# VIJAYA COLLEGE

**R V ROAD, BASAVANAGUDI, BANGALORE – 560 004**

# RESEARCH BULLETIN

# 2016-17

# Vijaya College

RV Road, Basavanagudi, Bangalore-560004

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# Message from the Dean

A long cherished dream of teams of Research oriented staff and students of the Vijaya College in the R. V. Road campus of the BHSHES, is realized with the publication of Research bulletin from the year 2017-18.

The bulletin serves as an outlet for the Research activities at both undergraduate and post-graduate levels in the College.

There is no doubt that the bulletin will serve as a fillip to augment the academic atmosphere in the College.

Hearty congratulations to Staff, Students and the Management.

Dr. A. K. ATRE
Joint Secretary, BHSHES
and
Dean, Vijaya College

# Message from the Principal

***"A desire can change nothing, a decision can change something but a determination can change everything".***

Our college has the privilege of having a healthy, harmonious ambience and rich values which have played pivotal role in shaping the future of innumerable students. Our mission is to transform students into Scientists, Professionals, Industrialists, and Business Tycoons. This is my firm belief that the rich values and traditions imbibed here would carry them to greater heights.

Empowerment of students for their all round development through education is our cherished motto. Our college is one of the prestigious and leading colleges in Bangalore and promotes sustained quality education to make the students courageous and competent. The college conducts a range of events to impart life skills and global competencies.

With proud legacy of 72 years, the college has excelled in every field. Many students have registered their presence in various fields at national and international levels.

I feel honoured and privileged to announce the launch of research activities in the form of a research Bulletin. This is a venture to promote an intellectual culture and Research temperament in the college

The Research Bulletin with its vastness covers fields of pure and applied science, commerce and management studies. This Research Bulletin will serve as a platform to promote research, Innovative thinking among students and faculty members.

I strongly believe that our college has great potential to becoming a leading research centre in the field of education.

Research Bulletin Volume-1 is the great effort of the editorial board, staff and students of the college. The Research Bulletin has fulfilled its responsibility in helping the students and staff of the college to bring out their talents and showcase their several achievements in field of research. On this occasion I congratulate and express my heartfelt thanks to the Editorial Board,committee membersand students for their efforts in ensuring that a high quality Research Bulletin is delivered.

Mangala. N

Principal,
Vijaya College,
R. V. Road, Basavanagudi,
Bengaluru- 560 004.

# Message from the Co-ordinator

***If we knew what it was we were doing, it would not be called research, would it?*** *Albert Einstein*

***No one undertakes research in physics with the intention of winning a prize. It is the joy of discovering something no one knew before.*** *Stephen Hawking*

Research involves innovation. It requires constant effort, interest and encouragement.

It is a matter of great pride and pleasure that Vijaya College is launching a Research Bulletin for its research activities. This will be an important platform not only to exchange ideas but also explore newer vistas of research among the community of people interested in research at Vijaya College.

This effort is to encourage Vijaya College teachers and students to take advantage of the opportunity to avail this platform to showcase their research work and ideas. I am sure that this will help our college in achieving new heights in inter-disciplinary research. Please do give us your feedback and share your ideas for betterment of the bulletin in future issues. I wish everyone all the best.

Dr. A. S. Govind
Associate prof. In Physics
Research Co-ordinator
Vijaya College

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# ACTIVITIES OF PG DEPARTMENTS

# EFFECT OF Sr DOPING ON STRUCTURAL, ELECTRICAL, MAGNETIC AND THERMAL STUDIES ON $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) MANGANITES

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**Abstract:**

In this work, the series of $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) manganites has been studied on structural, electrical, magnetic and thermoelectric power properties. The samples were prepared by conventional solid-state reaction. XRD results show that the samples are crystallized in orthorhombic crystal structure with Pbnm space group. The observed grain size is decreasing with increase the concentration of Sr. Resistivity of the samples are found to exhibits insulating behaviour down to the low temperature. The magnetization results reveal that the AFM nature is observed in ZFC conditions, while FM behaviour is observed when the field is applied. The thermoelectric power (S) of the x=0.5 and 0.4 samples is negative at high temperature range. The samples with x=0.4 doped samples the measured S exhibits a crossover from positive to negative values. At x=0.3 and 0.2 show the positive S value for entire temperature.

***Keywords:*** Manganites, Rietveld refinement, Four probe method, Magnetization, Seebeck coefficient.

## Introduction:

The perovskite structure manganites generally represented by $RE_{1-x}AE_xMnO_3$ (RE=La, Eu, Sm, Gd., and AE=Sr, Ca, etc..) have attracted lot of attraction due to their exhibit interesting properties such as colossal magnetoresistance (*CMR*), metal–insulator transition (*MIT*), magnetocaloric effect (*MCE*) and colossal thermoelectric power (*CTEP*) [1–4]. These interesting properties are observed due to strong interconnection between the spin, charge and orbital ordering. These are manifested due to the interplay of the $e_g$ electron bandwidth (*W*), lattice disorder and the A site–cation disorder [5-6]. Correlation between these factors exhibits a significant change in magnetic transitions such as transformation from paramagnetic (*PM*) to ferromagnetic (*FM*) to antiferromagnetic (*AFM*) transition. The coexistence and competition between the double exchange (*DE*) and superexchange (*SE*) interaction is related ferromagnetic and antiferromagnetic nature in manganites respectively [7].

Among the rare earth manganites $Eu_{1-x}Sr_xMnO_3$ (*ESMO*) are interesting as they exhibit a nonmagnetic ground state (J=0) due to smaller ionic radii of $Eu^{3+}$ [8]. There are several reports on electrical and magnetic properties of these compounds and it is observed that these manganites do not show any metal to insulator transition [9] and also the electrical resistivity decreases with increase in Sr content. The metal-insulator (*MI*) transition has been observed in $Eu_{0.6}Sr_{0.4}MnO_3$ compound with application of external magnetic

**Note: This work has been published in journal of alloys and compounds.**
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field. Huge electrical resistivity and colossal magnetoresistance have been observed in the *AFM* region and these properties are explained by the magnetic two phase states [10]. The pristine compound ($EuMnO_3$) exhibits weak *FM* and *AFM* transition, substitution of Ca and Sr elements enhances the *FM* region. The nature of phase transition depends on the extent of Sr content.

Although, several reports have been presented on electrical and magnetic of $Eu_{1-x}Sr_xMnO_3$ compounds, there are less reports are on thermal properties. To the best of our knowledge, there are no reports on thermoelectric power of $Eu_{1-x}Sr_xMnO_3$ systems. Hence it was evidently desirable to carry out such studies on $Eu_{1-x}Sr_xMnO_3$ (ESMO) system. In this communication, we report the effect of Sr doping on structural, electrical, magnetic and thermoelectric power of $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$).

## 2. Experimental details:

The samples of $Eu_{1-x}Sr_xMnO_3$ (ESMO) ($0.2 \leq x \leq 0.5$) were prepared using standard solid-state reaction method. To ascertain the purity of the samples and to estimate the lattice parameters, X-ray diffraction studies were done on all the samples. The surface morphology was imaged using Scanning Electron Microscopy (*SEM*) attached with Energy Dispersive X-ray (*EDAX*) analyzer. Temperature-dependent electrical resistivity $\rho(T)$ was measured using standard four-probe method. The magnetic properties of the samples were studied using a superconducting quantum interference device (*SQUID*) magnetometer and 9T PPMS based vibrating sample magnetometer. Thermo-electric power ($S$) measurements were performed using differential dc method.

## 3. Results and discussion:

### 3.1 Structural properties:

Fig. 1. shows that the X-ray diffraction (*XRD*) patterns for $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples. The results indicate that the samples are single phased without any trace of impurity phases. The samples are crystallized in the distorted orthorhombic structure with space group Pbnm. The *XRD* data were analyzed using Reitveld refinement method with FullProf program. The lattice parameters, unit cell volume, R factor and goodness of fit were analyzed using Reitveld refinement method. The fitting parameters shows that the theoretical results are in good agreement with measured data.

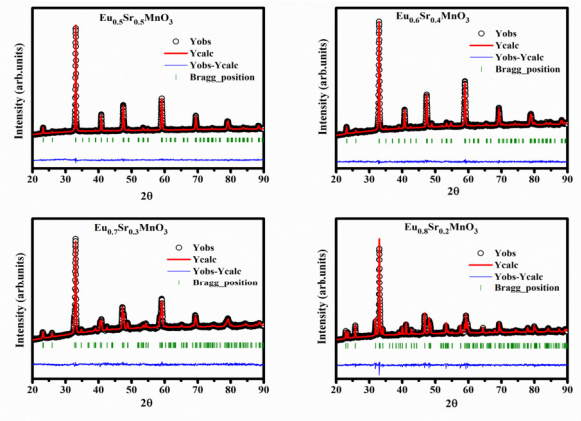


**Figure 1:** XRD pattern for typical compound of $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples. The observed intensities are shown as dots and calculated intensities are shown by solid line. Line at the bottom denotes the difference between the experimental and refined patterns.

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The surface morphologies of $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples are depicted in Fig.2. The grain sizes of samples were calculated from *SEM* results. To verify the stoichiometric deviation from the actual atomic Wt%, the *EDAX* spectrum was taken for different regions of $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$)) samples.

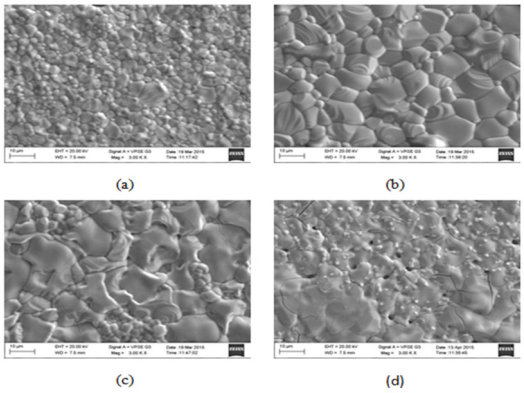


**Figure 2:** SEM images of (a)$Eu_{0.5}Sr_{0.5}MnO_3$ (b)$Eu_{0.6}Sr_{0.4}MnO_3$ (c)$Eu_{0.7}Sr_{0.3}MnO_3$ (d) $Eu_{0.8}Sr_{0.2}MnO_3$.

### 3.2 Electrical transport properties:

The temperature dependent electrical resistivity of the $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples is shown in Fig. 3. It observed that electrical resistivity increases monotonically with decreasing temperature and show insulating behaviour for entire temperature range. Fig. 3 shows that electrical resistivity decreases with increase in Sr content.

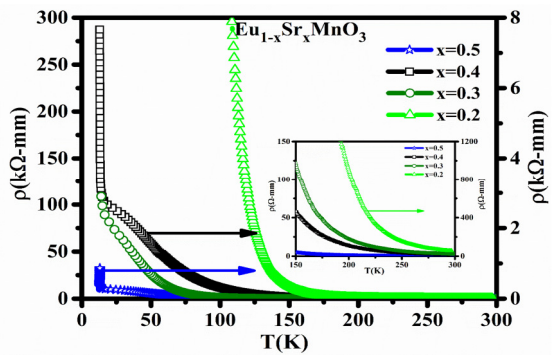


**Figure 3:** Electrical resistivity variation with temperature for $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples.

### 3.3 Magnetic properties:

Fig. 4 depicts the temperature dependent magnetization curves for $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples with applied magnetic field of 100 *Oe* in the temperature range 5–300K. Fig. 4 shows that the magnetization value is increasing when the temperature of the samples is decreased. The Curie temperature ($T_C$) for the samples was estimated by plotting *dM/dT* versus temperature curve as shown in the insets of Fig. 4.

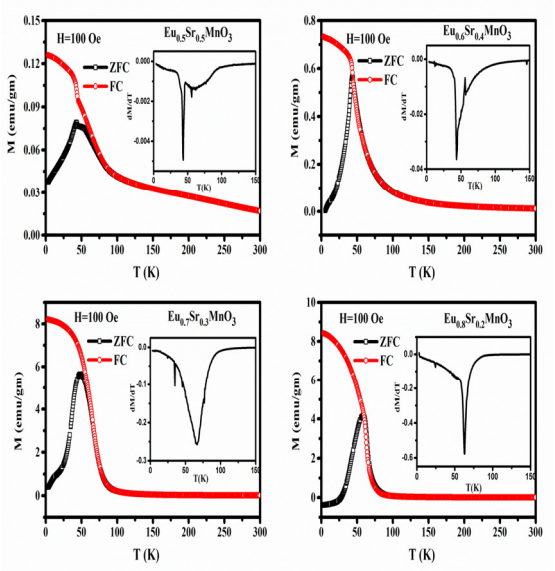


**Figure 4:** Variation of magnetization with temperature under applied magnetic field of 100 *Oe* for $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples. Insets show the *dM/dT* versus *T* curve.

### 3.4 Thermoelectric power (TEP):

Fig. 5 shows that the thermoelectric power (*S*) versus temperature (*T*) plots for the samples $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) in the temperature range 5 – 300K. The value of *S* is increasing with decrease in temperature, which indicates the weakening of metallicity in these compounds. This behaviour is consistent with the electrical resistivity. measurements. It is observed that *S* is decreasing with increase in concentration of Sr.

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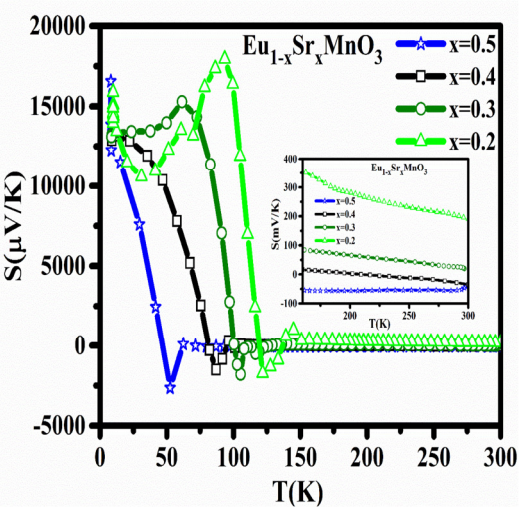


**Figure 5:** Variation of thermoelectric power with temperature of for $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples. Insets show the variation S value at high temperature.

## 4. Conclusions:

A series of $Eu_{1-x}Sr_xMnO_3$ ($0.2 \leq x \leq 0.5$) samples have been prepared using solid state reaction method. The samples show orthorhombic structure with Pbnm space group. A *SEM* result a show the grains size is decreasing with increase x. The insulating behaviour is observes for all the samples. The magnetization results reveal that *AFM* nature is observed in the ZFC condition and applying the magnetic flied which turns to *FM* nature for all the samples. The thermoelectric power value is decreasing with increase the Sr.

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# ORIENTATIONAL ORDER PARAMETER OF TWO CYANO NEMATOGENS BY OPTICAL SPECTROSCOPY

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**Abstract**

The orientational order parameter *S* has been estimated for two cyano nematogens, namely p-hexyloxybenzylidene p-aminobenzonitrile(6O.CN) and p-octyloxybenzylidene p-aminobenzonitrile (8O.CN) from the experimentally obtained refractive index data and density measurements. The orientational order parameter S has been estimated at different temperatures in their nematic phases using different theoretical models. The values obtained have been compared and discussed. Furthermore, the nematic cross over temperatures have also been estimated for these compounds.

**Keywords:** Schiff's base compounds; nematic; orientational order parameter; birefringence; density; crossover temperature.

## Introduction

The degree of ordering of the molecules in liquid crystals distinguishes its physical properties from that of liquids. The anisotropy manifested in the physical properties of liquid crystals is due to the molecular shape and the order existing in the constituent molecules. Most of the applications of liquid crystals rely on their anisotropic physical properties. The applicability of liquid crystals in various fields depends on their response to the external perturbations like temperature, mechanical stress, electric, magnetic fields, etc[1]. Hence, it is very much essential to have a detailed knowledge of the physical properties of liquid crystals. In particular, the orientational order parameter *S* is an essential parameter since several other physical properties of a liquid crystalline material are dependent on the value of *S*. The orientational order parameter of liquid crystal strongly depends on temperature because with the variations in temperature, the existing order is disturbed owing to thermal agitation. There are several experimental methods such as X-ray, NMR, ESR, diamagnetic anisotropy, optical spectroscopy, etc. to study the temperature dependence of orientational order parameter in liquid crystals. Here, we are employing an optical spectroscopy method which is a classical and widely accepted method to study the long-range orientational order in the nematic medium [2]. This method involves the measured refractive indices and/or density data, followed by calculation of polarizabilities employing different models. In addition to the order parameter, density studies also reveal information about the nature of phase transition, pre-transitional effects across different phase transformations and molecular ordering [3].The temperature dependence of the extraordinary and ordinary refractive indices ($n_e$, $n_o$) and its temperature gradient $dn_e/dT$ and $dn_o/dT$ are of great interest. In most of the nematics, $dn_e/dT$ is negative, while $dn_o/dT$ exhibits crossover behavior, i.e., changes sign from negative to positive. The temperature at which this crossover occurs is called the crossover temperature TCO. Liquid crystalline materials with large $dn_o/dT$ at room temperature and large TCO have found large applications in nonlinear optics [4]. In this paper, we report the estimated orientational order parameter and crossover temperatures of two Schiff's base cyano nematogens, namely p-hexyloxybenzylidene p-aminobenzonitrile (6O.CN) and p-octyloxybenzylidene p-aminobenzonitrile (8O.CN) using refractive indices and density measurements.

***Note: This work has been published in the journal "Phase Transitions",Vol.89.,No.5, 514-522, 2016)***

## 2. Theoretical background

The orientational order parameter can be obtained using the equation,

$$S = \frac{\alpha_e - \alpha_o}{\alpha_{\parallel} - \alpha_{\perp}} \qquad (1)$$

where $\alpha_e$ and $\alpha_o$ are the molecular polarizabilities for the extraordinary and ordinary rays respectively, and $\alpha_{\parallel}$ , $\alpha_{\perp}$ are the polarizability components parallel and perpendicular to the long axis of the molecule. The values of $\alpha_e$ and $\alpha_o$ have been calculated from the experimentally obtained refractive index and density data employing theoretical models due to Vuks [5] and Neugebauer[6]. The value of $(\alpha_{\parallel} - \alpha_{\perp})$ has been estimated separately using Haller approximation[7], Lippincott δ-function model[8] and molecular vibration methods[9]. From the calculated values, S has been determined using equation (1). Furthermore, *S* has also been estimated using only the refractive index data employing Vuks scaling factor method and birefringence method proposed by Kuczynski et al.,[10].

## 3. Experimental

The phase sequence exhibited by the compounds as observed from polarizing microscopy and DSC is given as follows:

6O.CN: (Cr) 37.1 °C (Nematic) 95.2 °C (Iso)

8O.CN: (Cr) 63.6 °C (Nematic) 95.8 °C (Iso)

The refractive indices (for λ=5893 Å) and density of the samples were measured at different temperatures in their nematic and isotropic phases. For the measurement of refractive indices, the well-known small-angle hollow prism technique and a modified prism spectrometer were used. Density measurements were carried out employing capillary tube technique. The refractive indices, density and temperature measurements were accurate to ±0.0004, ±0.0001 g/cm$^3$ and ±0.1 °C, respectively.

## 4. Results and discussion

The variation of refractive indices of the samples with temperature is observed. Figure 1 shows the variation of birefringence with reduced temperature ($T/T_C$). The variation of density ($\rho$) and thermal expansion coefficient ($\alpha$= -(1/ρ)(dρ/dT)) with temperature ($T$) in 6O.CN and 8O.CN is shown in Figures 2 and 3, respectively.

