_n, L_{n-4}, L_{n-6}, \ldots$

When 'n' is even the last characteristic polynomial in the above sequence is of the form L_{n-2r-2} so that $r = \frac{n-2}{2}$ and when 'n' is odd the terminating characteristic polynomial is L_{n-2r-3} for which $r = \frac{n-3}{2}$.

The uniqueness part is straightforward

Theorem 8: If L_n is the characteristic polynomial of a path on 'n' vertices then

$$L_n^2 = L_{2n} + L_{2n-2} + L_{2n-4} + \ldots + L_2 + L_0.$$

Proof: Replacing n with 2n and applying theorem 4 we reach the conclusion

The following theorem enables us to express any power 'm' of λ ($\lambda = L_1$), as a linear combination of $L_m, L_{m-2}, L_{m-4}, \ldots, L_{m-2r}$, '$m$', being a positive integer.

Theorem 9: $L_1^m = {}^{m-1}C_0 L_m + {}^{m-1}C_1 L_{m-2} + [{}^{m-1}C_2 - {}^{m-1}C_0] L_{m-4}$

$+ [{}^{m-1}C_3 - {}^{m-1}C_1] L_{m-6} + [{}^{m-1}C_4 - {}^{m-1}C_2] L_{m-8} \ldots + [{}^{m-1}C_r - {}^{m-1}C_{r-2}] L_{m-2r}$ where $r = \frac{m-1}{2}$, if m is odd and $r = \frac{m}{2}$, if m is even.

Proof: We use the principle of mathematical induction to prove this result. For $m = 1$, $L_1^m = L_1^1 = {}^{1-1}C_0 L_1 = L_1$, which is true. The result is true for $m = 2$ also, since $L_1^2 = \lambda^2 = (\lambda^2 - 1) + 1 = L_2 + L_0 = {}^1C_0 L_2 + {}^1C_1 L_0$.

The rest is mere computation.

Remark 10: This result is helpful to find out the linear combination of certain chemical trees when we apply Theorem 2 (ii) on edge deletions, as we see in the following example.

Example 11: Consider the tree T shown in Figure 2 which is the structural diagram of 2,2,3–trimethyl–3–ethyl pentane (223MMM3EC5) [1].

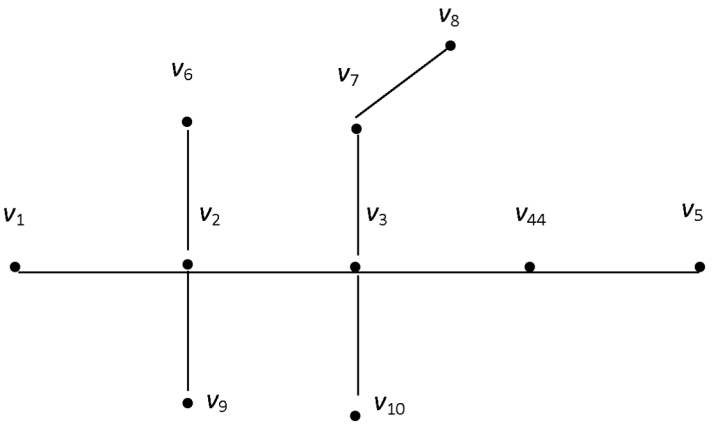

Figure 2

Deleting the edge v_2v_3 and applying Theorem 2 (ii) and Theorem 6, we have

$\phi(T, \lambda) = (L_4 - L_0)(L_6 - L_2 - L_0) - L_1^4 L_2^2$

By Theorem 9,

$L_1^4 = {}^3C_0L_4 + {}^3C_1L_2 + [{}^3C_2 - {}^3C_0]L_0 = L_4 + 3L_2 + 2L_0$ and

$L_2^2 = L_2L_2 = L_4 + L_2 + L_0$, by Theorem 8.

Therefore,

$\phi(T, \lambda) = (L_4 - L_0)(L_6 - L_2 - L_0) - (L_4 + 3L_2 + 2L_0)(L_4 + L_2 + L_0)$

$= (L_4L_6 - L_4L_2 - L_4 - L_6 + L_2 + L_0)$

$- (L_4^2 + L_4L_2 + L_4 + 3L_2L_4 + 3L_2^2 + 3L_2 + 2L_4 + 2L_2 + 2L_0)$

Now applying Theorem 4, we get

$\phi(T, \lambda) = (L_{10} + L_8 + L_6 + L_4 + L_2) - (L_6 + L_4 + L_2) - L_4 - L_6 + L_2 + L_0$

$- (L_8 + L_6 + L_4 + L_2 + L_0) - 3(L_6 + L_4 + L_2) - 2L_4 - (L_6 + L_4 + L_2)$

$- 3(L_4 + L_2 + L_0) - 2L_2 - L_4 - 3L_2 - 2L_0$

$= L_{10} - 6L_6 - 12L_4 - 12L_2 - 5L_0.$

Theorem 12: $L_n^3 = \sum_{r=0}^{n} (r+1)L_{3n-2r} + \sum_{r=0}^{\left\lfloor \frac{n}{2} \right\rfloor - 1} (n-2r-1)L_{n-2(r+1)}$ where L_n is the characteristic polynomial of a tree on 'n' vertices.

Proof: Assume that 'n' is even.

$L_n^3 = L_n^2 L_n = [L_{2n} + L_{2n-2} + L_{2n-4} + L_{2n-6} + \ldots + L_{n+2} + L_n + L_{n-2} + \ldots + L_2 + L_0]L_n$

$= L_{2n}L_n + L_{2n-2}L_n + L_{2n-4}L_n + \ldots + L_{n+2}L_n + L_nL_n + L_nL_{n-2} + \ldots + L_nL_2 + L_n$

$= [L_{3n} + L_{3n-2} + L_{3n-4} \ldots + L_{2n+2} + L_{2n} + L_{2n-2} + \ldots + L_{n+2} + L_n]$

$+ [L_{3n-2} + L_{3n-4} + \ldots + L_{2n+2} + L_{2n} + L_{2n-2} + \ldots + L_{n+2} + L_n + L_{n-2}]$

$$+ [L_{3n-4} + \ldots + L_{2n+2} + L_{2n} + L_{2n-2} + \ldots + L_{n+2} + L_n + L_{n-2} + L_{n-4}] + \ldots$$

$$+ [L_{2n+2} + L_{2n} + L_{2n-2} + \ldots + L_{n+2} + L_n + L_{n-2} + \ldots + L_4 + L_2]$$

$$+ [L_{2n} + L_{2n-2} + \ldots + L_{n+2} + L_n + L_{n-2} + \ldots + L_4 + L_2 + L_0]$$

$$+ [L_{2n-2} + \ldots + L_{n+2} + L_n + L_{n-2} + \ldots + L_4 + L_2] + \ldots$$

$$+ [L_{n+2} + L_n + L_{n-2}] + L_n.$$

$$= L_{3n} + 2L_{3n-2} + 3L_{3n-4} + \ldots + (n+1)L_n + (n-1)L_{n-2} + (n-3)L_{n-4} + \ldots + 3L_2 + L_0$$

$$= \sum_{r=0}^{n} (r+1)L_{3n-2r} + \sum_{r=0}^{\frac{n}{2}-1} (n-2r-1)L_{n-2(r+1)}$$

If 'n' is odd, the value of 'r' in the second sum varies from 0 to $\left\lfloor \frac{n}{2} \right\rfloor - 1$. Thus in general we have, $L_n^3 = \sum_{r=0}^{n} (r+1)L_{3n-2r} + \sum_{r=0}^{\left\lfloor \frac{n}{2} \right\rfloor - 1} (n-2r-1)L_{n-2(r+1)}$.

Construction 13. Let P_k, P_m, P_n be three paths with 'k', 'm' and 'n' vertices respectively where $k \le m \le n$. Let w be a new vertex. Now adjoin w to any of the pendant vertices of each of the paths P_k, P_m, and P_n. The newly obtained graph consists of $k + m + n + 1$ vertices, $k + m + n$ edges and we denote it by $S(n,m,k)$. This graph is a rooted tree, rooted at w with three branches.

Theorem 14: The characteristic polynomial of $S(n,m,k)$ denoted by $L_{n,m,k}$ is given by

$$L_{n,m,k} = \begin{cases} L_{n+m+k+1} - \sum_{r=1}^{k} rL_{n+m+k-(2r+1)} - k \sum_{r=k+1}^{m} L_{n+m+k-(2r+1)} \\ - \sum_{r=m+1}^{n} (m+k-r)L_{n+m+k-(2r+1)} - \sum_{r=n+1}^{\left\lfloor \frac{n+m+k-1}{2} \right\rfloor} (n+m+k-2r)L_{n+m+k-(2r+1)} \end{cases}$$

where $m + k > n$.

Corollary 15: If $m + k \le n$, the above formula reduces to

$$L_{n,m,k} = \begin{cases} L_{n+m+k+1} - \sum_{r=1}^{k} rL_{n+m+k-(2r+1)} - k \sum_{r=k+1}^{m} L_{n+m+k-(2r+1)} \\ - \sum_{r=m+1}^{m+k-1} (m + k - r)L_{n+m+k-(2r+1)} \end{cases}$$

Theorem 16: The characteristic polynomial of $S(n,n,n)$ denoted by $L_{n,n,n}$ is given by

$$L_{n,n,n} = L_{3n+1} - \sum_{r=1}^{n} rL_{3n-(2r+1)} - \sum_{r=1}^{\left\lfloor \frac{n-1}{2} \right\rfloor} (n-2r)L_{n-(2r+1)} .$$

Remark 17: Theorem 2.41 can also be obtained from Theorem 2.39 by substituting $k = m = n$. When $k = m = n$ the sum $\sum_{r=1}^{k} rL_{n+m+k-(2r+1)}$ in equation (1) of Theorem 2.39

Becomes $\sum_{r=1}^{n} rL_{3n-(2r+1)}$. Also the sums $k \sum_{r=k+1}^{m} L_{n+m+1-(2r+1)}$ and $\sum_{r=m+1}^{n-m} (k-r)L_{n+m+k-(2r+1)}$ which are sum of respective terms for $r > n$ vanishes.

Hence, equation (1) of Theorem 2.39 reduces to

$$L_{n,n,n} = L_{3n+1} - \sum_{r=1}^{n} rL_{3n-(2r+1)} - \sum_{r=1}^{\left\lfloor \frac{n-1}{2} \right\rfloor} (n-2r)L_{n-(2r+1)} .$$

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BIOLOGICAL APPLICATIONS OF NOVEL METAL-SCHIFF BASE COMPLEX FROM O-VANILLIN AND FURFURYL AMINE AND ITS PHYSICOCHEMICAL, SPECTROSCOPIC, CRYSTALLOGRAPHIC CHARACTERIZATION

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ABSTRACT

Schiff bases are condensation products of primary amines with carbonyl compounds. Schiff base-coordination complexes gain importance day by day in the present scenario because of their interesting applications in the catalytic, magnetic, and biological fields. Schiff's base formed from o-vanillin and furfuryl amine and their Co (II) and Ni (II) complexes were prepared herein. We employed FT-IR spectroscopy, TGA-DSC analysis, Magnetic susceptibility measurements, Single crystal XRD, Elemental (CHN) analysis etc. We also carried out the biological applications of the prepared complexes in the fields of antibacterial activity.

1. Introduction

Co-ordination chemistry is the study of metal complexes. The transition metals form many complex compounds in which a central metal ion and is surrounded by several ligands which are attached to it by co-ordinate covalent bonds. It is essential that the central ion should have vacant orbitals to accommodate lone pairs of electrons donated by the ligands. The atom in the ligand which may donate the electron pair is named donor atom or co-coordinating atom. The first systematic attempt at explaining the formation, structure, isomerism, bonding, and reactions of a coordination compound was made by Alfred Werner and is known as the father of co-ordination chemistry. Diverse properties (physical and chemical) and structural aspects of coordination compounds which helps to understand the fundamentals of many bio-chemical processes. Co-ordination compounds have several applications which depend on their unusual stability. They play a significant role in industry, functioning of critical components of biological systems and life process. A few important compounds are porphyrin, chlorophyll, haemoglobin etc. Co-ordination compounds have several applications including separation of specific metal ions and catalysis.

Schiff bases are one of the extensively studied classes of ligands in metal coordi-

nation chemistry [1]. Structurally, they're nitrogen analogue of an aldehyde or ketone during which the carbonyl group (CO) has been replaced by an imine or azomethine group, with general structure R-CH=N-R' (Fig. 1), where R and R' is linear or cyclic alkyl and/or aryl group which may be differently substituted [2] [3]. Schiff bases can be prepared by the condensation reaction of a primary amine with carbonyl compounds such as aldehyde or ketone under conditions [2].They coordinate to metal ions by means of azomethine nitrogen. Schiff base complexes are most widely used organic compounds because of its easy availability, facile syntheses, and electronic properties. They have many applications in dye industry and in biology including fungicidal, agrochemical, antibacterial, antifungal, antiviral, anticancer, antioxidant, anti-inflammatory, antimalarial activity etc. It also acts as catalyst in several reactions such as oxidation of organic compounds, polymerization reaction, reduction reaction of ketones or thionyl chloride, aldol reaction, epoxidation of alkenes and Diels-Alder reaction [4].

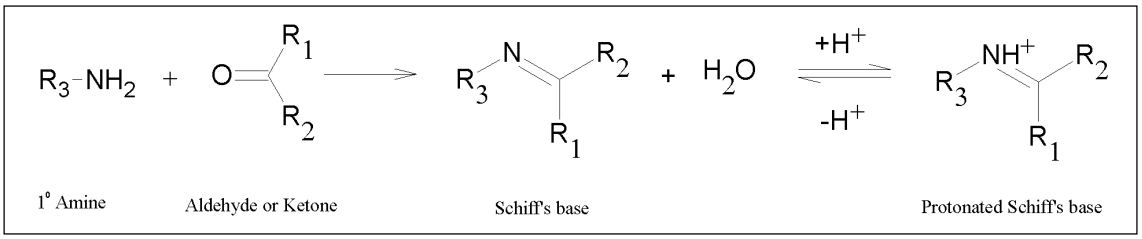


Fig. 1 - General scheme for formation of Schiff bases.

Nickel (II) forms many complexes with co-ordination number ranging from 3 to 6. Softer ligands such as phosphorous and sulphur ligands generally form four co-ordinate complexes with a strong preference to square planar geometry. Nickel tends to add further ligands to it and produce complexes with co-ordination number 5 and 6 also. The applications of Ni (II) complexes are extremely varied and of great importance [4].

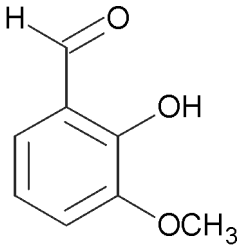
Schiff bases are the most widely used organic compounds for industrial purposes and exhibit a broad range of biological activities. Schiff base compounds and their metal complexes are very important as catalysts in various biological systems, polymers, dyes, and medicinal and pharmaceutical fields. They comprise miscellaneous therapeutically potent applications in the field of medicinal chemistry. They find use in birth control, food packages and as an O2 detector. Schiff's bases chelate also used in quantitative analysis as an analytical chemical reagent and/or separation reagents and have synthetic applications in the field of the organic and inorganic chemistry. They have been shown to exhibit a broad range of biological activities, including antifungal, antibacterial, antimalarial, antiproliferative, anti-inflammatory, antiviral, and antipyretic properties[5]. Schiff bases are found to be a versatile pharmacophore for design and de-

velopment of various bioactive lead compounds. Schiff bases appear to be a crucial intermediate during a number of enzymatic reactions involving interaction of an enzyme with an amino or a carbonyl group of the substrate. The common Schiff bases are crystalline solids, which are feebly basic but at least some form insoluble salts with strong acids [6].

Ortho-vanillin became extremely popular in coordination chemistry due to its Schiff bases. Indeed, the first homo-and heterometallic complexes containing o-vanillin as a main ligand were reported after those containing its Schiff bases. Moreover, some of these compounds combine two useful physical properties, opening new routes towards multifunctional materials [7]. The synthesis of Mn (II), Co (III), Ni (II), Fe (II), Cu (II) & Zn (II) Schiff base complexes having ligand derived from o-Vanillin and glycine is one of them [8]. An unsymmetrical tridentate Schiff base ligand derived from 1:1 M condensation of ortho-vanillin with 2-mercaptoethylamine[1]. Studies of schiff base complexes of Co (II), Ni (II), Cu (II) and Zn (II) incorporating indole-3-carboxaldehyde and m-aminobenzoic acid were screened by Nair et al. The activity order of the synthesized compounds is as follows: Cu (II) > Co (II) > Ni (II) > Zn (II) > Ligand. In addition, chelation may enhance or suppress the biochemical potential of bioactive organic species [2] [9]. Some Cu (II), Co (II), and Ni (II) complexes are reported by using Schiff base ligand derived from 2-amino-3-hydroxypyridine and 3-methoxysalicylaldehyde and were investigated for their invitro antimicrobial activities against the numerous bacteria and fungi [4]. A significant number of Schiff base metal complexes are reported as reasonably successful models of biological compounds [10]. Schiff base derivatives were prepared by the condensation of 2-hydroxy-3-methoxybenzaldehyde (o-vanillin) and 3-hydroxy-4-methoxybenzaldehyde (iso-vanillin) with 5-methylfurfuryl and the characterisation of its nickel complex was done by Cemal Senol et al. Vanilline and furfurylamine Schiff base derivatives are very useful biochemical materials having biological activities. Although the oxygen atom of the furan ring could not coordinate to the transition metals, the special tendency of the oxygen atom will be effective on the crystal structures of the complexes [11]. In the present study, the synthesis and characterization of Nickel (II) nitrate complex of Schiff's base formed from o-vanillin and furfuryl amine were carried out. We employed FT-IR spectroscopy, TGA-DSC analysis, Magnetic susceptibility measurements, single crystal XRD, elemental (CHN) analysis etc. We also carried out the biological applications of the prepared complexes in the fields of antibacterial activity.

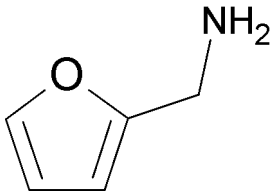
2. Experimental Methods

The ligand, 2-hydroxy-3-methoxybenzaldehyde (o-vanillin) used for the preparation of the complex. O-vanillin is a fibrous, light yellow crystalline solid. It does not have the characteristic and intense odour of vanilla, present in a variety of food products, it is not specifically sought after, and is therefore less commonly produced and encountered food additive.



Structure of o-vanillin
[2-hydroxy-3-methoxybenzaldehyde]

Furfuryl amine is an aromatic amine typically formed from the reductive amination of furfural with ammonia. Its chemical formula is C_5H_7NO. The structure of furfuryl amine is,



The structure of furfuryl amine

Here the Schiff's base is formed from the reaction of o-Vanillin with furfuryl amine. Later this is coordinated with nickel nitrate to get the nickel coordinated Schiff's base complex. 7.6 g of o-Vanillin is mixed with 4.45 g of furfuryl amine in alcohol medium (20 mL). The contents are refluxed for 3 h. The Schiff's base (SB) formed is separated and dried. It is recrystallized from ethyl alcohol and the solubility is noted in various solvents. Nickel nitrate solution in water is refluxed with Schiff's base in the ratio 1:2.5 in 20 mL of pure ethyl alcohol for 3 h. The product obtained is dried and purified. The Ni-SB complex now formed is abbreviated as Ni-SB.

The physico-chemical methods employed in the present investigation for the characterization of the complex were FT-IR spectroscopy, CHN elemental analysis, single crystal XRD, Magnetic susceptibility measurements and TGA-DSC analysis. The structures of newly synthesized ligand and its complexes were characterized by Fourier Transform Infrared spectra were recorded on PerkinElmer spectrum Two Infrared spectrometer with ATR Facility. The spectra are used to find the various functional groups. This technique reveals the energies of possible stretching and deformation vibrations within the structure. The assignment of these vibrations to specific chemical groups allows the qualitative and quantitative identification of the chemical components and therefore a better comprehension of its behaviour in different environments. The percentage of elements C, H, N, S and O in the organic compounds are analysed with Elementar Vario EL III CHN analyser. The crystal parameters like the crystal structure, space group, unit cell dimensions (á, â, ã and a, b, c) are obtained from x-ray diffraction technique. The SCXRD technique is taken using Bruker Kappa Apex II instrument.

Thermogravimetric analysis of transition metal complexes was one of the useful techniques to identify the status of water molecules in complexes as well as to know the stability of the metal complexes. In this technique the mass loss (%) of the sample is continuously recorded as a function of time or temperature, when it is heated or cooled at a controlled rate. The thermogram obtained can give valuable information like the dependence of the mass change on temperature, the composition of the sample, the

thermal stability, the pattern of decomposition and the product formed. Thermogravimetric curve is obtained by plotting the mass percentage on the ordinate decreasing downwards and the temperature or time on abscissa increasing from left to right. Universal V4.5A TA Instruments are used. DSC (Differential Scanning Calorimetry) measures the amount of heat energy absorbed or released by a sample, when it is heated or cooled or held at a constant temperature.

Magneto-chemistry is used to investigate the magnetic properties of transition metal complexes. Magnetic moment of all the complexes was measured at room temperature using Sherwood Scientific Magnetic susceptibility balance. This would also give the clear idea about the number of unpaired electrons in the central metal atom or ion in the complex. In first row transition metals,

- Spin only magnetic moment cab be calculated using the equation,

$$M_{(s,\,o)} = [4S(S+1)]^{1/2}$$

- Gram susceptibility was calculated using the formula

$$\div_g = C_{bal} X\, l\, X(R-R_0)\, /mX10^9$$

Where,

R-balance reading with sample

R_0-Balance reading without sample

C_{bal} – a constant for balance

l- Length of the sample in cm

m- Mass of the sample in gm

- Molar susceptibility was calculated using the expression,

$$\div_M = \div_g M$$

M- Molar mass of sample

- Diamagnetic corrections were computed from Pascal's constant. The corrected Molar susceptibility value was calculated from the expression.

$$\div_a = \div_m + \div_{dia}$$

- The effective magnetic moment was calculated from the Molar susceptibility values using the expression.

$$\mu_{eff} = 2.828(\div_a XT)^{1/2}\ BM$$

The values of effective magnetic moment, μ_{eff} as a function of n the number of unpaired electrons is given below.

No of unpaired electrons (n)	μ_{eff} (BM)
1	1.73
2	2.83
3	3.87
4	4.90
5	5.92
6	6.93

The *in-vitro* antimicrobial potential of the prepared samples was estimated using the agar well diffusion method. One gram-positive (*Staphylococcus aureus*-MTCC 96) and one gram-negative (*Escherichia coli-MTCC 443*) bacterial stains and one fungal stain (*Aspergillus niger*) are used for the

analysis. They are originally obtained from microbial type culture collection, Chandigarh, India. Wells of about 6mm diameter were bored using a well cutter on grown microbes and 50 micro litres of the samples (1mg/mL) were poured into separate wells and were incubated for 24 h in the case of bacteria and one week in the case of fungi and the inhibitory zone in mm was measured. Measurements were replicated and the mean diameter was calculated which reflected the inhibitory nature of the samples.

3. Results and Discussions

3.1 Appearance and Solubility

The Schiff's base has a light-yellow colour which changes to orange yellow on complex formation. The melting point of the Schiff's base is 79^0C. The solubility of the Schiff's base obtained from o-vanillin and furfuryl amine are tabulated in Table 1.

Table 1: The solubility of the Schiff's base in different solvents

SOLVENT	SOLUBILITY
Ethyl acetate	Soluble
Ethanol	Soluble
n-hexane	Insoluble
Acetone	Soluble
Benzene	Soluble
$CHCl_3$	Soluble
Acetonitrile	Soluble
Ethyl ether	Soluble (partially)
DMF	Soluble
Water	Soluble (partially)
2-Propanol	Soluble (partially)

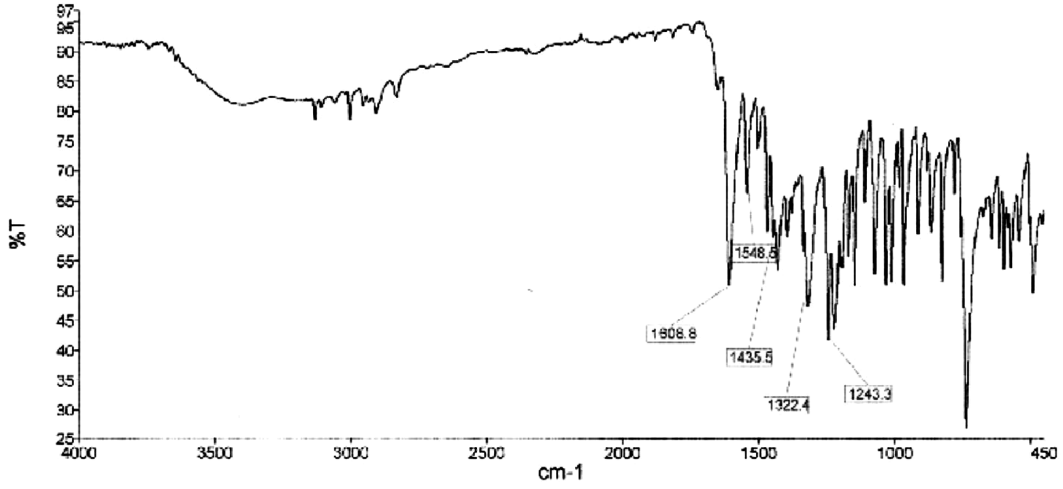
3.2 FT-IR Spectra

The FT-IR spectra of the samples are given below (Fig.2). The spectra of the free ligand (a) show absorption peaks at 1657.8 cm^{-1}indicating the -CH=N-$_{stretching}$ vibration. On complexation, this band shifted to 1608 cm^{-1}in the complex (b). These peaks are due to azomethine group and is shifted to lower frequency indicating it is coordinated to the metal ion through the nitrogen atom. The major peaks in the Schiff's base are 3150.2cm^{-1}, 1627.7cm^{-1}, 1465.6cm^{-1}, 1424.2cm^{-1}, 1250.8cm-1 and 1032.2cm^{-1}. These are due to O-H$_{stretching}$, aromatic -C=C-$_{stretching}$, phenolic C-O$_{stretching}$ etc. The major peaks in the Ni (II) complex are 3290cm^{-1}, 1548.5cm^{-1}, 1435.5cm^{-1}, 1322cm^{-1}, 1243.3cm^{-1}. The bands observed at 1548.5cm^{-1} and 1322.4cm^{-1}in the complex is due to the $\acute{\imath}_4$ and $\acute{\imath}_1$ vibrations of the nitrate group. The difference in wavenumbers between two highest frequency bands ($\acute{\imath}_4$- $\acute{\imath}_1$) of the nitrate is 226.1cm^{-1} indicating that the nitrate group is monodentately coordinated to the metal ion in this complex. Generally, all the vibrational peaks of the metal-Schiff's base complexes are in the range of 600-1600 cm^{-1}. The Schiff's base ligand act as a bidentate ligand. Thus, a coordination six may be assigned to the metal ion in this complex. The important FT-IR spectral bands of the ligand and its complex are described in the Table 2.