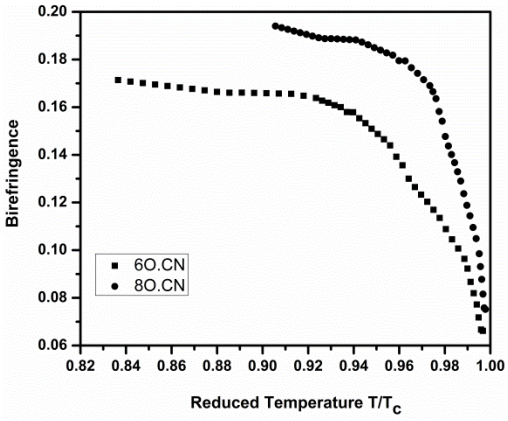


Figure 1: Variation of birefringence with reduced temperature in 6O.CN and 8O.CN.

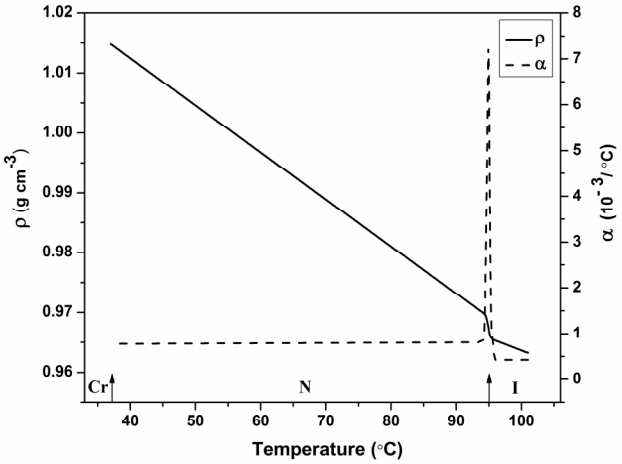


Figure 2: Variation of density ($\rho$) and thermal expansion coefficient ($\alpha$) with temperature in 6O.CN.

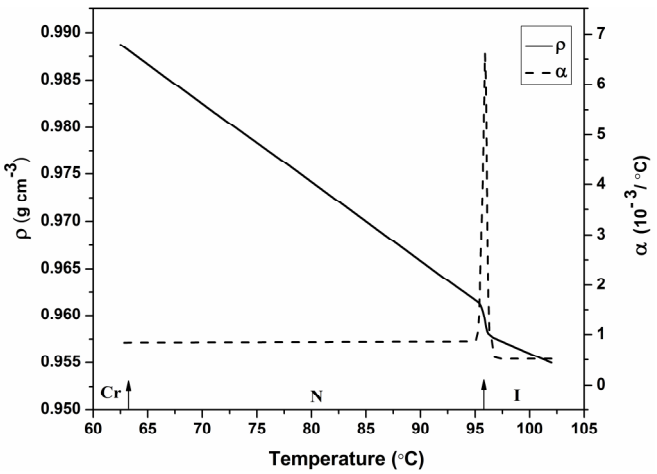


Figure 3: Variation of density ($\rho$) and thermal expansion coefficient ($\alpha$) with temperature in 8O.CN.

The values of order parameter obtained from different methods are shown in Figures 4 and

***Note: This work has been published in the journal "Phase Transitions",Vol.89.,No.5, 514-522, 2016)***

5.The values of order parameter computed using $\alpha_e$ and $\alpha_o$ obtained from Vuks [5] and Neugebauer [6] models and $(\alpha_{||} - \alpha_{\perp})$ obtained using Lippincott δ-function model [8], molecular vibration methods [9] are found to vary slightly in comparison to those estimated using the Haller approximation method [7].

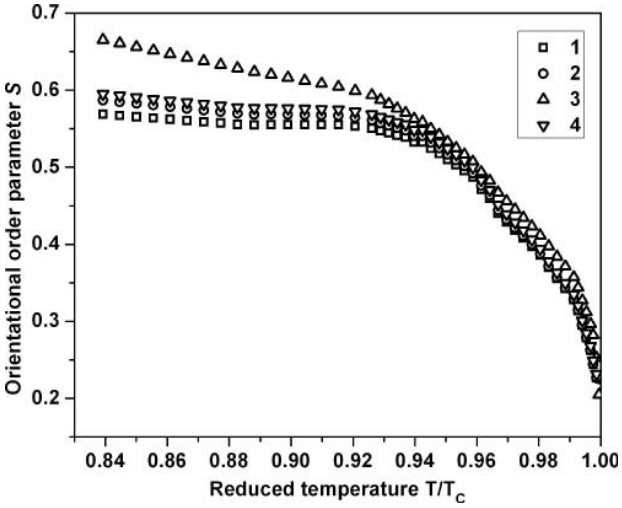


Figure 4: Variation of order parameter with reduced temperature in 6O.CN. S determined: (1) using polarizabilities estimated from Vuks model and polarizability anisotropy determined from Haller method; (2) Vuks scaling factor method; (3) using polarizabilities estimated from Neugebauer model and polarizability anisotropy determined from Haller method; (4) birefringence method.

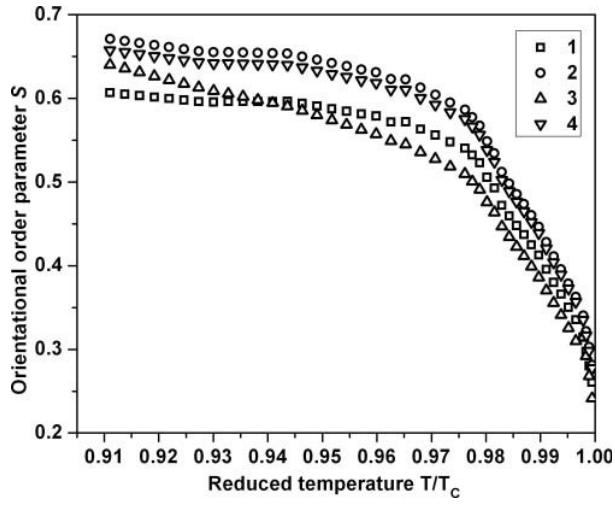


Figure 5: Variation of order parameter with reduced temperature in 8O.CN. S determined: (1) using polarizabilities estimated from Vuks model and polarizability anisotropy determined from Haller method; (2) Vuks scaling factor method; (3) using polarizabilities estimated from Neugebauer model and polarizability anisotropy determined from Haller method; (4) birefringence method.

From the experimental results, we can observe that in both the compounds, the isotropic refractive index ($n_i$) shows a nominal increment with temperature. As the sample reaches the nematic phase (i.e., at the isotropic -nematic transition temperature, $T_C$), the isotropic ray splits up into ordinary ray and extraordinary ray and hence we obtain $n_e$ and $n_o$ correspondingly. Below $T_C$, $n_e$ increases while $n_o$ decreases and both saturate as the nematic phase stabilizes. The birefringence ($\delta n = n_e - n_o$) lies in the range of 0.06-0.17 and 0.07-0.20, respectively, in 6O.CN and 8O.CN (Figure 1).The density graph of these samples (Figures 2 and 3) shows the linear decrease with the increase in temperature in both the nematic and isotropic phases. However, in the vicinity of $T_C$, it decreases steeply before it attains the equilibrium value of the isotropic phase. The distinct density jumps and the thermal expansion coefficient maxima indicate the first-order nature of the Nematic-Isotropic transition. The values of $S$ calculated from different methods are shown in Figures 4 and 5.The order parameter are close to each other near $T_C$ and diverge at temperatures deep in the nematic phase. Further, the values of $S$ estimated using birefringence method agree well with those estimated using Vuks scaling factor method in the entire nematic range. This indicates that the results favor Vuks model rather than Neugebauer model as in other Schiff's base compounds [11,12]. It is to be noted that, Vuks model assumes the local field experienced by the molecule in the liquid crystalline phase to be isotropic, while Neugebauer model assumes the local field to be anisotropic. On the other hand, the birefringence method completely ignores the local field effects and hence is neutral. The values of TCO of both 6O.CN and 8O.CN (97.68K and 247.67K respectively) lie much below their nematic range which indicates that these compounds show a strong light deflection [12].

***Note: This work has been published in the journal "Phase Transitions",Vol.89.,No.5, 514-522, 2016)***

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# SYNTHESIS AND ANTIMICROBIAL ACTIVITY OF NOVEL 5-SUBSTITUTED-*N*-(SUBSTITUTED-*2H*-[1, 3]OXAZINO[6, 5-B]QUINOLIN-3(*4H*)-YL)-3-PHENYL-*1H*-INDOLE-2-CARBOXAMIDES[†]

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**Abstract**

*(E)*-5-Substituted-*N*'-[(1,2-dihydro-substituted-2-oxoquinolin-3-yl)methylene]-3-phenyl-*1H*-indole -2-carbohydrazides **3a-h,** obtained by the reaction of 5-substituted-3-phenyl indole-2-carbohydrazides **1a-b** and 1, 2-dihydro-substituted-2-oxoquinoline-3-carboxaldehydes **2a-d** on further reaction with sodiumborohydride followed by treatment with formaldehyde yielded 5-substituted-*N*'-[(1, 2-dihydro-substituted-2-oxoquinoline-3-yl)methyl]-3-phenyl-*1H*-indole-2-carbohydrazides **4a-h** and 5-substituted-*N*-(substituted-*2H*-[1, 3] oxazino [6, 5-b]quinolin-3(*4H*)-yl)-3-phenyl-*1H*-indole-2-carboxamides **5a-h** respectively. Structures of the all the newly synthesized compounds were confirmed by spectral data. All these compounds have been screened for their antibacterial activity against *Staphylococcus aureus*, *E. coli*, *B. substilus*, antifungal activity against *A. niger* & *C. albicans* and antituberculosis activity against *M. tuberculosis* ($H37R_v$).

## Introduction[1-4]:

Heterocycles bearing nitrogen, sulphur and oxygen atoms in their structure constitute the core structure of a number of biologically interesting compounds. Indole and its derivatives occupied a unique place in the chemistry of nitrogen heterocyclic compounds because of their varied biodynamic properties viz, antiviral, antihepatitis-B virus, antioxidant activity, antituberculosis activity and cyclooxygenase-2 inhibitors. The heterocyclic containing quinoline ring system has attracted the attention of the chemists because of possessing significant biological activities. Many indolo [2, 3-c] isoquinolines reported from our laboratory have been found to possess bactericidal and fungicidal activities. Several 1,3-benzoxazine derivatives reported in the literature were found to possess antireserpine, analgesic, anti-inflammatory, tranquillizing, sedative, bactericidal, bacteriostatic, smooth muscle relaxant, cytotoxicity & antiproliferative activity and spermicidal activities.

[†]Published in
**Indian J. Chem., 55B, 2016, 1511-1519**.

In light of above findings and in continuation of our research work on indoles[5-12],we hereby report the synthesis and antimicrobial activity of some 5-substituted-*N*'-((2-hydroxy-substituted-quinolin-3-yl)methyl)-3-phenyl-*1H*-indole-2-carbohydrazides **4a-h** and 5-substituted-*N*-(substituted-*2H*-[1, 3]oxazino[6, 5-b]quinolin-3(*4H*)-yl)-3-phenyl-*1H*-indole-2-carboxamides **5a-h,** having indole and quinolinooxazine moieties in their structure with the hope getting compound with more potent antimicrobial and antituberculosis activity by making use of **3a-h** as starting materials where in nitrogen atom of $NH_2$ group of 5-substituted-3-phenyl indole-2-carbohydrazide has become the part of oxazine nitrogen of quinolino-1, 3-oxazine system (**Scheme I**).

## Materials and Methods:

The starting materials (**3a-h**) were prepared according reported method[8].

### General procedure for the synthesis of (4a-h)

Sodiumborohydride (0.044mol) was added to a solution of compound **3a-h** (0.001mol) in methanol (10ml) and the mixture stirred for 30 min. at room temperature. The residue separated, on pouring the reaction mixture into ice-cold water was filtered, washed with water, dried and purified by crystallization from dioxane to furnish **4a-h** in a good yield.

**General method for the preparation of (5a-h):**

Compound **4a-h** (0.001mol) and formalin (37%, 1 ml) was refluxed in ethanol (10 ml) for 5 h. The residue obtained after pouring the reaction mixture into ice-cold water was filtered, washed with water, dried and purified by recrystallization to give **5a-h** in a good yield. The compounds **5a**, **5b**, **5e** and **5h** recrystallized from dioxane and compound **5c, 5d, 5f** and **5g** from benzene.

**Antibacterial and antifungal activity:**

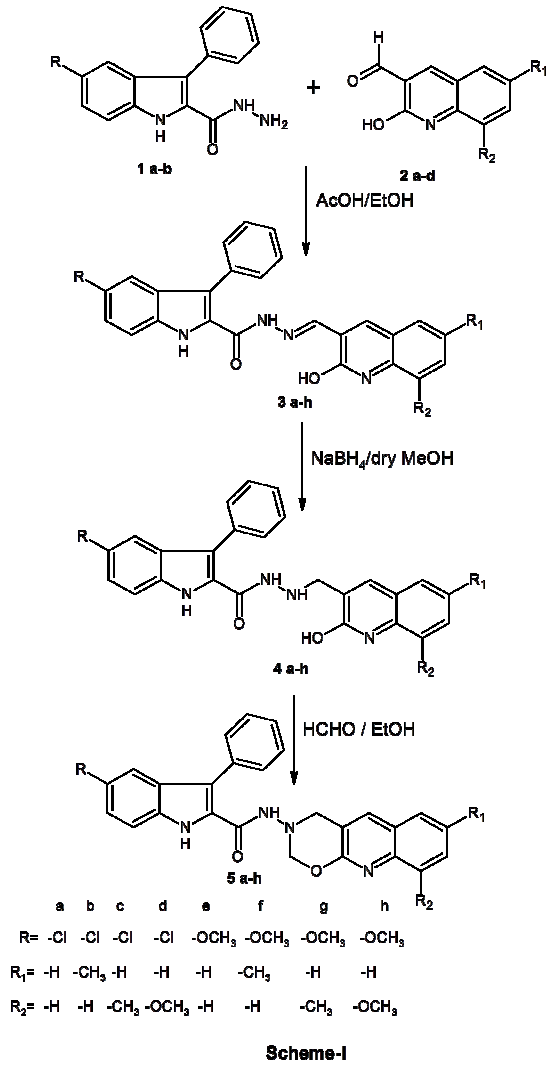
The *in vitro* biological screening of the compounds was undertaken against the bacteria *S. aureus, E.Coli* and *B. subtilus*, fungi *A. niger* and *C. albicans* by cup-plate method[9] using nutrient agar as medium. Then holes of 6 mm diameter were punched carefully using a sterile cork borer and these were filled with test solutions (1000 µg/ml in DMF) and DMF used as control. The plates were incubated at $37^0$C for 24 h in case of antibacterial activity and 72 h in case of antifungal activity. The diameter of the zone of inhibition for all the test compounds was measured and the results were compared with the standard drug Gentamycin for antibacterial activity and Nystatin for antifungal activity at the same concentration (1000 µg/ml in DMF) as that test drugs and tabulated in **Table I**.

**Anti-tuberculosis activity:**

*Invitro* antituberculosis testing was carried out against the human virulent strain *Mycobacterium tuberculosis* ($H37R_v$) by the method[9] of disperse culture technique using Kirchner's medium method containing Tween-80. To sterile Kichner disperse medium (4.5 ml) dispersed in borosilicate test tube (150 x 20 mm), was added 0.5 ml of sterile normal bovine serum, inactivated by heating at $56^0$C for 30 min.

**Results and Discussions:**

The Schiff bases **3a-h** were prepared according to the procedure reported by us and reacted with sodium borohydride in dry methanol afforded **4a-h** in a good yield.




**Scheme-I**

Compound **4a** in its IR spectrum showed absorption bands at 1682 1723, 3062, 3188, 3361 and 3381 $cm^{-1}$ due to C=O/C=O and NH/NH/NH/NH functions respectively. Five singlets and a multiplet, observed at 3.50, 5.68, 10.41, 10.62, 11.05 and 6.90-7.89 δ in its $^1$H NMR spectrum of compound **4a** were due to the two protons of methelene function attached to 3-position of quinoline moiety, four protons of four NH functions and thirteen aromatic protons respectively. Mass spectrum of compound **4a** exhibited molecular ion peak $M^{+\bullet}$ at 442, 444 (68%, 18%) and 255, 257 (100%, 32%, base peak) which corresponds to its molecular weight. All these data proves the formation of compound **4a** from compound **3a**.

Compounds **4a-h** when allowed to react with formalin in ethanol under refluxed conditions furnished **5a-h** in good yield.

The IR spectrum of **5a** exhibited absorption bands at 1180, 1670, 3261 and 3308 $cm^{-1}$ due to C-O-C, C=O and NH/NH functions respectively. In the $^{1}$HNMR (in δ) spectrum of **5a** four protons of two methelene protons of oxazine moiety have resonated as two distinct singlets at 4.25 & 4.68, A multiplet appeared in the region 7.01-7.89 accounts for thirteen aromatic protons. Two distinct singlets observed at 9.95 and 11.05 are due to proton on indole NH and proton of amide function respectively. Mass spectrum **5a** displayed molecular ion peak $M^{+\cdot}$ at 454, 456 (100%, 34%), which is equivalent to its molecular weight and base peak of the compound. These data clearly proves the formation of compound **5a** from **4a**.

**Antibacterial and antifungal activity:**

The results showed that the compounds **4a, 4b, 4d, 5a** and **5b** showed good activity and compounds **4c, 4e, 5c, 5d** and **5g** exhibited moderate activity against *S. aureus* when compared to that of standard drug Gentamycin. Compounds **4a, 4b, 5a, 5c** and **5d** showed good activity and compounds **4d, 4e** and **5b** exhibited moderate activity when compared to that of standard drug Gentamycin against *E.coli*. Compounds **4a, 4b, 4d, 5a** and **5b** showed good activity and compounds **4e,5c**, **5d**, **5e** and **5g** exhibited moderate activity against *B.substilus* when compared to that of standard drug Gentamycin. Compounds **4a, 4b, 5a, 5b** and **5d** showed good activity and compounds **4d, 4f, 4g, 4h, 5c** and **5g** exhibited moderate activity when compared to that of standard drug Nystatin against *A. Niger*. Compounds **4a, 4b, 5a, 5b** and **5d** showed good activity and compounds **4c, 4d, 4e, 4f, 4g, 4h, 5c, 5e** and **5f** exhibited moderate activity when compared to that of standard drug Nystatin against *C. Albicans* (**Table I**).

**Anti-tuberculosis activity:**

The results showed that the compounds **4a**, **4b**, **5a** and **5b** inhibited the growth of mycobacterium at concentration 12.5 μg/ml. Compounds **4c**, **4d**, **4e**, **4g**, **5c**, **5d**, **5e**, **5f** and **5h** exhibited moderate activity when compared to that of standard drug Streptomycin against *M. tuberculosis*. Rest of the compounds tested showed less activity against the *M. tuberculosis*. Under these conditions standard Streptomycin was sensitive at concentration 6.25 mg/ml and control*N*, *N*-dimethylformamide did not show any antituberculosis activity (**Table I**).

**Conclusions:**

The synthesis of the target novel compounds (*E*)-5-substituted-*N*'-[(substituted-2-hydroxy-6-methylquinolin-3-yl) methylene]-3-phenyl-*1H*-indole-2-carbohydrazides **4a-h** and 5-substituted-*N*-(substituted-*2H*-[1,3]oxazino[6,5-b]quinolin-3(*4H*)-yl)-3-phenyl-*1H*-indole-2-carboxamides **5a-h** were achieved according to the steps indicated in **Scheme I**. These reactions are simple, easily carried under normal reaction conditions and these systems are novel and hitherto unknown.