Table 2: FT-IR spectral bands of Schiff's base and Metal-Schiff's base complex

Compound	í(CH=N)	í4(NO_3)	í1(NO_3)
o-VAN	1657.8	-	-
[Ni-SB]	1608	1548.5	1322.4

(a)



(b)

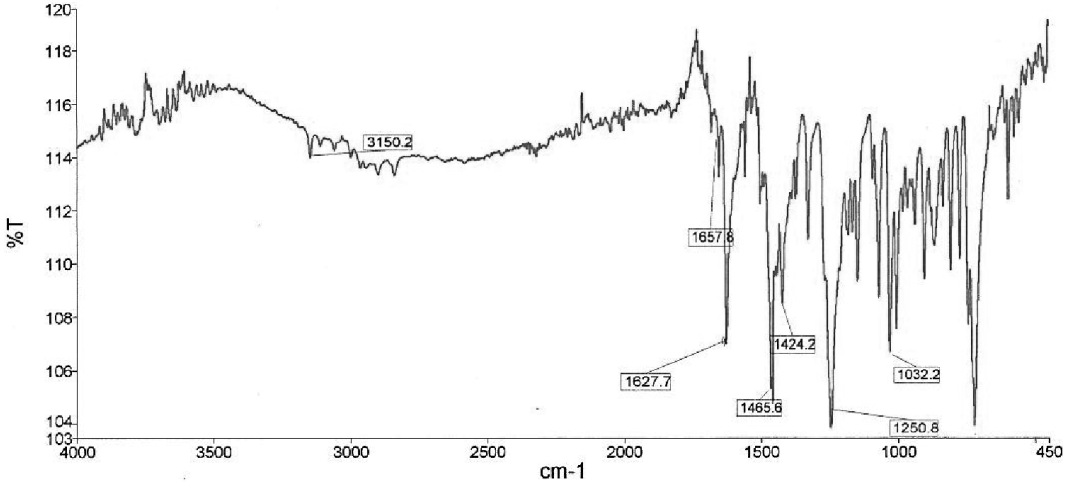


Fig. 2 FT-IR spectra of (a)Schiff's base and (b) Ni (II) Schiff's base complex

3.3 Elemental Analysis

The CHN analysis of Schiff's base has proved its formation. The data of the analysis is tabulated in Table 3.

Table 3: CHN data of Schiff's base

% Of Elements	Theoretical values	Experimental values
N	6.06	6.03
C	67.53	67.46
H	5.62	6.11

From the CHN elemental analysis, it is clear that the theoretical and experimental values are almost same.

3.4 Single Crystal XRD

From the single crystal XRD, the formula of the Schiff's base is $C_{13}H_{13}NO_3$. The formula weight of the complex is 231.24. The unit cell dimensions a, b, and c are 9.0818 A^o, 12.5444 A^o, and 11.3 A^o. The bond angles are Alpha (á) = 90^0, Beta (â) = 113.10 (4) ^{0} and Gamma (ã) = 90^0. From the X-Ray diffraction technique, the information about the crystal type obtained is monoclinic and the space group is P21/c. The Pictorial representation of the Schiff's base complex is given in Fig. 3 (a, b).

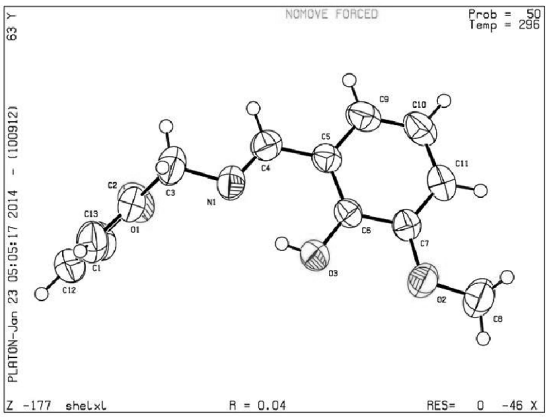
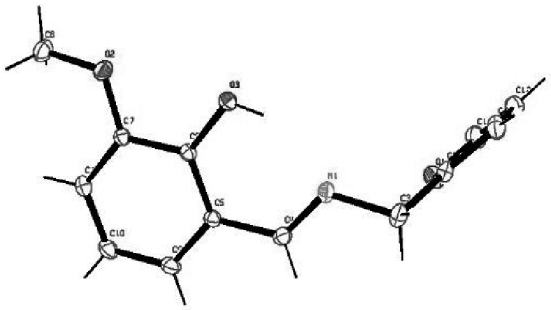


Fig. 3 Single crystal XRD of Schiff's base($C_{13}H_{13}NO_3$)



3.5. TGA-DSC Analysis

The TGA-DSC thermograms of the SB (a, b) and the complex (c, d) are given in Fig.4. The TGA curves showed the thermal decomposition of the complexes that has happened through several steps. The different groups in the ligands cause a decrease in the stability of the complexes. The elimination of water from moisture is denoted by the peak in the range of 50-90^{o}C for the Schiff's base. The final residue is the anhydrous oxide of the metal (NiO) as is evident from the percentage of the residue formed.

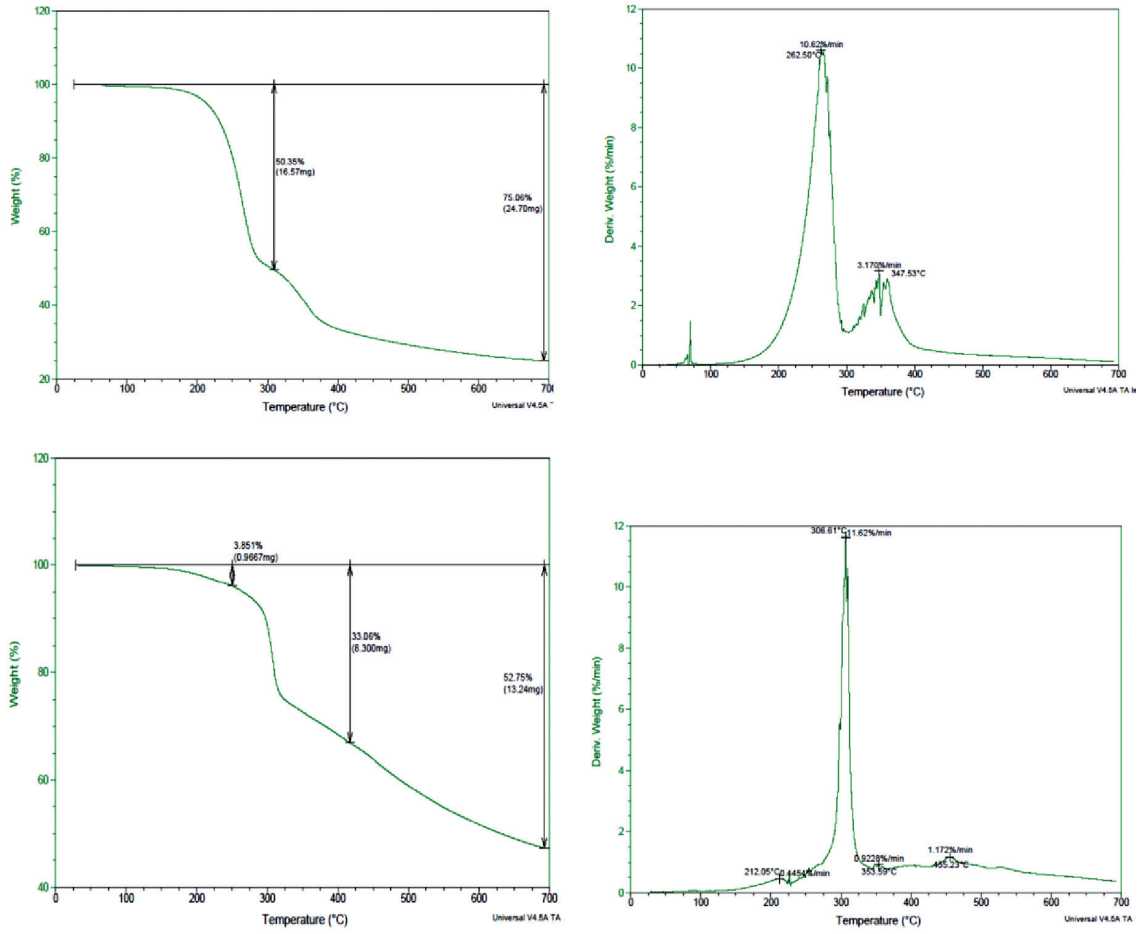


Fig. 4 TGA-DSC curves of Schiff's base and Ni (II) complex

Table 4: TGA-DSC data of Schiff's base and Ni (II) complex

Compound	No. of Stages	TGA Peak (°C)	Mass loss (%)
SB	I	262.5	10.62
	II	347.53	3.170
Ni (II)-SB	I	306.61	11.62
	II	352.59	0.923
	III	455.23	1.172

The pattern of decomposition of the complexes and the corresponding mass loss with the probable entity and mass loss (%) is given in Table 4. The complexes were ther-

mally stable to 306° C and by the partial loss of the organic moieties the decomposition occurs. The TGA and DSC curves (a) and (b) indicate that the ligands and begin to decompose at262.5 and 347.53° C respectively. (c) and(d) denotes that of the complex and the decomposition begins at 306.61, 352.59, 455.23° C. Comparison of the decomposition temperature of the ligands shows that the metal complex decomposes at higher temperatures than that of the ligand.

3.6. Magnetic Susceptibility

The effective magnetic moment of the complex is calculated is very close to the expected value of the magnetic moment where an atom of d^8 configuration (2.8 -4.0 BM). The closeness of the value reveals that the molecular composition assigned is correct and the sample is pure. Otherwise, the values would not be comparable since both the molecular mass and the mass of the sample are involved in the calculation of effective magnetic moment. The values obtained are summarized in Table 5.

Parameter calculated	Value
Gram susceptibility	7.9069×10^{-6}
Molar susceptibility	3273.19×10^{-6}
Corrected molar susceptibility	3303.19×10^{-6}
Effective magnetic moment	2.805 BM

Table 5: Summary of calculation of the effective magnetic moment

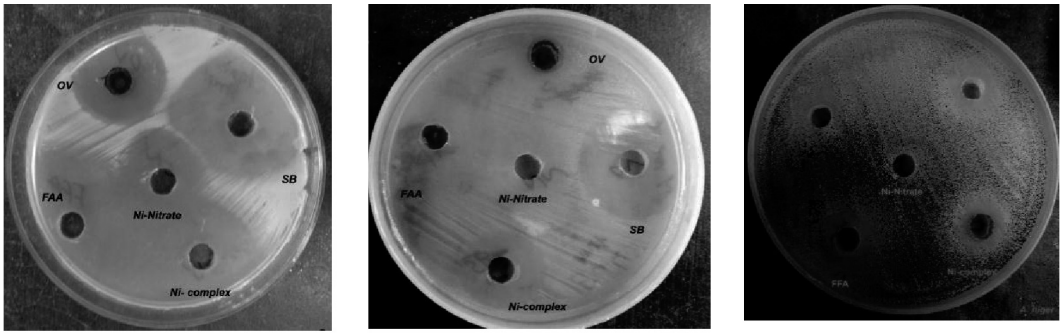
3.7. Antibacterial Activity

The results obtained from the activity are tabulated in Table 6 follows. The photographs of the tested microbial plates are given below Fig.5.

Table 6: antimicrobial data-Zone of inhibition in mm

Cultures	OV	SB	FFA	Ni-Nitrate	Ni-Complex
S. *aureus*	2.8	3.2	2.5	2.4	2.8
	2.6	3.1	2.4	2.4	2.8
	2.6	3.2	2.5	2.4	2.7
	2.7	3.2	2.5	2.3	2.8
	2.6	3.4	2.5	2.4	3.0
	2.8	3.2	2.5	2.4	2.8

E. Coli	2.6	3.5	1.8	1.6	2.5
	2.4	3.4	1.9	1.4	2.3
	2.7	3.4	1.8	1.4	2.3
	2.5	3.4	1.8	1.4	2.5
	2.5	3.4	1.7	1.5	2.4
	2.4	3.5	1.8	1.4	2.3
A. Niger	1.0	1.4	1.8	0	1.5
	0.9	1.4	1.8	0	1.5
	0.7	1.3	1.8	0	1.4
	0.8	1.3	1.9	0	1.5
	0.7	1.4	1.8	0	1.4
	0.6	1.4	1.7	0	1.4



(a) (b) (c)

Fig. 5 Photographs of the tested microbial plates (a) *S. Aureus*, (b) *E. coli* and (c) *A. Niger*

The high zone of inhibition shown by Ni-SB complex shows it has higher antimicrobial activity than the Schiff's base and metal ions. The ligands with the N and O donor atoms might have inhibited enzyme production and the thus deactivates the action of microorganisms.

4. Conclusion

Ni (II) complex of the ligand has been synthesized and characterized by infrared, elemental analysis, magnetic susceptibility measurement, thermogravimetric analysis.

The analytical data suggests that the molecular formula is Ni $(SB)_2(NO_3)_2$ and other analyses also suggests that the Ni-SB Complex possess the same formula. The azomethine linkage of the free ligand is found to be shifted in the IR spectrum of the complex, suggesting that is co-ordinated to the metal ion. The difference between the

frequencies Q_4 and Q_1 attributed to the nitrate ion revealed that the nitrate is monodentately co-ordinated.

The infrared spectral data propose a coordination number of six to the metal ion in this complex. The magnetic susceptibility values are also in good agreement with the expected values confirming that the molecular composition and purity of the prepared complex. The antibacterial activity of the complex and the Schiff's base shows they can be used to inhibit the growth of various bacteria and fungus. The TGA-DSC analysis find out the mass dependence of the sample as a function of temperature. The elemental analysis and single crystal XRD give information about various parameters.

Based on the analytical data octahedral geometry is proposed for the Ni (II)complex with the ligand. The manganese ion is six-coordinated through the N atom and O atom hydroxyl group and thus the ligand is coordinated in a bidentate fashion.

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POSITRON ANNIHILATION SPECTROSCOPIC CHARACTERIZATION OF FREE-VOLUME DEFECTS IN POLYMERIC BLENDS

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ABSTRACT

The size and the concentration of free volume defects in polymeric systems are monitored and their variations accurately traced using positron annihilation lifetime (PALS). The motivation behind the adoption of this particular protocol of characterization is that the polymeric blends like IPN (Interpenetrating networks) can act as platforms for designing cost effective toughened plastic with controlled morphology and mechanical properties. Thus, the correlation between PALS results with mechanical properties is given special emphasis in this work. This new modality of characterization versus composition uplifts and widens the application prospects of elastomer-thermoplastic blends.

Key words: Interpenetrating networks (IPN); positron annihilation; free volume defects; mechanical properties.

1. Introduction

Multi-component polymeric materials facilitate a new fabrication route to combine the properties of different polymers into one tailor-made material.[1] Homogeneous distribution of one polymeric component in another polymeric system is the necessary and sufficient condition for the design of multi-component polymeric systems with excellent performance characteristics.[2] The synthesis of an interpenetrating polymeric network (IPN) provides a promising path in this direction. IPNs are a combination of incompatible polymer networks in which at least one of the polymers is synthesized and / or cross-linked in the presence of the other.[3]

Amorphous materials like rubber and plastic are characterized by a rich concentration of free volume defects, which are the unoccupied regions available for segmental motion within the polymer material. In addition to the intra- and intermolecular interactions and the segment and chain motions, the size, concentration and distribution of atomic-scale free volume holes often play important roles to control the macroscopic properties of polymers.[4] The free volume defects arise due to the inefficient chain

packing or thermally induced segmentation and their role is of primary importance especially in the variations of the physical properties when subjected to external experimental treatments. Precise quantifications of the free volume characteristics of a polymer are therefore important especially in the context of their dependence on the amounts of additives and the durations of treatments. Positron annihilation spectroscopy (PALS) has been a versatile experimental probe used in the exploration of this problem and its success has been reported in a large number of published research works by several authors.[5-7]Among the several parameters which can be precisely measured, the "pick-off" annihilation lifetime and intensity of the orthopositronium (o-Ps) atoms are useful in the estimation of the sizes and concentrations of free volume defects where they are predominantly localized within the samples.[8]

There have been a few studies reported in literature outlining the reliability and importance of PAS as the pivotal tool in defect studies and IPN characterization.[9] Low et al[10] had proposed a method to tune the cavity size and free volume distribution in polyimide membranes of IPN pattern using this technique. Kumar et al[11] have published an article in which they tried to establish a correlation between PALS observations and mechanical properties of IPN.

2. Experimental details

2.1. Materials and methods

Styrene butadiene rubber (SBR) used for this study was supplied by Indian Synthetic Rubber Limited (ISRL) and methyl methacrylate (MMA), dicumyl peroxide (DCP 99%), divinyl benzene (DVB) and benzoyl peroxide (BPO) were purchased from Sigma-Aldrich. Toluene, used as the solvent for transport studies, was purchased from Merck, India Ltd.

2.2. Preparation of IPNs

Poly methyl methacrylate (PMMA) is toughened by interspersing it in nano particulate form into a polymer matrix such as rubber.[12] SBR was masticated with DCP (1/2/3 per hundred gram rubber (phr)) in a two-roll mixing mill at room temperature as per ASTM standards. The curing behavior of SBR compounds were studied on a Rheometer and the optimum cure time was determined. The mixture was vulcanized at 423 K on a hydraulic press and a cross-linked SBR sheet was obtained.

The composition of the IPN and semi-IPN samples was determined on the basis of their final weights. The IPNs and semi-IPNs using benzoyl peroxide as the initiator (for MMA) can be represented as ${}^{a}SBP_{c}D_{d}$ where *a* indicates the weight of DCP per 100 gram of SBR rubber, S denotes SBR rubber, B represents benzoyl peroxide (initiator for MMA polymerization), P is used for PMMA, *c* indicates weight percentage of PMMA, D stands for divinyl benzene and *d* corresponds to the wt. % of the divinyl benzene content. The preparation procedure of IPN is schematically represented in Fig. 1 and, as examples of nomenclature, the compositions of some of the typical IPNs and semi-IPNS have been summarized Table 1.

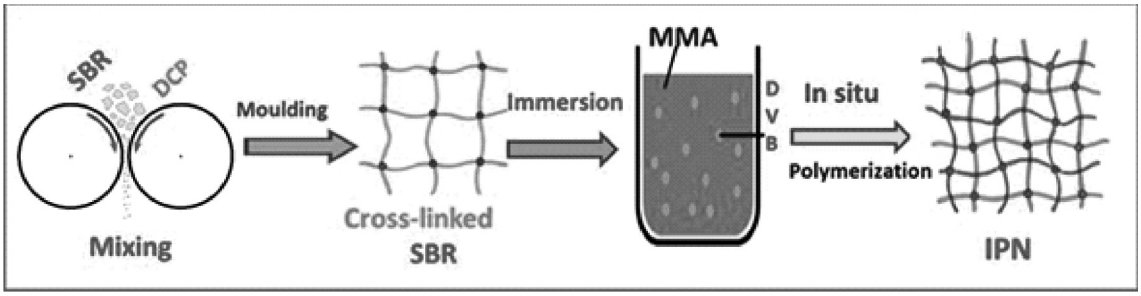

Fig. 1. Schematic representation of IPN formation.

Table 1 The compositions of some of the IPNs and semi-IPNs

Type of IPN	DCP (*a*) (phr)*	Wt. % of SBR/PMMA ((100-*c*)/*c*)	DVB (*d*) (wt. %)
$^{1}S_{100}$ (Pure SBR)	1	100	0
$^{1}SBP_{50}D_{0}$	1	50/50	00
$^{1}SBP_{30}D_{4}$	1	70/30	4
$^{1}SBP_{50}D_{4}$	1	50/50	4
$^{1}SBP_{70}D_{4}$	1	30/70	4
$^{1}SBP_{50}D_{6}$	1	50/50	6
$^{2}SBP_{50}D_{2}$	2	50/50	2
$^{3}SBP_{50}D_{2}$	3	50/50	2

*1, 2 and 3 phr represent 1, 2 and 3 gm of DCP per 100 gm of SBR.

2.3. Mechanical properties

Tensile strength (TS) and elongation at break (EB %) were measured using a tensile testing machine at a crosshead speed of 50 mm/min. The TS measurements were done using dump bell shaped specimens and at room temperature, as per the ASTM D-412 test method. The Shore A hardness was measured using a durometer for the semi-IPNs and IPNs. The density of the samples was measured at room temperature by the hydrostatic technique using ASTM D-792 Active Standard.

2.4. PALS measurements

Positron annihilation experiments were performed by sandwiching a ^{22}Na radioactive source with the samples under study. The source was prepared basically as a deposition of aqueous solution of $^{22}NaCl$ in dilute HCl acid on a well-annealed Ni foil and covered by folding the extended portion of

the foil over the deposited area. In this manner, positrons penetrate on either side through the thickness of the foil (~ 2 mg cm^{-2}) in order to enter the sample. A small fraction (9.23%) of the positrons gets annihilated within the Ni foil with lifetime 0.1069 ns and a fraction equally small (10.46%) from the source material itself with lifetime 0.3481 ns. An insignificant (0.70%) but still not ignorable fraction of positrons gets annihilated after backscattering from the sample. Their lifetimes were expectedly large (~ 3.423 ns). These three lifetimes and the corresponding intensities constitute the "source correction terms" in the positron lifetime data analysis and the same were estimated by first acquiring a separate spectrum on pure, well-annealed single crystalline Al samples.[13] The ranges of penetration of the energetic positrons emitted by the source within the samples were first calculated and sufficient numbers of pieces of the sample making more than these thicknesses are used on either side of the source to stop all the positrons completely within the samples. This prevents the escape of positrons into atmospheric air and the possible error in the measurements and analysis.

The gamma rays are captured by BaF_2 scintillators coupled with XP2020Q photomultiplier tubes in the case of positron lifetime measurements and by high pure germanium detectors in the case of Doppler broadening measurements. Positron annihilation lifetime spectroscopic (PALS) measurements were carried out using a slow-fast gamma-gamma ray coincidence setup with a time resolution (full width at half maximum) of 0.180 ns under the experimental conditions. The high pure germanium detectors used were of resolution 1.30 keV at 511 keV (the positron annihilation gamma ray energy). About 2 million counts were collected under each positron lifetime spectrum. In the case of coincidence Doppler broadening spectroscopic (CDBS) measurements, about twenty million coincidence events had been generated under the two-parameter spectrum from the counts collected individually by the detectors. The positron lifetime data were analyzed using the PALSfit program.[14] A software called LAMPS indigenously developed by the TIFR-BARC Pelletron Group, Mumbai had been used for the CDBS data acquisition and analysis.[15]

3. Results and discussion

3.1. PALS analysis

The positron lifetime spectra of the polymeric samples are expected to have extended multi exponential decay trend as the long-lived orthopositronium (o-Ps) atoms will be present within the free volume defects and interfaces in appreciable concentrations.[16] This is evident from Fig. 2 where the spectra have been peak-normalized and plotted. The curves also illustrate the sensitivity of the PALS technique to the changes in free volume characteristics of the samples when there is a change in the SBR:PMMA ratios. The analysis of the positron lifetime spectra of all the present samples using the PALSfit program yielded three positron lifetime components with respective relative intensities. The longest among them, designated as t_3 with intensity I_3, is the lifetime

of o-Ps atoms formed within the free volume defects and undergoing annihilation through the "pick-off" process forced by the material environment around. As popularly known, o-Ps is the metastable bound state of an electron and positron with their spins aligned in the same direction and hence in a triplet state (i.e., total spin is 1). This energetically higher state is unstable and has the tendency to rapidly transform to the other lower energy state called parapositronium (p-Ps, spin singlet state) through the exchange of its electron for one with antiparallel spin from the material surroundings. The lifetime of the Ps is thus reduced to a few nanoseconds. As the annihilation is through a p-Ps state emitting two (even number of) gamma rays, the events will populate the annihilation gamma ray photo peak.

The magnitude t_3 (ns) of the "pick-off" annihilation lifetime of the o-Ps can be used as a measure of the radius R(Å) of the free volume cavity through the Tao-Eldrup relation [17]

$$\tau_3 = 0.5\left[1 - \frac{R}{R_0} + \frac{1}{2\pi}\sin\left(\frac{2\pi R}{R_0}\right)\right]^{-1} \quad (2)$$

where $R_0 = R + \mathrm{D}R$ and $\mathrm{D}R$ = 1.66 Å is the electron layer thickness of the free volume cavities. It is assumed that the cavities are spherical in shape which may not be always truly realistic. A constant A = 1/600 Å^{-3} is introduced while estimating the total fractional free volume within the polymer matrix using the relation (where the intensity I_3 decides the unit of f_v)

$$f_v = AV_f I_3 \quad (3)$$

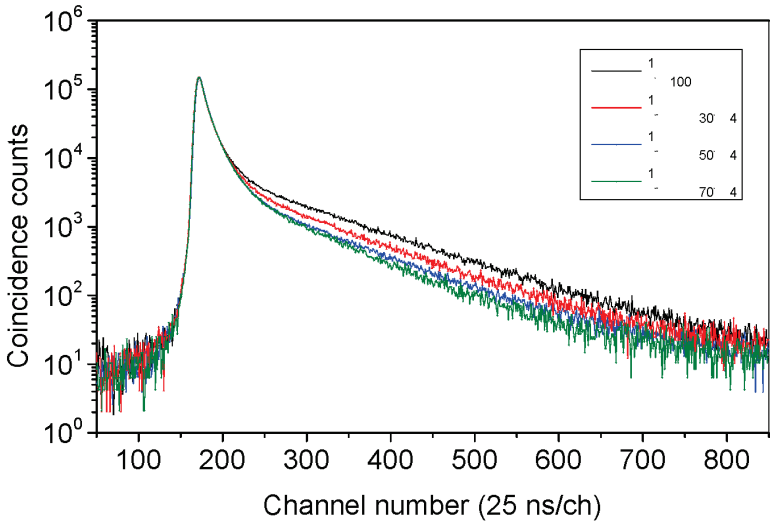

Fig. 2. (Color online only) Peak normalized positron lifetime spectra of the IPN samples (D_4 series) with varying PMMA concentrations, illustrating the multi exponential decay with long extended positron lifetimes.