All the newly synthesized compounds **4a-h** and **5a-h** were tested for their antibacterial activity against *S. aureus, E. coli* and *B. substilus* and antifungal activity against *A. niger* and *A. flavous.* Compounds **4a, 4b, 4d, 5a, 5b** and **5d** showed good activity against the above microorganisms tested when compared with those of standards Gentamycin and Nystatin which were used at the same concentration (1000 μg/ml in DMF) as that of test drugs.

All the newly synthesized compounds **4a-h** and **5a-h** were tested for their antituberculosis activity against *M. tuberculosis.* Compounds **4a**, **4b**, **5a** and **5b** showed good activity when compared with standard drug Streptomycin.

**Table I. Antimicrobial activity of newly synthesized compounds 4a-h and 5a-h.**

| Compds | Zone of inhibition in mm* (activity index) | | | | | Antituberculosis activity in MIC (µg / mL) |
|---|---|---|---|---|---|---|
| | Antibacterial activity (1000 µg/mL) | | | Antifungal activity (1000 µg/mL) | | |
| | *S. aureus* | *E. coli* | *B. subtilus* | *A .niger* | *C. albicans* | |
| **4a** | 21 (0.95) | 18 (0.90) | 18 (0.85) | 21 (0.95) | 19 (0.86) | 12.5 |
| **4b** | 19 (0.86) | 19 (0.95) | 18 (0.85) | 20 (0.90) | 18 (0.85) | 12.5 |
| **4c** | 15 (0.68) | 14 (0.70) | 13 (0.61) | 14 (0.63) | 15 (0.71) | 50 |
| **4d** | 19 (0.86) | 15 (0.75) | 18 (0.85) | 15 (0.68) | 16 (0.76) | 25 |
| **4e** | 15 (0.68) | 15 (0.75) | 14 (0.66) | 14 (0.63) | 15 (0.71) | 50 |
| **4f** | 12 (0.54) | 14 (0.70) | 13 (0.61) | 15 (0.68) | 15 (0.71) | 100 |
| **4g** | 14 (0.63) | 14 (0.70) | 13 (0.61) | 15 (0.68) | 16 (0.76) | 50 |
| **4h** | 12 (0.54) | 14 (0.70) | 12 (0.57) | 15 (0.68) | 16 (0.76) | 100 |
| **5a** | 21 (0.95) | 18 (0.90) | 20 (0.95) | 19 (0.86) | 20 (0.95) | 12.5 |
| **5b** | 19 (0.86) | 15 (0.75) | 19 (0.90) | 20 (0.90) | 18 (0.85) | 12.5 |
| **5c** | 15 (0.68) | 18 (0.90) | 14 (0.66) | 16 (0.72) | 16 (0.76) | 25 |
| **5d** | 16 (0.72) | 17 (0.85) | 15 (0.71) | 19 (0.86) | 19 (0.90) | 25 |
| **5e** | 12 (0.54) | 14 (0.70) | 15 (0.71) | 14 (0.63) | 15 (0.71) | 50 |
| **5f** | 12 (0.54) | 12 (0.60) | 13 (0.61) | 14 (0.63) | 16 (0.76) | 50 |
| **5g** | 14 (0.63) | 12 (0.60) | 15 (0.71) | 15 (0.68) | 14 (0.66) | 100 |
| **5h** | 13 (0.59) | 11 (0.55) | 14 (0.66) | 12 (0.54) | 11 (0.52) | 50 |
| **Standard** | 22 | 20 | 21 | 22 | 21 | 6.25 |
| **Control (DMF)** | - | - | - | - | - | - |

*Diameter of well (bore size) - 6 mm,

**Activity index=**Inhibition zone of the sample/Inhibition zone of the standard.

**Acknowledgement:**

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# Synthesis, Characterization and Biological Evaluation of Oxazolone Derivatives

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**Abstract**
A series of six 4-aryl Benzelidene-2-phenyl-5- oxazolone derivatives were synthesized by condensation of aromatic aldehydes with N-benzoyl glycine (Hippuric acid) in the presence of sodium acetate and acetic anhydride at room temperature in ethanol. Six of the compounds are new derivatives. The structures of the compounds were evaluated based on 1H-NMR , IR and FTIR methods and by elemental analysis. .All the derivative compounds prepared were tested for their antimicrobial activity by disk diffusion technique. Test organisms: Bacteria like Staphylococcus aureusMTCC 7443 and Salmonella typhimuriumMTCC 733 Fungi like C.albicans and A.flavus The results were compared with those of the standard 0.5% Ciprofloxacin. The derivatives with Salicylaldehyde and cinnamaldehyde were showed excellent activities against E. coli. and Staphylococcus aureusMTCC 7443 : than Salmonella typhimuriumMTCC 733 bacteria. It also showed reasonable activity withFungi like C.albicans than A.flavus

**Keywords:** N-Benzoyl Glycine, Aromatic aldehyde, Oxazolones , Antibacterial Activities

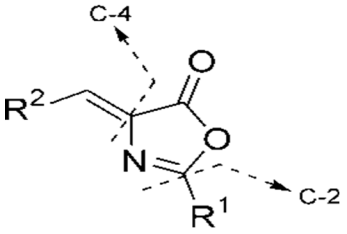
## II. INTRODUCTION

For many decades, increasing resistance against human pathogens that cause serious infections is one of the main topics of interest for medicinal thechemists. Many medicines were developed against bacterial infections. Since many decades, active heterocyclic compounds are one of the main topics of interest for the medicinal chemists as it displays a number of pharmacological activities.

Mostly Nitrogen- Sulphur- and Oxygen-containing five- and six-member heterocyclic compounds like oxazolones have enormous significance in the field of medicinal chemistry and these are class of small heterocyclic compounds which have acquired more importance in recent years due to their pharmacological activities.

Oxazolones are five membered heterocyclic compounds containing nitrogen and oxygen as hetero atoms. The C-2 and C-4 positions of oxazolone are responsible for their various biological activities such as analgesic[1], anti-inflammatory, antidepressant[2], anticancer, antimicrobial[3], antidiabetic[4] and antiobesity Oxazol-5-ones contain correspondence numerous reactive sites allowing for a diverse set of possible modifications.

Hence we aimed to design novel derivatives containing a variety of oxazolone derivatives with structural variation at C-2 and C-4 positions were synthesized and evaluated anti-microbialactivities.




## I. MATERIALS AND METHODS

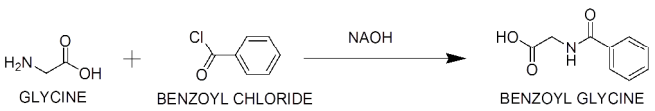
All the chemicals were of synthetic grade and commercially procured from SD fine Chemicals Ltd. Mumbai, India. Melting points were recorded on Electric melting point apparatus and are uncorrected. IR spectra were recorded on FT-IR 8400S, Fourier Transform (SHIMADZU) Infrared spectrophotometer using KBr disc method. The 1H-NMR spectra were recorded in $CDCl_3$ on AVANCE 300MHZ NMR Spectrophotometer using TMS as an internal standard. Thin layer chromatography analyses were performed on pre-coated silica gel plates (G 350, Merck).

**Procedure**

**SCHEME 1:** General Synthesis of Phenyl Glycine or Hippuric acid from Glycine

Glycine (10gm) is first dissolved in 10% sodium hydroxide solution (100ml) and reaction mixture is kept in ice cold water and benzoyl chloride (21.6ml) is added drop wise with continuous stirring after addition of all benzoyl chloride pH of the reaction mixture is adjusted to 2-3 with concentrated HCl and the precipitate of phenyl glycine obtained.

SCHEME -1




**SCHEME:2**

**Preparation of Different Oxazolones:**

Hippuric acid(0.01m), acetic anhydride(0.04m), sodium acetate(0.01m), aromatic aldehyde(0.04m), are taken in a conical flask and the reaction mixture is heated for 15mins on heating mantle then the reaction mixture is cooled for 5mins and 2-3 drops of ethanol is added and the ice cold water is poured into the reaction mixture to get the precipitate of oxazolones

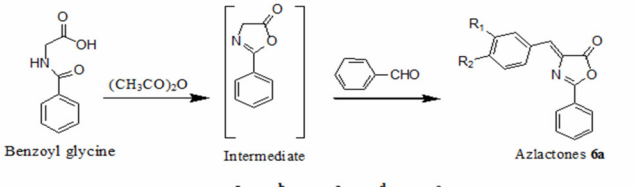
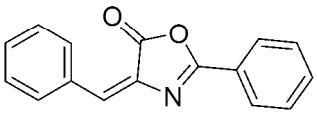
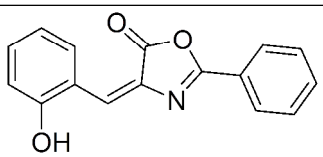
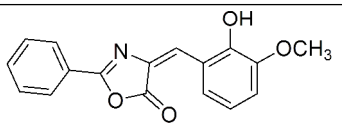
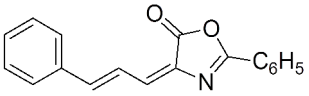



**Table 1:** Physical Constants Data of Synthesized Compounds

| SL NO | STRUCTURE | MOLECULAR FORMULA (mol.weight) | % YIELD | M.P IN °C |
|---|---|---|---|---|
| 2a |  | $C_{16}H_{11}NO_2$ (249) | 70 | 170 |
| 3a |  | $C_{16}H_{11}NO_3$ (261) | 65 | 167 |
| 4a |  | $C_{17}H_{13}NO_4$ (295) | 54 | 192 |
| 5a |  | $C_{18}H_{13}NO_2$ (275) | 75 | 180 |

1. AntibacterialAssay: **Determination of Antimicrobial activity;** 100 µl Inoculum of test cultures was inoculated on Muller Hinton Agar plates (90 mm) for bacterial .Test compounds (10µl, 10 mg/mL), and ciprofloxacin (2.5 µl, 1 mg/mL) were impregnated on 6mm sterile Whatmann No. 1 Disks for bacterial cultures. Test compounds and standard disks were placed on Agar plates.The plates were Incubated @ 35 $^0$C for 24-48 hrs and observe for zone of inhibition around the disk.
2. **Inoculum:**

Cell suspension prepared from cultures grown on Trypticose soya broth adjusted to 1-2 x $10^5$ cells/mL. For fungi spore suspension of the cultures grown on Sabouraud Dextrose agar was adjusted to 1-2 x $10^5$ cells /mL.

**Test concentrations: drug concentration prepared** Test compounds: 10 mg/mL in 10% DMSO in Methanol. Control: 10% DMSO in Methanol.

**RESULTS AND DISCUSSIONS**

**Chemistry**: Oxazolone derivatives were synthesized by condensation of substituted aromatic aldehydes with Hippuric acid using sodium acetate as a catalyst in ethanol at room temperature. The synthesized compounds were scaled for yield and purified by recrystallization with suitable solvent system. The purified compounds are identified/characterized by following methods melting point, solubility, thin layer chromatography and results were listed in table 1, the synthesized compounds were characterized using different spectroscopic techniques. The IR spectrum showed characteristic band of carbonyl group at 1772cm$^{-1}$ and C=N at 1352 cm$^{-1}$. $_1$H-NMR spectrum showed characteristic pattern of peaks. The methyl protons appeared in the region of 3.84 ppm, whereas the aromatic protons appeared at 6.89–8.12 ppm.

**Antibacterial Activity:**

All the compounds 2a to 5a were tested for their antibacterial activity against B**acteria** Staphylococcus aureus MTCC 7443 &Salmonella typhimurium MTCC 733&**Fungi** C.albicans,A.flavus and E. coli, by **disk diffusion technique** .But many people have reported by zone of inhibition method against E.Coli B. subtilis, B. subtilis, S. aureus, P. aeruginosa, and K.pneumoniae [6]. The results were compared with those of the standard 0.5% Ciprofloxacin. Compounds (3a) showed excellent activities against only for E. coli, which is very difficult to treat with traditionally used antibiotics. The most active compound against E. coli was compound (3a) against all other derivatives. All the compounds from 2a to 5a showed very low and nil activity against B**acteria** Staphylococcus aureus MTCC 7443 &Salmonella typhimurium MTCC 733&**Fungi C**.albicans,A.flavus

| **Test Organisms** | **Test Compounds** | **Concentration (µg/disk)** | **Zone of inhibition** |
|---|---|---|---|
| *E.Coli* | 2a | 200 | 7 |
| | 3a | 200 | 18 |
| | 4a | 200 | 10 |
| | 5a | 200 | 2 |
| | Ciproflaxacin | 2.5 | 20 |
| *Staphylococcus aureus* | 2a,3a | 200 | 3 |
| | 4a,5a | 200 | No inhibition |
| *Salmonella typhi* | 2a,3a | 200 | No inhibition |
| | 4a ,5a | 200 | No inhibition |
| | Ciproflaxacin | 2.5 | 15.00 ± 0.00 |
| *C.albicans* | 2a | 200 | No inhibition |
| | 3a | 200 | No inhibition |
| | 4a | 200 | Inhibition but Not measurable |
| | 5a | 200 | |
| | Crystal Violet | 100 | 21.00 ± 1.00 |
| *A. flavus* | 2a to 5a | 200 | No inhibition |
| | Crystal Violet | 100 | 25.00± 2.00 |

## CONCLUSION

It is concluded based on the biological activities of the synthesized oxazolone derivatives, it could be concluded that they are therapeutically active antibacterial agents, among all synthesized compounds the compound (3a) showed better antibacterial activity against Escherichia coli bacteria, compared with standard ciprofloxacin.

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# Copper complex of isatin Schiff base encapsulated in zeolite as active heterogeneous catalyst: an efficient protocol for the acetylation reaction

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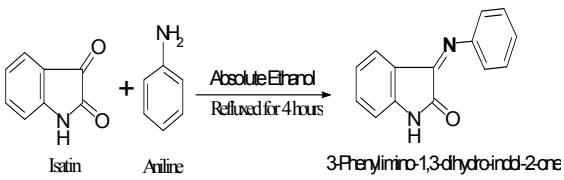
**Abstract:** Copper (II) complex of 3-phenylimino-1,3-dihydro-indol-2-one encapsulated in the super cages of zeolite-Y has been synthesized by flexible ligand method and characterized by various physicochemical measurements. The catalytic activity of cationic exchanged zeolite, copper complex of ligand and complex encapsulated inside the zeolite was investigated for the decomposition of H2O2 and for the acetylation of p-cresol. All catalysts show good to excellent yield. The results showed that conversion of p-cresol varies in the order homogeneous complex < Na-Y-Zeolite < Cu-Y-Zeolite < heterogeneous complex.

**Keywords**: Encapsulation; Zeolite-Y; Catalyst; Hydrogen peroxide; Decomposition; Acetylation

## Introduction

The need for cleaner processes, many new and interesting technologies are emerging, especially in fine chemicals where high selectivity to the desired product is crucial [1-3]. Therefore, the design of novel heterogeneous technologies is gaining importance in the enantioselective oxidations and in different organic transformations. In this work, studies on the synthesis and characterization of zeolite Y encapsulated complex of Cu(II) with 3-phenylimino-1,3-dihydro-indol-2-one is presented. The structure of the ligand is shown in Scheme 1. Application of the complexes for acetylation of p-cresol was studied and the results of these studies are discussed.




**Scheme 1.** Synthesis of 3-phenylimino-1,3-dihydro-indol-2-one

## Experimental

### *Synthesis of heterogeneous catalyst*

Metal exchanged Cu-Y-zeolite (7 g) was added to a solution of the ligand (4.5 g). The mixture was refluxed with stirring for 24 h on an oil bath. The ligand penetrates through the channels of zeolite and complex is formed. The product obtained was soxhlet extracted using a suitable solvent to remove excess ligand and surface species. The Soxhlet extraction was continued until extract becomes colourless indicating complete removal of the species to be eliminated. The uncomplexed metal remaining in the zeolite was removed by back exchange of zeolite with NaCl solution (0.1 M) by stirring for 24 h. It was then filtered, washed free of chloride ions, and finally dried at 150 $^0$C for 24 h to get the required encapsulated complexes.

***Catalytic activity measurements***

*Decomposition of $H_2O_2$*

The catalysts were activated by heating to 120 $^0$C for 2 h. 3.95 ml of 30 % $H_2O_2$ was added to 25 mg of catalyst and it was stirred for 1 and 2 h at room temperature respectively. The unreacted $H_2O_2$ was then estimated [3] .

***Acetylation of p-cresol (solvent free reaction)***

The reaction was carried out in a 50 ml double necked round bottom flask fitted with a water cooled condenser. In a typical reaction, p-cresol (5 mmol, 0.5406 g), acetic anhydride (7.5 mmol, 0.7656 g) and 0.5 g of catalyst was added and stirred at room temperature for constant stirring. The progress of the reaction was monitored by TLC, and the mixture was diluted with sodium bicarbonate (10 %; 15 ml), then extracted with dichloromethane (20:9:3). Organic layer was evaporated to dryness to afford the acetylated product.

***Recycling of the catalyst***

At the end of the reaction, catalyst was filtered washed with dichloromethane, dried at 110 $^0$C for 1 h. Then it is used for acetylation reaction under optimized condition[5].

## Results and discussion

*Synthesis and characterization of catalysts*

Synthesis of the metal complexes encapsulated in the zeolite cages of Na-Y was carried out by the flexible ligand method [6]. To compare the properties of the encapsulated complexes, the metal exchanged zeolite and neat complexes of Cu (II) with ligand were also prepared and characterized by various physicochemical techniques. The analytical data obtained were in good agreement with the data available in literature [4]. The significant reduction in surface area and pore volume as a result of encapsulation of complexes within the zeolite pores is due to the blocking of the pores by the formation of the metal complexes. The decrease in surface area values suggests the formation of metal complexes inside the zeolite cages [Table 1].

*Surface area measurement data*

**Table 1.** Surface area measurement data

| Sl. no. | Compound | Surface area ($m_2$/g) | Pore volume (cc/g) |
|---|---|---|---|
| 1 | Z-Y | 25.80 | 0.105 |
| 2 | Heterogeneous complex | 20.74 | 0.093 |

*Powder X-ray diffraction studies*

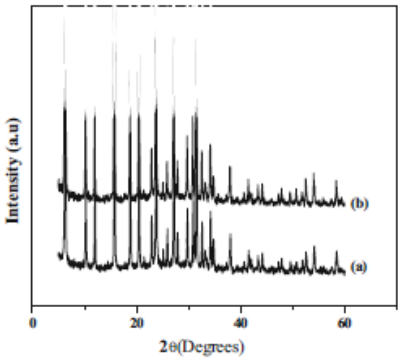



**Fig. 1.** PXRD patterns of zeolite-Y and its encapsulated complex. (a) Z-Y and (b) Heterogeneous complex

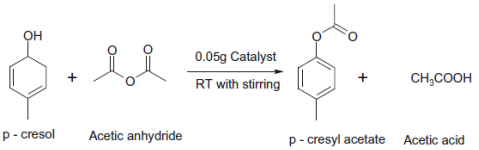
*FTIR spectra*

**Table 2.** Absorbtion bands in the IR spectra of the ligand and its complexes

| Sl. no. | Ligand/ complex | $\nu_{OH}$ ($cm^{-1}$) | $\nu_{NH}$ ($cm^{-1}$) | $\nu_{C=O}$ ($cm^{-1}$) | $\nu_{C=N}$ ($cm^{-1}$) |
|---|---|---|---|---|---|
| 1 | Ligand | | 3465 | 1749 | 1647 |
| 2 | Copper complex | 3539 | 3463 | 1741 | 1627 |

***Catalytic studies***

*Acetylation of p-cresol*




**Scheme 2.** Acetylation of p-cresol

**Table 3**. Percentage conversion of p-cresol

| Sl. no. | Catalyst used | Amount (g) | Time (min) | % Conversion of p-cresol |
|---|---|---|---|---|
| 1 | Without catalyst | | 140 | 50 |
| 2 | Homogeneous | 0.05 | 90 | 65 |
| 3 | Na-Y-zeolite | 0.05 | 105 | 50 |
| 4 | Cu-Y-Zeolite | 0.05 | 90 | 55 |
| 5 | Heterogeneous | 0.05 | 70 | 75 |

Decomposition of $H_2O_2$

**Table 4.** Percentage decomposition of $H_2O_2$

| Sl. no. | Catalyst used | Amount (g) | % Decomposition of 30 % $H_2O_2$ | |
|---|---|---|---|---|
| | | | After 1 h | After 2 h |
| 1 | Homogeneous | 0.025 | 4.25 | 5.69 |
| 2 | Na-Y-zeolite | 0.025 | 0.33 | 1.26 |
| 3 | Cu-Y-Zeolite | 0.025 | 0.99 | 1.49 |
| 4 | Heterogeneous | 0.025 | 1.41 | 1.99 |

### *Recycling test*

Phenol hydroxylation reaction was carried out by using recycled catalyst for the zeolite encapsulated complex. A comparison of the percentage conversion of phenol for the fresh and the recycled catalysts shows that there is small decrease in the activity of recycled catalysts may be because of the presence of adsorbed molecules. But the selectivity for the product formation remains almost unaltered.

## Conclusions

Cu(II) complex of 3-phenylimino-1,3-dihydro-indol-2-one have been encapsulated in the super cages of zeolite-Y. Physicochemical analysis gave clear evidence for their encapsulation. This was confirmed by running a blank reaction. No leaching of metal ions was detected in the solution. The influence of different parameters such as the amount of catalyst, temperature, time etc., was studied and these factors show different catalytic activities in the decomposition of $H_2O_2$ and acetylation of p-cresol. Copper encapsulated zeolite complex (heterogeneous catalyst) shows maximum conversion of 75 %. Comparable IR and XRD patterns of fresh and used encapsulated catalysts suggest that these can be used further for catalytic study. Hence the heterogeneous catalyst has very high activity towards acetylation of p-cresol in addition to good conversion rate in fewer periods when compared to homogeneous catalyst, copper exchanged zeolite, Sodium form of zeolite Y in solvent free condition.

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# JACOBI-SOHNCKE TYPE MIXED MODULAR EQUATIONS AND THEIR APPLICATIONS

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**Abstract**

In this paper, we establish Jacobi-Sohncke type several new mixed modular equations for composite degrees 1, 3, $n$ and $3n$. As an application, we establish the modular relations between the Ramanujan-Selberg continued fractions $H(q)$, $H(q^3)$, $H(q^n)$ and $H(q^{3n})$ for $n = 2, 3, 4, 5, 7, 9, 11$ and also we obtain congruence relations for color overpartitions of $n$ with odd parts.

Keywords: Modular equation, Theta-function, continued fraction
2010 Subject classification: primary 33D10, secondary 11A55, 11F27

## 1 Introduction

We start the introduction by defining a modular equation in brief. The complete elliptic integral of first kind is defined as

$$K(k) := \int_0^{\frac{\pi}{2}} \frac{d\phi}{\sqrt{1-k^2\sin^2\phi}} = \frac{\pi}{2}\sum_{n=0}^{\infty}\frac{\left(\frac{1}{2}\right)_n^2}{(n!)^2}k^{2n} = \frac{\pi}{2}\,{}_2F_1\left(\frac{1}{2},\frac{1}{2};1;k^2\right), \tag{1.1}$$

where $0 < k < 1$ and ${}_2F_1$ is the ordinary or Gaussian hypergeometric function defined by

$${}_2F_1(a,b;c;z) := \sum_{n=0}^{\infty}\frac{(a)_n(b)_n}{(c)_n\,n!}z^n, \quad 0 \le |z| < 1,$$

$(a)_0 = 1$, $(a)_n = a(a+1)\cdots(a+n-1)$ for $n$ a positive integer and $a$, $b$, $c$ are complex numbers such that $c \neq 0, -1, -2, \ldots$. The number $k$ is called the modulus of $K$, and $k' := \sqrt{1-k^2}$ is called the complementary modulus.

Let $K$, $K'$, $L$ and $L'$ denote the complete elliptic integrals of the first kind associated with the moduli $k$, $k'$, $l$ and $l'$ respectively. Suppose that the equality

$$n\frac{K'}{K} = \frac{L'}{L}, \tag{1.2}$$

holds for some positive integer $n$. Then a modular equation of degree $n$ is a relation between the moduli $k$ and $l$ which is induced by (1.2). Following Ramanujan, set $\alpha = k^2$ and $\beta = l^2$. Then we say $\beta$ is of degree $n$ over $\alpha$. The multiplier $m$ is defined by

$$m = \frac{K}{L}. \tag{1.3}$$

However, if we set

$$q = \exp\left(-\pi K'/K\right), \quad q' = \exp\left(-\pi L'/L\right), \tag{1.4}$$

we see that (1.2) is equivalent to the relation $q^n = q'$. Thus a modular equation can be viewed as an identity involving theta-functions at the arguments $q$ and $q^n$. The theory of modular equations dates back to 1771 and 1775, when J. Landen records Landen's transformation in his papers [4], [5]. But actually the theory commenced when A. M. Legendre, in his paper derived a modular equation of degree 3 in 1825. C. G. J. Jacobi established modular equations of degree 3 and 5 in his famous book [3]. L. A. Sohncke established modular equations of degrees 7, 11, 13, 17 and 19 in his papers [14], [15]. Subsequently many mathematicians have contributed to the theory of modular equations. Ramanujan's contributions in the area of modular equations are immense. For more details one can see the following papers [6], [7], [8], [9].

*Remark* 1.1. The equation involving $\alpha^{1/8}$ and $\beta^{1/8}$ is referred to as Jacobi-Sohncke type modular equation.

Following are the special cases of Ramanujan's general theta function,

$$\varphi(q) := f(q,q) = \sum_{n=-\infty}^{\infty} q^{n^2} = \frac{(-q;-q)_\infty}{(q;-q)_\infty}, \tag{1.5}$$

$$\psi(q) := f(q,q^3) = \sum_{n=0}^{\infty} q^{n(n+1)/2} = \frac{(q^2;q^2)_\infty}{(q;q^2)_\infty}, \tag{1.6}$$

$$f(-q) := f(-q,-q^2) = \sum_{-\infty}^{\infty}(-1)^n q^{\frac{n(3n-1)}{2}} = (q;q)_\infty, \tag{1.7}$$

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and

$$\chi(q) := (-q;q^2)_\infty, \tag{1.8}$$

where

$$f(a,b) = \sum_{n=-\infty}^{\infty} a^{n(n+1)/2} b^{n(n-1)/2}, \quad |ab| < 1,$$

and

$$(a;q)_\infty = \prod_{n=0}^{\infty} (1-aq^n), \mid q \mid < 1.$$

Let $K$, $K'$, $L_1$, $L_1'$, $L_2$, $L_2'$, $L_3$ and $L_3'$ denote complete elliptic integrals of the first kind corresponding, in pairs, to the moduli $\sqrt{\alpha}$, $\sqrt{\beta}$, $\sqrt{\gamma}$ and $\sqrt{\delta}$, and their complementary moduli, respectively. Let $n_1$, $n_2$ and $n_3$ be positive integers such that $n_3 = n_1 n_2$. Suppose that the equalities

$$n_1 \frac{K'}{K} = \frac{L_1'}{L_1}, \ n_2 \frac{K'}{K} = \frac{L_2'}{L_2} \text{ and } n_3 \frac{K'}{K} = \frac{L_3'}{L_3} \tag{1.9}$$

hold. Then a "mixed" modular equation is a relation between the moduli $\sqrt{\alpha}$, $\sqrt{\beta}$, $\sqrt{\gamma}$ and $\sqrt{\delta}$ that is induced by (1.9). We say that $\beta$, $\gamma$ and $\delta$ are of degrees $n_1$, $n_2$ and $n_3$, respectively over $\alpha$. The multipliers $m = K/L_1$ and $m' = L_2/L_3$ are associated with $\alpha$, $\beta$ and $\gamma$, $\delta$.

In this paper, we establish several new Jacobi-Sohncke type mixed modular equations in Section 3 by using the results enlisted in Section 2. As an application, in Section 4 we obtain several modular relations for Ramanujan-Selberg continued fractions and in Section 5, we discuss the congruence properties of overpartition $p-$tuples of $n$ with odd parts.

# 2 Preliminary Results

In this section, we collect the results which are useful in proving our main results.

**Lemma 2.1.** *1. [1, Ch.18, p.215] If $\beta$ is of degree 2 over $\alpha$, then*

$$\beta = \left(\frac{1-\sqrt{1-\alpha}}{1+\sqrt{1-\alpha}}\right)^2. \tag{2.1}$$

*2. [1, Ch.19, Entry 5 (ii), (xiii), pp. 230-231] If $\beta$ has degree 3 over $\alpha$, then*

$$(\alpha\beta)^{1/4} + \{(1-\alpha)(1-\beta)\}^{1/4} = 1. \tag{2.2}$$

$$N - \frac{1}{N} = 2\left(M - \frac{1}{M}\right), \tag{2.3}$$

*where $M = (\alpha\beta)^{1/8}$ and $N = (\beta/\alpha)^{1/4}$.*

**Lemma 2.2.** *Let $q$ be defined as in* (1.4)*, then*

$$\chi(q) = 2^{1/6}(\alpha(1-\alpha)/q)^{-1/24}, \tag{2.4}$$

$$\chi(-q) = 2^{1/6}(1-\alpha)^{1/12}(\alpha/q)^{-1/24}, \tag{2.5}$$

*where $\alpha = k^2$, $k$ is called the modulus of $K$.*

*Proof.* For proofs of (2.4) and (2.5), see [1, Entry 12 (v),(vi), Ch.17, p.124]. □

**Lemma 2.3.** *[1, Ch.18, Entry 24(v), p.216] If we replace $\alpha$ by $1-\beta$, $\beta$ by $1-\alpha$, and $m$ by $n/m$, where $n$ is the degree of the modular equation, we obtain a modular equation of the same degree.*

# 3 Mixed Modular Equations

In this section, we derive several Jacobi-Sohncke type mixed modular equations.

We set

$$P := \{\alpha\beta\gamma\delta\}^{1/16}, \tag{3.1}$$

$$Q := \left\{\frac{\alpha\beta}{\gamma\delta}\right\}^{1/16}, \tag{3.2}$$

$$R := \left\{\frac{\alpha\gamma}{\beta\delta}\right\}^{1/16} \tag{3.3}$$

and

$$T := \left\{\frac{\alpha\delta}{\beta\gamma}\right\}^{1/16}. \tag{3.4}$$

Throughout this section, we use the following notations

$$\mathbb{P}_\kappa := \left(P^\kappa + \frac{1}{P^\kappa}\right), \tag{3.5}$$

$$\mathbb{Q}_\kappa := \left(Q^\kappa + \frac{1}{Q^\kappa}\right), \tag{3.6}$$

$$\mathbb{R}_\kappa := \left(R^\kappa + \frac{1}{R^\kappa}\right) \tag{3.7}$$

and

$$\mathbb{T}_\kappa := \left(T^\kappa + \frac{1}{T^\kappa}\right). \tag{3.8}$$

By rewriting the equation (2.3), we obtain the following lemmas.

**Lemma 3.1.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, $n$ and $3n$ respectively, then*

$$\alpha^{1/2} = u^2\left(\frac{-a+s}{2}\right), \tag{3.9}$$

$$\gamma^{1/2} = v^2\left(\frac{-b+t}{2}\right), \tag{3.10}$$

*where $a = 2\left(u - \frac{1}{u}\right)$, $b = 2\left(v - \frac{1}{v}\right)$, $u = (\alpha\beta)^{1/8}$, $v = (\gamma\delta)^{1/8}$, $s^2 = a^2+4$ and $t^2 = b^2+4$.*

**Lemma 3.2.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, $n$ and $3n$ respectively, then*

$$\alpha^{1/4} = \left(\frac{a+s}{2u}\right), \tag{3.11}$$

$$\gamma^{1/4} = \left(\frac{b+t}{2v}\right), \tag{3.12}$$

*where $a = \frac{1}{2}\left(u^2 - \frac{1}{u^2}\right)$, $b = \frac{1}{2}\left(v^2 - \frac{1}{v^2}\right)$, $u = (\beta/\alpha)^{1/8}$, $v = (\delta/\gamma)^{1/8}$, $s^2 = a^2+4$ and $t^2 = b^2+4$.*

**Theorem 3.1.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 3 and 9 respectively, then*

$$\mathbb{Q}_6 + 2\mathbb{Q}_4 - 5\mathbb{Q}_2 + 4\mathbb{P}_2 + 12 = 4\mathbb{P}_2\mathbb{Q}_2, \tag{3.13}$$

$$\mathbb{R}_4 + 2\mathbb{R}_2 + \mathbb{T}_4 = \mathbb{R}_2\mathbb{T}_4 + 4, \tag{3.14}$$

$$T^6 - \frac{1}{T^6} - 3\left(T^2 - \frac{1}{T^2}\right) = 4\left(\frac{T^2}{P^2} - \frac{P^2}{T^2}\right). \tag{3.15}$$

**Theorem 3.2.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 2 and 6 respectively, then*

$$P^4+Q^4-2\left[P^2Q^2+\frac{2}{P^2Q^2}\right]+4=0, \tag{3.16}$$

$$\left[\frac{T^2}{R^2}+\frac{R^2}{T^2}\right]=2+\left[\frac{T}{R}+\frac{R}{T}\right]\left[T^2R^2-\frac{1}{T^2R^2}\right]. \tag{3.17}$$

**Theorem 3.3.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 4 and 12 respectively, then*

$$\begin{aligned}&P^8+Q^8+16\left[\frac{P^2}{Q^2}+\frac{Q^2}{P^2}\right]\left[3P^2Q^2+\frac{8}{P^2Q^2}\right]\\&-4\left[P^4Q^4+\frac{16}{P^4Q^4}\right]\left[\frac{P^2}{Q^2}+\frac{Q^2}{P^2}\right]+6P^4Q^4+\frac{128}{P^4Q^4}\\&-32\left[P^2Q^2+\frac{8}{P^2Q^2}\right]-112\left[\frac{P^2}{Q^2}+\frac{Q^2}{P^2}\right]+160=0,\end{aligned} \tag{3.18}$$

$$\begin{aligned}&\frac{R^4}{T^4}+\frac{T^4}{R^4}+4\left[\frac{R^2}{T^2}+\frac{T^2}{R^2}\right]-8\left[R^4T^4+\frac{1}{R^4T^4}\right]\\&-7\left[\frac{R}{T}+\frac{T}{R}\right]\left[R^4T^4-\frac{1}{R^4T^4}\right]-4\left[R^4T^4+\frac{1}{R^4T^4}\right]\\&\times\left[\frac{T^2}{R^2}+\frac{R^2}{T^2}\right]+\left[\frac{T^3}{R^3}+\frac{R^3}{T^3}\right]\left[\frac{1}{R^4T^4}-R^4T^4\right]+22=0.\end{aligned} \tag{3.19}$$

**Theorem 3.4.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 5 and 15 respectively, then*

$$\mathbb{Q}_6-10\mathbb{Q}_4-5\mathbb{Q}_2-60=16\mathbb{P}_4-20\mathbb{P}_2-20\mathbb{P}_2\mathbb{Q}_2, \tag{3.20}$$

$$\mathbb{R}_4+20=\mathbb{T}_6-5\mathbb{T}_4+15\mathbb{T}_2. \tag{3.21}$$

**Theorem 3.5.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 7 and 21 respectively, then*

$$\begin{aligned}&\mathbb{Q}_8+28\mathbb{Q}_6+112\mathbb{Q}_4+364\mathbb{Q}_2-64\mathbb{P}_6+224\mathbb{P}_4-448\mathbb{P}_2\\&-308\mathbb{P}_2\mathbb{Q}_2+112\mathbb{P}_4\mathbb{Q}_2-84\mathbb{P}_2\mathbb{Q}_4+686=0,\end{aligned} \tag{3.22}$$

$$\mathbb{R}_6-14\mathbb{R}_4+49\mathbb{R}_2-\mathbb{T}_8-14\mathbb{T}_4+7\mathbb{R}_2\mathbb{T}_4-70=0. \tag{3.23}$$

**Theorem 3.6.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 9 and 27 respectively, then*

$$\begin{aligned}&\mathbb{Q}_{18}-42\mathbb{Q}_{16}-159\mathbb{Q}_{14}-2160\mathbb{Q}_{12}-2372\mathbb{Q}_{10}-40056\mathbb{Q}_8\\&-27684\mathbb{Q}_6-311760\mathbb{Q}_4-332806\mathbb{Q}_2-904764=2^{12}\mathbb{P}_{12}\\&+2^{10}\mathbb{P}_{10}\left(12-15\mathbb{Q}_2-\mathbb{Q}_4\right)+2^8\mathbb{P}_8\left(412-96\mathbb{Q}_2+93\mathbb{Q}_4\right.\\&\left.+12\mathbb{Q}_6+\mathbb{Q}_8\right)+2^6\mathbb{P}_6\left(2124-9\mathbb{Q}_{10}-54\mathbb{Q}_8-381\mathbb{Q}_6\right.\\&\left.+2^5\mathbb{Q}_4-3210\mathbb{Q}_2\right)+2^4\mathbb{P}_4\left(33676+36\mathbb{Q}_{12}+167\mathbb{Q}_{10}\right.\\&\left.+1332\mathbb{Q}_8+1314\mathbb{Q}_6+10866\mathbb{Q}_4-11481\mathbb{Q}_2\right)\\&+2^3\mathbb{P}_2\left(54876-37\mathbb{Q}_{14}-177\mathbb{Q}_{12}-1419\mathbb{Q}_{10}\right.\\&\left.-1470\mathbb{Q}_8-10969\mathbb{Q}_6+6849\mathbb{Q}_4-75255\mathbb{Q}_2\right),\end{aligned} \tag{3.24}$$

$$\begin{aligned}&\mathbb{T}_{14}+12\mathbb{T}_{12}+85\mathbb{T}_{10}+342\mathbb{T}_8+913\mathbb{T}_6+1356\mathbb{T}_4\\&+1113\mathbb{T}_2+670=\mathbb{R}_{16}+\mathbb{R}_{12}\left(102+56\mathbb{T}_2+9\mathbb{T}_4\right)\\&-\mathbb{R}_8\left(\mathbb{T}_{10}+9\mathbb{T}_8+54\mathbb{T}_6+140\mathbb{T}_4+105\mathbb{T}_2+26\right)\\&+\mathbb{R}_4\left(\mathbb{T}_{12}+6\mathbb{T}_{10}+34\mathbb{T}_8+114\mathbb{T}_6+414\mathbb{T}_4\right.\\&\left.+1040\mathbb{T}_2+1350\right).\end{aligned} \tag{3.25}$$

**Theorem 3.7.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 11 and 33 respectively, then*

$$\begin{aligned}&\mathbb{Q}_{12}+88\mathbb{Q}_{10}+374\mathbb{Q}_8+3696\mathbb{Q}_6+4015\mathbb{Q}_4+17336\mathbb{Q}_2\\&+12980=2^{10}\mathbb{P}_{10}+5632\mathbb{P}_8+9856\mathbb{P}_6+23936\mathbb{P}_4\\&+21032\mathbb{P}_2-4532\mathbb{P}_2\mathbb{Q}_2+10560\mathbb{P}_4\mathbb{Q}_4-2816\mathbb{P}_8\mathbb{Q}_2\\&-14432\mathbb{P}_4\mathbb{Q}_2-14080\mathbb{P}_6\mathbb{Q}_2+3520\mathbb{P}_6\mathbb{Q}_4+836\mathbb{P}_2\mathbb{Q}_8\\&-2464\mathbb{P}_4\mathbb{Q}_6+10472\mathbb{P}_2\mathbb{Q}_4-1804\mathbb{P}_2\mathbb{Q}_6,\end{aligned} \tag{3.26}$$

$$\begin{aligned}&\mathbb{R}_{10}+11\left(2\mathbb{R}_8+5\mathbb{R}_6-20\mathbb{R}_4+56\mathbb{R}_2-64\right)=\mathbb{T}_{12}\\&-11\left(2\mathbb{T}_8+25\mathbb{T}_4+10\mathbb{T}_4\mathbb{R}_4-\mathbb{T}_4\mathbb{R}_6-15\mathbb{T}_4\mathbb{R}_2\right).\end{aligned} \tag{3.27}$$

# 4 Modular identities for Ramanujan-Selberg continued fraction

The continued fraction identity

$$\begin{aligned}H(q)&:=\frac{q^{\frac{1}{8}}}{1+}\,\frac{q}{1+}\,\frac{q^2+q}{1+}\,\frac{q^3}{1+}\,\frac{q^4+q^2}{1+\cdots}\\&=\frac{q^{\frac{1}{8}}(-q^2;q^2)_\infty}{(-q;q^2)_\infty},\qquad |q|<1,\end{aligned} \tag{4.1}$$

appears as Formula 5 [12, p.290] and was first proved by Selberg [13, eq.(54)]. C. Adiga, M. S. Mahadeva Naika and Ramya Rao [**?**] have obtained two integral representations for $H(q)$, also derived a relation between $H(q)$ and $H(q^n)$ and some explicit evaluations of $H(q)$. Mahadeva Naika et al. [10],[11] have obtained several integral representations and also Rogers-Ramanujan type functions for $H(q)$.