The variations of these two parameters, i.e., R and f_v, have been used to interpret the results of positron annihilation measurements on several classes of materials [22] and will be adopted here too. Besides, a plot of I_3 versus R or f_v also helps to understand the distribution of free volume defects in the polymer and to monitor the changes during the sample treatments. Although much focus has been given to the variations of the free volume lifetime and intensity components (t_3 and I_3), little importance has been given normally to the values and variations of the other lower lifetime t_2 and its intensity I_2. This component has its origin in the annihilation of positrons (in contrast to Ps) in the free volume defects. More importantly, the shortest lifetime t_1 and its intensity I_1 will have the lifetimes of p-Ps (t_p = 0.125 ns) of intensity $I_p = (1/3)\, I_3$ admixed in it along with contributions of free annihilations of positrons with electrons. Still, the advantage as well as the focus of utilization of PAS as the probe is that the sizes and concentrations of free volume defects can be directly monitored and their variations can be accurately traced.

3.1.1. Effect of the blend ratio

The variations of the individual positron annihilation parameters with respect to blend ratio of SBR and PMMA in IPN (D_4 series) are given in Fig. 3. From pure SBR sample ($^1S_{100}$) to IPN with 70% PMMA loading ($^1SBP_{70}D_4$), $\hat{o}_3$ and I_3 values are getting reduced. The addition of PMMA in the SBR sample seems to cause also decreases in the radius and concentration of the available free volume. The fall of the intensity I_3 from 30.10 to 16.93% is a considerable decrease. This is due to the interpenetration and intercalation of PMMA between the SBR polymer chains and causes reduction in available free volume of the SBR matrix. The variation further reveals that the size as well as the concentration of the free volume defects gets reduced as the PMMA incorporation in IPN enhances.

As mentioned in the introduction, the purpose of incorporation of PMMA to SBR is to fabricate materials with properties ranging from reinforced rubber to toughened plastic. For this, the resultant IPNs should undergo plastic deformation without inviting fractural damage. This can be facilitated with the help of a reduction in size and intensity of the free volume defects in the polymer and interestingly this is indicated by the variations of the o-Ps lifetime $\hat{o}_3$ and its intensity I_3. There is an overall decrease of the free volume size and concentration with the addition of PMMA.

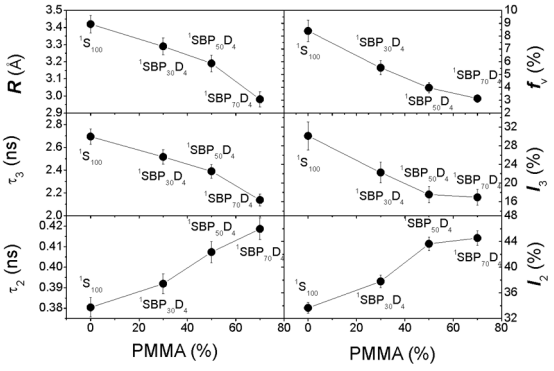

Fig. 3. The variations of the different positron lifetimes and their relative intensities and the free volume radius and concentration with the concentration of PMMA in the IPN samples (D_4 series).

3.2. Mechanical properties analysis

The analysis of the mechanical properties can be considered as one of the important tools in IPN characterization and is dependent on the available free volume in the polymeric system. The effects of blend ratio on the physico-mechanical properties of IPN can be summarized as given in Table 2.

Table 2 The composition and the mechanical properties of the IPNs (D_4 Series).

Composition	Density (g/cm^3)	Tensile strength (TS) (MPa)	Percentage elongation at break (EB) (%)	Young's Modulus (MPa)	Hardness Shore A
$^1S_{100}$	0.95	[illegible]	149.16±12.4	1.74	42
$^1SBP_{30}D_4$	1.05	8.07±0.3	124.78±12.3	4.01	79
$^1SBP_{50}D_4$	1.07	13.76±0.4	81.14±7.8	32.73	82
$^1SBP_{70}D_4$	1.10	15.44±0.5	33.80±6.4	362.02	88
P_{100}	1.19	39.60±1.3	3.58±0.6	2166.12	-

From the table, it is clear that the density and hardness of IPN enhance with increase in PMMA (plastic content)[22] in the corresponding IPN samples. The said physical properties of IPN enhance with decrease in size and concentration of free volumes in it. The stress–strain curves for IPNs are depicted in Fig. 4.

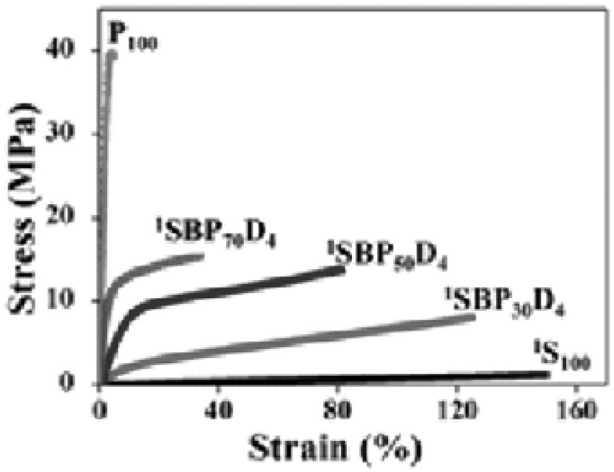

Fig. 4. The stress–strain curves for IPNs of varying SBR/PMMA ratios.

The deformation pattern of each IPN under an applied stress is sought to be clarified in Fig. 3. The deformation tendency of SBR ($^1S_{100}$) is of a typical elastomer in nature. On the addition of PMMA, the deformation pattern changes. The gradual change from the rubbery to the plastic nature can be visualized in the stress–strain curve as we move from 30 to 70 % of PMMA. IPN with 70% PMMA ($^1SBP_{70}D_4$) shows the typical plastic nature and the IPN with 70% SBR ($^1SBP_{30}D_4$) shows a rubbery nature.[23] From the stress–strain curves, we can determine the Young's modulus[24] of the IPNs and these values increase with increasing PMMA content. As the PMMA concentration in IPN increases, the free volume size and concentration of the corresponding IPN decrease. It can be seen that, as free volume fraction of IPN decreases, the tensile strength increased but the percentage elongation at break decreased. The variation in tensile strength and percentage elongation at break with respect to free volume changes are in the expected lines,[25] i.e., lower tensile strength and higher percentage elongation at break for IPNs with higher free volume content.

4. Summary and conclusions

A series of SBR/PMMA IPNs and semi-IPNs has been prepared by adopting sequential polymerization protocol. Positron annihilation spectroscopy has been successfully conducted to characterize the free volume properties of these systems. Their transport behavior in toluene and the mechanical properties were measured and correlated with PALS results of free volume sizes and concentrations. The free volume defects reduce in size and concentration with the incorporation of PMMA in SBR.Higher tensile strength and lower percentage elongation at break was observed for IPN system with lower free-volume content (i.e., in the case of $^1SBP_{70}D_4$).

Finally, it is pointed out that the fabricated IPN system with SBR/PMMA ratio 50/50 ($^1SBP_{50}D_4$) with high tensile strength, Young's modulus, low free volume fraction, reasonable elongation at break and co-continuous morphology can act as a potential candidate for toughened plastic with cost effectiveness. This new modality of characterization uplifts and widens the application prospect of this type of elastomer- thermoplastic IPNs.

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REVIEW OF MICROWAVE FILTERS EMPLOYING SPLIT RING RESONATORS(SRR) AND COMPLEMENTARY SPLIT RING RESONATORS (CSRR)

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1. Microwave filters

Microwave communication links are an important practical application of the microwave technology and are used to carry data, voice and video over distances ranging from intercity links to deep – space spacecraft. Filters find applications virtually in any type of communication, radar or test and measurement system. In some applications such as communication satellite and mobile communication devices, it is critical that filters be devised with small size, light weight, and lower cost along with stringent electrical characteristics. Planar filter geometries are well suited for meeting these requirements.

The recent advances in novel materials and fabrication technologies, including monolithic microwave integrated circuit (MMIC), microelectro mechanical systems (MEMS), micromachining, high-temperature superconductor (HTS) and low temperature co-fired ceramic (LTCC) technology stimulated the development of new types of filters. The substrate integrated waveguide (SIW) is a promising technology considering its advantages as a new microwave transmission media with the advantages of both the rectangular waveguides and planar transmission line. The upcoming filter realizations utilize SIW to a large extent for microwave as well as millimetre wave communications.

A survey of the major techniques used in the design of microwave filters is presented by Ralph Levy et al. [1]. It is shown that the basis for much fundamental microwave filter theory lies in the realm of lumped –element filters, which indeed are actually used directly for many applications at microwave frequencies as high as 18 GHz. Many types of microwave filters are discussed with the objective of pointing out the most useful ones, especially for the newcomer to this area.

1.1 Microstrip filters employing split ring resonators (SRRs)/complementary split ring resonators (CSRRs)

The electromagnetic behaviour of split ring resonator (SRR) and complementary split ring resonator (CSRR) coupled to planar transmission lines are analysed in litera-

ture. Coupling mechanism of these elements to the host transmission line are studied and analytical equivalent–circuit models are proposed for the isolated and coupled SRR/ CSRRs [2, 3]. From these models, the stopband/passband characteristics of the analysed SRR/CSRR loaded transmission lines are derived.

A compact bandpass filter (BPF) using a combination of the coupled uniform impedance resonator (CUIR) and the single CSRR is investigated in [4]. Two transmission zeros of the proposed BPF can be controlled by tuning the dimension of CSRR at higher stopband. Here, the size of the proposed BPF has a reduction of 26%, compared with the size of the conventional parallel coupled BPF.

The propagation characteristics of a microstrip line loaded with an array of SRRs as superstrate is investigated [5]. The presence of SRRs over the microstrip line leads to an effective negative permeability in a narrowband, where the signal propagation is inhibited. The width and attenuation of the rejected frequency band depends on the height of the superstrate as well as its relative position with the microstrip line.

The use of SRR loaded waveguide for the design of a band-reject filter with adjustable bandwidth is reported [6]. The width of the stopband can be adjusted by suitably positioning the SRR array in the waveguide. The rejection band can be made very narrow by placing the array at the electric-field minimum. The stopband attenuation depends on the number of unit cells in the array.

Bandpass filter design using metallic SRR at optical frequencies is theoretically investigated in [7]. The transmission and reflection coefficients of the SRR array is also analysed.

Design of a compact microstrip band reject filter is proposed [8]. The device consists of an open loop rectangular resonator (OLRR) coupled to a microstrip line. The transmission line has a U –bend which enhances the coupling with the OLRR element and reduces the size of the filter.

A comparative investigation of SRR and CSRR based band reject filters is performed [9]. These compact filters are obtained by loading simple 50 &! microstrip lines with SRRs and CSRRs that have exactly the same shape and dimensions. Unlike the previous studies, the stopband characteristics of these filters, such as resonant frequency, bandwidth, sharpness, and amount of attenuation in the rejection region is based on the number of SRR or CSRR stages, are investigated in detail and comparative manner. Both the filter structure and S-parameters are shown in Fig.1.

Inter-digital capacitance loaded loop resonators (IDCLLRs) are used to design microstrip band reject filters [10]. The analysed structures are based on the coupling of IDCLLRs to a conventional 50 &! microstrip line. The main features of the IDCLLRs are small dimensions (much smaller than the wavelength at resonance) and more structural parameters (provide flexibility in design). Novel configurations of CSRR with dual mesh- shaped couplings and defected ground structures (DGS) are

introduced to design the high performance of wide passband and stopband BPF [11]. This paper presents low insertion loss (0.82 dB), symmetry and sharper transmission zero level (-51.88 dB), using DGS and alternative coupling of CSRR

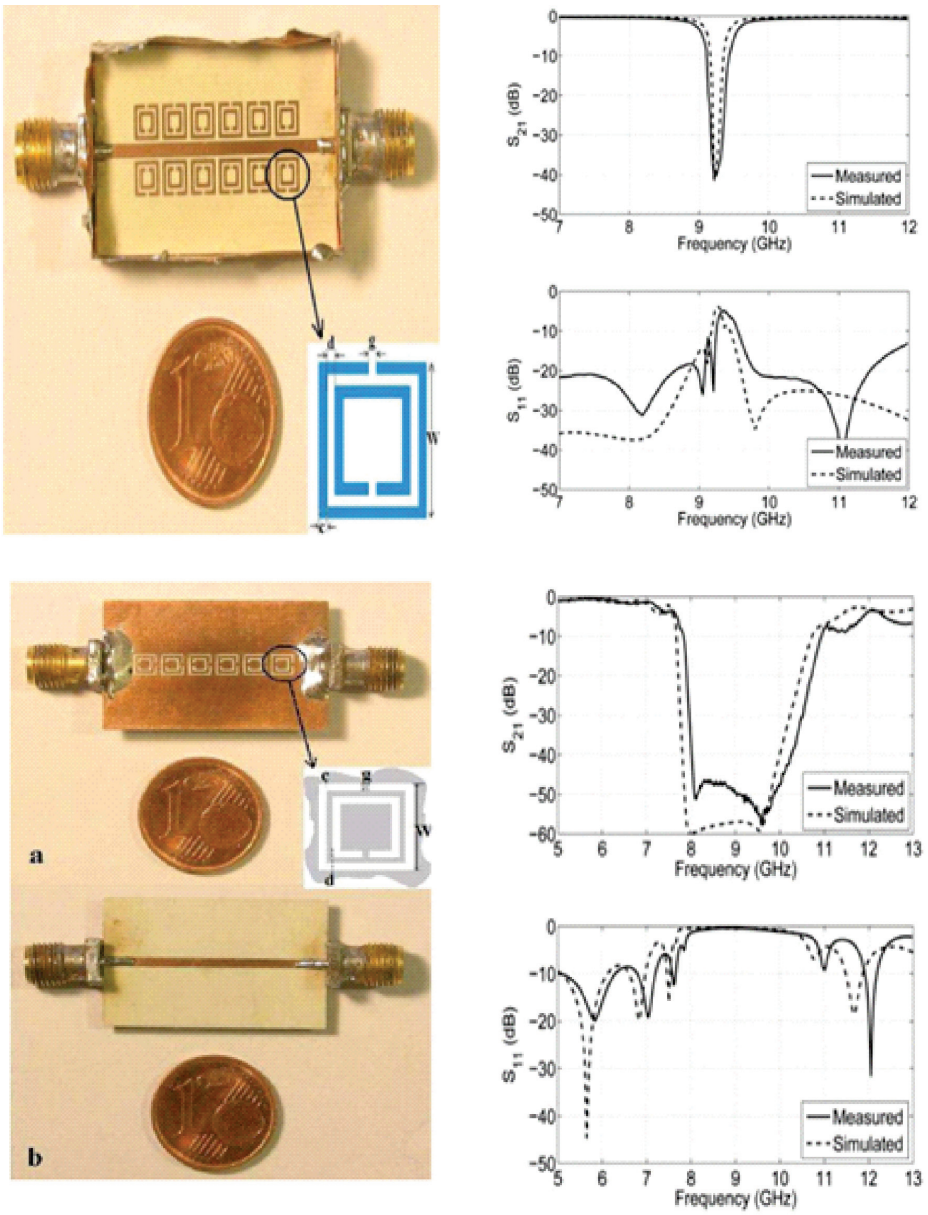

Fig. 1. Microstrip line coupled SRR/CSRR Filter [9] (a) Fabricated Filter structure (SRR) (b) S-Parameters (c) Fabricated Filter structure (CSRR) (d) S-Parameters

A novel compact microstrip bandpass filter using folded open loop resonator is presented in [12]. The resonator elements are placed in close proximity to parallel coupled microstrip lines. The presence of undesired harmonics is eliminated by properly modifying the configuration of the folded resonator. Another novel SRR configuration is proposed in [13]. The proposed resonator can generate two notches without increasing the physical size. A microstrip lowpass filter (LPF) is designed on the proposed resonator. The cut off frequency of the designed LPF is 3.7 GHz and the stopband with an attenuation level lower than 20 dB is obtained from 3.9 to 7.5 GHz. Miniaturized nested SRR structure is proposed in [14]. The nested SRR structure incorporates multiple SRRs in a compact nested structure, and has more split gaps than the conventional SRR structure. Compared with the conventional SRR, this nested SRR has better performance on miniaturization and high-Q value. This novel BPF is very compact and has good in- and out-band performances.

A microstrip bandstop filter (BSF) based on square SRR is proposed in [15]. The design steps consist of two parts. The first one consists of LPF characterized by a cut off frequency of 3.5 GHz. In the second part, square SRRs are used to pass from a LPF to bandstop filter. Finally the BSF is produced by an array of miniaturized loaded SRRs close to a microstrip line. High selectivity compact microstrip BPF with a flexibility controllable bandwidth, based on multi-path source-load couplings and a rectangular-type SRR is presented in [16]. The SRR is enclosed between the capacitively coupled source and load transmission feed lines, form the structure of the proposed BPF. The main advantage of this structure is its high selectivity due to the presence of multiple transmission zeros. In addition, the bandwidth of the proposed filter can be flexibly controlled by varying the magnetic coupling gap between the SRR and the feed lines. The measured passband insertion and return loss are -0.83 dB and 27.23 dB respectively.

Conclusion

The SRRs and CSRRs can be employed in various planar transmission techniques like microstrip, SIW, coplanar for the realization of devices like antennas, filters, diplexers, mixers etc. These structures are used for establizing the most popular metamaterials concept in the microwave communication systems.

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CHROMATIC *M*-POLYNOMIAL OF CERTAIN GRAPHS

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ABSTRACT

A topological index of a graph G is a real number which is preserved under isomorphism. Extensive studies on certain polynomials related to these topological indices have also been done recently. In a similar way, chromatic variations of certain topological indices and the related polynomials have also been discussed in the recent literature. In this paper, the notion of chromatic M-polynomial is introduced and determined this polynomial for certain fundamental graph classes.

Keywords: Graph colouring, M-polynomial, chromatic M-polynomial, χ^--chromatic M-polynomial, χ^+-chromatic M-polynomial.

MSC2020: 05C15, 05C31.

1. Introduction

For all terms and definitions, not defined specifically in this paper, we refer to [10]. Further, for graph colouring, see [2]. Unless mentioned otherwise, all graphs considered here are undirected, simple, finite and connected.

A *proper vertex colouring* of a graph G is an assignment $\varphi: V(G) \to \mathcal{C}$ of the vertices of G, where $\mathcal{C} = \{c_1, c_2, c_3, \ldots, c_\ell\}$ is a set of colours such that adjacent vertices of G have different colours. The cardinality of the minimum set of colours which allows a proper colouring of G is called the *chromatic number* of G and is denoted $\chi(G)$. The set of all vertices of G which have the colour c_i is called the *colour class* of that colour c_i in G. The cardinality of the colour class of a colour c_i is said to be the *strength* of that colour in G and is denoted by $\theta(c_i)$. We can also define a function $\zeta: V(G) \to \{1,2,3, \ldots, \ell\}$ such that $\zeta(v_i) = s$ if and only if $\varphi(v_i) = c_s; c_s \in \mathcal{C}$.

A vertex colouring of a graph G having of the colours with minimum subscripts may be called a *minimum parameter colouring* (see [6]). If we colour the vertices of G in such a way that c_1 is assigned to maximum possible number of vertices, then c_2 is assigned to maximum possible number of remaining uncoloured vertices and proceed in this manner until all vertices are coloured, then such a colouring is called a χ^-*-colouring* of G. In a similar manner, if c_ℓ is assigned to maximum possible number of vertices, then $c_{\ell-1}$ is assigned to maximum possible number of remaining uncoloured vertices and proceed in this manner until all vertices are coloured, then such a colouring is called a χ^+*-colouring* of G.

A *topological index* of a graph G is a real number which is preserved or invariant under isomorphism. The chromatic versions of certain topological indices have been introduced in [6]. In this paper, we discuss the chromatic analogue of certain polynomials related to the topological indices of a graph G.

2 Chromatic M-Polynomial of Graphs

Throughout this study, we use the chromatic colouring of the graphs under consideration. Motivated by the studies on Schultz polynomial of graphs (see [1, 4, 5]), we can now introduce the chromatic M-polynomial as follows:

Definition 2.1 Let G be a connected graph with chromatic number $\chi(G)$. Then, the *chromatic M-polynomial* of G, denoted by $\mathcal{M}_\chi(G,x,y)$, is defined as

$$\mathcal{M}_\chi(G,x,y) = \sum_{u,v\in V(G)} M_{i,j}x^i y^j.$$

where M_{ij} is the number of edges in G whose one end vertex has the colour c_i and the other end vertex has the colour c_j with respect to the given χ-colouring of G.

Definition 2.2 Let G be a connected graph with chromatic number $\chi(G)$ and φ^- and φ^+ be the minimal and maximal parameter colouring of G. Then,

(i) the χ^-*-chromatic M-polynomial* of G, denoted by $\mathcal{M}_{\chi^-}(G,x,y)$, is defined as

$$\mathcal{M}_{\chi^-}(G,x,y) = \sum_{u,v\in V(G)} M^-_{i,j}x^i y^j$$

where M_{ij}^{-} is the number of edges in G whose one end vertex has the colour c_i and the other end vertex has the colour c_j with respect to the given χ^{-}-colouring of G, and

(ii) the χ^{+}-*chromatic M-polynomial* of G, denoted by $\mathcal{M}_{\chi^{+}}(G,x,y)$, is defined as

$$\mathcal{M}_{\chi^{+}}(G,x,y) = \sum_{u,v \in V(G)} M_{i,j}^{+} x^i y^j$$

Where $M_{i,j}^{+}$ is the number of edges in G whose one end vertex has the colour c_i and the other end vertex has the colour c_j with respect to the given χ^{+}-colouring of G.

Now, we can determine the chromatic M-polynomials of certain fundamental graph classes.

Proposition 2.3 *Let P_n be a path on n vertices. Then, $\mathcal{M}_{\chi^{-}}(G,x,y) = (n-1)xy^2$.*

Proof. Let P_n be a path on n vertices. It has $\chi(G) = 2$ such that the vertices take the colours c_1 and c_2 alternatively. Since P_n has $n-1$ edges and each of which has the colour c_1 and c_2 at either ends, we have $\mathcal{M}_{\chi^{-}}(G,x,y) = (n-1)xy^2$. (1)

Using the same argument above and interchanging the colours c_1 and c_2 in the Equation 1, we get the next result.

Corollary 2.4 *Let P_n be a path on n vertices. Then, $\mathcal{M}_{\chi^{+}}(G,x,y) = (n-1)x^2y$.*

The following result determines the chromatic M-polynomial of cycles.

Proposition 2.5 *Let C_n be a cycle on n vertices. Then,*

$$\mathcal{M}_{\chi^{-}}(G,x,y) = \begin{cases} nxy^2, & if \quad n \quad is \ even; \\ (n-2)xy^2 + xy^3 + x^2y^3, & if \quad n \quad is \ odd\,. \end{cases} \qquad (2)$$

Proof. Let C_n be a cycle on n vertices. Then, there are two cases:

Case-1: Let n be an even number. Then, all the alternative vertices of C_n are labeled with the colours either c_1 or c_2. Thus, both end vertices of all the edges are coloured either with c_1 or with c_2. There are n such edges. Hence, $\mathcal{M}_{\chi^{-}}(G,x,y) = nxy^2$.

Case-2: Let n be an odd number. Let $v_1, v_2, v_3, \ldots, v_n$ be the vertices of C_n. Among them, the vertices $v_1, v_3, v_5, \ldots, v_{n-2}$ are coloured with c_1 and $v_2, v_4, v_6, \ldots, v_{n-1}$ are

coloured with c_2 and the vertex v_n is coloured with c_3. Then, there are $n-2$ edges have either of the ends coloured with the colours c_1 or c_2. The ends of the edge $v_{n-2} - v_{n-1}$ has the colours c_2 and c_3 and that of the edge $v_{n-1} - v_1$ has the colours c_3 and c_1. Hence, $\mathcal{M}_{\chi^-}(G,x,y) = (n-2)xy^2 + xy^3 + x^2y^3$. (3)

Proposition 2.6 *Let C_n be a cycle on n vertices. Then,*

$$\mathcal{M}_{\chi^+}(G,x,y) = \begin{cases} nx^2y, & if \quad n \quad is \ even; \\ (n-2)x^3y^2 + x^3y + x^2y, & if \quad n \quad is \ odd\,. \end{cases}$$

Proof. Let C_n be a cycle on n vertices. Consider the two cases:

Case-1: Let n be an even number. Since either of the ends of each edge of C_n is marked with the colours c_2 or c_1, $\mathcal{M}_{\chi^+}(G,x,y) = nx^2y$.

Case-2: Let n be an odd number. Interchanging the colours c_1 and c_3 in the Equation 3, we get, $\mathcal{M}_{\chi^+}(G,x,y) = (n-2)x^3y^2 + x^3y + x^2y$.

Proposition 2.7 *Let $K_{m,n}$ be any bipartite graph with k edges. Then, $\mathcal{M}_{\chi^-}(G,x,y) = kxy^2$.*

Proof. The chromatic number of any bipartite graph $K_{m,n}$ is 2. Thus, for every edge, the ends are marked with the colours either c_1 or c_2. Since there are k edges, $\mathcal{M}_{\chi^-}(G,x,y) = kxy^2$. □

A similar proof can be given for the χ^+- chromatic M- polynomial of $K_{m,n}$. Thus, $\mathcal{M}_{\chi^+}(G,x,y) = kx^2y$.