In this section, we establish modular relations between Ramanujan-Selberg continued fractions $H(q)$, $H(q^3)$, $H(q^n)$ and $H(q^{3n})$ for $n=2,3,4,5,7,9,11$. We define

$$w:=4H(q)H(q^3)H(q^n)H(q^{3n}), \tag{4.2}$$

$$x:=\frac{H(q)H(q^3)}{H(q^n)H(q^{3n})}, \tag{4.3}$$

$$y:=\frac{H(q)H(q^n)}{H(q^3)H(q^{3n})}, \tag{4.4}$$

$$z:=\frac{H(q)H(q^{3n})}{H(q^n)H(q^3)}. \tag{4.5}$$

Throughout this section, we use the following notations

$$\mathbb{W}_\kappa:=\left(w^\kappa+\frac{1}{w^\kappa}\right), \tag{4.6}$$

$$\mathbb{X}_\kappa:=\left(x^\kappa+\frac{1}{x^\kappa}\right), \tag{4.7}$$

$$\mathbb{Y}_\kappa:=\left(y^\kappa+\frac{1}{y^\kappa}\right), \tag{4.8}$$

$$\mathbb{Z}_\kappa:=\left(z^\kappa+\frac{1}{z^\kappa}\right). \tag{4.9}$$

**Lemma 4.1** ([10], Th.3.2)**.** *We have*

$$H(q) = \frac{\alpha^{1/8}}{\sqrt{2}},$$

*where $q$ is as defined in* (1.4) *and $\alpha = k^2$, $k$ is called the modulus of $K$.*

Using the above lemma in the corresponding Jacobi-Sohncke type mixed modular equations obtained in the previous section, we deduce the following theorems.

**Theorem 4.1.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 2 and 6 respectively, then*

$$w^2 + x^2 - 2\left(wx + \frac{2}{wx}\right) + 4 = 0, \tag{4.10}$$

$$\left(\frac{y}{z} + \frac{z}{y}\right) = 2 + \left(\sqrt{\frac{y}{z}} + \sqrt{\frac{z}{y}}\right)\left(yz - \frac{1}{yz}\right). \tag{4.11}$$

**Theorem 4.2.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 3 and 9 respectively, then*

$$\mathbb{X}_3 + 2\mathbb{X}_2 - 5\mathbb{X}_1 + 4\mathbb{W}_1 + 12 = 4\mathbb{W}_1\mathbb{X}_1, \tag{4.12}$$

$$\mathbb{Y}_2 + 2\mathbb{Y}_1 + \mathbb{Z}_2 = \mathbb{Y}_1\mathbb{Z}_2 + 4, \tag{4.13}$$

$$z^3 - \frac{1}{z^3} - 3\left(z - \frac{1}{z}\right) = 4\left(\frac{z}{w} - \frac{w}{z}\right). \tag{4.14}$$

**Theorem 4.3.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 4 and 12 respectively, then*

$$\begin{aligned} &w^4 + x^4 + 16\left[\frac{w}{x} + \frac{x}{w}\right]\left[3wx + \frac{8}{wx}\right] \\ &- 4\left[w^2x^2 + \frac{16}{w^2x^2}\right]\left[\frac{w}{x} + \frac{x}{w}\right] + 6w^2x^2 + \frac{128}{w^2x^2} \\ &- 32\left[wx + \frac{8}{wx}\right] - 112\left[\frac{w}{x} + \frac{x}{w}\right] + 160 = 0, \end{aligned} \tag{4.15}$$

$$\begin{aligned} &\frac{y^2}{z^2} + \frac{z^2}{y^2} + 4\left(\frac{y}{z} + \frac{z}{y}\right) - 8\left(y^2z^2 + \frac{1}{y^2z^2}\right) \\ &- 7\left(\sqrt{\frac{y}{z}} + \sqrt{\frac{z}{y}}\right)\left(y^2z^2 - \frac{1}{y^2z^2}\right) \\ &- 4\left(y^2z^2 + \frac{1}{y^2z^2}\right)\left(\frac{y}{z} + \frac{z}{y}\right) \\ &+ \left(\sqrt{\frac{y^3}{z^3}} + \sqrt{\frac{z^3}{y^3}}\right)\left(\frac{1}{y^2z^2} - y^2z^2\right) + 22 = 0. \end{aligned} \tag{4.16}$$

**Theorem 4.4.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 5 and 15 respectively, then*

$$\mathbb{X}_3 - 10\mathbb{X}_2 - 5\mathbb{X}_1 - 60 = 16\mathbb{W}_2 - 20\mathbb{W}_1 - 20\mathbb{W}_1\mathbb{X}_1, \tag{4.17}$$

$$\mathbb{Y}_2 + 20 = \mathbb{Z}_3 - 5\mathbb{Z}_2 + 15\mathbb{Z}_1, \tag{4.18}$$

**Theorem 4.5.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 7 and 21 respectively, then*

$$\begin{aligned} &\mathbb{X}_4 + 28\mathbb{X}_3 + 112\mathbb{X}_2 + 364\mathbb{X}_1 - 64\mathbb{W}_3 + 224\mathbb{W}_2 + 686 \\ &- 448\mathbb{W}_1 - 308\mathbb{W}_1\mathbb{X}_1 + 112\mathbb{W}_2\mathbb{X}_1 - 84\mathbb{W}_1\mathbb{X}_2 = 0, \end{aligned} \tag{4.19}$$

$$\mathbb{Y}_3 - 14\mathbb{Y}_2 + 49\mathbb{Y}_1 - \mathbb{Z}_4 - 14\mathbb{Z}_2 + 7\mathbb{Y}_1\mathbb{Z}_2 - 70 = 0. \tag{4.20}$$

**Theorem 4.6.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 9 and 27 respectively, then*

$$\begin{aligned} &\mathbb{X}_9 - 42\mathbb{X}_8 - 159\mathbb{X}_7 - 2160\mathbb{X}_6 - 2372\mathbb{X}_5 - 40056\mathbb{X}_4 \\ &- 27684\mathbb{X}_3 - 311760\mathbb{X}_2 - 332806\mathbb{X}_1 - 904764 = 2^{12}\mathbb{W}_6 \\ &+ 2^{10}\mathbb{W}_5\left(12 - 15\mathbb{X}_1 - \mathbb{X}_2\right) + 2^8\mathbb{W}_4\left(412 - 96\mathbb{X}_1 + 93\mathbb{X}_2\right. \\ &\left.+12\mathbb{X}_3 + \mathbb{X}_4\right) + 2^6\mathbb{W}_3\left(2124 - 9\mathbb{X}_5 - 54\mathbb{X}_4 - 381\mathbb{X}_3\right. \\ &\left.+2^5\mathbb{X}_2 - 3210\mathbb{X}_1\right) + 2^4\mathbb{W}_2\left(33676 + 36\mathbb{X}_6 + 167\mathbb{X}_5\right. \\ &\left.+1332\mathbb{X}_4 + 1314\mathbb{X}_3 + 10866\mathbb{X}_2 - 11481\mathbb{X}_1\right) \\ &+ 2^3\mathbb{W}_1\left(54876 - 37\mathbb{X}_7 - 177\mathbb{X}_6 - 1419\mathbb{X}_5 - 1470\mathbb{X}_4\right. \\ &\left.-10969\mathbb{X}_3 + 6849\mathbb{X}_2 - 75255\mathbb{X}_1\right), \end{aligned} \tag{4.21}$$

$$\begin{aligned} &\mathbb{Z}_7 + 12\mathbb{Z}_6 + 85\mathbb{Z}_5 + 342\mathbb{Z}_4 + 913\mathbb{Z}_3 + 1356\mathbb{Z}_2 + 1113\mathbb{Z}_1 \\ &+ 670 = \mathbb{Y}_8 + \mathbb{Y}_6\left(102 + 56\mathbb{Z}_1 + 9\mathbb{Z}_2\right) - \mathbb{Y}_4\left(\mathbb{Z}_5 + 9\mathbb{Z}_4\right. \\ &\left.+54\mathbb{Z}_3 + 140\mathbb{Z}_2 + 105\mathbb{Z}_1 + 26\right) + \mathbb{Y}_2\left(\mathbb{Z}_6 + 6\mathbb{Z}_5 + 34\mathbb{Z}_4\right. \\ &\left.+114\mathbb{Z}_3 + 414\mathbb{Z}_2 + 1040\mathbb{Z}_1 + 1350\right). \end{aligned} \tag{4.22}$$

**Theorem 4.7.** *If $\alpha$, $\beta$, $\gamma$ and $\delta$ are of degrees 1, 3, 11 and 33 respectively, then*

$$\begin{aligned} &\mathbb{X}_6 + 88\mathbb{X}_5 + 374\mathbb{X}_4 + 3696\mathbb{X}_3 + 4015\mathbb{X}_2 + 17336\mathbb{X}_1 \\ &+ 12980 = 2^{10}\mathbb{W}_5 + 5632\mathbb{W}_4 + 9856\mathbb{W}_3 + 23936\mathbb{W}_2 \\ &+ 21032\mathbb{W}_1 - 4532\mathbb{W}_1\mathbb{X}_1 + 10560\mathbb{W}_2\mathbb{X}_2 - 2816\mathbb{W}_4\mathbb{X}_1 \\ &- 14432\mathbb{W}_2\mathbb{X}_1 - 14080\mathbb{W}_3\mathbb{X}_1 + 3520\mathbb{W}_3\mathbb{X}_2 + 836\mathbb{W}_1\mathbb{X}_4 \\ &- 2464\mathbb{W}_2\mathbb{X}_3 + 10472\mathbb{W}_1\mathbb{X}_2 - 1804\mathbb{W}_1\mathbb{X}_3, \end{aligned} \tag{4.23}$$

$$\begin{aligned} &\mathbb{Y}_5 + 11\left(2\mathbb{Y}_4 + 5\mathbb{Y}_3 - 20\mathbb{Y}_2 + 56\mathbb{Y}_1 - 64\right) = \mathbb{Z}_6 \\ &- 11\left(2\mathbb{Z}_4 + 25\mathbb{Z}_2 + 10\mathbb{Z}_2\mathbb{Y}_2 - \mathbb{Z}_2\mathbb{Y}_3 - 15\mathbb{Z}_2\mathbb{Y}_1\right). \end{aligned} \tag{4.24}$$

# 5 Congruence relations for overpartition with odd parts

An overpartition of $n$ is a non increasing sequence of natural numbers whose sum is $n$ in which the first occurrence of a number may be overlined. Let $\overline{p}(n)$ denote the number of overpartitions of an integer $n$. For convenience, we set $\overline{p}(0) = 1$. For example, there are four overpartitions of 2
2, $\overline{2}$, $1+1$, $\overline{1}+1$.
S. Corteel and J. Lovejoy [2] provided the generating function $\overline{p}(n)$ as

$$\sum_{n=0}^{\infty}\overline{p}(n)q^n = \frac{(-q;q)_\infty}{(q;q)_\infty}. \tag{5.1}$$

Similarly, let $\mathbb{P}(n)$ be the number of overpartitions of $n$ in which only odd parts are considered.

$$\sum_{n=0}^{\infty}\mathbb{P}(n)q^n = \frac{(-q;q^2)_\infty}{(q;q^2)_\infty}. \tag{5.2}$$

Now from (2.4) and (2.5), we can write

$$(1-\alpha)^{-1/8} = \frac{\chi(q)}{\chi(-q)} = \sum_{n=0}^{\infty}\mathbb{P}(n)q^n. \tag{5.3}$$

By Lemma 2.3, equations (3.1), (3.2), (3.3) and (3.4) reduces to

$$A := \{(1-\alpha)(1-\beta)(1-\gamma)(1-\delta)\}^{1/16}, \tag{5.4}$$

$$B := \left\{\frac{(1-\alpha)(1-\beta)}{(1-\gamma)(1-\delta)}\right\}^{1/16}, \tag{5.5}$$

$$C := \left\{\frac{(1-\beta)(1-\delta)}{(1-\alpha)(1-\gamma)}\right\}^{1/16}, \tag{5.6}$$

$$D := \left\{\frac{(1-\beta)(1-\gamma)}{(1-\alpha)(1-\delta)}\right\}^{1/16}. \tag{5.7}$$

Let $l$, $m$ be positive integers with $l \neq m$, we define the following :

$$\sum_{n=0}^{\infty} \mathbb{P}^p_{l,m}(n)q^n = \frac{\chi^p(q)\chi^p(q^l)\chi^p(q^m)\chi^p(q^{lm})}{\chi^p(-q)\chi^p(-q^l)\chi^p(-q^m)\chi^p(-q^{lm})}, \tag{5.8}$$

where $\mathbb{P}^p_{l,m}(n)$ denotes the number of overpartitions of $n$ with odd parts in $4p$ colors in which, $p$ colors appears in only multiples of $l$, another $p$ colors appears in multiples of $m$ and remaining $p$ colors appears only in multiples of $lm$.

Let

$$\sum_{n=0}^{\infty} \mathbb{Q}^p_{l,m}(n)q^n = \frac{\chi^p(q)\chi^p(q^l)\chi^p(-q^m)\chi^p(-q^{lm})}{\chi^p(-q)\chi^p(-q^l)\chi^p(q^m)\chi^p(q^{lm})}, \tag{5.9}$$

where $\mathbb{Q}^p_{l,m}(n)$ denotes the number of overpartitions of $n$ in $2p$ colors in which $p$ colors appears only in odd parts that are not multiples of $m$, and another $p$ colors appears only in odd parts that are multiples of $l$ but are not multiples of $lm$.

Let

$$\sum_{n=0}^{\infty} \mathbb{R}^p_{l,m}(n)q^n = \frac{\chi^p(q)\chi^p(-q^l)\chi^p(q^m)\chi^p(-q^{lm})}{\chi^p(-q)\chi^p(q^l)\chi^p(-q^m)\chi^p(q^{lm})}, \tag{5.10}$$

where $\mathbb{R}^p_{l,m}(n)$ denotes the number of overpartitions of $n$ in $2p$ colors in which $p$ colors appears only in odd parts that are not multiples of $l$, and another $p$ colors appears only in odd parts that are multiples of $m$ but are not multiples of $lm$.

For $l$, $m$ relatively prime, let $\mathbb{T}^p_{l,m}(n)$ denotes the number of overpartitions of $n$ into odd parts with $p$ colors that are not multiples of $l$ or $m$. The generating function for $\mathbb{T}^p_{l,m}(n)$ satisfies,

$$\sum_{n=0}^{\infty} \mathbb{T}^p_{l,m}(n)q^n = \frac{\chi^p(q)\chi^p(-q^l)\chi^p(-q^m)\chi^p(q^{lm})}{\chi^p(-q)\chi^p(q^l)\chi^p(q^m)\chi^p(-q^{lm})}. \tag{5.11}$$

**Theorem 5.1.** *We have*

$$\mathbb{Q}^3_{3,5}(2n) \equiv \mathbb{P}^2_{3,5}(2n) \ (mod\ 5), \tag{5.12}$$

$$\mathbb{R}^2_{3,5}(2n) \equiv \mathbb{T}^3_{3,5}(2n) \ (mod\ 5), \tag{5.13}$$

$$\mathbb{T}^9_{3,5}(2n) \equiv \mathbb{P}^4_{3,5}(2n) \ (mod\ 5). \tag{5.14}$$

**Theorem 5.2.** *We have*

$$\mathbb{Q}^4_{3,7}(2n) \equiv \mathbb{P}^3_{3,7}(2n) \ (mod\ 7), \tag{5.15}$$

$$\mathbb{R}^3_{3,7}(2n) \equiv \mathbb{T}^4_{3,7}(2n) \ (mod\ 7). \tag{5.16}$$

**Theorem 5.3.** *We have*

$$\mathbb{Q}^9_{3,9}(2n) \equiv \mathbb{Q}^7_{3,9}(2n) \ (mod\ 2). \tag{5.17}$$

**Theorem 5.4.** *We have*

$$\mathbb{Q}^6_{3,11}(2n) \equiv \mathbb{Q}^2_{3,11}(2n) \ (mod\ 2), \tag{5.18}$$

$$\mathbb{Q}^6_{3,11}(2n) \equiv \mathbb{P}^5_{3,11}(2n) \ (mod\ 11), \tag{5.19}$$

$$\mathbb{R}^5_{3,11}(2n) \equiv \mathbb{T}^6_{3,11}(2n) \ (mod\ 11). \tag{5.20}$$

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# ACTIVITIES OF UG DEPARTMENTS

# Theoretical Study of Nematic to Isotropic Transition in Porous Media

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**Abstract:** Experimental observations show that the N-I transition temperature ($T_{NI}$) for LC embedded in solid porous materials is lower compared to that of the bulk LC and $T_{NI}$ is reduced linearly with the inverse pore diameter. To explain this, various theoretical studies have been proposed. We propose to use the mean field approach. We modify the Maier-Saupe (M-S) mean field theory to include the *disordering* effects of porosity as a disordering surface potential. A molecule near the surface is assumed to feel the mean field potential (M-S type) and also the surface induced potential. We calculate the values of the nematic order parameter and hence find the $T_{NI}$ for different pore diameters. The weighted average of the order parameter is calculated considering the cylindrical symmetry of the pores. Our calculations on the variation of $T_{NI}$ with pore diameter agree with experimental data. Also, the calculated values of specific heat peak decreases with decrease in pore radius, in agreement with experimental trends.

Key words: PACS. 61.30-v - Liquid crystals. ;PACS. 61.30.Cz - Theory and models of liquid crystal structure,;PACS. 64.70.Md - Transitions in liquid crystals,;PACS. 61.30.Pq - Microconfined liquid crystals.

## 1. Introduction

Liquid crystals made of rod-like organic molecules are now known to exhibit more than twenty different types of symmetries [1]. The simplest of them is the uniaxial nematic (N) which exhibits only a long-range orientational order of the rods. The relevant order parameter is a second rank tensor, as the director $\hat{\boldsymbol{n}}$, which is a unit vector along the average orientation direction of the rods is *apolar* in nature. The Maier-Saupe (MS) molecular mean field theory [2] successfully captures the qualitative features of the nematic-isotropic (N-I) transition, though it is based on the attractive intermolecular interactions only.

Study of confined liquid crystals is of fundamental and technological importance as most of the liquid crystals in device components is located near hard confining interfaces. The surface effects have length scales that are comparable with the length scales of the bulk correlations [3, 4]. Hence, the equilibrium director configuration depends on the elastic constants, surface coupling, the size of the system and its density as well as on applied external fields. There are several studies mainly with dielectric spectroscopy [5, 6, 7], differential scanning calorimetry [8], NMR [4, 9] and X-ray scattering [10], on the molecular dynamics of different alkylcyanobiphenyls in porous media. Also, self-ordered nanoporous aluminum oxide (AAO) [11, 12] has been widely used. Experiments show that the confinement imposed by the rigid AAO pore walls can suppress phase transitions [13, 14]. The nematic-to-isotropic, crystal-to-nematic, and supercooled liquid-to-glass temperatures are studied in the liquid crystal 4-pentyl-4′-cyanobiphenyl (5CB) confined in self-ordered nanoporous alumina and the nematic-to-isotropic and the crystal-to-nematic transition temperatures are found to reduce linearly with the inverse pore diameter [15].

Many models like Potts spin model [16], random field Ising model [17], model based on dilution [18], model based on Monte Carlo simulation [19], simple model for size-dependent transition temperature [20] have been proposed.

In this work, we consider the effect of confinement on the nematic to isotropic (N-I) transition temperature. We propose to use the molecular mean field approach. We modify

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the M-S mean field theory [2] to include the *disordering* effects of porosity as a disordering surface potential.

## 2. Theoretical Model

We have earlier proposed a simple extension of M-S theory to account for the enhancement of the nematic order parameter in thin cells [21, 22] and an extension of Mc Millan theory to account for a surface induced smectic phase [23]. In these [21-23], a molecule near the surface is assumed to feel the mean field potential and also surface induced potential.

The distance from the surface of the pore, into the medium is denoted by z. The medium is assumed to be made up of layers of thickness dz parallel to the pore wall. $U_i$ is the molecular mean field potential of i$^{th}$ molecule at z. $S_z$ is the order parameter for molecules in the layer between z and z + dz. A molecule at z feels the mean field potential (M-S type) and also surface induced potential. The exact nature of the variation of surface potential with respect z is not known experimentally. The potential has to be maximum at z = 0 and zero at large distances from the surface. Thus, as in [21] the surface induced potential for the $i^{th}$ molecule is taken empirically to decay exponentially:

$$U_{iS} = U_S e^{-\frac{z}{r_0}} \qquad (1)$$

where, $U_S = AU_0$ is surface potential at z = 0 and $r_0$ is the characteristic length. $U_0$ is the MS parameter given by $U_0 = 4.541\ kT_{NI}$ where k is the Boltzmann constant. The layer thickness is taken to be quite small, comparable to molecular length [21, 22]. The constant 'A' is to be estimated later.

The mean field is not provided by the entire bulk medium since the interaction beyond few layers is negligible. Also the effect of gradient dS/dz and its elastic energy effects are shown to be very small [24]. Hence, for M-S type mean field also, we use S instead of $S_z$ as in the earlier paper [21, 22]. As the pores are cylindrical, it is convenient to measure the distance (r) from the axis of the cylinder and we use r = R-z where R is the radius of the pore. Weighted average of S is found due to cylindrical symmetry as

$$S_{av} = \frac{\int_0^R S(r) 2\pi r dr}{\int_0^R 2\pi r dr} \qquad (2)$$

## 3. Expression for Free energy and order parameter

As explained above, the potential of the i$^{th}$ molecule at z is written as

$$U_i = -U_0 S P_2(\cos\theta_i) + U_{iS} \qquad (3)$$

Where $P_2$ is the 2$^{nd}$ Legendre polynomial and $\theta_i$ is the angle between nematic director and the long axis of the i$^{th}$ molecule.

The average internal energy per molecule is

$$\frac{U}{N} = -\frac{U_0 S^2}{2} + AU_0 e^{-\frac{z}{r_0}} S \qquad (4)$$

where N is the Avagadro number, the factor 1/2 appears since each pair is counted twice while averaging over the mutual interactions. The order parameter $S$ is found using equation (2).

The Molar entropy is $\xi = -Nk\langle \ln f \rangle$ where $\langle \ln f \rangle = \int_0^1 f \ln f dx$ with $x = \cos\theta$, $f$ is the probability distribution function and < > represents the statistical average.

The average Helmholtz free energy per molecule is F = U − Tξ given by

$$\frac{F}{NkT} = -\frac{U_0 S^2}{2kT} + \frac{AU_0}{kT} e^{-\frac{z}{r_0}} S + < \ln f > \qquad (5)$$

Hence the order parameter is

$$S = \int_0^1 f P_2(x) dx \qquad (6)$$

minimizing $F$ w.r.t $f$ we get,

$$f = \frac{e^{\frac{U_0}{kT}\left(S - Ae^{-\frac{z}{r_0}}\right) P_2(x)}}{Z} \qquad (7)$$

where $Z = \int_0^1 f dx$ is the partition function.

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Substituting for <*f*ln*f*> we get

$$\frac{F}{NkT} = \frac{U_0 S^2}{2kT} - \ln Z \qquad (8)$$

The terms of surface potential depending on $P_2(\cos\theta)$ in equation (3) cancel out in $F$ on substituting for entropy part in equation (5). However, it affects $S$ and hence $F$ through $f$ (see equations 7).

Minimizing $F$ w. r. t $S$, we get

$$S = \int_0^1 f P_2(x) dx \qquad (9)$$

which satisfies the self consistency condition.

The molar specific heat at constant volume is given by

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V \qquad (10)$$

## 4. Calculations and results

The constant A is taken to be positive since the random pore walls have disturbing effect. The weak anchoring energies are of the order of $10^{-5}$ J $m^{-2}$ [1]. Typical molecular weights and density of liquid crystal compounds being 250 and 1 gram/cc respectively [1], the anchoring energy per molecule is found to be of the order of $10^{-3}$ kT for T = 300K. Thus, we use A = 0.003. The necessary integrals are evaluated numerically using 32 point Gaussian quadrature method in double precision. Numerical iteration is used to adjust $S$ for self consistency. Weighted average of $S$ is found using equation (2) for a given value of $R$. Free energy is the calculated and $T_{NI}$ is found. The calculations are repeated for different pore diameters D = 2R. Variation of $T_{NI}$ as a function of 1/D is shown in figure (1).

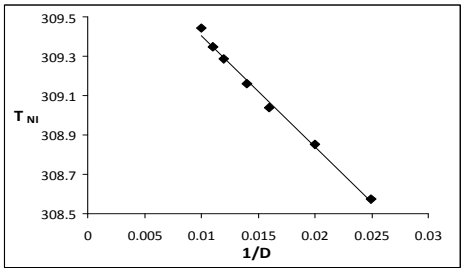


**Figure-1.** Variation of $T_{NI}$ (in $^0$C) as a function of 1/D ($nm^{-1}$) is shown for A = 0.003.

On fitting a straight line, we get $T_{NI} = 309.97 - \frac{56.3}{D}$. We see that the $T_{NI}$ is found to reduce linearly with the inverse pore diameter as seen in the experiment [15]. Also, experimentally [15], $T_{NI} = 310 - \frac{55}{D}$ by differential scanning calorimetry and $T_{NI} = 307.3 - \frac{47}{D}$ by dielectric spectroscopy. It is seen that the calculated values agree well with experimental data.

We have also calculated molar specific heat at constant volume using equation (10). The variation of $\frac{C_{V\,peak}}{NkT_{NI}}$ as a function of pore radius (R) is shown in figure (2).

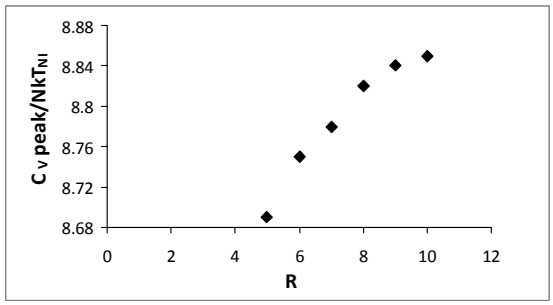


**Figure-2.** Variation of ($C_V/NkT_{NI}$) as a function of R (nm) is shown for A = 0.003.

It is seen that the specific heat peak decreases with decrease in pore radius. This trend agrees with experiment [7]. The values can not be compared since we have found $C_V$ where as experimentally $C_P$ is measured.

## 5. Conclusion

We have extended MS theory to include a disturbing surface potential to explain the reduction in nematic to isotropic transition temperature compared to the bulk when the liquid crystal is embedded in a porous material. Experimental data show that $T_{NI}$ reduces linearly with the inverse pore diameter and the specific heat peak decreases with decrease in pore radius. Calculated values agree well with the experimental data. The model is being further extended to include the smectic layering potential and further work is under progress.

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# STUDY OF THE EFFECT OF SOAP CONCENTRATION ON SURFACE TENSION OF WATER THROUGH LASER DIFFRACTION METHODS.

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**Abstract**

Soaps and detergents play an important role in dirt removal by decreasing the surface tension of water. This decreased surface tension is due to the hydrophobic and hydrophilic ends of the soap molecules forming a layer between the water molecules. In this experiment we study the effect of concentration of liquid detergents on the surface tension of water, and hence its cleansing potential.

The apparatus consists of an electrical vibrator that creates standing waves in the liquid medium, which acts like a grating. A laser beam is focused on it and due to diffraction, equally spaced fringes are observed on the screen. Surface tension is calculated by observing the effect of different frequencies on fringe width. Viscosity of liquids is found using a light meter which measures the intensities of the different fringes formed. Solutions of liquid detergents with distilled water are prepared which are used as the fluid medium for diffraction. The surface tension experiment is carried out accordingly for various concentrations.

Surface tension of distilled water was found to be approximately 60 $mNm^{-1}$ and the viscosity of distilled water, 0.98 mPa.s.

The surface tension of distilled water dropped from 60 $mNm^{-1}$ to as low as 32 $mNm^{-1}$ when detergent was added to it. Also, with increase in concentration of detergent, there was a slight noticeable dip in the surface tension of water. There was no discernable change in the surface tension after a particular concentration.

We were able to conclude that an optimal amount of detergent is sufficient to effectively remove dirt and stains, rather than employing a higher concentration. There is also an indication of a possible saturation limit.

## Introduction

Surface tension is the property of liquids by virtue of which the surface of the liquid behaves like a stretched membrane. This property helps in the propagation of waves on the surface. When a standing wave is formed on a bound surface, it can be considered as a grating to produce well-defined diffraction patterns. When the wavelength of the standing waves is less than a critical wavelength, surface tension dominates and hence can be quantified through the diffraction patterns.

In this experiment, an electric vibrator is used to create standing waves which act as grating for the diffraction of the incident laser beam. From diffraction theory it can be shown that $f^2 = \frac{\sigma\, 2\, \pi\, sin^3\, \theta}{\rho \lambda^3 L^3} (x)^3$ ($Hz^2$)

Viscosity of a liquid is the internal friction exerted by liquid layers to their relative motion. When waves propagate through the liquid, this internal property comes into play and causes damping. Based on the viscosity, these waves will have different amplitudes, thereby allowing us to determine the same using diffraction patterns. In this experiment, to determine viscosity, we use

$$\eta = \frac{3}{8} \frac{\delta\, \sigma}{\pi}$$ (mPa.s)

Soap molecules are long chain hydrocarbons with a hydrophilic head and a hydrophobic tail. The hydrophobic ends are pushed to the surface, causing a dip in the surface tension of water. This affects the cleansing capacity of the soap.

Here, the effect of concentration of soap on the surface tension of water and the optimal amount of detergent soap needed to cleanse at a reasonable rate are looked into.

## Method

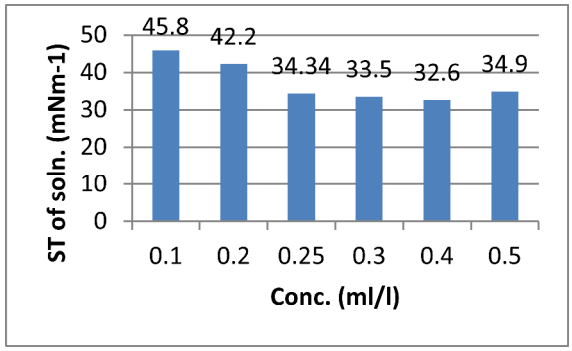
The laser light sensor assembly is moved in steps along the track. The x–displacements of the assembly and the corresponding y-displacements of the laser spot are noted. A graph is plotted and glancing angle(θ) is calculated.

To measure the surface tension(σ), keeping the frequency(*f*) constant, the distance between the second-order maxima above and below the central maximum is measured and fringe width(*x*) calculated. This is repeated for various frequencies. A graph of $x^3$ against $f^2$ is plotted and the surface tension of the liquid is calculated.

To measure the viscosity(η), the frequency is set to 100 Hz and the light sensor is adjusted such that the first order maximum of the diffraction pattern falls on the aperture. The vibrator is displaced away from the point of incidence of the laser in steps of 0.5 cm and the *Vrms* reading is adjusted to get the light meter reading as 100.A graph of *ln(Vrms) vs* displacement *S* is plotted, and the experimentally determined viscosity is obtained.

To measure the surface tension of soap solutions, the aforementioned surface tension experiment is carried out for different concentrations of detergent solutions.

## Results




The surface tension of distilled water was found to be approximately 60 $mNm^{-1}$ and the viscosity,0.98mPa.s.

We observe the surface tension of distilled water drop from 60 $mNm^{-1}$ to as low as 32 $mNm^{-1}$ when detergent is added to it. Also, with increase in concentration of detergent, there is a slight noticeable dip in the surface tension of water. This indicates that an optimal amount of detergent is sufficient to effectively remove dirt and stains, rather than employing a higher concentration. Yet, there is no discernable change in the surface tension after a particular concentration. This is probably indicative of the saturation limit.

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# Physics research training projects: An initiative from Department of Physics UG

The department of physics (UG), with an intension to nurture research interest among the students, is encouraging BSc students to take up projects. Department of Physics purchased two International Physics Olympiad (IPhO) kits from Homi Bhabha Center for Science Education (HBCSE) Mumbai. This involves measurements using diffraction of light from LASER. A manual was provided with the kits regarding the experiments that could be performed.

The group of students selected to carry out the projects are

Darshan, ,Girish Sharma and Srividya from Third B.Sc 'A' section

Sahana C S from second B.Sc 'A' Section

Vishal Gowda, Kiran and Hemanth kumar from Third B.Sc 'E' section.

Initially students were given training to perform the following experiments

1. Determination of geometrical parameters of a helical spring using diffraction pattern.

2. Determination of geometrical parameters of a double helix like pattern using diffraction.

3. Measurement of angle between laser beam and water surface.

4. Determination of surface tension of the given water sample.

5. Determination of viscosity of the given water sample.

Students were encouraged to come up with their ideas in modifying the experiments.

After training, they have determined the surface tension and viscosity of soap solutions of various concentrations which is presented as a separate article.

Presently a new group of students are working, namely

Chetan Sharma, Nitin H M , Krishnan, Nagendra from second Bsc 'A'

Manikanta second Bsc 'C'

They continuing the project work by determining the surface tension and viscosity introducing various impurities into water.

# BIODEGRADATION OF POLYPHENOLS BY ARTHOBACTER CITREUS

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ABSTRACT: Polychlorophenols such as pentachlorophenols and trichlorophenols are major environmental pollutants. Tetrachlorophenol can be naturally produced while pentachlorophenol is anthropogenic in origin. The main sources of polychlorophenol contamination are from their production, application & discharge. Polychlorophenols are harmful to all life forms because they disrupt the integrity and function of biological membranes. Their metabolites are also toxic. The most efficient and economical approach for removal of polychlorophenols is bioremediation. Bacteria can degrade polychlorophenols under both aerobic and anaerobic conditions and fungi are able to aerobically metabolize them. The aerobic breakdown of aromatic compounds starts with monooxygenases or dioxygenases that introduce hydroxyl groups into the aromatic rings and further channelizes the metabolites into TCA cycle for the complete mineralization. However polychlorophenols are converted to substituted quinols before ring cleavage. In the present study we have isolated a microorganism capable of degrading high concentrations of polychlorophenols. The microorganism has been identified as Arthrobactercitreus by biochemical studies. Studies have revealed that the enzyme machinery which is capable of degrading ordinary phenols, nitrophenols, halophenols and cresols are also capable of degrading polychlorophenols. Identification of metabolites by TLC and Spectroscopic methods are indicative of the degradative pathway involving the formation of tetrachloroquinone, tetrachloroquinol, trichloroquinol, dichloroquinol, chloromalylacetate and ketoadipate which enters the TCA cycle.
KEYWORDS: Biodegradation, polyphenols, Arthrobacter.

This paper was presented at the UGC sponsored national conference on Environment and Pollution, held on 23-24 March 2017, at National College, Basavanagudi, Bangalore and got II place under best paper award.

**INTRODUCTION:** Polychlorophenols and their derivatives are widely used as fungicides, pesticides and herbicides. Despite regulation for their usage and release, they remain as the major group of pollutants, highly toxic to humans. Microbial degradation of chemicals in the environment is an important route for removal of pollutants. Bioremediation of pollutants aims to increase the natural rates of biodegradation to produce non toxic end products. Single strain of bacteria is often chosen, so that biochemical interpretations of the degradation process is simplified. Arthrobacter are the basic soil bacteria, but have been found to perform several important functions when the Earth is poisoned by nasty chemicals. Arthrobactercitreus isolated from a contaminated site is known to degrade high concentrations of pencils phenolic derivatives in industrial effluents.

**RESULTS AND DISCUSSION:**

Degradation of Trichlorophenols and Pentachlorophenols occurred in 24 hours. The microorganisms tolerated

Trichlorophenols and Pentachlorophenol concentrations up to 12mM and 15mM respectively. TLC analysis and spectrophotometric analysis of the intermediates suggest that Pentachlorophenol is degraded to Tetrachloroquinone, then to Tetrachloroquinol and further to Trichloroquinol and Dichloroquinol. Dichloroquinol is then converted to Chloromalyl acetate and then to maleyl acetate further converted to betaketo-adipate which enters TCA cycle.

In case of Trichlorophenols, it is first converted to Dichloroquinol and finally to beta keepadipate similar to Pentachlorophenols which enters the TCA cycle. Pentachlorophenolmonoxygenase, Tetrachloroquinonereductase, Tetrachloroquinoldehalogenase ,Dichloroquinoldioxygenase are the key enzymes involved in the above said conversions during the degradation of Pentachlorophenols and Trichlorophenols.

The proposed pathway adopted by the Arthrobactercitreus for the degradation of Pentachlorophenols and Trichlorophenols can be confirmed by assaying for the key enzymes.

**CONCLUSION:**

The present study reports that the isolated Arthrobactercitreus strain which has been already adopted to grow on phenol has an additional ability to degrade Pentachlorophenolsand Trichlorophenols.

The study reveals that Arthrobactercitreus strain can effectively degrade Pentachlorophenols and Trichlorophenols even at higher concentrations. The organism is capable of degrading Nitrophenols, Cresols, Polychlorophenols and other toxic aromatic, therefore, it has a high potential for its use in the development of microbial technology for bioremediation.