The propositions mentioned above lead to an important theorem.

Theorem 2.8 *A graph G with m edges has $\chi(G) = 2$ if and only if $\mathcal{M}_{\chi^-}(G,x,y) = mxy^2$ or $\mathcal{M}_{\chi^+}(G,x,y) = mx^2y$.*

Proof. Let G be a graph with m edges such that $\chi(G) = 2$. Then, the end vertices of every edge will be coloured either with the colour c_1 or with the colour c_2. Since all the m edges are coloured like this, we have, $\mathcal{M}_{\chi^-}(G,x,y) = mxy^2$. Conversely, let $\mathcal{M}_{\chi^-}(G,x,y) = mxy^2$. Suppose $\chi(G) \geq 3$. It implies that the proper colouring of G involves a third colour c_3. Let u be a vertex whose colour is c_3. Since it is a proper colouring, $d(u) \geq 2$ with at least two vertices v_1 and v_2 are adjacent to u having colours c_1 and c_2. Then, $\mathcal{M}_{\chi^-}(G,x,y)$ of the path $v_1 - u - v_2$ will be such that

$xy^3 + x^2y^3$, which is a contradiction. Interchanging the colours c_1 and c_3 lead to the proof for $\mathcal{M}_{\chi^+}(G, x, y) = mx^2y$.

Lemma 2.9 *The chromatic M- Polynomial of any bipartite graph G with m edges is* mxy^2.

Since every tree T on $n \geq 2$ vertices is a bipartite graph, we have,

Lemma 2.10 *Let T be any tree on n vertices and* $n-1$ *edges. Then,* $\mathcal{M}_{\chi^-}(T, x, y) = (n-1)xy^2$.

Let $G = P_n + K_1$. Then G is called an $n - fan$ graph on $n+1$ vertices. Next, we find the chromatic M- Polynomial of $n - fan$ graph.

Theorem 2.11 *Let G be an* $n - fan$ *graph on* $n+1$ *vertices. Then,*

$$\mathcal{M}_{\chi^-}(G, x, y) = \begin{cases} (n-1)xy^2 + \frac{n}{2}xy^3 + \frac{n}{2}x^2y^3, & if \quad n \quad is \ even; \\ (n-1)xy^2 + \frac{n+1}{2}xy^3 + \frac{n-1}{2}x^2y^3, & if \quad n \quad is \ odd. \end{cases} \tag{4}$$

Proof. Let $G = P_n + K_1$ be an $n - fan$ graph on $n+1$ vertices. It is clear that the chromatic number of an $n - fan$ graph is 3. We have two cases arise:

Case-1: Let n be an even number. The Figure 1 is an example of an $n - fan$ graph with even n. The Table 1 shows the colour pairs and the number of edges available for the given pairs. Thus, we get, $\mathcal{M}_{\chi^-}(G, x, y) = (n-1)xy^2 + \frac{n}{2}xy^3 + \frac{n}{2}x^2y^3$.

Case-2: Let n be an odd number. The Figure 2 is an example of an $n - fan$ graph with odd n. The possible colour pairs and their frequencies are given in the Table 2. Thus, we get, $\mathcal{M}_{\chi^-}(G, x, y) = (n-1)xy^2 + \frac{n+1}{2}xy^3 + \frac{n-1}{2}x^2y^3$.

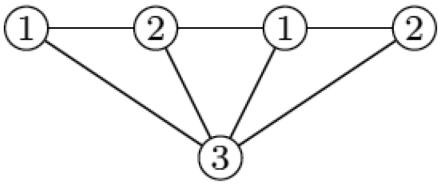

Figure 1: The 4-fan graph on 5 vertices.

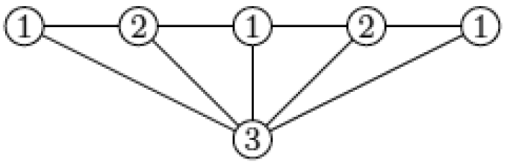

Figure 2: The 5-fan graph on 6 vertices.

Colour pairs	Number of pairs
(c_1, c_2)	$n-1$
(c_1, c_3)	$\frac{n}{2}$
(c_2, c_3)	$\frac{n}{2}$

Table 1: $n - fan; n$ is even.

Colour pairs	Number of pairs
(c_1, c_2)	$n-1$
(c_1, c_3)	$\frac{n+1}{2}$
(c_2, c_3)	$\frac{n-1}{2}$

Table 2: $n - fan; n$ is odd.

Similarly, by interchanging the colours c_1 and c_3 in the Equation 4, we get,

Theorem 2.12 *Let G be an $n - fan$ graph on $n+1$ vertices. Then,*

$$\mathcal{M}_{\chi^+}(G, x, y) =$$
$$\begin{cases} (n-1)x^3y^2 + \frac{n}{2}(x^3y + x^2y), & if \quad n \quad is \ even; \\ (n-1)x^3y^2 + \frac{n+1}{2}x^3y + \frac{n-1}{2}x^2y, & if \quad n \quad is \ odd. \end{cases}$$

Theorem 2.13 *Let $W_n = C_n + K_1$ be a wheel graph on $n+1$ vertices. Then,*

$$\mathcal{M}_{\chi^-}(G, x, y) =$$
$$\begin{cases} nxy^2 + \frac{n}{2}(xy^3 + x^2y^3), & if \quad n \quad is \ even; \\ (n-2)xy^2 + \frac{n-1}{2}(xy^4 + x^2y^4) + xy^3 + x^2y^3 + x^3y^4, & if \quad n \quad is \ odd. \end{cases} \quad (5)$$

Proof. Let $W_n = C_n + K_1$ be a wheel graph on $n+1$ vertices. Let $v_1, v_2, v_3, \dots, v_n$ be the vertices of the rim C_n and u be the vertex at the center K_1. Consider the two cases:

Case - 1: Let n be even. Since the chromatic number of W_n with even n is 3, the vertices of C_n take the colours c_1 and c_2 and the vertex K_1 takes the colour c_3. Then, there are n edges having the colour codes (c_1, c_2) and $\frac{n}{2}$ edges each with colour codes (c_1, c_3) and (c_2, c_3). Thus, $\mathcal{M}_{\chi^-}(G, x, y) = nxy^2 + \frac{n}{2}(xy^3 + x^2y^3)$.

Case - 2: Let n be odd. From the Table 3 we have,

Colour pairs	Number of pairs
(c_1, c_2)	$n-2$
(c_1, c_3)	1
(c_1, c_4)	$\frac{n-1}{2}$
(c_2, c_3)	1
(c_2, c_4)	$\frac{n-1}{2}$
(c_3, c_4)	1

Table 3: $W_n; n$ is odd.

Thus, $\mathcal{M}_{\chi^-}(G, x, y) = (n-2)xy^2 + xy^3 + \frac{n-1}{2}(xy^4 + x^2y^4) + x^2y^3 + x^3y^4$.

Reversing the colours c_1, c_2, c_3 and c_4 into c_4, c_3, c_2 and c_1 in the Equation 5, we get,

Theorem 2.14 *Let $W_n = C_n + K_1$ be a wheel graph on $n+1$ vertices. Then,*

$$\mathcal{M}_{\chi^+}(G, x, y) = \begin{cases} nx^3y^2 + \frac{n}{2}(x^3y + x^2y), & if \quad n \quad is \ even; \\ (n-2)x^4y^3 + x^4y^2 + \frac{n-1}{2}(x^4y + x^3y) + x^3y^2 + x^2y, & if \quad n \quad is \ odd\,. \end{cases} \tag{6}$$

Definition 2.15 *Let W_n be a wheel graph on $n+1$ vertices such that $W_n = C_n + K_1$. The Generalised-wheel graphs denoted as mW_n on $mn+1$ vertices and $2mn$ edges is the the join $mC_n + K_1; m \in \mathbb{N}$.*

Theorem 2.16 *For mW_n on $mn+1$ vertices,*

$$\mathcal{M}_{\chi^-}(G,x,y) =$$
$$\begin{cases} mnxy^2 + \frac{mn}{2}(xy^3 + x^2y^3), & if \quad n \quad is \ even; \\ m(n-2)xy^2 + m\frac{n-1}{2}(xy^4 + x^2y^4) + & \\ m(xy^3 + x^2y^3 + x^3y^4), & if \quad n \quad is \ odd\,. \end{cases}$$

and

$$\mathcal{M}_{\chi^+}(G,x,y) =$$
$$\begin{cases} mnx^3y^2 + \frac{mn}{2}(x^3y + x^2y), & if \quad n \quad is \ even; \\ m(n-2)x^4y^3 + m\frac{n-1}{2}(x^4y + x^3y) + & \\ m(x^4y^2 + x^3y^2 + x^2y), & if \quad n \quad is \ odd\,. \end{cases}$$

Proof. Let $mW_n = mC_n + K_1; m \in \mathbb{N}$ be a wheel graph on $mn+1$ vertices. Let $v_{11}, v_{12}, v_{13}, \ldots, v_{1n}$, be the vertices of the cycle C_1, $v_{21}, v_{22}, v_{23}, \ldots, v_{2n}$, be the vertices of the cycle C_2 ..., and $v_{m1}, v_{m2}, v_{m3}, \ldots, v_{mn}$, be the vertices of the cycle C_m, and u be the vertex at the center K_1. Using the results in the Equations 5 and 6 on each cycle $C_i; i = 1,2,3, \ldots, m$ as in the Figure 3, we get,

$$\mathcal{M}_{\chi^-}(G,x,y) =$$
$$\begin{cases} mnxy^2 + \frac{mn}{2}(xy^3 + x^2y^3), & if \quad n \quad is \ even; \\ m(n-2)xy^2 + m\frac{n-1}{2}(xy^4 + x^2y^4) + & \\ m(xy^3 + x^2y^3 + x^3y^4), & if \quad n \quad is \ odd\,. \end{cases}$$

and

$$\mathcal{M}_{\chi^+}(G,x,y) =$$
$$\begin{cases} mnx^3y^2 + \frac{mn}{2}(x^3y + x^2y), & if \quad n \quad is \ even; \\ m(n-2)x^4y^3 + m\frac{n-1}{2}(x^4y + x^3y) + & \\ m(x^4y^2 + x^3y^2 + x^2y), & if \quad n \quad is \ odd\,. \end{cases}$$

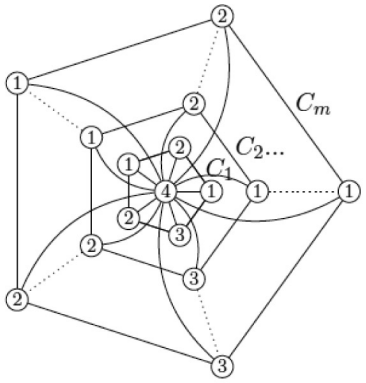

Figure 3: A generalised-wheel graph on m cycles.

If each vertex in the rim C_n of a wheel graph is attached to corresponding isolated vertex, then the resultant graph is called as a *Helm* graph H_n. If these pendant vertices are joined again to the central vertex, the new graph is called as a *Flower graph* A_n [3]. The Flower graph A_n has $2n+1$ vertices and $4n$ edges. If the corresponding vertices of two cycles C_n of order n are joined and all these vertices are made adjacent to an external vertex, such a graph is known to be a *Djembe graph* DJ_n[8].

Theorem 2.17 *For the flower graph* A_n,

$$\mathcal{M}_{\chi^-}(G,x,y) =$$
$$\begin{cases} 2nxy^2 + n(xy^3 + x^2y^3), & if \quad n \quad is \ even; \\ (2n-3)xy^2 + nxy^4 + (n-1)x^2y^4 + & \\ 2xy^3 + x^2y^3 + x^3y^4, & if \quad n \quad is \ odd\,. \end{cases}$$

and

$$\mathcal{M}_{\chi^+}(G,x,y) =$$
$$\begin{cases} 2nx^3y^2 + n(x^3y + x^2y), & if \quad n \quad is \ even; \\ (2n-3)x^4y^3 + nx^4y + (n-1)x^3y + & \\ 2x^4y^2 + x^3y^2 + x^2y, & if \quad n \quad is \ odd\,. \end{cases}$$

Proof. Let A_n be a Flower graph with $2n+1$ vertices and $4n$ edges. Then the underlying graph is also a wheel graph and its colour pairs can be taken exactly as in the pairing in the Equation 5. Consider the two cases:

Case - 1: Let n be even. Then, the vertices $v_1, v_3, \ldots, v_{n-1}$ can be coloured with the colour c_2 and the remaining vertices with the colour c_1 as shown in the Figure 4. From the Table 4, we have, $\mathcal{M}_{\chi}\text{-}(G, x, y) = 2nxy^2 + n(xy^3 + x^2y^3)$.

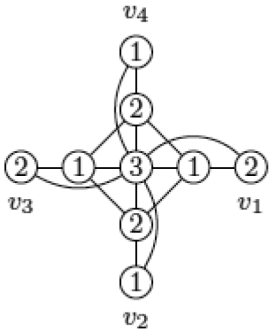

Figure 4: An even flower graph A_4.

Colour pairs	Number of pairs
(c_1, c_2)	$2n$
(c_1, c_3)	n
(c_2, c_3)	n

Table 4: $A_n; n$ is even.

Case - 2: Let n be odd. Then, the vertices $v_1, v_3, \ldots, v_{n-2}$ can be coloured with the colour c_2 and the remaining vertices with the colour c_1 as shown in the Figure 5. From the Table 5 we have, $\mathcal{M}_{\chi}\text{-}(G, x, y) = (2n-3)xy^2 + nxy^4 + (n-1)x^2y^4 + 2xy^3 + x^2y^3 + x^3y^4$.

Colour pairs	Number of pairs
(c_1, c_2)	$2n-3$
(c_1, c_3)	2
(c_1, c_4)	n
(c_2, c_3)	1
(c_2, c_4)	$n-1$
(c_3, c_4)	1

Table 5: $A_n; n$ is odd.

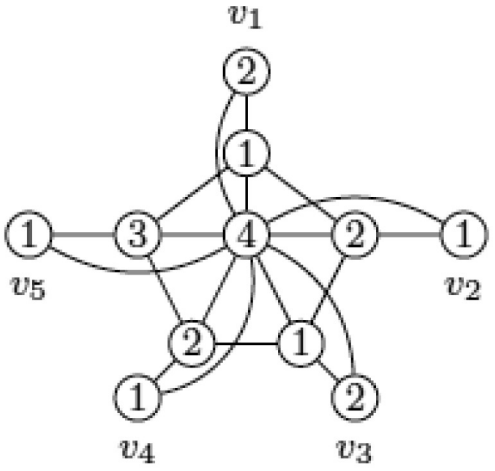

Figure 5: An odd flower graph A_5.

Similarly, we can prove that

$$\mathcal{M}_{\chi^+}(G,x,y) =$$
$$\begin{cases} 2nx^3y^2 + n(x^3y + x^2y), & if \quad n \quad is \ even; \\ (2n-3)x^4y^3 + nx^4y + (n-1)x^3y + & \\ 2x^4y^2 + x^3y^2 + x^2y, & if \quad n \quad is \ odd\,. \end{cases}$$

Let us examine the chromatic M- polynomial of one more wheel-based graph namely, the Djembe graph.

Theorem 2.18 *For the Djembe Graph DJ_n,*

$$\mathcal{M}_{\chi^-}(G,x,y) =$$
$$\begin{cases} 3nxy^2 + n(xy^3 + x^2y^3), & if \quad n \quad is \ even; \\ 3(n-2)xy^2 + (n-1)(xy^4 + x^2y^4) + & \\ 3(xy^3 + x^2y^3) + 2x^3y^4, & if \quad n \quad is \ odd\,. \end{cases}$$

and

$$\mathcal{M}_{\chi^+}(G,x,y) =$$
$$\begin{cases} 3nx^3y^2 + n(x^3y + x^2y), & if \quad n \quad is \ even; \\ 3(n-2)x^4y^3 + (n-1)(x^4y + x^3y) + & \\ 3(x^4y^2 + x^3y^2) + 2x^2y, & if \quad n \quad is \ odd\,. \end{cases}$$

Proof. Let DJ_n be a Djmbe graph with $2n+1$ vertices and $5n$ edges. In a Djembe graph, since the corresponding vertices of two wheel graphs are connected, they can not be given the same colour. Thus, we change the order of the colours as given in the example (see Figures 6 and 7). From the Tables 6 and 7, we have,

$$\mathcal{M}_{\chi}(G,x,y) =$$
$$\begin{cases} 3nxy^2 + n(xy^3 + x^2y^3), & if \quad n \quad is \ even; \\ 3(n-2)xy^2 + (n-1)(xy^4 + x^2y^4) + & \\ 3(xy^3 + x^2y^3) + 2x^3y^4, & if \quad n \quad is \ odd\,. \end{cases}$$

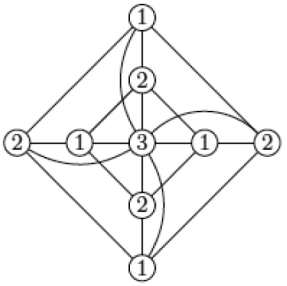

Figure 6: An even Djembe graph DJ_4.

Colour pairs	Number of pairs
(c_1, c_2)	$3n$
(c_1, c_3)	n
(c_2, c_3)	n

Table 6: $DJ_n; n$ is even.

Colour pairs	Number of pairs
(c_1, c_2)	$3(n-2)$
(c_1, c_3)	3
(c_1, c_4)	$n-1$
(c_2, c_3)	3
(c_2, c_4)	$n-1$
(c_3, c_4)	2

Table 7: $DJ_n; n$ is odd.

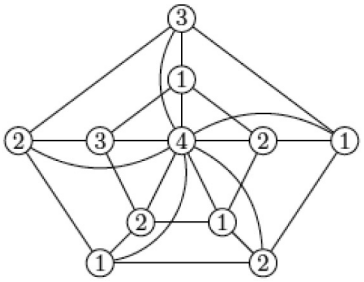

Figure 7: An odd Djembe graph DJ_5.

Similarly, we can prove that

$$\mathcal{M}_{\chi^+}(G,x,y)=\begin{cases}3nx^3y^2+n(x^3y+x^2y) & if \quad n \quad is \ even;\\ 3(n-2)x^4y^3+(n-1)(x^4y+x^3y)+ & \\ 3(x^4y^2+x^3y^2)+2x^2y & if \quad n \quad is \ odd\,.\end{cases}$$

The *Lever graph* L_n is the graph obtained by taking the one point union of $n \geq 2$ copies of C_3 and $n-1$ copies of K_2 [7].

Theorem 2.19 *For the Lever Graph* L_n,

$$\mathcal{M}_{\chi^-}(G,x,y)=(2n-1)xy^2+n(xy^3+x^2y^3)$$

and

$$\mathcal{M}_{\chi^+}(G,x,y)=(2n-1)x^3y^2+n(x^3y+x^2y).$$

Proof. The chromatic number of a Lever graph L_n can be identified as 3. Thus, the vertices of the path $u_{11},u_{21},\dots,u_{n1}$ can be coloured with the colours c_1 and c_2 alternatively and the vertices $u_{13},u_{23},\dots,u_{n3}$ can be coloured with c_3 and remaining vertices with the colours c_2 and c_1 alternatively will give the required result (see Figure 8).

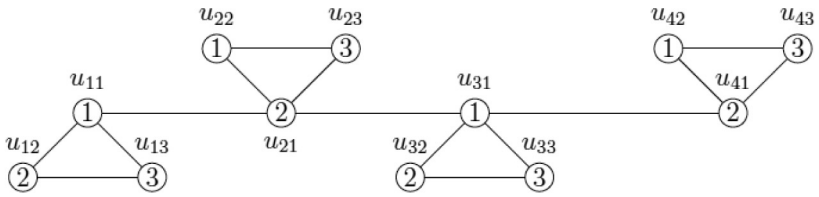

Figure 8: A Lever graph L_4.

Colour pairs	Number of pairs
(c_1, c_2)	$2n-1$
(c_1, c_3)	n
(c_2, c_3)	n

Table 8: Lever graph L_n

From the table 8, we have, $\mathcal{M}_{\chi^-}(G,x,y) = (2n-1)xy^2 + n(xy^3 + x^2y^3)$. In a similar manner, we can prove that $\mathcal{M}_{\chi^+}(G,x,y) = (2n-1)x^3y^2 + n(x^3y + x^2y)$.

The *Diamond Necklace graph* D_n is the graph on n vertices obtained by taking the one point union of $n \geq 2$ copies of $K_4 - e$ (diamond) graphs and $n-1$ copies of K_2. The diamond necklace graph D_n is equivalent to the corona product $P_n \odot P_3;\ n \geq 2$[7].

Theorem 2.20 *For the Diamond Necklace graph* D_n,

$$\mathcal{M}_{\chi^-}(G,x,y) =$$
$$\begin{cases} (3n-1)xy^2 + \frac{3n}{2}(xy^3 + x^2y^3) & if \quad n \quad is \ even; \\ (3n-1)xy^2 + \frac{3n-1}{2}xy^3 + \frac{3n+1}{2}x^2y^3 & if \quad n \quad is \ odd\,. \end{cases}$$

and

$$\mathcal{M}_{\chi^+}(G,x,y) =$$
$$\begin{cases} (3n-1)x^3y^2 + \frac{3n}{2}(x^3y + x^2y) & if \quad n \quad is \ even; \\ (3n-1)x^3y^2 + \frac{3n-1}{2}x^3y + \frac{3n+1}{2}x^2y & if \quad n \quad is \ odd\,. \end{cases}$$

Proof. In a Diamond Necklace graph D_n, the vertices $u_{i,1}; i = 1,2,\dots,n$ can be coloured alternatively with colours c_1 and c_2. The vertices $u_{i,3}; i = 1,2,\dots,n$ can be coloured with c_3. Note that the pair of vertices $u_{i,2}, u_{i,4}; i = 1,2,\dots,n$ can be coloured with the same colour but the colour changes alternatively according to the colour of $u_{i,1}; i = 1,2,\dots,n$ (for example, see Figure 9).

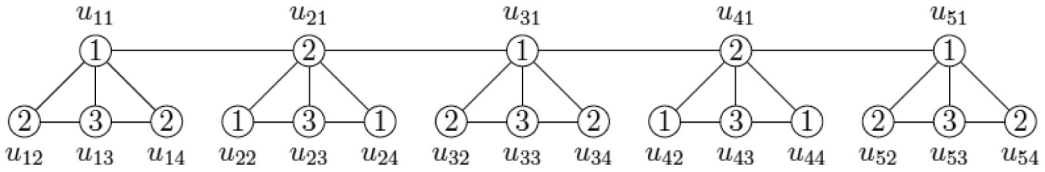

Figure 9: A Diamond Necklace graph D_5.

From the Tables 9 and 10, we have,

$$\mathcal{M}_{\chi^-}(G,x,y) =$$
$$\begin{cases} (3n-1)xy^2 + \frac{3n}{2}(xy^3 + x^2y^3) & if \quad n \quad is \ even; \\ (3n-1)xy^2 + \frac{3n-1}{2}xy^3 + \frac{3n+1}{2}x^2y^3 & if \quad n \quad is \ odd\,. \end{cases}$$

Colour pairs	Number of pairs
(c_1, c_2)	$3n-1$
(c_1, c_3)	$\frac{3n}{2}$
(c_2, c_3)	$\frac{3n}{2}$

Table 9: $D_n; n$ is even.

Colour pairs	Number of pairs
(c_1, c_2)	$3n-1$
(c_1, c_3)	$\frac{3n-1}{2}$
(c_2, c_3)	$\frac{3n+1}{2}$

Table 10: $D_n; n$ is odd.

Similarly, we can prove that

$$\mathcal{M}_{\chi^+}(G,x,y) = \begin{cases} (3n-1)x^3y^2 + \frac{3n}{2}(x^3y + x^2y) & if \quad n \quad is \ even; \\ (3n-1)x^3y^2 + \frac{3n-1}{2}x^3y + \frac{3n+1}{2}x^2y & if \quad n \quad is \ odd\,. \end{cases}$$

Since the chromatic number of a graph G is n if and only if $G = K_n$, we have the following result.

Theorem 2.21 $\mathcal{M}_{\chi^-}(G,x,y) = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x^i y^j$ *and* $\mathcal{M}_{\chi^+}(G,x,y) = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x^j y^i$ *if and only if* $G = K_n$.

3 Conclusion

In this paper, we have introduced a new concept called chromatic M-polynomial of certain fundamental and derived graphs. The study can be extended for several other graph classes, graph operations and graph products. Investigating new polynomials of this kind corresponding to several known topological invariant of graphs also seem to be promising.

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QUEST FOR AN 'ALL-IN-ONE MATERIAL': THE STORY OF GRAPHENE

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ABSTRACT

Since its discovery in 2004, graphene is being visualised as the miracle material whose realm spans into many fields, including the most awaited electronics industry which is already nearing a bottleneck due to the consequences suggested by Moore's Law. This article is an attempt to critically examine the realities of graphene research with a viewpoint that it could be a silicon killer. At first, a review of the exotic physical, chemical and mechanical properties of the two-dimensional material is conducted keeping in mind 100 % purity of the material. This follows a discussion on several device prototypes in which graphene overshadowed many other materials but with certain pragmatic flaws in terms of real-life execution and economy of those proposed plans. And the last section of this article showcases some of the promises graphene has already fulfilled and some others which are at the end of the tunnel waiting for the light. This includes products in the sports and lifestyle industry that offer lightweight high strength materials for various applications and a few other energy solutions based on graphene. The article is concluded with a remark on the growing graphene economy.

Keywords: Graphene, Graphene Super Capacitors, Graphene Batteries, Graphene Coatings, Graphene Bullet Proof Vests.

Introduction

It has been more than a decade since the term 'graphene' is associated with the future direction of science and technology. We think it is high time to critically evaluate the 'fact vs. fantasy' in this highly active area of research. It was silicon that had a long period of reign as the 'all in one material' until recent developments in the nanocarbon world. Though fullerenes and carbon nanotubes took the attraction for a decade or so, graphene took the centre stage as a challenge to the throne of silicon from the year 2004 due to a number of exciting results from the Manchester group led by Prof. Andrei Geim and Prof. Konstantin

Novoselov (Novoselov *et al., 2004*, 2005). The questions one must seriously ask are, whether graphene is really a silicon killer or not? and to what extent are the promises fulfilled? or will it only be a complementing platform to the vast network of silicon applications?

As a first step towards answering these queries, one must initially draw a comparison between the developmental stages of both of these materials *ie* silicon vs graphene. Though silicon and its oxides are visualised as the present backbone of the electronics industry; that was not the case in the early days of its material development. Most of the mass production developments and material doping techniques were proceeded for silicon keeping a few other applications in mind except electronics. Some of these applications include (i) the use of siloxanes (Steinfink *et al.* 1955) as polymers for dental impressions and industrial impression, (ii) resins for adhesive purposes, (iii) as quartz for various applications and (iii) as pigments in paints (Polestak & Thompson, 1986). It was in bell laboratories (shortly after the discovery of the transistor) that silicon started to take the centre stage of modern civilization through its oxides and its derivatives, majorly being utilised for integrated chips which in turn fast-forwarded the information revolution. This was fuelled by the advancements in making single crystals and high-quality thin films of silicon and its oxides. Similar to the present story of graphene, silicon-based materials have also been recognised in the 1960s for their superior electronic and mechanical properties (Pfann, 1974).

Contrary to the story of the family of silicon materials, graphene has been visualised as the future direction of electronics since the beginning of current advancements in nanocarbon. Such a highlight has its origin in the superlative physical properties of graphene as discussed below. Though there were a number of theoretical advancements with regard to the sp^2 carbon family of materials (Wallace, 1946), especially from the group of Mildred Dresselhaus at MIT (Lespade *et al.*, 1982 & Malard *et al.*, 2009), they were mostly related to the electronic and phononic structure of graphitic materials. Nevertheless, one must admit that those theoretical developments catapulted the materialisation of graphene. It was the discovery of graphene using the scotch tape method (micromechanical exfoliation) from highly oriented pyrolytic graphite which put the term graphene into the limelight (Novoselov *et al.,* 2004*)*. It was not for the mere discovery of graphene that Geim and Novoselov received the Nobel Prize for Physics in 2010, but for the thoughtful experiments that they conducted on graphene. Those experiments revealed many exotic properties of graphene revealing a plethora of possibilities to the scientific and technology community with graphene as the centre. Let us look at these properties without much reference to the various synthesis techniques which will only be discussed when needed.

Graphene: The physical and chemical properties

It is known to be the material with the highest value of Young's modulus reported

so far for any man-made material of 2.4 TPa for a single layer of suspended graphene which were made (J. U. Lee et al., 2012). In order to draw a comparison with the highest value of Young's modulus reported prior to this was 1.05 T Pa (Klein & Cardinale, 1993) for the well-known hard material diamond. Not only that Young's modulus is among the highest, but it also has a higher value of mechanical strength for a single sheet. Focused ion beam bombarding onto graphene shows that it is also a tough material with a stress intensity factor of 4 M Pa. Combining all these gives a material with high mechanical strength which could be used for high strength materials for various applications which will be discussed later.

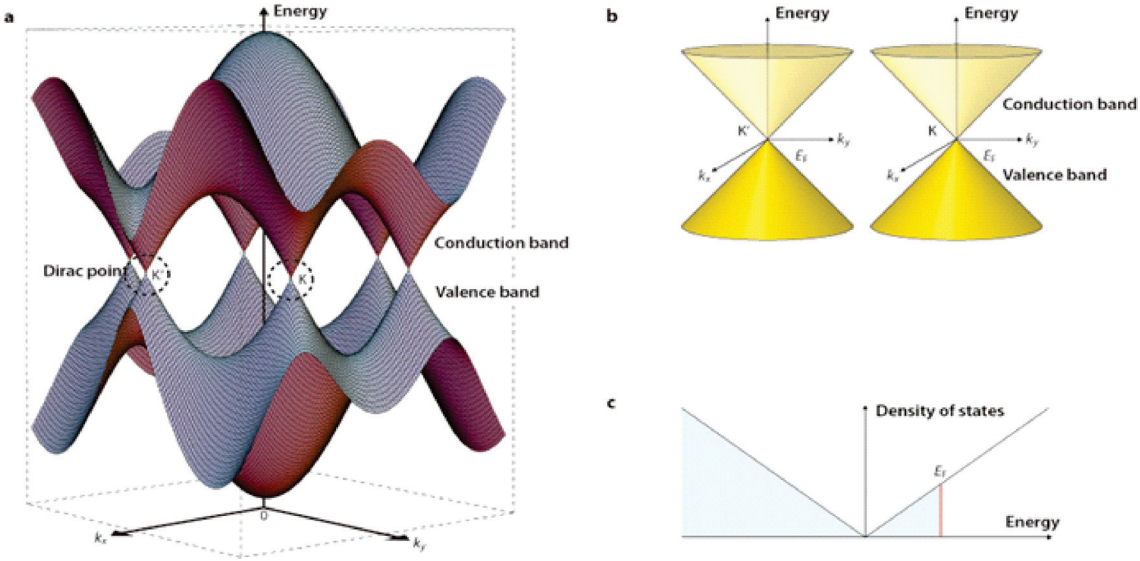

Figure 1. (a) Electronic structure of graphene in its first Brillouin Zone. **(b)** the close up of the E vs k which is already marked in circles in (a) which shows the occupied and unoccupied regions in an undoped graphene. (c) shows the density of states near the K point for an N doped graphene. (Image adopted with permission from Ando, 2009).

Graphene is found to absorb ~2.3 % of visible light incident on graphene which is significant considering its single atom thick dimension (Nair *et al.*, 2008) and the optical absorption of graphene is found to depend only on the fine structure constant. This also leads to a well-defined interference pattern on substrates such as silicon which enables the identification of a number of layers of graphene in a stacked configuration even with the naked eye despite their negligible dimensions when compared to light wavelengths. Optical property will be crucial to some of the proposed applications of graphene.

Many of the other properties of graphene such as mechanical, optical and vibrational properties will have some connection with its electronic property which is something that sets this material apart from all other material known so far. For one it has a unique electronic band structure unlike any other material as given in figure 1. The unit cell of graphene contains only two atoms (A and B) which are arranged inside a unit cell which is a parallelogram and its translation in space lead to honeycomb lattice that we are quite familiar with. The reciprocal lattice is also a hexagonal one with its Brillouin zone as in figure 1. In order to calculate the electronic band structure of graphene the nearest neighbour interaction and next-nearest neighbour interactions are considered (Ando, 2009). The resultant gives eigenvalue is plotted as a function of k-values which gives such a unique pattern as in figure 1. The most important region is near one of the symmetry points *i.e.* K-point where the E vs k plot becomes *linear* (Figure 1 b) rather than quadratic (which is usually the case with many materials). Such a linear relation is what makes its unique electronic properties leading to the relativistic nature of electrons in graphene. Not only that it is linear one can easily shift the Fermi level of the material making it highly tunable to become p-doped or n-doped (Figure 1 c). It is at this point that even the technology world began to think that this is a suitable material just like silicon. Unlike silicon (semiconductor) graphene is a semi-metal with a zero bandgap. There is also a demonstration wherein bi-layer and tri-layers of graphene can show bandgap. This along with the highest reported value of electron mobility (Morozov *et al.*, 2008) > 200,000 cm^2/Vs makes it a potential candidate for device applications.

Since graphene offers a relatively chemically inert surface it was thought of being used in protective layers. Authors own research work on making graphene using quite commercially viable method on SS substrate using alcohol precursors (John *et al.*, 2011) initiated a discussion as to how graphene can be used for corrosion resistance which is of industrial relevance in many fields. Graphene has been observed to show anti-bacterial (Shulga & Shulga, 2020) properties which combined with its low reactivity made people seriously think of bioapplications of it.

Onset of device prototypes: promising enough?

Several device prototypes were projected, mostly keeping in mind the silicon replacement potential of graphene. The prime one has to be the high-frequency transistor developed at IBM. The device showed a cut-off frequency of 100 GHz at 240 nm of graphene channel length (Y. Lin *et al.*, 2010). Though it showed high frequency it was not the highest of frequencies possibly but with a remarkable channel thickness of 1 carbon atom (*ie.* 0.36 nm). But the ambipolar (it can show electron-based conductivity and hole-based conductivity by suitable doping) nature of charge carriers in graphene was quite tempting for technologists (Avouris & Xia, 2012). Graphene was

also tried as a frequency mixer on an integrated circuit (Y. M. Lin *et al.*, 2011). The unique nature of the interaction of graphene with various regions of electromagnetic spectrum such as infrared and in THz spectral region (due to the intra-band transition or carrier absorption) makes it a suitable candidate in the most celebrated alternative of electronics, *i.e.* photonics (Gabor *et al.*, 2011). Though there are a number of device protypes in the electronics and photonics side of the material, the need for material quality/purity, challenges in the method of material fabrication and challenges in being incorporated into ICs troubled the technology community from the beginning.

It was in this wake that a team sponsored by Samsung devised a method to make large area high-quality graphene which is of the size of square feet and demonstrated its utility in touch screen applications. This paper is one of the most cited papers in graphene (Bae *et al.*, 2010) which also projected graphene as a challenge to the ITO-based conducting thin film industry. The next obvious step in furthering these developments towards a carbon-based integrated circuit is to demonstrate monolithic all carbon construction of any circuitry. This came without much delay by utilizing the process called selective catalytic growth of graphene and graphitic layers as interconnects (Park *et al.*, 2012) using atmospheric chemical vapor deposition technique. They also formed a 3-dimensional network of top gated graphene-graphite field effect transistors. Certainly, this was a promising step towards an all-carbon platform which could potentially be a silicon killer, but with not much performance improvements thereafter; whereas silicon technology was perfected over several decades and hence more work was needed henceforth. The immediate advancement was the demonstration of on chip energy storage. Graphene supercapacitors were printed onto the device which has to be powered by laser-scribing on graphene oxide (GO) which was already deposited on the chip (El-Kady *et al.,* 2013). The laser scribing reduces GO to form graphene layers which act as capacitor plates and the GO act as perfect dielectric giving an extremely high energy density of 200 W/cm^3. This also has the advantage that the device is flexible and scalable to suit various applications without much degradation in its performance with a good cycling stability. This could in principle power wearable electronics and can store energy from alternative energy sources such as solar panels and so on.

Despite all its successes in device prototypes graphene yet showing signs of lagging behind silicon in terms of processability just as many other semiconductors who were showing promises in many fields but were outsmarted by the well-established processing technologies by silicon. Though a bit late, people started realising the flaws in this approach and initiated measures to not just directly replace silicon but rather to incorporate graphene into a complementary-metal oxide-semiconductor platform (Neumaier *et al*., 2019) which has to be a continuing effort to make it all the way through. Biomedical applications of graphene have also been attracting attention for quite some time. The GO produced using modified Hummers

method which are 3-4 layers of graphene oxide is acting as gene / drug carrier for therapeutic applications. High specific area and high oxygen functionality is what makes it biocompatible and it can act as a drug binding agent using different functional groups to conjugate with DNA, drugs and various biomolecules (Shen *et al*., 2012). There are a few diseases for which gene therapy is found to be promising and hence the role of graphene is being explored in this area.

Into the market from the high time

Displays: Apart from all the claims, superlatives and ongoing promises, let us closely look at what has actually been delivered by graphene so far. According to the author, thin displays with touch integration will be one of the clicking points of graphene as shown way back in 2010 by the Samsung led team. Even now there have been reports coming with improved performance of graphene-based touch screens which could potentially be a market itself with multiple functionalities (Zhichao *et al.*, 2022). Not only that it can be a transparent conductive membrane with touch integration and feedback, but it could also act as an illuminating layer which could do the job of manyfold materials (such as ITO and OLEDs). Shanghai base company name Power Booster Technology has announced their touch screen product for mobile applications based on graphene (Figure 2 yellow region). Realme has announced that their GT 2 series smartphones with AMOLED screens have an integrated cooling technology based on graphene. Graphene based ink used in Siren Technology security smart packaging from Vorbeck Materials is probably the first commercial product based on graphene. This is a tamperproof security packaging based on graphene incorporated conductive ink (https://www.graphene-info.com/vorbeck-materials).

Figure 2. Shows a conveyor belt like evolution of representative graphene products as shown by the top arrow which shows the existing (in market) graphene-based products on the green side whereas products which are in the prototype stage are on the red side. The ones shown in the middle (yellow portion) are the ones which are currently being tested as commercial products.

Fitness Apparels: Products based on graphene's high mechanical strength are probably the best bet for graphene so far. We are likely to see a number of products in the sports industry in which graphene is the active material. In fact, we already have a number of products in the market such as tennis rackets (YouTek Graphene Speed Series rackets from Head) which they claim are lighter and stronger than their existing products. Though it's a trade secret what material they are using in this racket, it is likely that they are graphene flakes. Bi-cycle wheels are made of graphene nanoplates with more heat dissipation and high lateral stiffness. A bi-cycle frame with high mechanical strength even with sub-Kg weight was developed by Dassi Bikes, UK (Figure 2, green section). This is contradictory to our common understanding that the material strength increases as its weight increases and hence it is likely that many mechanical structures are likely to see a graphene transition in the coming future such as fishing rods, sports shoes and graphene all-season jackets and so on. Another study on the ability of graphene to resist micro bullets fired on them gives a hint to what it can do in terms of protection for soldiers in the combat fields. The micro ballistic experiments on 10- 100 layers of graphene (J. H. Lee *et al.*, 2014) showed high strain rate behaviour which suggests that the material could be twice effective than stainless steel in blocking a projectile. There have also been graphene coatings (Detroit Pro Graphene) on cars which can protect the surface of the paintwork in many ways by (i) resisting corrosion, (ii) by protecting the surface from scratches (iii) by keeping the surface relatively cool and by (iv) its hydrophobicity.

Energetic graphene: Another area in which graphene could show its true potential is in the energy sector in very many ways. Starting from simple heat-dissipating materials for keeping the battery cool in electric vehicles to anode materials in batteries to the much-celebrated supercapacitors. Supercapacitors can store more energy than normal capacitors, but their energy storage capacity is less than that of normal batteries. Even though their energy density is between both the normal capacitors and batteries they have niche applications in areas wherein sudden surges of power should be released such as an accelerating electric train and so on. Also in scenarios wherein the power grid has to dispense peak power surges in prime operating hours, graphene supercapacitors could be of utility in such applications where fast charging and fast discharging with higher energy flow (Ke & Wang, 2016). There are a number of firms that have already claimed to be having graphene-based supercapacitors such as Angstron Materials, Skeleton Technologies, CRRC (Chinese agency) with 2.8/ 30000 Farad capacitors for locomotive applications (Figure 2, red section). A US-based company named Real Graphene is claiming to have produced a graphene battery and a power bank. The power bank is of capacity 10000 MAH whereas its batteries are of capacity 3000 MAH which can be fully charged in less than 20 minutes whereas it takes about an hour for other similar capacity batteries. Moreover, it is safer than other options because of the excellent ther-

mal dissipation of graphene (video link is given). Since it also contains Li-ions they claim that it will be a natural replacement for existing batteries.

Graphene goes environmental: Most of the production methods of graphene are thought to have been greatly energy-expensive ones with low yields in terms of weight. Though one can get a square meter of graphene one must not ignore the fact that it is only one atom thick and the volume of the materials that we get is quite minimal and hence a way to create graphene flakes of more mass is what everyone has been looking for. Hence it is remarkable that the team from Rice University did just that using a technique they call flash graphene. The main attraction of this method is that one can make any trash material into graphene flakes of gram quantities with millisecond short current pulses. The whole graphene industry is excited about this mass production method of graphene at a time when people were looking at ways to improve the bonding strength of cement and tarmac (using graphene reinforcement) for civil construction. This could lead to the processing of materials such as waste tyres and so on to be used for better stability of civil structures in a recycling manner which could have a huge environmental impact.

To conclude the analysis, one must admit that graphene may not have had the big success that it anticipated in the most sought-after field of electronics, but it might be having its own niche market which is still opening up. Though we are yet to see a graphene electronic revolution we cannot rule that out either especially in the wake of integration with silicon technologies. Despite the slow growth, we must admit that the graphene economy is steadily growing from a million-dollar industry in 2010 to a billion-dollar economy by 2027 as projected by graphene communities worldwide. In the opinion of the author, we are yet to see the best graphene product and there is a lot to expect from this all-in-one material.

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A REVIEW OF LIQUID/SUPERCRITICAL CARBON DIOXIDE AND ITS APPLICATIONS

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ABSTRACT

Utilization of liquid and supercritical CO_2 as an environmentally benign alternative solvent platform has been one of the major thoughts of green chemistry. Over the years, many novel and innovative industrial strategies using this solvent system have developed by the inherent capabilities of this solvent system such as ease of solvent removal and tunability of solvent parameters. Despite its limitations in terms of understanding its full solvent capabilities, it has made inroads into several important areas such as fluoropolymer synthesis, dry cleaning, chemical separations and processing, microelectronic cleaning, pharmaceutical industry, textiles industry, extraction of natural products and synthetic organic chemistry. This review gives a summary of the evolution of green chemistry,

Keywords: Carbon dioxide, Supercritical, Green chemistry

Introduction

Over the past century, we are highly benefited by the advances in science. At the same time, we have paid an environmental price for this development. Reports from "United States Environmental Protection Agency" show that annual levels of toxic waste from the chemical industries are increasing every year. With the increasing population, non-renewable raw materials such as petroleum, natural gas etc., are disappearing very fast. The only tactical way to overcome this challenge is to switch on to renewable resources. This led researches to move on to alternative sustainable technologies also known as green chemistry.

The term Green Chemistry was initially proposed by Paul Anastas in 1991.

Green chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products.[1-3] Paul Anastas and John C. Warner developed 12 principles of green chemistry.

Solvents have become an inevitable part in the field of chemistry. They are being

widely used in commercial chemical manufacturing industries. Use of organic solvents such as benzene, xylene, toluene, methanol etc in the chemical industry is an issue of great environmental concern. The toxic and flammable behavior of the conventional solvents used in separation processes, biomedical, pharmaceutical and chemical industries possess a great challenge to green chemistry. Despite appropriate and profuse precaution, these solvents being non- renewable and recyclable keep on contaminating our air, land and water. Researchers found an alternative for this by developing solvent - free processes and by using green solvents. Of the green solvents, water has been the most popular choice so far but recently water has been followed by ionic liquids, fluorous solvents, bio solvents and supercritical fluids.[4,5] This review mainly emphasizes on the research going on in the field of green chemistry using supercritical CO_2 as solvent.

Supercritical Fluid (SCF)

Any substance above its critical temperature (T_C) and critical pressure (P_C) is known as a SCF. The critical point represents the highest temperature and pressure above which the gas cannot be liquefied (the substance can exist as a vapor and liquid in equilibrium). A substance above the critical point refers to a state where distinct liquid and gas phase do not exist. A SCF can hence effuse through solids like a gas, and dissolve materials like a liquid. Near to critical point, small changes in pressure or temperature will result in large changes in density. This allows many properties of a SCF to be fine-tuned. There is no surface tension in a supercritical fluid. SCFs provide remarkable opportunities as green solvents due to ease of solvent removal and their tunable properties by just altering temperature and pressure.[6,7]

Supercritical CO_2 ($scCO_2$)

Carbon dioxide usually behaves as a gas at standard temperature and pressure (STP), or as a solid called dry ice when frozen. Supercritical carbon dioxide is a fluid state of carbon dioxide when CO_2 is held at or above its critical temperature (304.25 K) and critical pressure (72.9 atm) and it can adopt properties midway between a gas and a liquid. At the supercritical state CO_2 can adopt properties midway between a gas and a liquid. CO_2 is an attractive SCF for many reasons i.e., very cheap and abundant in pure form, non-flammable and non-toxic, low critical temperature and critical pressure, environment friendly, non-polluting gas, easily recyclable etc.[8-11] Stability of CO_2 and relatively low temperature of the process allow most of the compounds to be extracted with little damage or denaturing. One of the main advantages of CO_2 is their complete miscibility with gases such as H_2 or O_2. Lack of solvent power discourages the use of $scCO_2$ in pharmaceutical industry at the same time low production volume of pharma is well suited to use SCF. Non-polar and slightly polar organic compounds are dissolvable in liquid and $scCO_2$. CO_2 being a linear molecule with no dipole moment, $scCO_2$ is a poor solvent for dissolving ionic and polar species.

Advantages of $scCO_2$ when compared

to water includes higher energy yield resulting from its low viscosity, better chemical interaction, higher temperature limit etc. Thermally labile compounds which were isolated using traditional methods (at elevated temperature) are now replaced by $scCO_2$. Unlike liquid solvents, dissolving power of SCF depends upon its density, which can be adjusted by slightly varying temperature and pressure. More favorable mass transfer can be achieved with SCF when compared to that of liquid solvents since SCF has higher diffusion coefficient and lower viscosity than that of liquid solvents. Selectivity of process and solubility of polar compounds in SCF CO_2 can be enhanced by adding small amount of other solvents like ethanol in the fluid.

Sugar acetates and supercritical CO_2

Even though CO_2 is a linear molecule with zero dipole moment, there is large charge separation due to slight positive charge of carbon and slight negative charge of oxygen. This charge separations leads to quadrupole moment.[12-14] Lewis acid- Lewis base interactions were also reported in CO_2 where CO_2 can act as both Lewis acid and Lewis base.[15] Carbon in CO_2 acts as electron deficient (Lewis base) and hence it interacts with electron rich centers (Lewis base). It was also reported that ab initio calculations of CO_2 compounds with carbonyl group identified the presence of a weaker C——H….O interaction that acts with LA-LB interaction with carbonyl system having H atom attached to the á carbon or the carbonyl.[16,17]

Sugar acetates contain per acetylated chains as CO_2-philic parts and unprotected hydroxyl groups as CO_2-phobic ones. Sugar acetates have high solubility in liquid and $scCO_2$.[18-27] These compounds may be modified as ionic or non-ionic surfactants for the formation of water in CO_2 or organic in CO_2 reverse micro emulsions by attaching hydrophobic or hydrophilic ends due to their high solubility in $scCO_2$. Sugar acetates have advantages over other CO_2 soluble compounds due to its high solubility in liquid and supercritical CO_2 under mild conditions along with other advantages such as biocompatible, nontoxic, non flourinated and renewable.

These compounds as CO_2-philic moieties can be used for the preparation of functional surfactants for water-in-CO_2 and organic-in-CO_2 microemulsions systems, as well as the use of CO_2 as a solvent in specialized carbohydrate synthesis, purification, and crystallization.

Sugar acetates also act as a novel cosolvent and excipient system for pharmaceutical and biological applications to reduce the excessive waste of organic solvents utilized in current pharmaceutical processing. Sugar acetates, known as attractive CO_2-philic compounds, have potential uses as controlled release agents, and surfactants for micro emulsion systems in CO_2-based processes.

Observations show that CO_2 also have high solubility in these sugar derivatives. If this is the case, these compounds may have great potential to be used as materials for the separation of CO_2 from gas sources such as natural gas, flue gas, and various prepared

fuel gases. The possible application of sugar acetates as separation materials of CO_2 was also evaluated by comparing them with ionic liquids, a kind of nonvolatile CO_2-philic material that are considered in current research studies for the separation of CO_2.

The main challenge in the applications of $scCO_2$ in this field is that many substances are insoluble or only sparingly soluble due to the non-dipolar nature of these environmentally benign solvents.

Applications of liquid and $scCO_2$

By the time researchers realized that "pollution prevention" approach is much sustainable and appropriate than "end-of-pipe" approach followed in many waste management methods, efforts were taken to replace conventional solvents by liquid/ $scCO_2$. Significant progress in this field have developed supercritical fluid-based technologies that can be widely used in variety of industrial applications.

Extraction of natural products using $scCO_2$ is considered as the oldest and the most developed industrial application of $scCO_2$, with wide applications especially in food industry.[28] Among the various extractions carried out using $scCO_2$, decaffeination of caffeine is the first commercialized one.[29] Extraction of hops during the beer brewing process is yet another important application using $scCO_2$. Other examples for extractions using $scCO_2$ includes, extraction of fats and oils, decaffeination of tea, extraction of cholesterol, lipids etc.[29-31] Later, $scCO_2$ was applied for extractions in pharmaceutical, forensic and nutraceutical field too.[32] In addition to extraction, SCF chromatography is another SCF technology that has been commonly used as an alternative to conventional liquid chromatographic separation and this technique has been mainly utilized by food and pharmaceutical industries.

$scCO_2$ have also gained much attention in the area of polymer synthesis and processing. As already mentioned, Joseph DeSimone et al. has synthesised fluoropolymers for the first time, using CO_2 as a solvent based on its very high solubility in CO_2. Synthesis of CO_2-soluble surfactants were reported by many groups, since surfactants plays a significant role in the synthesis of polymers and other polymer processing which includes extractions, coatings, drug delivery and so on.[33] Nowadays, $scCO_2$ is regarded as the most viable and promising alternative polymerization solvent and so far swelling, plasticization, synthesis and processing of large number of polymers has been reported.[34-38] CO_2 is reported to plasticize variety of amorphous polymers and is able to significantly reduce their glass transition temperatures. Preparation of polymer composites and to control their morphology is a major challenge in biomaterials processing.[39,40] Howdle and co-workers have reported that $scCO_2$ can be used to synthesize polymeric composites incorporating guest materials without any loss of activity of the polymer.[41] Application of $scCO_2$ in the production of polymer systems for drug delivery is already well established.[42]

SCF technology also proposes intriguing possibility in the field of photolithographic technology wherein no solvent of

any kind, whether organic/aqueous are used in coating nor in any of the developing steps.[43]

Nano chemistry, a recently emerged and fast growing branch of chemistry, is always grateful to supercritical fluid technologies since numerous novel works are reported in this arena.[44-46] Precipitation of particles into micro and nano particles can be easily and much more effectively achieved using supercritical fluid technologies instead of conventional methods such as spray-drying, freeze-drying etc.[47,48] any drawbacks associated with the conventional methods such as solute degradation, high residual solvent concentration, poor control on particle size, structural changes and so on can be rectified or completely eliminated by replacing them with $scCO_2$. Rapid expansion of supercritical solutions (RESS), supercritical antisolvent precipitation etc. are some of the SCF techniques applied for particle formation especially for pharmaceutical applications wherein solubility and bioavailability of pharamaceutical compounds can be increased by size reduction.[49] In pharmaceutical industry, SCFs are mainly utilized for the purpose of micronization, preparation of solid dispersions and polymorphic control.[50,51]

By now, dry dyeing processes using $scCO_2$ as dyeing solvent is well established in textile industry.[52,53] Defects associated with conventional dyeing process such as generation of huge amount of waste water, energy intensive drying process etc, can be eliminated downright. Low viscosity and high diffusion rate of $scCO_2$ facilitates CO_2-dye mixture to penetrate the material. Likewise, it is not surprising that liquid/$scCO_2$ have been explored in dry cleaning applications. It is considered as the ideal and permanent sustainable alternative to perchloroethylene (PER) used as the most common solvent in dry cleaning process.[54] Again, decontamination of soil using $scCO_2$ is yet another application which has gained considerable attention and is considered as an attractive alternative to conventional method involving extraction with liquid solvents.[55] Supercritical drying is another important application which has been employed since the development of SCF technologies.[55] It is considered as the best alternative to conventional drying processes wherein the final product is efficiently dried without the requirement for high temperature.