Enzyme studies and understanding the genetics of phenolic degradation will be helpful in designing strategies for bioremediation of contaminated environments.

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# HOMOTOPY ANALYSIS METHOD TO SOLVE BOUSSINESQ EQUATIONS

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## ABSTRACT

In this paper, Homotopy analysis method is applied to the nonlinear coupled differential equations of classical Boussinesq system. We have applied Homotopy analysis method (HAM) for the application problems in [1, 2, 3, 4]. We have also plotted Domb-Sykes plot for the region of convergence. We have applied Pade for the HAM series to identify the singularity and reflect it in the graph. The HAM is a analytical technique which is used to solve non-linear problems to generate a convergent series. HAM gives complete freedom to choose the initial approximation of the solution, it is the auxiliary parameter h which gives us a convenient way to guarantee the convergence of homotopy series solution. It seems that more artificial degrees of freedom implies larger possibility to gain better approximations by HAM.

## Indexing terms/Keywords

Homotopy Analysis Method; Coupled Boussinesq Equations; Pade approximations.

## Academic Discipline And Sub-Disciplines

Mathematics, Fluid Mechanics;

## SUBJECT CLASSIFICATION

76N20

## TYPE (METHOD/APPROACH)

Homotopy Analysis Method , Pade Approximation.

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INTERNATIONAL JOURNAL OF MATHEMATICS AND COMPUTER RESEARCH

# Semi Analytic Approximate Solution Of Nonlinear Partial Differential Equations

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**Abstract:** Homotopy analysis method (HAM) is a very strong semi analytical method used to solve almost all nonlinear ordinary and partial differential equations. The effects of heat source/ sink of the boundary layer flow on a steady two dimensional flow and heat transfer past a shrinking sheet is studied by Homotopy Analysis Method. The series solution obtained by HAM is shown to be convergent for choosen h value which was obtained by h curve. Region of convergence is obtained by Domb-Sykes plot. We have also applied Pade for the HAM series and were able to identify the singularity and is reflected in the graph. The convergence of Homotopy series solution is obtained by the h curves. We find that HAM gives better approximation to the solutions.

**Keywords:** Homotopy analysis method, Domb-Sykes plot, Pade approximations, h-curves, Region of convergence.

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## Homotopy Analysis Method solution of a boundary layer flow over a stretching vertical sheet

Smt. Hema. D, Assistant Professor, Department of Mathematics, working under the minor research project by UGC completed in this academic year 2016-17 working with the above problem:

**Abstract**

The governing equations of steady, two-dimensional flow of a viscous and incompressible fluid adjacent to a vertical, continuously stretching sheet are

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

$$u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} = v\frac{\partial^2 u}{\partial y^2} + g(\beta(T - T_\infty))$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2}$$

with the boundary conditions

$Y=0$: $u = u_w(x)$, $v = 0$, $\frac{\partial T}{\partial y} = -\frac{q_w}{k}$, $y \to \infty$ : $u = 0$, $T = T_\infty$

Using similarity transformation, the above equation reduces to

$$f''' + (m+1)/2\, ff'' - m f'^2 + \lambda\theta = 0,$$

$$\frac{1}{\Pr}\theta'' + \frac{m+1}{2} f\theta' - n f'\theta = 0$$

subject to boundary conditions $f(0) = f_w$, $f'(0) = 1$, $f'(\infty) = 0$

Homotopy analysis method is applied to solve the above boundary layer equations. Results obtained are compared with the existing results.

## Homotopy Analysis Method For Heat transfer due to permeable stretching wall.

Smt. Sheela. M, Assistant Professor, Department of Mathematics, Vijaya college, working under the minor research project by UGC completed in this academic year 2016-17 working with the above problem

Flow of an incompressible electrically conducting fluid due to the stretching of a permeable flat **sheet** by B S Dandapat et.al. The governing equations are given by

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\left(\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B_0}{\rho}\right)u \, ,$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}$$

subject to conditions $\mathrm{u}(\mathrm{x},0)=\mathrm{Ax}, \mathrm{v}(\mathrm{x},0)=v_{\mathrm{w}}(\mathrm{x}), \mathrm{u}(\mathrm{x},\infty)=0.$

Using similarity transformation, the above equation reduces to

$$\mathrm{f}'''+\mathrm{f}''-(\mathrm{f}')^2-\mathrm{Hf}'=0$$

Subject to boundary conditions $\mathrm{f}(0)=\mathrm{f}_{\mathrm{w}}, \mathrm{f}'(0)=1, \mathrm{f}'(\infty)=0$

Homotopy analysis method is applied to solve the above boundary layer equations.
Results obtained are compared with the existing results.

# EFFECT OF SUCROSE AND BORIC ACID ON IN VITRO POLLEN GERMINATION OF CULTIVERS OF *Catharanthus roseus* L.

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**ABSTRACT**

In vitro pollen germination study was carried out with two cultivers (white and pink flowered) of ***Catharanthus roseus*** L. belonging to family Apocynaceae, using the Hanging drop method. Different concentrations of sucrose solution (5%, 10%, 15%, 20%, 25% )and varying concentrations of sucrose in combination with (100ppm) boric acid, i.e. 5%+100ppm, 10%+100ppm, 15%+100ppm, 20%+100ppm, 25%+100ppm were used as the germination medium .Percentage of germination and length of pollen tube were recorded after 3hrs and 6 hours of pollen mounting in nutrient medium. In the medium of sucrose, Pink variety showed maximum pollen germination (96.2%) in 15% sucrose solution and the maximum pollen tube length (1231.5µm) in 20% sucrose. The White variety showed maximum pollen germination (97.76%) in 25% sucrose solution and the maximum pollen tube length (1197.0µm) in 20% sucrose. In the medium of sucrose supplemented with boric acid (100ppm), the maximum pollen germination in pink variety was 97.3% in (15% sucrose + 100ppm boric acid) and the maximum pollen germination in White variety was 93.3% in (10% sucrose + 100ppm boric acid). The maximum pollen tube length in Pink variety was 1087.8µm in (15% sucrose+100ppm)boric acid and in White variety was 792.2 in (20%sucrose+100ppm boric acid) .

Key words: Pollen germination, Pollen tube length, *Catharanthus roseus*

**INTRODUCTION**: Pollen is a microgametophytes of seed plants, which produce male gametes . Pollination and pollen germination are important events and prerequisite for fertilization and formation of viable seeds.Pollen germination is the process of formation of pollen tube that carries the male gametes to the site of fertilization. Pollen germination indicates the viability of pollen grains and in vitro germination on artificial media is widely used as a test of viability in the field of plant breeding. ***Catharanthus roseus L.*** ***c***ommonly known as Madagascar Periwinkle is an evergreen, cultivated , ornamental, herbaceous plant. It is used in the treatment of Leukemia in children, lymphoma, diabetes, menstrual problems, asthma and cancer.

**OBJECTIVES OF THE STUDY**: To investigate the influence of culture media with different concentrations of sucrose and sucrose supplemented with boric acid in pollen germination and pollen tube growth of pink and white cultivar variety of ***Catharanthus roseus L.***

**MATERIALS AND METHODS**: Newly opened flowers of *Catharanthus roseus* L were collected in the morning and fresh pollen samples were germinated using solutions of sucrose and boric acid at different concentrations separately and in combinations. . Sucrose solution of different concentration (5%, 10%, 15%, 20%, 25%) was prepared distilled water . (Sucrose+ Boric acid) solution where boric acid was kept constant (100ppm) and sucrose with

different concentration (5%, 10%, 15%, 20%, 25%) was prepared by dissolving 5,10,15,20 &25 gms of sucrose in 100ml of 100ppm boric acid in water, separately. Hanging drop method was followed for germination. A pollen grain was considered as germinated if pollen tube length at least becomes twice greater than the diameter of the pollen grains. Pollen tube length was calculated ,using micrometry .Observations were documented at a time interval of 3 hrs to know the germination percentage and pollen tube length .

**RESULT:** Studies on in vitro pollen germination in Pink variety and white variety of ***Catharanthus roseus*** , observed at different time intervals indicated the following results as summerised in the following tables.

**Table 1**: **Table showing Effect of sucrose on in vitro pollen germination *Catharanthus roseus* – Pink variety**

| Concentration of sucrose solution(%) | After 3hr | | After 6hr | |
|---|---|---|---|---|
| | Germination(% | Mean tube length(µm) | Germination(%) | Mean tube length(µm) |
| 5 | 83.7 | 347.396 | 88.7 | 543.296 |
| 10 | 85.22 | 679.12 | 93.7 | 604.678 |
| 15 | 96 | 578.58 | 96.2 | 595.536 |
| 20 | 90 | 1166.258 | 92 | 1231.558 |
| 25 | 93.3 | 648.858 | 95 | 673.896 |

**Table 2**: **Table showing Effect of sucrose on in vitro pollen germination on *Catharanthus roseus*** white variety

| Concentration of sucrose solution(%) | After 3hr | | After 6hr | |
|---|---|---|---|---|
| | Germination (%) | Mean tube length(µm) | Germination (%) | Mean tube length(µm) |
| 5 | 64.77 | 248.14 | 80.68 | 517.959 |
| 10 | 85.88 | 444.04 | 94.04 | 639.94 |
| 15 | 92.26 | 478.779 | 94.41 | 653 |
| 20 | 93.98 | 617.738 | 96.75 | 1197.076 |
| 25 | 96 | 748.338 | 97.76 | 883.639 |

**Table 3**: **Table showing Effect of (sucrose + boric acid) on in vitro pollen germination on *Catharanthus roseus*** white variety

| (sucrose+boric acid) concentration | After 3hr | | After 6hr | |
|---|---|---|---|---|
| | Germination | Mean tube length(µm) | Germination | Mean tube length(µm) |
| 5%+100ppm | 55.7 | 156.72 | 72.9 | 321.276 |
| 10%+100 ppm | 86.6 | 248.14 | 93.33 | 487.529 |
| 15%+100 ppm | 85.43 | 326.5 | 93.20 | 561.58 |
| 20%+100ppm | 70.80 | 591.618 | 91.97 | 792.219 |
| 25%+100ppm | 84.77 | 648.119 | 93.0 | 735.278 |

Effect of sucrose individually showed good result, but sucrose in combination with boric acid promoted pollen germination as well as tube development. Bursting of pollen grains was observed at increase in sucrose solution. With an increase in the concentration of sucrose in combination with 100ppm boric acid, germination percentage increased. Pollen tube length was more or less found to be corresponding to the percentage of pollen germination.. Addition of 100ppm of boric acid to different concentration of sucrose solution considerably enhanced pollen tube growth.

## CONCLUSION:

In the present study it was observed that percentage of pollen germination was less in sucrose alone. When boric acid was added to the medium, germination percentage as well as pollen tube growth was more. In the absence of boron, pollen tubes showed abnormalities like coiling and bursting.The maximum percentage of pollen germination is 96.2% in 15% of sucrose solution in Pink variety and the maximum pollen tube length is 1231.558µm in 20%sucrose. The maximum percentage of pollen germination is 97.76% in 25% of sucrose solution in White variety and the maximum pollen tube length is 1197.079µm in 20% of sucrose. In the medium of sucrose supplemented with boric acid (100ppm), the maximum pollen germination in pink variety is 97.3% in 15% sucrose + 100ppm boric acid and maximum pollen tube length is 1087.898µm in 15% sucrose+100ppm boric acid .The maximum pollen germination in White variety is 93.335 in 10% of sucrose + boric acid. and in White variety is 792.219 in 20%sucrose+100ppm boric acid.

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## Department of Microbiology
## Research Activities of the department from April 2016 to April 2017

## 1. Paper Publications(Research Paper)

### ISOLATION OF MULTIPLE DRUG RESISTANT (MDR) BACTERIA FROM HOSPITAL ENVIRONMENT

**Madhumita Ghosh Dastidar[1] and M. Razia[2]**

***International Journal of Current Microbiology and Applied Sciences***

**Volume 5 Number 7 (2016) pp. 48-53**

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[2]Department of Biotechnology, Mother Teresa Women's University, Kodaikanal, India

**A B S T R A C T**

A multiple drug resistant (MDR) bacteria are a class of bacteria which is resistant to different classes of antibiotics and cause severe complications in humans as well as animals. This study investigated for isolation and identification and the antimicrobial resistance patterns of *P. aeruginosa* clinical isolates obtained from hospitalized patients. The results confirmed the occurrence of drug resistant strains of *P. aeruginosa*. In this study, molecular identification of 16SrRNA was performed and phylogenetic tree was constructed using a nearly complete sequence within the 16S rDNA gene *P. aeruginosa*. The result shows that the isolate belongs to the species *P. aeruginosa*. Amikacin, ciprofloxacin and Ceptazidine were found to be the most effective antimicrobial drugs. Therefore calls for a very judicious, rational treatment regimens prescription by the physicians to limit the further spread of antimicrobial resistance among the *P. aeruginosa* strains.

## 2.Paper Publications(Review Paper)

### ANTIBIOTIC RESISTANCE IN BACTERIA-A MENACE

**1, Madhumita Ghosh Dastidar and 2Razia, M.**

**Asian Journal of Science and Technology**

**Vol. 07, Issue, 06, (2016) pp.3082-3086,**

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**ABSTRACT**

Antibiotic resistance in microorganisms has become a critical health issue and has evolved to become a worldwide health threat. Over a decade, the resistance level of bacteria has increased many folds due to various factors, accounting to the added pressure on the environmental pollutions. When bacteria become resistant to an antibiotic, that medicine

becomes less effective. Medical treatment of people infected with drug-resistant organisms can become more
complicated, leading to longer hospital stays, increased health care costs, and in extreme cases, to untreatable infections. Prevention of antibiotic drug resistance can be achieved by rational uses according to the instructions of medical practitioners, by educating mass publics and health care workers, also by using combined therapy, alternative treatments or search for new resources. This review focuses on the history of development of antibiotics, the broad mechanism of antibiotic resistance and enlists some of the factors which contribute to the resistance and alternative ways to overcome resistances.

## 3. Paper Publications(Research Paper)

# PRODUCTION OF BIOPLASTICS FROM MICROORGANISMS.

**Sneha Bhat, Nichith K R, Kiran Y, Nagendra M, Pallavi S L, Shreya S, Pruthvi B and *Madhumita Ghosh Dastidar.**

**International Journal of Advanced Research**

**Volume5 Number2 (2017) ,pp.2710-2716**

*Vijaya College, Department of Microbiology, R.V.Road, Basavangudi, Bangalore.

**ABSTRACT**

The deleterious effects of synthetic plastics and their products have become a major concern for researchers. Bioplastics or plastics produced by the microorganism is a promising replacement for the conventional synthetic plastics. Polyhydroxyalkanoate a biologically produced biodegradable substance that has characteristic properties similar to that of conventional plastics. Polyhydroxyalkanoates are secondary metabolites of microorganisms which are produced under stressful conditions. In this work, four different samples were collected. These strains were then morphologically and biochemically characterized. The strains producing polyhydroxyalkanoates from each sample were identified by Sudan Black staining. A 48-hour culture of these strains was harvested and alkali lysis method was used to isolate polyhydroxyalkanoate and polyhydroxyalkanoate was quantified. Sample 2 had the highest polyhydroxyalkanoate accumulation % (95.65%). The method used for the production and isolation of polyhydroxyalkanoate was cost effective and ecofriendly .

Environment Sustainability is responsibility of everyone. To reduce the burden on ecosystem increasing focus is on sustainable alternatives for conventional plastics, chemicals and fuels. The deleterious effects of synthetic plastics and their products have become a major concern for researchers.Bioplastics or plastics produced by the

microorganism is a promising replacement for the conventional synthetic plastics.Polyhydroxyalkanoate a biologically produced biodegradable substance that has characteristic properties similar to that of conventional plastics. Polyhydroxyalkanoates are secondary metabolites of microorganisms which are produced under stressful conditions. In this work, four different samples were collected. These strains were then morphologically and biochemically characterised. The strains producing polyhydroxyalkanoates from each sample were identified by Sudan Black staining. A 48-hour culture of these strains was harvested and alkali lysis method was used to isolate polyhydroxyalkanoate and was quantified.It was observed that highest polyhydroxyalkanoate accumulation was95.65%. The sample was purified further to get cost effective and ecofriendly Bioplstics.

## Research Papers Presented in Conferences

1. **Poster presented in International Conference on "SCIENCE AND TECHNOLOGY FOR MANAGEMENT OF EMERGING ENVIRONMENTAL ISSUES". Organized by Department of Environmental Science, Bangalore University & World Organization of Students and Youth (WOSY). On January 7th 2017.**

## Topic of the poster(Secured Best Paper Award)

# PRODUCTION of GREEN NANOPARTICLES FROM MICROORGANISMS

**Madhumita Ghosh Dastidar**

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**ABSTRACT**

Nanoscience and Nanotechnology are the study and application of extremely small things that can be used across all other science fields such as Chemistry,Biology,Physcis,Material science and Engineering.Nanotechnology. The Nanotechnology creats many new particles and devices with a vast range of applications in Medicine, Biomaterials,Electronics and Energy production.Nanobiotechnology are terms that refer to the merging of nanotechnology and Biological Science. Recently, the use of microorganisms to synthesize functional nanoparticles has been of great interest. These microbial processes have opened up new opportunities to explore novel applications. In contrast to chemical and physical methods, microbial processes for synthesizing nanomaterials can be achieved in aqueous phase under gentle and environmentally conditions. This approach has

become an attractive focus in current green bionanotechnology research towards sustainable development.

An important area of research in nanotechnology is the biosynthesis of silver nanoparticles which are found to have wide applications in the area of medicines, antioxditants, microbicidal agents, drug delivery, environment cleaning agent, food preservative agents etc. Among micro-organisms, bacteria,fungi and various plant extracts have received most attention for the biosynthesis of nanoparticles. The microbiologically synthesized metal nanoparticles are found to be eco-friendly, reliable, biocompatible and economic.

A novel approach for the green synthesis of silver nanoparticles (AgNPs) from aqueous solution of AgNO3 using fungus culture is reported in this work. As a part of investigation, several fungi were isolated from soil and these were treated with different concentrations of silver nitrate solution. Among which Aspergillus niger was found to be most promising organism which were able to convert these silver nitrate ($AgNO_3$) solution to silver nanoparticles extracellularly. The production of these nanoparticles was monitored by change in color of the silver nitrate solution treated fungus solution. The synthesis was observed within 24h, and AgNPs showed characteristic absorbance around 410 nm. Spherical nanoparticles of size 50-100 nm were observed in scanning electron microscopy. The AgNPs showed highly potent antimicrobial activity against Gram-positive, Gram-negative, and fungal microorganisms.It was observed that these nanoparticles acted as strong microbicidal agents. It may be concluded from this experiment that silver nanoparticles obtained from fungus are very significant and indicate that the synthesized silver nanoparticles may have an important advantage over conventional antibiotics.

## 2. Poster presented at UGC sponsored National Conference on BIOESSENCE-Integrated Health Care organized by Department of Life Sciences, Jyoti Nivas College,Bangalore on 11-12$^{th}$ January,2017.

**Topic of the poster**

## Isolation and Screening of Lignin Degrading Microbes and Its Applications

Madhumita Ghosh Dastidar, K Malavika,Akshaya simha.N, Ananth koushik.B, Aradhya.D, Harishmitha.N, Nayana.S, Nidhish.P,Shakthi Vignesh.S,Siri.G, Smruthi.B.K, Tavisha.V.K

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**Abstract**

Aromatic compounds, including phenols and aromatic amines, constitute one of the major classes of pollutants generate in environment. They are found in the wastewaters of a wide variety of industries including coal conversion, petroleum refining, resins and plastics, wood preservation, metal coating, dyes and other chemicals, textiles, mining and dressing, and pulp and paper. Most aromatic compounds are toxic and must be removed from wastewaters before they are discharged into the environment. Enzymatic treatment has been proposed by many researchers as a potential alternative to reduce pollution. A large number of enzymes from a variety of microorganisms have been reported to play an important role in an array of waste treatment applications. They can change the characteristics of a given waste to render it more amenable to treatment or aid in converting waste material to value-added products.