SCFs, especially $scCO_2$ has also found applications in the field of microelectronics as cleaning agents and is mainly applied for organic contamination removal.[56,57] In this process, contaminants dissolve in SCF and finally, it is removed together with the gas upon expansion.

Another promising area where SCF technology has been explored as reaction media involves phase-transfer catalysis (PTC).[58] PTC is considered as an important and effective method to conduct heterogeneous reactions with the aid of a catalyst. In 1996, Dillow and co-workers reported the first example of a PTC reaction carried out in $scCO_2$.[59] This was followed by a series of PTC reactions carried out in $scCO_2$.[60] In some particular cases, co-solvent is used in order to ensure complete dissolution in $scCO_2$.

SCF technology have also found interesting applications in the area of synthetic organic chemistry.[61] Hydrogenation reactions in $scCO_2$ are very common and frequently reported such as homogeneous catalytic, asymmetric and continuous hydrogenation.[62,63] Hydroformylation reactions, much similar to hydrogenation reactions, which are traditionally carried out in liquid solvent media are nowadays replaced with $scCO_2$.[64] Photochemical and radical reactions such as free radical halogenation reactions and thermally initiated radical reactions, are also performed in $scCO_2$.[114] Diels-Alder cycloaddition, Friedal-Crafts alkylation, Hecks reactions etc. are some common name reactions carried out in $scCO_2$ medium.[66,67] Researchers have also identified that $scCO_2$ medium may be used to perform oxidation reactions such as catalytic aerobic oxidation and oxidation by alkyl peroxide.[68] Palladium mediated coupling reactions in $scCO_2$ are also reported.[69]

Owing to the interesting features of $scCO_2$, exploding interests has been ignited in the preparation of environmentally friendly coatings.[70] Use of CO_2 as a solvent or co-solvent in the coatings and its related applications has gained much more attention due to the environmental concerns over the adverse effect of conventional solvents. Some processing as well as commercial profits are also claimed for the use of CO_2 in coating applications and some of them are CO_2 can be easily removed by just venting out and the operation costs can be reduced to greater extent. CO_2 can be used in the liquid or supercritical state since the physical properties of CO_2 can be varied by simply adjusting the temperature and pressure which is impossible to accomplish in the case with conventional solvents. Solvent properties of CO_2 are much improved at higher liquid densities and at the same time viscosities and interfacial tension are observed to be lower than conventional solvents which enable them to easily facilitate the transport of solvent to the imperfections on the surface to be covered, which is much beneficial for the coating on etched surfaces.[71] Till now, numerous compounds are found to be soluble in CO_2 and vice versa and hence, using them results in achieving low viscosity coating solutions.

Conclusion

This review aims to summarize the information present in literature about liquid/$scCO_2$, its solvent properties and various applications. In addition to being abundant and inexpensive, this solvent system has many environmentally friendly attributes such as non-toxicity, non-flammability and importantly, easily attainable critical temperature and pressure, making this as an environmentally acceptable and economically viable solvent alternative for the chemical industry. Despite its limitations in terms of understanding its full solvent capabilities, it has made inroads into several important areas such as fluoropolymer synthesis, dry cleaning, chemical separations and processing, pharmaceutical industry, textiles industry, microelectronic cleaning, extraction of natural products and synthetic organic chemistry.

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NUMERICAL SOLUTIONS FOR THE BOUNDARY LAYER FLOW OF A NANOFLUID PAST A SEMI-INFINITE FLAT PLATE WITH THERMAL RADIATION

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ABSTRACT

The chapter discusses the mathematical modelling and numerical solutions for the nanofluid flow past a semi-infinite vertical plate. The thermal phenomenon is studied in the presence of thermal radiative heat flux which is modelled based on the Rosseland approximation. Two flow cases (stationary plate and moving plate) are compared. The governing equations are solved by using apt similarity variables and then are solved using finite-difference-based solver (bvp5c) in MATLAB. The flow and thermal profiles are analysed. Nanoparticle loading favours the thermal profile and the heat transfer rate in the Blasius flow case (stationary plate). On the other hand, it decreases the heat transport in the Sakiadis flow case (moving plate). The thermal radiative heat flux is observed to enhance the thermal profile due to the additional energy gained by the nanofluid. The findings suggest that the use of nanofluids instead of conventional working fluids will improve the performance and efficiency of heat exchangers, drying processes and solar collectors.

Keywords: Nanofluid; Flat plate; thermal radiation; Blasius flow; Sakiadis flow.

1. Introduction

Nanofluids have led to revolutionary changes in thermal applications due to the improvised thermal performance. Nanofluids are widely used in heat exchangers, solar collectors, nuclear reactors, stellar cells, smart coatings, and electronic cooling systems. The dispersion of nano-sized particles has led to better thermophysical properties, as first noted by Choi and Eastman [1]. Apart from experimental studies, mathematical modelling of nanofluid flows are cost-effective and time-saving procedures to draw information regarding the thermal efficiency. The enhanced thermophysical properties were initially incorporated in mathematical modelling by using the single-phase model, where the liquid is

considered as a single homogeneous system [2]. The thermal performance of 36 nm and 47 nm alumina nanofluids were juxtaposed by Animasaun et al. [3]. The highest cross-flow velocity was obtained when 36 nm alumina nanoparticles were used in the base fluid. Some more interesting explorations on nanofluid flows and heat transfer characteristics can be seen in [4-6]. Thereafter, Buongiorno [7] proposed a two-phase nanoliquid model to analyze the convective heat transport by including the major slip factors - the haphazard motion of nanoparticles and thermophoresis. But the experimental validation of the fluid properties was more efficient using the single-phase models.

Flat plate solar collectors, heat exchangers and various cooling devices involve fluid flow past a plate. A higher heat transfer is of prime importance in such devices [8]. Hence, researchers have drawn their attention towards studying the thermal characteristics of various fluids across such configurations. Blasius, in 1908 pioneered the study of fluid flow in a quiescent fluid past a stationary plate [9]. Later, Sakiadis [10] incorporate the motion of the plate for more practical applicability. Thereafter, various researchers have done extensive studies to analyse the above boundary layer flows [11-13].

Thermal radiation is primarily used in heat exchangers, solar collectors and in doping. Raju et al. [14] have studied the flow of Eyring–Powell fluid in the presence of thermal radiation and nonlinear buoyant forces. They employed the Rosseland approximation to model the radiative heat flux. In this direction, the effect of radiation on the boundary layer flow of a micropolar fluid past an exponentially elongating surface was scrutinized by Mandal et al. [15]. Recently, Mackolil and Mahanthesh [16] explored the effect of thermal radiation and heat sources in the Marangoni convective flow of a nanoliquid. A higher thermal field was reported in the presence of radiative heat flux.

Owing to the applicability of the fluid flow past a vertical flat plate, the present study aims at comparing the flow and thermal profiles of the Blasius and Sakiadis flow cases for alumina-water nanofluid in the presence of thermal radiation.

2. Mathematical model

The laminar and steady flow of an incompressible alumina-water nanofluid that passes past a semi-infinite flat plate is considered. The nanofluid is assumed to be a homogeneous suspension such that there exists thermal equilibrium between the

nanoparticles and the base fluid without slippage. The viscous and Joule heating effects are neglected. Using conservation laws of mass, momentum, and energy, the governing equations can be modelled as follows (see [9,10, 16]):

Conservation of mass

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

Conservation of momentum

$$\rho_{nf}\big((\boldsymbol{q}\cdot\nabla)\boldsymbol{q}\big) = -\nabla p + \mu_{nf}\nabla^2\boldsymbol{q}, \tag{2}$$

Conservation of energy

$$\big(\rho c_p\big)_{nf}\big((\boldsymbol{q}\cdot\nabla)T\big) = k_{nf}\nabla^2 T - \nabla q_r, \tag{3}$$

where $\boldsymbol{q} = (u, v)$ is the velocity vector, p is pressure, T is temperature, q_r is the radiative heat flux, ρ, μ, c_p and k respectively denote the density, dynamic viscosity, specific heat, and thermal conductivity.

The $x-$axis is considered to be along the plate and the two-dimensional flow is such that the flow occurs in the region $y \geq 0$, where $y-$axis is taken normal to the plate. Also, U denotes the free stream velocity (inviscid flow) [10]. If L denotes the horizontal length scale of the plate, δ_v and δ_t represent the velocity and thermal boundary layer thickness at $x = L$ respectively, then using the boundary layer theory, $L \gg \delta_v$ and $L \gg \delta_t$. Using appropriate dimensionless variables and scaling, we get $\left|\frac{\partial^2 u}{\partial y^2} \gg \frac{\partial^2 u}{\partial x^2}\right|$ and $\left|\frac{\partial^2 T}{\partial y^2} \gg \frac{\partial^2 T}{\partial x^2}\right|$. Therefore, the component form of the equations (5) - (6) by eliminating the pressure term readily read as:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \tag{4}$$

$$\rho_{nf}\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = \mu_{nf}\frac{\partial^2 u}{\partial y^2}, \tag{5}$$

$$(\rho c_p)_{nf}\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = \alpha_{nf}\frac{\partial^2 T}{\partial y^2} - \frac{\partial q_r}{\partial y}, \tag{6}$$

The temperatures at the far-field and the surface of the plate are respectively T_∞ and T_w respectively. When the plate is assumed to be stationary (Blasius case [9]), then the boundary conditions are as given below:

$$\text{At } y = 0: v = 0, \quad u = 0, \quad T = T_w. \tag{7}$$

$$\text{As } y \to \infty: u \to U, \quad T \to T_\infty.$$

On the other hand, if the plate is assumed to be moving with a constant velocity U (Sakiadis case [10]), then the boundary conditions are as follows:

$$\text{At } y = 0: v = 0, \quad u = U, \quad T = T_w. \tag{8}$$

$$\text{As } y \to \infty: u \to 0, \quad T \to T_\infty.$$

The radiative heat flux is modeled using Rosseland approximation [15,16] which is apt as the fluid medium is considered to be optically dense. Therefore, the radiative heat flux is given as:

$$q_r = -\frac{4\sigma^*}{3k^*}\frac{\partial T^4}{\partial y} = -\frac{16\sigma^* T_\infty^3}{3k^*}\frac{\partial T}{\partial y}, \tag{9}$$

where, (k^*, σ^*) denote the coefficient of mean absorption and the Stefan-Boltzmann constant respectively. The above functional form is found by the linearized Taylor series expansion of T^4 about T_∞.

The Nusselt number (Nu) and the skin friction coefficient (Cf) are used to measure the heat transfer rate and the skin friction in the boundary layer flow [15]. In various practical applications, these quantities are of interest. Nu and Cf are defined as follows:

$$Nu = \frac{xq_w}{k_f(T_w - T_\infty)} \text{ and } Cf = \frac{\tau_w}{\rho_f U^2} \tag{10}$$

Where, q_w and τ_w are the heat flux and shear stress respectively, which are given by:

$$q_w = -k_{nf}\frac{\partial T}{\partial y} + q_r\Big|_{y=0} \text{ and } \tau_w = \mu_{nf}\frac{\partial u}{\partial y}\Big|_{y=0} \tag{11}$$

3. Solution methodology

In order to arrive at similarity solutions for the modelled problem, the below transformation variables are used:

$$\psi = \left(\frac{U\mu_f x}{\rho_f}\right)^{0.5} f(\eta),\ \theta(\eta) = \frac{T-T_\infty}{T_w-T_\infty}, \text{with } \eta = \left(\frac{U\rho_f}{\mu_f x}\right)^{0.5} y. \tag{12}$$

Where, ψ, θ, η represent the stream function, the dimensionless temperature, and the similarity variable respectively. Furthermore, $u = \frac{\partial \psi}{\partial y}$ and $v = -\frac{\partial \psi}{\partial x}$. Transforming variables convert equations into ordinary differential equations (see Eqns. (13)-(16)) which are functions of η as follows:

$$\frac{\mu_{nf}}{\mu_f}\frac{d^3 f}{d\eta^3} + \frac{1}{2}\frac{\rho_{nf}}{\rho_f}\frac{d^2 f}{d\eta^2} f = 0, \tag{13}$$

$$\left(\frac{k_{nf}}{k_f} + R\right)\frac{d^2\theta}{d\eta^2} + \frac{1}{2}\frac{(\rho c_p)_{nf}}{(\rho c_p)_f} Pr_f \frac{d\theta}{d\eta} f = 0, \tag{14}$$

with

Case 1: Blasius flow problem

$$f(0) = 0, \frac{df}{d\eta}(0) = 0, \theta(0) = 1, \frac{df}{d\eta}(\infty) = 1,\ \ \theta(\infty) = 0. \tag{15}$$

Case 2: Sakiadis flow problem

$$f(0) = 0, \frac{df}{d\eta}(0) = 1, \theta(0) = 1, \frac{df}{d\eta}(\infty) = 0,\ \ \theta(\infty) = 0. \tag{16}$$

where, $\text{Pr}_f = \left(\frac{\mu c_p}{k}\right)_f$ is the Prandtl number, $R = \frac{16\sigma^* T_\infty^3}{3k^* k_f}$ is the radiation parameter.

The nanofluid is modelled using the single-phase model. Experimental relations are used for viscosity and thermal conductivity (Corcione models [17]). The nanofluid density and specific heat capacity are modelled using the mixture theory. The models are summarized in Table 1. The remaining nanomaterial properties are modelled using the conventional mixture theory properties as given in Table 1.

Table 1: Effective thermophysical properties of the nanofluid (see [16, 17]).

Viscosity	$\mu_{nf} = \frac{\mu_f}{1-34.87\left(\frac{d_p}{d_f}\right)^{-0.3}\phi^{1.03}}$
Thermal conductivity	$k_{nf} = k_f\left\{1 + 4.4Re^{0.4}Pr^{0.66}\left(\frac{T}{T_{fr}}\right)^{10}\left(\frac{k_p}{k_f}\right)^{0.03}\phi^{0.66}\right\}$
Specific heat capacity	$(\rho c_p)_{nf} = (1-\phi)(\rho c_p)_f + \phi(\rho c_p)_s$
Density	$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_s$

In Table 1, $d_p = 47$ is the nanoparticle diameter, $d_f = 0.1\left(\frac{6M}{N\pi\rho_f}\right)^{\frac{1}{3}}$, M is the molecular weight of water, N denotes the Avogadro number, ϕ denotes the nanoparticle loading and ρ_f denotes the density of water at room temperature. Also, $Re = \frac{2\rho_f k_B T}{\pi\mu_f^2 d_p}$ denotes the Reynolds number, k_B denotes the Boltzmann constant, μ_f denotes the dynamic viscosity of water, Pr denotes the Prandtl number of water, T is the nanomaterial temperature, T_{fr} denotes the freezing point of water, and k_p, k_f denotes the thermal conductivities of alumina and water respectively.

The non-dimensional Nusselt number and the skin friction are obtained using the similarity variables in Eqn. (10) as given below:

$$Re_x^{-0.5}Nu = -\left(\frac{k_{nf}}{k_f} + R\right)\theta'(0) \text{ and } Re_x^{0.5}Cf = \frac{\mu_{nf}}{\mu_f}f''(0), \tag{17}$$

where the local Reynolds number is given by $Re_x = \frac{U\rho_f x}{\mu_f}$.

The system of ordinary differential equations is solved using the finite difference-based numerical solver (bvp5c) which produces accurate solutions to such nonlinear systems. The Prandtl number is fixed at 6.0674 for water at room temperature. In the computational domain, infinity is rescaled to 8. The solutions are plotted as profiles and the impact of volume fraction and thermal radiation are discussed in the next section.

4. Parametric discussion

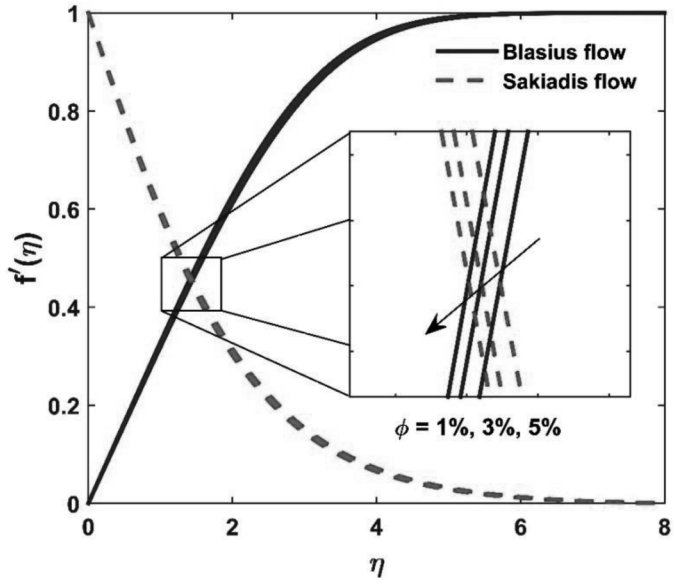

Fig. 1: Velocity profile of the nanofluid with respect to variation in ϕ when $R = 1$.

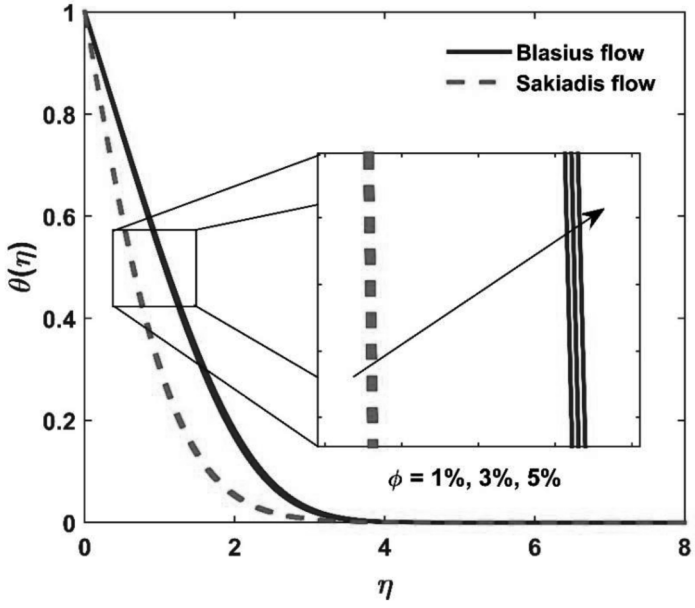

Fig. 2: Temperature profile of the nanofluid with respect to variation in ϕ when $R = 1$.

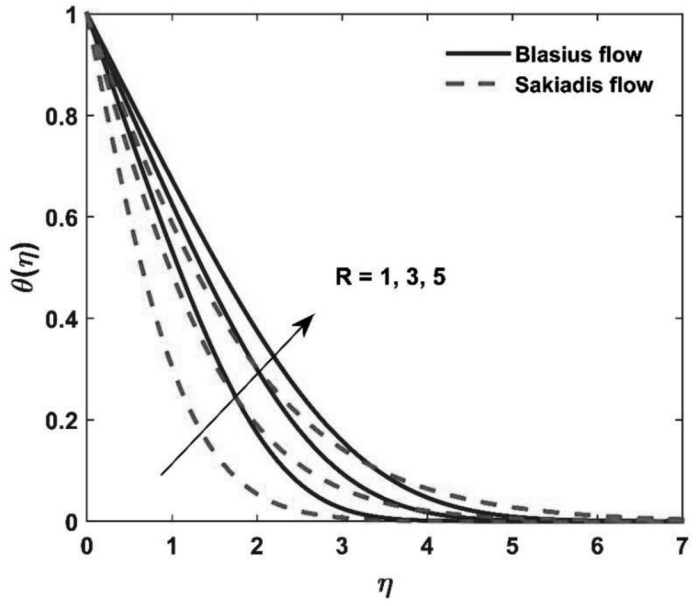

Fig. 3: Temperature profile of the nanofluid with respect to variation in R when $\phi = 3\%$.

Table 2: Nusselt number values for different nanoparticle volume fraction (ϕ).

Nanoparticle volume fraction (ϕ)	Nusselt number ($Re_x^{-0.5}Nu$)	
	Blasius flow	Sakiadis flow
1%	0.414743616534892	2.025097270133372
2%	0.439852537319169	1.744633585905396
3%	0.487583312646122	1.185985821905692
4%	0.534572679102739	0.236251908595403
5%	0.578963211944512	0.004655728000381

The velocity profiles for the Blasius and Sakiadis flow problems for the alumina-water nanofluid is shown in Fig. 1. For the Blasius flow case, the velocity profile asymptotically approaches 1 from 0, whereas for the Sakiadis flow, the velocity profile approaches 0 asymptotically from 1. A higher nanoparticle loading has a decreasing impact on the nanofluid velocity. This can be attributed to the fact that a higher

nanoparticle loading leads to an increment in the nanofluid viscosity which in turn leads to a lower velocity.

The temperature profiles for both the flow cases are of the same nature (approach 0 asymptotically from 1). Nanoparticle loading is found to increase the thermal field slightly (see Fig. 2). This is due to the increase in the fluid thermal conductivity. The radiative heat flux also has an incremental effect on the temperature of the nanofluid. Physically this is because the additional energy obtained from the thermal radiation supplements to the thermal field of the nanofluid. As seen from Table 2, a larger nanoparticle volume fraction improves the heat transport in the Blasius flow case whereas the opposite is observed in the Sakiadis flow case.

5. Concluding remarks

The boundary layer flow of alumina-water nanofluid past a vertical flat plate is modelled mathematically using the boundary layer theory. Apt similarity variables and finite-difference-based solver is employed to arrive at solutions. The nanoparticle volume fraction is found to have a negative effect on the velocity whereas it enhances the temperature. Moreover, the heat transfer is enhanced in the Blasius flow case, whereas the opposite is observed when the plate moves. Thermal radiation increases the temperature of the nanofluid. Therefore, it is highly beneficial to use nanofluids as the working fluids in flat plate solar collectors and heat exchangers. The mathematical model developed in this chapter can be extended by incorporating various external effects based on the physical situation that is modelled.

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C. LITERATURE

A LOG BRIDGE TO LINGUISTIC LIBERATION: A PSYCHOLINGUISTIC READING OF CUSS WORDS IN *CHURULI*

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Churuli, a 2021 feature film which initiated heated arguments among political parties and orthodox cinema lovers, is observed as a film with 'an overdose of foul language' by the Kerala High Court in response to the petition filed by Sri. Peggy Fen regarding the excessive use of cuss words in the film. But on the contrary to the expectation of the petitioner and the conservative cinema lovers, the same court rejected the petition considering the report of a team headed by the Director General of Police which stated that nothing illegal was observable in the cinema and the court observed that, "Language in cinema is director's call. Cinema is the artistic creation of the director and it is his discretion to choose the language". It was in 2017, when the college magazine *Viswa Vikyatha Theri* released by the college union of Zamorin's Guruvayurappan College which won accolades, awards and disapprovals, the readership in Kerala debated much about the cuss words in Malayalam and their etymology. When the wave of protest initiated by the college magazine was about to die out, Pellissery fanned it with his *Churuli* to perpetuate the controversy affirming the hitherto obstructed linguistic freedom.

Churuli, the Malayalam film named after a small village in Idukki, captured the minds of the progressive lot and made the conservatives to frown due to the abundance of cuss words which has now become the vogue of the new generation cinema. *Churuli* , the Malayalam psychological thriller, celebrates the freedom of informal language in the guise of cuss words after *Joji,* yet another 2021 film with a difference. Lijo Jose Pellissery, the avant garde film director who gave visual form to the story of Vnoy Thomas scripted by S. Hareesh, narrated the story of human evolution from the primitive man to the ultra-modern man in a time frame of about two hours. Like a classical drama which has prologue and epilogue, *Churuli* opens with an animated narrative of a Namboothiri who attempted to trap a phantom that misleads travelers. In spite of the confidence of the Namboothiri to chain the phantom, the phantom misleads him in the guise of an ant eater which the Namboothiri met on the way. The predominance of spiral image throughout the film

justifies the title of the film 'Churuli' which evokes an air of spirality and a gyre.

The epilogue which reverberates with the story of the Namboothiri and the phantom is the replica of the whole film. The story revolves round the hinge pin of 'monomyth' which is apparent in the quest for multifarious incomprehensible people and phenomena in Churuli. Two police men: Antony (Chemban Vinod Jose) and Shajivan (Vinay Fort) in the guise of menial workers who are hired to work in the plantation of Thankanchettan (Joju Jose) braved into the dense hamlet of Churuli in search of a fugitive. They alighted from a bus and had breakfast from a country tea shop where a native man reads the newspaper aloud and chuckles when he reads the news story of two Americans made captive by the aliens. The subsequent scene where the two police men in a jeep travelling with other commuters are strangers like aliens is the visualization of the news story that preceded.

Swear words, cuss words, profane words, bad words- the unacceptable words are known in terms and shades of meanings, but they refer to the same group of words which are always pertinent to human body parts, sexual behaviours, lesser animals and even human body effluvia. Swear words and profane words ring an air of religious undertones. About swearing Kate Burridge in her book *Forbidden Words (2006)* remarks, "The extension of profanity from irreligious language to incorporate obscene language took swearing and (to a lesser extent) oaths with it." (Burridge 76). She also comments on the unstoppable nature of swearing as: "Swear words are socially and emotionally indispensable, vital part of our linguistic repertoires that help us mitigate stress, cope with pain, increase strength and endurance and bond with friends and colleagues." (80)

Cuss words are linguistic taboos ubiquitous in every community. They offer discomfort and linguistic consciousness in the users of every language. Burridge further vivifies the development of taboos in a community which contain the freedom of its people. She meticulously comments:

Taboos arise out of social constraints on the individual's behaviour where it can cause discomfort, harm or injury. People are at metaphysical risk when dealing with sacred persons, objects and places; they are at physical risk from powerful earthly persons, dangerous creatures and disease. A person's soul or bodily effluvia may put him/her at metaphysical, moral or physical risk, and may contaminate others; a social act may breach constraints on polite behaviour. (Burridge 1)

The jeep on this context functions as a time machine which carries the passengers to the distant past or to time immemorial. The jeep braved dense forest, winding mud path, narrow and treacherous terrain and stuck on a log bridge. The bridge connects the world of formality and civility with the one that is outrightly informal and primitive. When crossing the bridge, the commuters become strangers and their language become profane and rude to the outsiders. The sudden change of disposition and character is a repeated frame tale in Indian my-

thologies, as the Vikramadithya Tales take after this frame tale. The cuss words the jeep driver showered on Antony inducted him to the world of barbarity. The duo reaches a country toddy shop where country liquor is served and the ambiance of the shop is quite eerie and the people seem strangers.

The duo continues their investigation secretly by trying to extract information about Joy, in search of whom the duo reached there. The cinema amply contains stereotypical nomenclature which takes the spectators to the 1978 Malayalam movie *Lisa* which immortalized the name "Alavaladi Shaji" (Scoundrel Shaji). Many of the characters are nameless and their existence become fluid in the narrative. Very often the people of Churuli become double faced entities and incomprehensible.

The obscure and mysterious country liquor shop is the hinge pin of this narrative as it forms a microcosm of Churuli as a mysterious place of liberty. It is a space where cuss words form the formal linguistic element. Many an occasion the characters celebrate the wordplay of using cuss words and celebrate the freedom of speech. The characters seem to relieve of their frustrations using the deafening cuss words. The equality of gender in using the cuss words amazes the spectators, as the female characters like Pengal, Thankan's wife and the tavern keeper Philip's wife resort to cuss words to relieve of their anger and frustration without any inhibition of uttering bad words. The hitherto monopoly of using abusive words is challenged as all the female characters use the abusive language profusely with liberty.

The Social critics observe that there are ultimately four functions attached to the use of profane languages. They are: Expletive function, abusive function, the social function and stylistic function. The expletive function suggests that the cuss words are used in intense emotional situations, when one is angry frustrated or under high pressure. When the jeep driver in *Churuli* swears at Antony, he was angry and in order to give went to the frustration he bore with while crossing the dilapidated log bridge. Again, when the toddy shop owner was threatened by Thankan, the shop owner's wife showers them with cuss words as a means to express her anger. The abusive function of swearing is to insult a person or to dispirit him. When the police men first time meet Thankan, Thankan unleashes a charade of cuss words which were insulting to the duo and they got dispirited. All the characters on the seen use abusive words one another and insult one another giving a shock to the spectators. The social function of swearing suggests bond between the characters. When the jeep driver reaches the country liquor shop, he greets Philip, the shop owner, with bad words and the obscene response from Philip indicates the social function of profane words. The stylistic function denotes using cuss words to drive home the attitude of the person or the gravity of the information communicated. When Shajeevan responds to his counterpart Antony using cuss words, the situation is suggestive of the stylistic function of employing profane words.

Violence, whether physical or verbal, is apparently an inevitable part of new genera-

tion cinemas. Much of the violence which might occur physically is replaced with verbal violence in this film. If the film didn't employ very many cuss words, it would have been a film abundant in physical violence. Hence, *Churuli* as a film addresses the cathartic function of swearing which relieves people, irrespective of gender and age, of their pent-up feelings in the guise of cuss words. In *Forbidden Words* Kate Burridge again comments on the semantic change of swearing as, "Language is used as a shield against malign fate and the disapprobation of fellow human beings; it is used as a weapon against enemies and as a release valve when we are angry, frustrated or hurt. Throughout the book we are struck by the amazing poetic inventiveness of ordinary people, whose creations occasionally rival Shakespeare." (2)

The etymology of the word 'profane' takes us to the classical Latin word 'profaunus' which is a combination of 'pro' meaning 'outside' and 'faunum' meaning 'temple'. Thus, 'profaunus' literally means 'outside the temple'. Churuli as a cinema justifies this nomenclature, when the tavern is clothed as a church for the sacrament of 'holy communion', the space is free from profane words. But with the shifting of the church as tavern, the profane language thrives.

The origin of swear words is untraceable as they may be as old as the origin of language. Every language is dynamic, as new words are added to the repertoire of the vocabulary of a language and the old words are discarded, but the cuss words tend to prevail withstanding the passage of time, except the semantic changes. The meanings may vary and they may assume different semantic functions with the turn of centuries. The open defecation, hunting and savage life all constitute primitive life in Churuli.

The common men, who take after the primitive hunters and gatherers, in Churuli, are familiar with the use of swearing. About the use of vulgar language, Melissa Mohr in her book *Holy Shit* (2013) comments as, "Vulgar language makes a class distinction—it is that spoken by ordinary, uneducated folk. It has become a synonym for swearing because "the common people" have through the centuries been thought to be more likely than others to employ profane or obscene language." (Mohr 17) The 'gyre' which is redundant throughout the cinema is evocative of the gyre of civilization. The primitive hunting -gathering society to the ultramodern civilization where travelling to the space and other planets deem to be an everyday activity, but this progress seems to be spiral in nature as it is encapsulated in Churuli. As the Brahmin in the prologue wanders through the labyrinth unable to find an exit, the epilogue in which the two cops with Mayiladumparambil Joy wander through the forest without finding an exit rely on swearing to relieve their frustration which is indicative of the immortal nature of cuss words.

What is uncommon in Churuli is the use of cuss words by women. Traditionally, women were deemed to be soft spoken gender who employ alternate medium to assert

themselves. Michael Gauthier comments in his book *Profanity And Gender: A Diachronic Analysis Of Men's And Women's Use And Perception Of Swear Words* (2000), " Since women do not have the same tools as men to affirm themselves, that is, "strong language" and assertiveness, they often develop differing practices to reinforce their in-group recognition." (34). But the women folk in *Churuli* assert themselves using profane words and stand next to women. Hence, a gender neutral space is formed with the liberal use of cuss words.

Churuli, as a place of umpteen liberty, reshapes itself as a bogue that sucks people in. The cultural environment in Churuli is quite murky, as it is peopled with fugitive criminals and alcoholics. To that insane community come two cops who psychologically fit themselves in effortlessly and often forget their target and wallow in the primitive freedom of sexuality and profanity. In his book *The Neuro-Psycho-Social Theory of Cursing (1998)* Timothy Jay comments as:

In the psychological system, it is assumed that a speaker acquires linguistic competence and exhibits linguistic performance as the result of psychological development within a sociocultural language context. Different cultures and different languages, of course, present different sets of linguistic and semantic constraints on dirty word use. This is to say that although individual speakers in one society might learn to speak the dominant language, each person 's use of curse words is determined by his or her psychological development within a given linguistic, familial, and cultural environment. (Jay 19)

The excessive use of cuss words and obscene phrases brought *Churuli* to the notice of the public as a film that propagates swearing and socially unacceptable vulgar phrases. As the film progresses the frequency of swearing decreases. In her article on "On the Psychology of Swearing" (2012) Jessica Love encapsulates the findings of Timothy Jay, a professor at the Massachusetts College of Liberal Arts as," And we do so at a rate of about one taboo word per 200 words. This rate, however, differs dramatically among age groups (swearing peaks in adolescence), between genders (men swear more often and more offensively), and most importantly and perhaps obviously of all, from one individual to the next." (Love 1)

Churuli is populated with migrated people who elude law and make this inaccessible location as a hide out for them. Once entered the loop-life of Churuli they are sucked into the paradisical life in the primitive paradise. Like the ant eater in the prologue that misleads the Brahmin, Myladumparambil Joy who encapsulates life in Churuli as a paradisical life that offers liberty to hunt in the wilderness, drink alcohol and fornicate and the suggestive freedom to swear.

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'मैं वो शंख महा शंख' समस्याओं पर एक नजर

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हमारे देश में ऐसे अनेक व्यक्ति है जो समाज के केंद्र या मुख्यधारा में नहीं रहता। वे समूह जो आम जनता की तुलना में अधिक गरीबी और सामाजिक बहिष्कार के शिकार होते है, उन्हीं लोगों की ओर इस संग्रह में कवि ने पाठकों का ध्यान आकृष्ट करते दिखाई देते हैं। अल्प संख्यक समूह के अंतर्गत आनेवाले ये 'हाशियेकृत जनवर्ग' सामाजिक जीवन में सहभागिता हेतु संघर्षरत रहते है। लिंग, प्रजाति, जन्म, धर्म आदि के आधार पर पक्षपात का सामना कर रहे लोगों को हाशियेकृत जनवर्ग में शामिल किया जाता है। सामाजिक, सांस्कृतिक, आर्थिक दशाओं के परिप्रेक्ष्य में हाशियेकृत जन की परिभाषा बदलती रहती है। हाशियेकृत जनवर्ग के अंतर्गत महिलाएं और बालिका शिशु, बच्चे, प्रवासी, श्रमिक, शरणार्थी, राष्ट्रीय अल्पसंख्यक, निशक्तजन, वृद्ध, आदिवासी लोग, आंतरिक रुप से विस्थापित लोग, एलजीबीटी, अनुसूचित जाति और जनजाति, वेश्यावृत्ति में सम्मिलित महिलाएं, एड्स संक्रमित और खानाबदोश या यायावर जैसे अनेक वर्ग आते हैं। हाशिए कृत जनवर्ग विभिन्न प्रकार के भेदभाव का सामना करते हैं जैसे रोजगार के अवसरों का अभाव, शिक्षा का अभाव, राष्ट्रीय संसाधनों तक पहुंच का अभाव, खाद्य साधनों का अभाव, निर्धनता की स्थिति, मानवाधिकारों का उल्लंघन, सामाजिक सुरक्षा का अभाव, पौष्टिक भोजन और स्वास्थ्य सुविधाओं का अभाव। मैला ढोने वाले, कूड़ा उठाने वाले, झुग्गी में रहने वाले, सफाई कर्मचारी, एकल अभिभावक, शरणार्थी, सजा काट चुके व्यक्ति आदि भी हाशिए पर स्थित समुदाय में शामिल है। दुनिया भर में होने वाले तमाम प्रकार के मूल्य विघटन एवं मानवीय त्रासदी के कारण आज हाशिए पर खड़े मानव के प्रति पक्षधरता प्रकट करने का विचार अधिक मूल्यवान हो गया है। यह एक जागरूक चेतना है। मानव भविष्य के प्रति पक्षधरता प्रकट करना समकालीन कविता की घुरी मानी जा सकती है। आम आदमी के प्रति हमदर्दी प्रकट करने वाली समकालीन हिंदी कविता की एक व्यापक पृष्ठभूमि है और वह भारत की राजनैतिक एवं सामाजिक विसंगतियों से एकदम जुड़ी हुई है। अरुण कमल जैसे कवि केवल अपना प्रवक्ता नहीं है, वह समस्त जन एवं समस्त जीवों के एवं ब्रह्मांड की आवाज़ है। वह केवल एक खंड या कोटी की ओर से नहीं बल्कि सब की ओर से बोलता है। 'मैं वो शंख महाशंख' शीर्षक का अर्थवत्ता भी यह है। इस संकलन में कवि ने शंख महाशंख के तरह गणना से बाहर कर दी गई निर्बल किंतु संघर्षशील लोगों की कविताएं शामिल किया है।

"जब भी उनकी गिनती गलत होगी
जब भी वे हिसाब मिला नहीं पाएंगे
मैं हँसूंगा आंकड़ों के पीछे से तालियां देता
वो मैं हूं मैं वो अंक वो शंख महाशंख।"[1]

देश विभाजन के बाकिपत्र

भारत का विभाजन माउण्टबेटन योजना के आधार पर निर्मित भारतीय स्वतंत्रता अधिनियम 1947 के आधार किया गया था। 14 अगस्त 1947 के आधी रात को भारत और पाकिस्तान कानूनी तौर पर दो स्वतंत्रत राष्ट्र बने।विभाजन के दौरान हुई हिंसा में करीब 10 लाख लोग मारे गए और करीब 1.46 करोड़ शरणार्थियों ने अपना घर-बार छोड़कर बहुमत सम्प्रदाय वाले देश में शरण ली। विभाजन से दोनों समुदायों में दुश्मनी बढ़ गई। समुदायों में जो दुश्मनी है वह राष्ट्रों के बीच भी है। दोनों देश एक दूसरे के प्रति शत्रुतापूर्ण भाव रखता है। जब भी पाकिस्तान में किसी भारतीय पर जुल्म किया जाता है तो उसकी प्रतिक्रिया भारतीय मुसलमानों को भी भुगतनी पड़ती है। यदि कोई भारतीय भूल से सीमा पार कर चला जाता है तो उसे गिरफ्तार कर संगीन से संगीन इल्जाम लगाए जाता है। पाकिस्तान ने जिन भारतीयों को बंदी बनाया है उन्हें बाहर निकालने केलिए भारत सरकार भी कुछ करते नहीं है। भूल से सीमा पार करना मृत्यु का वरण । दोनों देशों के बीच नफरत इतनी बढ़ गई है कि सब भूल गए है एक जमाने में भारत और पाकिस्तान एक था और हिंदु मुसलमान एक दूसरे को भाई मानते थे। नफ़रत ने दो मुल्क और करोड़ों जनों को अलग कर रखा है। भारत-पाकिस्तान सीमा कागज़ में सींचा हुआ हाशिए की तरह है। एक पृष्ट की अंक होने पर भी दो हिस्सों में बाँटे हुए। नफ़रत के कारण भारत भूल जाते है कि पाकिस्तानी भी उनकी तरह इंसान ही है, पाकिस्तानियों की सोच भी कुछ दूसरा नहीं है। 'जब तुम किसी के करीब आते हो' कविता में अरुण कमल कहता है कत्ल करने हेतु जब तुम किसी के करीब जाएँगे और उसकी ज़िंदगी को नज़दीक से देखेंगे तो तुम्हें उसे मारना निरर्थक लगेगा। सांप्रदायिकता और राष्ट्रप्रेम ने लोगों के बीच घृणा के अलावा कुछ बाकि नही रखा। इस अवसर पर कवि की इच्छा है एक दुनिया जहाँ कोई भेद नहीं हो।

"मैं तो चाहता हूँ सारी धरती सारे समुन्दर एक हो जाए और हम इस

तरह पृथ्वी पर टहलें जैसे अपने टोले में एक आँगन से दूसरे आँगन।"[2]

इन सबकी बीच ध्यान देने की एक बात यह है कि सीमा पार करने के कारण जेल में बंद होनेवाले ज़्यादातर लोग मछुआरे, चरवाहे, बंजारे चंचल, नौजवान जैसे आम कोटी के जन है। जिनके हाथ में सत्ता है उनके बीच सीमा की समस्या नहीं है। सीमाएँ आम कोटी की जन केलिए बनी है। आजीविका केलिए दिन भर दौडते सामान्य जन और सुख लोलुपता में डूबे अमीरों के बीच की फासला बहुत बड़ा है। 'मैं ने लाहौर में एक तोता देखा' कविता कुछ पंक्तियों में बहुत कुछ कहकर जाते है। 'तोता' को हाशिए कृत जन के प्रतीक मानना गलत नहीं होगा। कवि कहता है कि उन्होंने लाहौर में एक तोता देखी जो बिलकुल अपने देश की तोता जैसी थी। फर्क यही था कि लाहौर का यह तोता उर्दू और पंजाबी बोलते थे। दुनिया में जितने देश है उन देशों में अलग भाषा बोलने वाले

तोता होंगे या नी हाशियेकृत जन वर्ग। उन लोगों की जात-धर्म कोई नहीं पूछेंगा। जैसे पिंजड़े में बंद तोता बाहर निकलने केलिए तरसते है, उसी प्रकार हाशियेकृत लोग अपने जीवन के हाशियों से, अभावों से बाहर निकलने हेतु संघर्षरत रहते है। 'मातृभूमि पर प्यार' कविता में कवि देशप्रेम के बारे में कहते है। जब वह पाकिस्तान में थे तब बाघा सीमा पर झंडे उतारने की परेड देखकर उनके अंदर देशप्रेम जागा। कहने का तात्पर्य यह है कि भारतीय होने के बावजूद देश के प्रति प्रेम या राष्ट्रीयता का भाव अपने अंदर जगाने केलिए उन्हें वह परेड देखना पड़ा। स्वतंत्रता प्राप्ति के इतने साल बाद लोगों के दिल में राष्ट्रप्रेम कम हो गया है। सीमा की रक्षा करनेवाले जवानों में जो राष्ट्रप्रेम है उसकी आधा अंश भी सीमा से पर रहनेवालों में खोजना मुश्किल है। उन लोगों के अंदर सिर्फ किसी विशेष अवसर पर होनेवाले भावबोध के समान देशप्रेम जिंदा है।

बेघरपन

बेघर होना स्थिर, सुरक्षित और पर्याप्त आवास की कमी की स्थिति है। बेघर में वे लोग भी शामिल है जो किसी सार्वजनिक या निजी स्थान पर सोते हैं, जो मनुष्यों के लिए नियमित सोने के आवास के रूप में उपयोग के लिए नहीं बनाया गया है। बेघर लोगों की गिनती और उनकी जरूरतों की पहचान करने पर कोई पध्दतिगत सहमति नहीं है। इसलिए अधिकांश शहरों में केवल अनुमानित बेघर आबादी ही जानी जाती है। कुछ लोग आर्थिक परिस्थितियों के कारण बेघर होते है तो कुछ व्यक्तिगत जीवन शैली पसंद के रूप में बेघर होना चुनते हैं। जिनके पास घर होते है वह लोग बेघर लोगों को एक दिन के लिए भी आश्रय देने से इनकारते है। आजकल इंसान ,इंसान पर भरोसा करने से डरते हैं। इंसानियत और विश्वास की कमी की आधारभूत कारणों में एक बढ़ते जा रहे आर्थिक असमानता है। दिल में सहानुभूति के भाव होने पर भी डर के कारण अभावग्रस्तों के मुंह पर आज के आदमी दरवाजा बंद कर देते हैं।

"तुम एक घर / बंद मत करो द्वार
नहीं इस रात मत छोड़ो शीत में / बाहर"[3]

'परिवर्तन' नामक कविता में भी कवि इस बात को सूचित करते दिखाई देते हैं। हर इंसान की तरह बेघर लोग भी घर के सपने देखते हैं। 'इच्छा थी' कविता में कवि ऐसे सपनों से मुलाकात करवाती है। इस कविता में एक ऐसे आदमी का चित्रण किया गया है जो मेहंदी के अहातेवाले घर की सुंदर सपने रखते है। लेकिन एक एक दिन गुजरने की भागदौड़ में वह अपने सपने पीछे छोड़ते हैं।कुछ लोग अपनी जिंदगी से परेशान होकर घर छोड़ते हैं। उनके लिए घर एक बोझ है। वो लोग जिम्मेदारियों से दूर भागने की कोशिश में घर को पीछे छोड़ते है । और ऐसा भी होता है कि जब आदमी अपने घर परिवार की जिम्मेदारियां उड़ाने में असमर्थ बन जाता है तो घरवाले उसकी उपेक्षा करते है।

"जब तुम सब कुछ खोकर खाली हाथ
अपने ही घर लौटोगे शाम को
तब पाओगे वह तुम्हारा घर नहीं"[4]

निर्बल जन

हर समाज में संपन्न और समर्थ व्यक्तियों के साथ साथ निर्बल, निर्धन और वंचित व्यक्तियां भी

जीवित है। संपन्न और समर्थ व्यक्ति अपने फायदे के लिए निर्बल और निर्धन व्यक्तियों को उनके अधिकारों से वंचित रखते है। आसपास देखने पर शोषित निर्बल व्यक्तियों की हजारों कहानी यूं ही मिल जायेंगी। उनका शोषण सदियों से होता आ रहा है, और आगे भी होगा। क्योंकि इन शोषणों के खिलाफ दो दिन से ज्यादा कोई भी आदमी बात नहीं करता। निर्बल की आवाज को बहुत आसानी से कुचल देते है समाज। हमारे देश में आज भी करोड़ों निर्बल, निर्धन लोगों को भूखे पेट सोने पड़ते हैं, वहीं हमारे देश के शासक अपने घर में हर दिन दीवाली मनाते है, उनके मेज हमेशा भोजनों से भरे रहते है। 'वित्तमंत्री की साथ नाश्ते की मेज़ पर' कविता पढ़ते वक्त धनी और गरीब व्यक्ति के बीच का अंतराल साफ नजर आ जाते है। आम आदमी अपना खेत, घर, जेवर और बर्तन बिककर एक एक दिन आगे बढ़ाने की कोशिश में लगे रहते हैं। वह भविष्य के प्रति आकुल नहीं, उसकी सारी व्यथा वर्तमान से जुड़े हुए होते हैं। वह जानता है कि अगले दिन अगर किसी ट्रक के नीचे उसका शरीर चांपा गया तो भी पूछने केलिए कोई नहीं होगा।

"अब कोई नहीं पूछता यह दुनिया ऐसी क्यों है
बेबस कंगालों और बर्बर अमीरों में बंटी हुई"[5]

कवि ने 'कुछ परिभाषाएं' नामक कविता में कहा है कि:"जो जितना ज्यादा लोगों का जितना ज्यादा नुकसान कर सके / वो उतना ही बड़ा है।"[6] ऊंचे पदों में अलंकृत ज्यादात्तर लोग अनगिनत निर्बल निर्धन लोगों को दबोचकर ही उन पदों पर विराजित है। अधिकारी वर्ग के गुड़िया बनकर उधर से इधर, इधर से उधर निर्बल भागते रहते है।

वृद्धावस्था

जन्म से मृत्यु तक मानव शैशव, बाल्य, किशोर, युवा वृद्ध आदि चरणों से गुजरते है। वृद्धावस्था में एक व्यक्ति शारीरक और मानसिक दृष्टि से कमजोर होता जाता है। इतना ही नहीं वह सामाजिक व आर्थिक दृष्टि से शक्तिहीन व संदर्भहीन भी होता जाता है। आयु बढ़ने के साथ शरीर में अनेक बीमारियाँ आ जाती है, इंद्रिय कमजोर होने लगती है। शारिरिक कार्यक्षमता घटने और सामाजिक उपयोगिता कम होने पर वृद्ध व्यक्ति को अनेक मानसिक चिन्ताएं घेर लेती है जिससे उसकी नींद कम हो जाती है। एकाकी परिवार में रहनेवाला वयस्क व्यक्ति का जीवन कठिनाइयों से भरा हुआ होता है। क्योंकि वहाँ उसकी देखभाल करनेवाला कोई नहीं होता है। बुजुर्ग माँ-बाप की देखभाल करने हेतु लोग आजकल किसी सेवक की नियुक्ति करते है। सेवक चाहे कितना भी अच्छा हो फिर भी बुजुर्ग व्यक्ति की आँखों में अपने संतानों की खोज चमकते रहते है।

"दर्द से ऐंठते बार बार कंठ भिंगोते
किसी के इंतजार में ताकते अखिरी बूंद तक
सूखते
कभी जब वे सो जाते खुले मुँह उनके दांत
चमकते रात में"[7]

वृद्धावस्था में पारिवारिक माहौल में रहना अनिवार्य होता है। क्योंकि बुढ़ापे की अनुभूति व्यक्ति को शारीरिक रूप से नहीं बल्कि मानसिक रूप से ही बहुत असहाय महसूस करवाता है। उस समय घर की माहौल या बच्चों की गातिविधियों से उन्हें आनंद मिलते है। बुजुर्ग होने पर ज़्यादातर लोग अपना

भूतकाल और मृत्यु के बारे में सोचते है। वह उन मुश्किल हालातों की याद करते हैं जिनसे वह निडर होकर लड़ाई किये थे, उन मधुर लम्हों की याद करते है जब वह पहली बार अपने जीवन साथी को देख था। पुराने यादों में अपने कार्यक्षमता और विजय देखकर उसकी सीना चौड़ा जाते है।

"यह जीवन एक पत्तर था छाती पर
जिसे चारों तरफ से घास ने ढाँप लिया"[8]

ज़्यादातर लोग बुजुर्ग लोगों को बोझ के समान देखते है। ऐसे बुजुर्ग लोग अपने आप घर छोड़ने का इच्छुक बन जाते है। मानसिक रूप से अकेलापन के शिकार बनते जाते है वृद्धजन।

विद्रोह

विद्रोही वह व्यक्ति है जो विद्रोही गतिविधियों में हिस्सा लेता है। विद्रोह किसी उत्पीड़न की स्थिति और अस्वीकृति की भावना से उत्पन्न होता है। इस संग्रह के दूसरे हिस्से की ज्यादातर कविताओं में विद्रोह के भाव दृष्टाव्य है। 'आवर्त' के संपादक वीरेश चंद्र की स्मृति में रचे गए 'आवर्त' नाम के कविता में अरुण कमल ने एक विद्रोही व्यक्ति की छवि पाठकों के सामने प्रस्तुत किया है। सामाजिक असमानताओं के खिलाफ जब विद्रोही व्यक्ति लड़ते है तब सब उसका संघर्ष देखते हैं, लेकिन उसके घाव कोई नहीं देखता। दूसरों के लिए संघर्षरत होने के कारण वह खुद को चोट पहुंचाता है। आजकल लोगों को चुप रहने की आदत पड़ चुकी है। उसकी आंखों के सामने कितनी भी बड़ी दुर्घटना घटित हो, वह उस घटना को नजर अंदाज कर के आगे बढ़ते हैं। 'थूक' नामक कविता में कवि एक घटना बताता है। एक गुंडा प्राचार्य मान बहादुर सिंह के साथ दुर्व्यवहार कर रहा था। हजारों विद्यार्थी जमा थे, लेकिन किसी ने भी गुंडा को रोकने की कोशिश नहीं की। कॉमरेड सुधीर घटना जानकर सबसे कहता है कि अगर उस समय सब मिलकर थूक देते तो वह गुंडा में ऐसी हरकत करने की हिम्मत कम पड़ सकता था।

"यही तो कहते रहे कवि मान बहादुर जीवन भर
पर कितना कम थूक है अब इस देश के कंठ में।"[9]

'जीभ की गधा' नामक कविता में जीभ और दांत प्रतीकात्मक है। दांतों के डर से जीभ यहां चुप नहीं रहता। यहां धमकानेवाले दांतों को जीभ निडर होकर उत्तर देते दिखाई देते है। ताकतवर हमेशा निर्बल व्यक्ति को दबोचने की कोशिश करेगा। लेकिन एक विद्रोहात्मा को कराना उनके बस की बात नहीं होती। जब सारे दुनिया अन्याय देखकर मुंह फेरना सीखोगे तब भी विद्रोही व्यक्ति असमानताओं पर सवाल पूछना बंद नहीं करेगा। विद्रोही व्यक्ति अपने अधिकारों से वंचित जनवर्ग को उनके अधिकारों के लिए लड़ने के लिए प्रेरित करते हैं, निर्बल से उसकी चुप्पी तोड़ने का आह्वान करते हैं। अपना पक्ष मजबूत होने के कारण निडर होकर अपने हक केलिए लड़ने के लिए वह निर्बलों से कहते रहते हैं।

"अब कंठ खोल गाने का दिन है
अब धूप में देह तपाने का दिन है
उठो बांधो हाथ में हाथ
और घेर lo धरती।"[10]

'खुली मुट्ठी' नामक कविता में दो निर्बल व्यक्ति विद्रोही बनने का चित्र खींचा गया है। कविता में एक नौजवान दो मजदूरों के साइकिलें बर्बाद करते हैं। साइकिल के बिना काम पर जाना उन दोनों के लिए मुश्किल थी। वो दोनों उस अन्याय के खिलाफ हड़ताल करने के चित्र कवि ने खींचा है। यह कविता निर्बल को निस्सारता से देखने वाले संपन्न वर्ग के पर्दाफाश करते हैं।

"जिनका जीवन साल से नहीं दिन से नापा
जाता है
वे असंगठित मजदूर थे खुली हुई मुट्ठी–
देश खड़ा हो रहा था।"[11]

मूल्य विघटन

सामाजिक मूल्यों का क्रमिक विघटन चिंता का विषय है। एक दूसरे के सुख दुख में काम आना तथा मानव कल्याण के इच्छुक रहना आदि मानवीय मूल्यों का सीख है। मानवीय मूल्यों का ह्रास होने पर समाज के लोग आपस में लड़ेंगे- झगड़ेंगें, लोग स्वार्थ बनेंगे और इससे समाज कमजोर होगा।

बुजुर्ग के आदर करने केलिए हमारी संस्कृति में बहुत सारे रीति रिवाज है। आज भी लोग इन रीति रिवाजों का पालन करते हैं। मगर आजकल लोग इन रीति-रिवाजों का पालन दूसरों को दिखाने केलिए करते हैं। उन आचारों के पीछे छिपा हुआ अर्थ और उसके महत्व से ज़्यादातर लोग अंजान है।'क्रिया' नामक कविता में मात्र रीति रिवाज के पालन करने हेतु अंतिम क्रिया करनेवाले लोगों को दर्शाया गया है। लोग आजकल दूसरों के अच्छाइयों को नज़रअंदाज़ करते है। दूसरों की बुराई को बढ़ा-चढ़ाकर अन्यों के सामने पेश करते है। चोरी करनेवाले हर इंसान बुरा नहीं होता, कभी उसके परिस्थितियाँ उसे चोर बनाता है। लेकिन लोगों के सामने चोर, चोर होता है। लोग उसकी हालातों को समझने की कोशिश नहीं करेंगे। उसे घृणा से देखेंगे और हाशियेकृत करेंगे

" वह रंगे हाथ पकड़ा गया था मूर्ति चुराते
दुबला पतला साँवला लड़का
जिसने एक बार आटे की भारी झोला
मेरे हाथ से ले घर तक पहुँचाया था।"[12]

'बारात दरवाजे लगी' नामक कविता में लड़केवालों का खमंड और लड़कीवालों की निस्सहायता दिखाई गई है। स्त्री की आदर और मर्यादा करना हमारे संस्कृति है। मगर पुरुष केंद्रित समाज में ये बातें सिर्फ बात बनकर रह जाते है।

'एक भक्त का संवाद' आस्था से जुड़े हुए खोखलापन को व्यक्त करने वाली कविता है। हम कहते है कि सब भगवान की देन है। फिर मंदिर में दान देकर अपना नाम मंदिर के दीवार में लिखवाते है। यहां कवि भगवान की 'देन' को अपना नाम देकर वापस मंदिर में 'दान' के रूप में देनेवाले रीति की मजाक उठाते हैं।

"यह कैसी भक्ति है प्रभु, कैसा विनय
तुम्हारे ही दान को देकर दानी बन रहे है
माया के दास"[13]

सरकार

हमारा राज्य निरंतर बदलती हुई सरकारों द्वारा प्रशासित होते हैं। हर नई सरकार कुछ व्यक्तियों का समूह होती है जो राजनीतिक फैसले लेती है या उनपर नियंत्रण रखती है। जब यह शासक वर्ग अपने फायदे के लिए जनता को अनदेखा करता है तब सारा लोकतांत्रिक व्यवस्था का जड़ हिलते हैं। शासक वर्ग चुनाव के समय जनता से मुस्कुराकर मिलते हैं, गले मिलते है लेकिन चुनाव के बाद जनता से सिर फेर लेता है।

"'काम करता था पैसा पाता था मर गया मर गया...चलो

साफ करो भीड़, जल्दी करो जल्दी, आ रहे होंगे सुप्रीमो।'"[14]

जिनके पास धन और अधिकार होते है वह गुना कर के आसानी से कानून को थोका देते है। मगर चुनाव में जन उसे हराते है। 'घर और घूर' नामक कविता भ्रष्टित नेताओं के लिए लिखी गई चेतावनी है। लेकिन सच बात तो यह है कि धनी व्यक्ति बार बार हारने पर भी संघर्षरत रहते है।

"इन करोड़पति सांसदों से कैसे पार पाऊंगा भला
चाहे मेरे पक्ष में खड़े हो लाखों गरीब फिर भी ये पैसा है जो

जीतेगा और हम हारेंगे
फिर भी लड़ेंगे हर तरह से लड़ेंगे।"[15]

'एक कला वादी प्रस्ताव' नामक कविता में कवि कहते है कोई भी सरकार बहुत अच्छी नहीं होती इसलिए बहुत अच्छा लेखक किसी को पसंद नहीं आता। लेखक जब खुलकर लिखते है तब बहुत सारे पाठक उससे प्रभावित हो जाते है। इसलिए हर सरकार अपने खिलाफ लिखने वाले लेखकों को ठोकते है।

निष्कर्ष

निर्बल किंतु संघर्षशील लोगों की उन्नमन के लिए अरुण कमल की कलम निरंतर चलती रहती है। उनकी हर एक कविता पाठक को सोचने के लिए विवश करती है। 'मैं वो शंख महा शंख' की कविताओं में अनावश्यक अलंकार या भाषा का प्रयोग नहीं है। जो कुछ भी कवि ने लिखा है, वह अपने आप में संपूर्ण है। जैसे उनकी 'पीछे से' कविता में उन्होंने कहा है :

"कितना सुंदर है संसार दिन के दो बज
मनोहर शांत
और यह सब मैं देख रहा हूं
गुलेल के पीछे से।"[16]

वह इस संसार को अपनी पैनी दृष्टि से देखते है। कवि केलिए दुनिया की तमाम चमक–दमक और रंग से भरी तस्वीरों से अधिक महत्वपूर्ण 'निगेटिव फोटो' सी तस्वीर है। क्योंकि उन 'नेगेटिवेस' में दुनिया को खूबसूरत बनानेवाले सपनों और संघर्षों का उम्मीद तथा आकांक्षा से भरा एक हरा–भरा संसार है। नवसाम्राज्यवादी समय में पीछे छूटते जा रहे लोगों

और आदर्शों तथा परंपराओं को अपनी कविताओं में आवाज़ देते हुए नजर आता है कवि।

हर रात हर चीज से डरता हुआ और सुनसान घर में अकेले बचे रह जाने की नियति से बचा लेने की गुहार करता हुआ निर्बल के साथ साथ अन्यायों के खिलाफ आवाज़ उड़ाने में निर्बल को प्रेरित करनेवाले संघर्षरत विद्रोही भी 'मैं वो शंख महा शंख' के कविताओं में है। निर्बल जीवन की निस्सारता, आर्थिक असमानता, अकेलापन, अभावग्रस्त जीवन, झूठे राजनीति, धार्मिक खोखलापन ऐसे अनगिनत समस्याओं की ओर अरुण कमल की कविता पाठकों को ले चलते है।

"क्या तुम जानते हो कि जब तुम पढ़ रहे थे
तब तुम्हारे सटे कमरे में खून हो रहा था रात?"[17]

जीवन कुछ लोगों के साथ अनुचित है। जन्म से लेकर मृत्यु तक असमानताओं से भरा लोक में जीने वाले जन वर्ग की याद दिलाने वाली कविताओं से भरा है 'मैं वो शंख महा शंख'।

संदर्भ ग्रंथसूची

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2. मैं वो शंख महा शंख,अरुण कमल, पृ:30
3. मैं वो शंख महा शंख, अरुण कमल, पृ:13
4. मैं वो शंख महा शंख, अरुण कमल, पृ:14
5. मैं वो शंख महा शंख, अरुण कमल, पृ:56
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17. मैं वो शंख महा शंख, अरुण कमल, पृ: 77

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साठोत्तरी कहानियों में चित्रित दाम्पत्य जीवन में पति का स्वरूप

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विवाह समाज व्यवस्था का एक अत्यंत आवश्यक अंग है। विभिन्न प्रकार के परंपरागत रस्मों तथा विश्वासों के प्रतिमान विवाह-पद्धति के साथ जुडे हुए हैं। राधाकृष्णन के मतानुसार, "विवाह एक परिपाटी ही नहीं बल्कि मानव-समाज का एक अंतनिर्हित लक्षण है।वह प्रकृति के जैविकीय प्रयोजनों तथा मनुष्य के सामाजिक प्रयोजनों के बीच एक समायोजन है।"(1) विवाह का संबन्ध एक बहुत घनिष्ठ संबन्ध है। विवाहित जोडे को सदा एक दूसरे के साथ रहना तथा एक दूसरे केलिए जीना है। दाम्पत्य जीवन की सफलता केलिए पति-पत्नी के बीच प्रेम, संयम, सेवा, उदारता की भावना होना आवश्यक है। प्राचीन काल से ही पुरुष को ही समाज और परिवार में उच्च स्थान दिया गया और आज भी यह परंपरा चली आ रही है। पुरुष ही घर का मालिक है। घर के मुखिया होने के कारण घर के सभी कार्यों का निर्वाह पुरुष को ही संभालना पडता है। शादी के बाद पुरुष पति बन जाता है।

पत्नी घर की देवी है तो पति घर का देवता है,घर का स्वामी है। स्वामी होने के नाते पति पर पूरे परिवार का दायित्त्व रहता है। उसके आचरण एवं व्यवहार का परिवार पर बहुत गहरा एवं दूरगामी प्रभाव पडता है। अतएवं पति को चरित्रवान विवेक शील, सहनशील, धैर्यवान एवं सहृदय होना चाहिए। उसके आचरण एवं व्यवहार का परिवार पर बहुत गहरा एवं दूरगामी प्रभाव पडता है। पति घर के मुखिया है।पति के विचार, चिंतन एवं चरित्र का प्रभाव पूरे परिवार पर पडता है। पुरुष को अपने परिश्रम, कर्तव्य से कभी पीछे नहीं हटना चाहिए। घर की कर्ताधर्ता पुरुष है। यदि पुरुष अपने कर्तव्य अच्छी तरह न निभाया तो दाम्पत्य जीवन में दरार पड जाने की संभावना है। पति घर का दायित्व अच्छी तरह निभाया तो पत्नी के मन में पति के प्रति प्रेम की भावना बढ जाती है। ममता कालिया की 'काली साडी', स्नेह ठाकुर की

'एहसास' आदि कहानियों में इस तरह का संदर्भ देखने को मिलता है।

पुरुष शारीरिक सुख मात्र ध्यान में रखकर दाम्पत्य जीवन में प्रवेश में करना नहीं चाहिए। यदि पुरुष केवल काम की भावना मन में रखते हुए दाम्पत्य जीवन में प्रवेश कर लिया तो दाम्पत्य कभी भी सुखमय न बन पाता। भौतिक सुख को प्रधानता देनेवाले पति भंवर की तरह एक फूल से दूसरे फूल की ओर मंडराता रहता है। वेद राही की कहानी 'अपने अंदर की अदालत' में नायक पत्नी शीला में सारी रौनक होने पर भी अन्य नारी की ओर आकर्षित हो जाता है। प्रेमिका घर बुलाने पर वह पहले न जाने का निर्णय लेता। लेकिन समय आने पर उसमें आए बदलाव के बारें लेखक का कहना है कि, "मन ही मन 'न,न' करते हुए मैं पौने पाँच बजे कार में बैठा और गाँधीनगर की तरफ चल पडा।"(2) आर्थिक हितों अथवा शारीरिक सुखों के प्रलोभन में आने पर दाम्पत्य सार्थक और शांतिमय नहीं रह जाता है। महीपसिंह की 'गंध', मेहरुन्नीस परवेज की 'शनाख्त' आदि कहानियों में इस तरह का संदर्भ देखने को मिलता है।पति में त्याग और बलिदान, प्रेम और करुणा, मानवीय सद्भाव की भावना है तो ही पत्नी के साथ उनका दाम्पत्य संबंध स्थिर आनंद प्रदान हो जाता है।

विश्वासदाम्पत्य जीवन का आधारभूत तत्व है। शक ऐसी प्रवृत्ति है, जिसका कोई इलाज नहीं है। जब तक यह बना रहता है तब तक पारस्परिक कटुता भी बनी रहती। एक घिनौना शक जीवन को मैला कर देता है। दाम्पत्य जीवन में प्रवेश करने के बाद पति में पत्नी के प्रति विश्वास की भावना होना आवश्यक है। इसके छीजते ही घर परिवार की खुशियाँ भी छीजने लगती है और एक दिन यह दशा हो जाती है कि परिवार बिखर जाता है। मेहरून्निसा परवेज की 'टोना', ममता कालिया की 'इरादा' आदि कहानियों में इस तरह का संदर्भ देखने को मिलता है। विश्वास के बिना दाम्पत्य जीवन सुखमय नहीं होता।

पुरुष के दंभपूर्ण व्यवहारों के कारण बोझिल बने हुए दाम्पत्य का चित्रण साठोत्तरी कहानियों में देखा जा सकता है। मनुष्य की बुद्धि ही उसके इस अहं को जन्म देती है। अपनी बुद्धि और शक्ति के बल पर वह भोक्ता बन जाता है और बाकी सभी को भोग्य बन देता है।इस तरह की मानसिकता वाला पति पत्नी पर अपना पूर्ण अधिकार रखना चाहता है। उसका पौरूष और अहं उसे हर पल, हर क्षण उकसाता रहता है। परन्तु यह अहं की प्रवृत्ति प्राय: दाम्पत्य जीवन में अवसाद की भावनाओं को ही जन्म देने का कार्य़ करती हैं। मोहन राकेश की 'एक और जिन्दगी' शीर्षक कहानी में इस तरह का एक संदर्भ देखने को मिलता है। इस कहानी में बीना और प्रकाश के बीच अहं का टकराव हो जाता है। अहं का टकराव का परिणाम तलाक की तरह निकलता है। दाम्पत्य संबन्धों में आए बदलाव देखकर लेखक का कहना है कि, "पति-पत्नी के अहं के टकराव के कारणब्याह के साथ जो सूत्र जुडना चाहिए था वह जुड नहीं सका था।"(3) दीप्ति खंडेलवाल की 'संधिपत्र', मेहरुन्निसा परवेज की 'अयोध्या से वापसी' आदि कहानियों में इस तरह का संदर्भ देखने को मिलता है। आधुनिक जमाने में इस तरह की मानसिकतावाले पुरूषों की संख्या बढ रही है। इसके कारण दाम्पत्य जीवन में दरार पड रहे हैं। पति और पत्नी दोनों के दो

अलग व्यक्तित्व होते हैं जिसमें कुछ बातें एक दूसरे के अनुकूल तो कुछ एक दूसरे के प्रतिकूल भी होते हैं। जीवन को सुंदर ढंग से चलाने केलिए पति को न पसंद की बातों को भी जीवन साथी के अनुकूल बनाना पडता है। ऐसा कर दिया तो उसका दाम्पत्य जीवन सफल हो जाता है।

संसार में धन का बहुत महत्व है। जीवन निर्वाह केलिए धन जरूरी है। जीवन जीने केलिए जिन साधनों की जरूरत होती है, उनकी प्राप्ति अर्थ के द्वारा ही होती है। सुखमय पारिवारिक जीवन केलिए भिन्न-भिन्न आयामों के साथ अर्थ भी महत्वपूर्ण आसाम है। घर की सभी जरूरतों की पूर्ति केलिए धन की आवश्यकता है। अर्थ को समस्त संबन्धों का केन्द्रबिन्दु माना जाता है। आज सहूलियत अधिक चाहिए। इच्छाएँ भी महँगाई की तरह बढ गयी है और जब पति पत्नी की इच्छाएँ पूरी नहीं कर पाती तो घर में झगडे तथा तनाव शुरू होते हैं। ऐसी स्थिति में पति-पत्नी तने-तने रहते और संबन्धों की मधुरता नष्ट होने लगती है। मन्नू भंडारी की 'शायद', मोहन राकेश की 'सुहागिन' आदि कहानियों में इस तरह का संदर्भ देखने को मिलता है। दाम्पत्य जीवन को सफलतापूर्वक आगे बढाने केलिए अर्थ की जरूरत है। अर्थ मानव जीवन का एक महत्वपूर्ण अंग बन गया है।

आधुनिक जमाने में पति और पत्नी में एक दूसरे के प्रति त्याग सहिष्णुता मिटती जा रही है। पति को पत्नी का भरण एवं रक्षण करना चाहिए। आज के भौतिकवादी युग में अधिकतर पुरुष दाम्पत्य को इन्द्रिय-तृप्ति, भोग-विलास एवं मौज-मस्ति का साधन मान लिया है और दाम्पत्य जीवन के मूल उद्देश्य से भटक गए हैं।जब तक दम्पतियों का मिलन आध्यात्मिक मिलन में परिणत नहीं हो जाता, दाम्पत्य जीवन की सफलता दुर्लभ है।

सन्दर्भ ग्रन्थ सूची

1 डॉ साधना अग्रवाल, वर्तमान हिन्दी महिला कथा लेखन और दाम्पत्य जीवनपृ.8

2 वेद राही, अपने अंदर की अदालत, पृ.231

3 मोहन राकेश, एक और जिन्दगी, पृ.91

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'ब्याहता' में अभिव्यक्त नारी मन का अंतरद्वन्द्व

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हिन्दी के समकालीन लेखिकाओं में डॉ. प्रेमा खुल्लर सशक्त हस्ताक्षर हैं। वे बचपन से कविकर्म में लीन थी। उनकी आरंभिक कविताएँ विभिन्न पत्र-पत्रिकाओं में प्रकाशित हैं। आकाशवाणी तथा दूरदर्शन के विविध केन्द्रों में उनकी काव्य-गोष्ठियाँ प्रस्तुत हैं। उनकी प्रसिद्ध प्रकाशित कृतियाँ राह बना लूँगी, अंकित कर दूँ, शब्दों के दायरे (काव्य-संग्रह), छटपटाहट, ब्याहता, तलाश (कहानी-संग्रह), मैं सोचती हूँ (चिन्तन), श्री महाभागवत उपपुराण (अनुवाद) आदि हैं।

एक परिवार को आगे बढ़ाने में स्त्री का महत्वपूर्ण योगदान है। समकालीन माहौल में उसे सुदूर ले जाने के लिए नारी निरंतर प्रयत्नशील है। वह हमेशा चिंतनशील रहती है। वे सदैव सक्रिय हैं। वे अपनी 'मल्टी टैस्किंग स्किल' का सर्वथा उपयोग करती हैं। इससे वे परिवार एवं समाज में जीत हासिल करती है। डॉ. प्रेमा खुल्लर की कहानियाँ पारिवारिक संबंधों की हैं। कमलेश्वर जी की राय में, "प्रेमा खुल्लर की कहानियों में खास तौर पर पारिवारिक सदस्यों के बीच संबंधों की कई बारीक भावनात्मकता की परतें खुलती है। हर परिवार में सभी सदस्यों का अपना अस्तित्व होता है। चाहे वह सास, बहू, ननद, देवर हो अथवा बुजुर्ग दादा-दादी"१ इनमें स्त्री केन्द्र में होने के साथ-साथ अपनी अस्तित्व तथा अभिमान को सदा कायम रखने की कोशिश करती रहती है। 'ब्याहता' में नारी की भावनात्मकता एवं द्वंद्वात्मकता द्रष्टव्य है।

'ब्याहता' की जात्यानी पति पौरूष एवं बच्चों के साथ ख़ुशी से जी रही थी। एक बड़े परिवार का सभी दायित्व उनके कंधे पर थी। फिर भी उसने उसे संभाला। उसकी बेटी मुस्कान की शादी जयंत नामक लड़के से होती है। जयंत से ज़्यादा पैसे वह लाती थी। पति के अहंभाव के कारण पारिवारिक जीवन में विघटन आ

जाती है। जात्यानी अपनी बेटी की ज़िन्दगी बर्बाद होती देखकर मानसिक रूप से बिखरती है। जयंत तो बहुत लोभी भी था। वह नारी को केवल भोग्या समझता था। झूठा अहंभाव तथा कर्तव्यों से दूर भागना सदैव वह बरक़रार रखता था। मुस्कान का शोषण करना उसका काम था। प्रेमा जी यों लिखती है, "नारी आज भी हर तरह से हर रूपों में शोषित की जा रही है, बस यह शोषण का रूप अलग है। उसे स्वतंत्रता दी गयी है,पर स्वतंत्रता की बागड़ोर कहीं ओर है। २ इस प्रकार वह तनाव एवं अन्तर्द्वन्द्व से तड़पती है। कर्तव्यनिष्ठ मुस्कान ने अपनी ज़िम्मेदारियाँ निभायी। जयंत ने उसकी नौकरी छुडवा दी और वह शराब की नशे में घर आने लगा। मुस्कान पूरी तरह मानसिक अन्तर्द्वन्द्व में पड़ गयी। अपने बच्चों का बचपन बिगड़ता देखकर वह और भी त्रस्त होने लगी। वह स्कूल में नौकरी करने लगी। लेकिन जयंत वहाँ भी हंगामा खड़ा कर दी। मुस्कान ने स्कूल छोड़ दी। जयंत की हरकतें बढ़ता जाता है। वह पूरी तरह बिखर चुकी थी। वह घर छोड़कर जात्यानी के पास गयी। मुस्कान में तनाव बढ़ती गयी। प्रेमा जी के शब्दों में, "मुस्कान अपनी ज़िन्दगी के बिखराव को खूब अच्छे से समझ रही थी। जयंत के बिना जीना तो वह नहीं चाहती थी पर उसके आतंग से वह इतनी त्रस्त हो गयी थी कि उसकी सूरत भी देखने की उसकी इच्छा नहीं होती। ३ उनके दो बच्चों के प्रति भी जयंत उपेक्षा से देखता था। बच्चे उससे बहुत प्यार करते थे। लेकिन सारी ज़िम्मेदारियाँ मुस्कान को ही निबाहनी थी। वह जीवन से घबरा गयी। परिस्थितियों से जूझना वह जानती थी। लेकिन अकेले उसका सामना करना डरती थी। प्रेमा जी लिखती है,"मुस्कान के लिए ज़िन्दगी जीना नहीं विवशता बनकर रह गयी थी। एक तरफ़ नौकरी, दूसरी तरफ़ घर परिवार व बच्चों की परवरिश, तीसरी तरफ़ उलझन देने वाला पति व समाज"४ जयंत की मारपीट को बढ़ता देखकर मुस्कान अदालत गयी। कोर्ट ने बीबी-बच्चों के प्रतिमाह खर्ची के लिए पैसे देने का ऑर्डर दे दी। जयंत से पैसा लेकर मुस्कान खुश न थी। जयंत दुबई चला गया और एक रकम मुस्कान के नाम भेजता गया। अंत में उनमें बदलाव आता है और वह अपने बीवी बच्चों को देखने आता है। प्रस्तुत कहानी में नारी का दर्द है, उनकी विवशता, तड़प एवं द्वन्द्व है। श्री शुकदेव सिंह लिखते हैं, "ब्याहता संग्रह की कहानियाँ एक स्त्री के द्वारा लिखी गयी हैं और प्रायः स्त्री के विषय में लिखी गयी हैं" ४ वास्तव में यह कहानी नारी मन के विभिन्न रूपों को प्रस्तुत करते हैं। नारी

हमेशा जीवन को अपनी परिस्थितियों के अनुकूल लाने की कोशिश करती रहती हैं। इस प्रयत्न में उसे बाहरी एवं भीतरी तनाव का सामना करना पड़ता है। फिर भी उसे झेलकर वह आगे बढ़ती है। जब कभी अन्तर्द्वन्द्व का शिकार बनती है, तब उसका सामना करके वह आगे की ओर चल जाती है। इस कहानी की मुस्कान भी ऐसी एक स्त्री है, जो मुश्किलों में भी मुस्कान के साथ जीना सीखती है।

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