Lignin, a complex organic polymer which form a basic structural component of plants and some algae. Chemically, lignin is made by 3 monomeric subunits namely Guaiacyl propane, syringyl propane and hydroxyphenylpropane. These monomer units are bonded by various ether and carbon-carbon bonds. Lignin is one of the most abundant organic polymers on earth. Hence, lignin degradation plays a significant role in the carbon cycle.

Currently, degradation of lignin has great attention since it is a major pollutant from paper-pulp mill effluent due to its intense unaesthetic brown colour, hydrophobicity and poor mechanical properties, tends to be a recalcitrant compound. Lignin degrading enzymes have applications in bioremediation of environment pollution.

A research work has been taken up to isolate microbes which degrade lignin and to extract lignolytic enzymes. Some bacteria and fungi degrade lignin by producing some enzymes like lignin peroxidase, manganese peroxidase and laccase. To achieve degradation of lignin under laboratory condition, lignin degrading microbes were isolated from various environment niches like soil, sewage and compost. Lignin degrading microbes were isolated using minimal salt media containing 1% alkaline lignin extract. A preliminary screening was done by performing biochemical tests, microbes were tested against a basic dye containing MSML media. The isolates were assayed for the presence of lignin peroxidase enzyme (LiP) and manganese-dependent lignin peroxidase enzyme (MnP). The crude extracts were studied on bioleaching of dye based industrial effluents.

3. **Poster presented in 5th National Conference on Emerging Trends and New Challenges in Biotechnology - Advances in Free Radicals and Antioxidants (NCETNCB 2017) organized by MGR College,Tamil Nadu on 2nd and 3rd February,2017.**

**Research paper (Oral)**

## Lignin Degradation Microbes and Its Potential in Industrial Applications

Madhumita Ghosh Dastidar, Akshaya simha.N, Ananth koushik.B, Aradhya.D, Harishmitha.N, Nayana.S, Nidhish.P,Shakthi Vignesh.S,Siri.G, Smruthi.B.K, Tavisha.V.K

**Department of Microbiology, Vijaya College R .V. Road, Basavanagudi, Bengaluru-560004**

**Research paper Research Paper(Oral persentation-Secured 3rd Prize)**

## Production of Green Plastics-A Solution to Environment Pollution

Madhumita Ghosh Dastidar Pallavi S.L, Nagendra M, Kiran Y, Shreya S,Pruthvi B, Sneha Bhat, Nichith K R.

1. **Research Paper-presented in National Conference on Environment and pollution organized by Department of Zoology, National College, (Autonomous), Basavanagudi, Bengaluru, on 23-03-2017 and 24-03-2017.**

**Research Paper**

## Dandruff Menace- Isolation and Inhibition of Causative Agents

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## ABSTRACT

Dandruff is one of the most common issues whose causal agent is still under contention. Environmental adulteration, stress is some of the predisposing factors which cause dandruff. Dandruff is a condition that people can pretty much self-diagnose from the symptoms of an itchy, dry, and scaly scalp. It usually affects

adolescence and adults. Dandruff is characterized by patches of loosely adherent flakes accompanied by itching.

The microbial origin of dandruff centers on the causal role of yeast belongs to genus Malassezia, fungus (Pityrosporum *ovale).* The role of Staphylococci, Propinobacterium and many other microbes are also prominent in producing typical flakes of the scalp. An In-House project has been taken up to isolate the dandruff causing microbes and to find there sensitivity towards antibiotics and herbal extracts. Through a technique called swabbing the dandruff causing microbes were isolated from a source and was cultured on Nutrient agar and Sabouraud's Agar media. The different microbes were identified through staining techniques. The sensitivity of these microbes towards antibiotics like Streptomycin, Tetracycline and Ciprofloxacin was checked by paper disc plate method. The Minimum Inhibitory Concentration (MIC) of these antibiotics was determined. The antibiotic resistance microbes were treated with various herbal extracts and it was given promising results for treatment of dandruff.

## Research Paper(Oral persentation-Secured Ist Prize)

## Environment Sustainability- Production of Bioplastics

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**ABSTRACT**

Environment Sustainability is responsibility of everyone. To reduce the burden on ecosystem increasing focus is on sustainable alternatives for conventional plastics, chemicals and fuels. The deleterious effects of synthetic plastics and their products have become a major concern for researchers.Bioplastics or plastics produced by the microorganism is a promising replacement for the conventional synthetic plastics.Polyhydroxyalkanoate a biologically produced biodegradable substance that has characteristic properties similar to that of conventional plastics. Polyhydroxyalkanoates are secondary metabolites of microorganisms which are produced under stressful conditions. In this work, four different samples were collected. These strains were then morphologically and biochemically characterised. The strains producing polyhydroxyalkanoates from each sample were identified by Sudan Black staining. A 48-hour culture of these strains was harvested and alkali lysis method was used to isolate polyhydroxyalkanoate and was quantified.It was observed that highest polyhydroxyalkanoate accumulation was95.65%. The sample was purified further to get cost effective and ecofriendly Bioplstic

# INVITRO ANTIBACTERIAL ACTIVITY OF LICHENS AGAINST ORAL MICROORGANISM OF HERBIVOROUS AND CARNIVOROUS ANIMALS

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## ABSTRACT

*Physcia americana, Parmotrema perlatum, Hypogymnia phylodes, Lepraria ecorticata* are the lichens species which was tested for their antibacterial activity against oral microorganisms of both herbivorous and carnivorous animals. The zone of inhibition was found more in the species of *Parmotrema perlatum* collected from southern zone of Karnataka, Coorg. Whereas other species did not show any positive result against the animal swabs. They were investigated for their grams nature and were found to be gram positive bacilli.

Key words: antimicrobial activity, animal swabs, southern zone.

## INTRODUCTION

Lichens are the mutualistic symbionts between fungus and algae, which are grown in moist places and pollution free zone areas. They are poorly found in the industrial areas and big cities (Henganuer, 1962). Lichen has major role in food and drug industries (Vartia, 1973, Richardson, 1988). Lichens produce many secondary metabolites which can be used as a protective guard against many pathogenic microorganisms (Lawrey, 1986, 1989).

Lichens have shown antibiotic, antibacterial, antiviral, antitumor, analgesic and antipyretic properties (Vartia, 1973, Critteenden and Ports 1991, Gollapudi et.al. 1994, Huneck 1999, Muller 2004). At present, a study is made to understand antibacterial activity using different lichen species obtained from various zone of southern Karnataka, both urban and rural regions, against the oral microorganisms obtained from cat, dog, cow, hen and rabbit.

## MATERIALS AND METHODS

**MICROORGANISM CULTURES**: Animal oral swabs were obtained and cultured them on nutrient agar medium and were later tested for grams nature.

**LICHEN SAMPLE COLLECTION:** Four lichen samples *Physcia americana (sample no.8)* from Bangalore, *Lepraria ecorticata (sample no.1),* P*armotrema perlatum (sample no.2) and Hypogymnia physodes (sample no.3)* species from Coorg district of Karnataka, India was

collected by scraping from the bark region using sterile blade and were preserved in the refrigerator in the vials.

**ANTIMICROBIAL ASSAY:** Animal oral swabs collected was streaked on nutrient agar medium and incubated for 24 hours and 37°C. Later appropriate inoculums was seeded in Muller Hinton agar medium. The entire four lichen sample used in the present study were tested for their antimicrobial activity by disk diffusion method (NCLL 1993), no.1 whatmann paper of size 6mm was dipped in distilled water and later soaked in different lichen samples followed by placing them on Muller Hinton agar medium of different oral swabs of animals. Antimicrobial activity was determined by measuring the diameter of the zone of inhibition around the disk for understanding the positive control of growth inhibition, Streptomycin and Gentamycin were used.

## RESULT

The antimicrobial activity of four lichen samples collected from southern region of Karnataka, India tested against the oral microorganisms of dog, cat, cow, hen and rabbit by estimating on the basis of the presence or absence of zone of inhibition with required diameter. The microorganisms used in the present study were analyzed for grams nature.

*Parmotrema perlatum* had strong antimicrobial activity inhibiting the bacteria of dog, cow and hen swab with inhibitory zone of 17mm, 10mm and 10mm and had nil effect on the oral swab of rabbit and cat (Table-1, Graph-1, Figure-1).

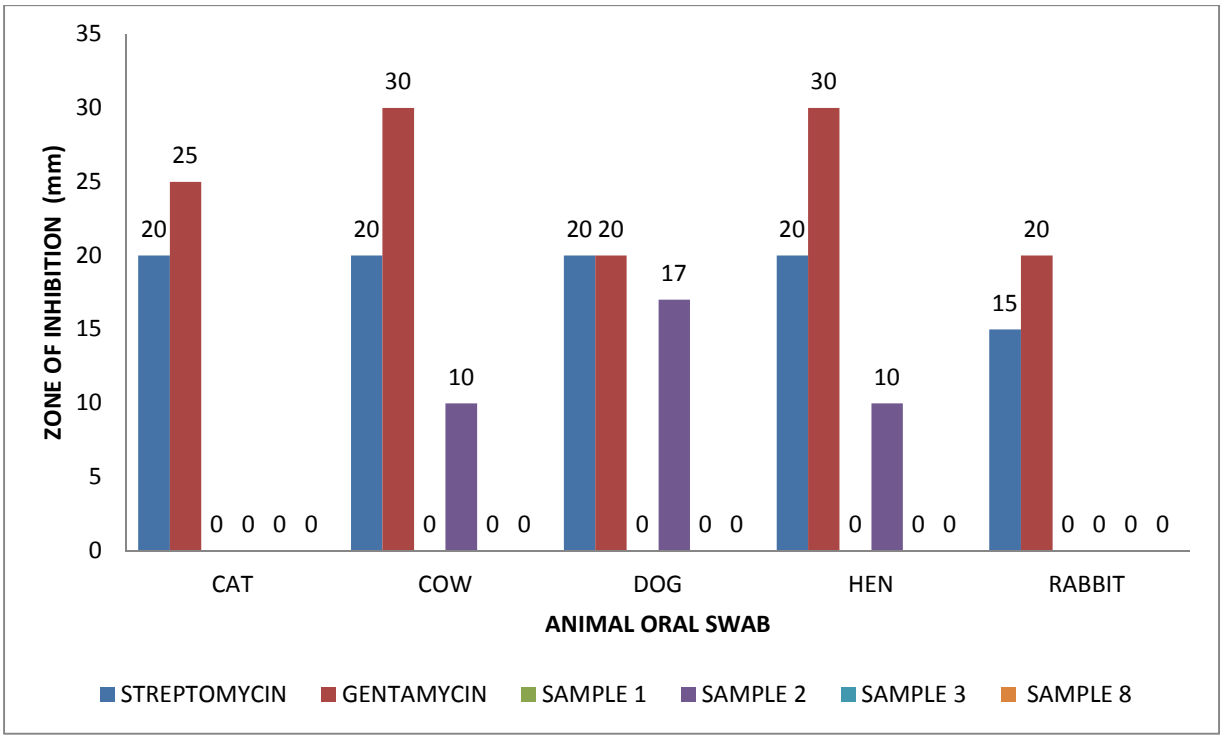
The zone of inhibition was zero with other lichen samples such as *Lepraria ecorticata, Hypogymnia physodes, Physcia americana* (Table-1, Grpah-1, Figure-2).

The positive control used in the present study, streptomycin and gentamycin inhibited the growth of all the bacteria tested. The bacteria tested for grams nature showed gram positive bacilli for all the oral swab used in the present study (Figure-3).

**TABLE-1: ANTIBACTERIAL ACTIVITY OF DIFFERENT LICHEN SPECIES**

| ANIMAL ORAL SWABS | | CAT | COW | DOG | HEN | RABBIT |
|---|---|---|---|---|---|---|
| LICHEN SPECIES | SAMPLE NUMBER | DIAMETER OF ZONE OF INHIBITION(mm) | | | | |
| *Lepreria ecorticata* | 1 | nil | nil | nil | nil | nil |
| *Parmotrema perlatum* | 2 | nil | 10 | 17 | 10 | nil |
| *Hypogymnia physodes* | 3 | nil | nil | nil | nil | nil |
| *Physcia americana* | 8 | nil | nil | nil | nil | nil |
| Control-Gentamycin | - | 25 | 30 | 20 | 30 | 20 |
| Control - Streptomycin | - | 20 | 20 | 20 | 20 | 15 |

**GRAPH – 1: ANTIMICROBIAL ACTIVITY OF LICHEN SPECIES**



## DISCUSSION

The present investigation showed marked results only in *Parmotrma perlatum* and not any other lichen sample .it may be due to poor solubility of insolubility of lichen substances present in the thalli of lichen.

Branislav *et.al* .,2009 has reported that the extract of lichens with acetone, methanol and aqueous showed large variation in their antimicrobial activity.

Thus, the similarity and differences with or without using extracts of different species of lichens are due to presence of different components with antimicrobial activity.

Investigators have reported that level of antimicrobial activity against gram negative and gram positive bacteria is different among different antibacterial agents. The experimental data of current study confirms some of lichens species can be used in manufacture of drug for treating many diseases caused by microorganisms.

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( Note: Fig., Graph and Pictures are not enclosed)


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# CHARACTERIZATION OF SOME BIRDS EGG AND THEIR CHOLESTROL ESTIMATION

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## ABSTRACT

A Study was conducted on varieties of birds eggs there by extracting yolk and albumin. The eggs of java, quail, hen and love bird were chosen for the study and they were procured from commercial farms, bird markets and breeding places. The physical characteristics such as weight, shape, size and colour of the egg were analysed. The yolk and their albumin were separated and incubated at $50^0$c for a period of 48 hours and their moisture loss was calculated. Similarly, the total cholesterol estimated found high in the hens egg followed by love birds, were least in the quail and java egg. Thus a conclusion was drawn that eggs of different birds are almost same colour but different in size, shape and possess different ratio of yolk and albumin.

**Key Words**: Yolk, Albumin, Java, Quail, Hen, Lovebird, Cholesterol.

## INTRODUCTION

There has been increase in using the number of eggs all over the world for the beneficial aspects present in it for the use of human being. At present, various type of fowls egg has been used for commercial purpose. Birds begin to loss weight as soon as they are laid but their volume and dimension do not change even after several days. The shell size of the birds vary from each other but the colour of shell remains same in hen, java and love birds except the quail bird have brown with white dots on its shell.

From centuries, chicken and its egg has been a good source of food due to high number of protein content in it. Consumption of saturated fats, rather than cholesterol in eggs leads to heart diseases, there is no recommended limit on egg consumption as per new in whole egg. General composition of large eggs, reported decade ago,consisted of 58% white, 31% yolk and 11% shell (Stadelman and Cotterill, 1977). The content of solids in whole egg is affected by factors such as ratio of yolk to white, and the solids content in yolk and white (Washburn,1979). The ratio of yolk to white varies widely with the size of eggs (Marion *et al*., 1964). The age of hens can affect eggs solids because egg weight increase with the age of hens (Fletcher *et al*., 1983). The proportion of yolk is reported to be less in small eggs than in larger ones (Kaminska and Skraba, 1991).

**HEN**

The chicken (Gallus gallus domesticus) is a domesticated fowl, a sub species of red jungle fowl , humans first domesticated chickens for the purpose of cockfighting in India and other Europe countries. It is one of the very commonly used as food source, there are variety of hens compared to other species of birds. The hen weighs around 2.5-3.5kg and life span is around 13yrs.

**QUAIL**

The quail (Coturnix coturnix) is one of the small bird, it measures roughly 7.1-8.62 in cm and weighs 3.2-4.62g. Its body colour is streaked brown with a white eye stripe. Its egg is oval shaped and it has a thick shell covering and also has special thick paper like covering inside the shell, its life span is 3-5 yrs. These are the species which feeds on seeds and insects on ground. It is very difficult to find and also reluctant to fly, the only indication of its presence is humming of songs by the male birds. After attaining an age of 6-8 weeks it breeds , laying around 6-12 eggs in a ground nest, it takes around 17-18 days to hatch

**LOVEBIRD**

It is one of the cute and beautiful bird, commonly found all over as pet birds which is also popular for its all time breeding. It's usually 13-17cm long and female weighs around 42-60g whereas male weighs 45-70. Its body is yellow near head and green with black stripes on the whole body, life span is 10-15 yrs. Love birds are generally fed with apples, coconut, rice, raspberry, spinach etc. It lays around 8-9 eggs and these will hatch within 14-20 days.

**JAVA BIRD**

The Java (Lonchura oryzivora), its a popular cage bird and found in large number in many countries. These birds have grey upper parts and breasts, pink belly, red eye ring , pink feet and thick red bill. It's about 15-17cm in length. Life span is 2-3 yrs, but some researchers have reported about 7 yrs. These birds feed mainly on grain and other seeds. They lay around 8 eggs and hatch within days.

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**MATERIALS AND METHODS**

The birds eggs were collected within the period of 2-3 days of its laying. The physical characteristics of egg were done and weighed, later their yolk were separated from albumin followed by their incubation at $50^0$C for a period of 3-4hrs, until all the moisture contents are completely removed and analysed using AOAC method (AOAC,1980). The cholesterol estimation in yolk and albumin of hen, quail, java and lovebirds was done using standard cholesterol solution at 600nm colorimeter reading.

1) **Cholesterol estimation method**:
   A) Cholesterol Solution – 0.02g of cholesterol is dissolved in 100ml of water.
   B) Reagent solution - 2 ml of Conc. Sulphuric acid dissolved in 40ml of acetic anhydride.
   C) Unknown solution preparation – 0.01g of yolk and albumin is dissolved in different test tubes containing 10 ml of distilled water each. From dissolved dissolution pipette 1ml of the solution in different test tubes and add 4ml of alkaline reagent for each test tube. Allow it in room temperature for 15 min and take the readings in colorimeter at 600 nm.

## RESULTS AND DISCUSSION

The study was carried out with an aim of knowing cholesterol content and their beneficial aspects of different birds egg and thus the commonly available birds in the market was considered for the study. The size of the eggs were in the range of medium to small were as the shapes are oval. The total egg weight of hen was found largest with 60.57 g, 9.0 g in quail, 2.20 g in love bird whereas the java egg is 1.96 g.(Table no.1)

The empty shell weight was proportionally high in hens egg with 6.45 g, quail egg with 1.62 g, less with javas egg of 0.21 g and least in lovebird of 0.1 g.(Table no.1)

The moisture loss of eggs is obtained by incubating eggs at different interval of time. The hens egg with respect to yolk was found to be 74.79% and albumin 77.1% thus has more moisture loss compared to other eggs. The quails moisture loss in yolk found to be 75.38% and albumin with 47.89% which is less compared to that of hens egg. Java moisture loss in yolk found to be 87.73% and albumin with 59.67% whereas lovebirds egg in yolk found to be 87.78% and albumin with 61.01% respectively (Table no. 2,3 and Graph 1,2) . Hen (gallus gallus)is considered as the only bird producing highest number of eggs and meat, providing a balanced diet for human population. They constitute 91% of global annual poultry income. It is said that quails egg contains highest of calcium than hens egg, as quail eggs has HDL cholesterol (good cholesterol) instead of LDL cholesterol (bad cholesterol).

The total percentage of cholesterol obtained by cholesterol estimation method found that hens egg has highest % of cholesterol of 0.21%, followed by love bird of about 0.20% where as quails and java egg has less % of cholesterol of 0.15% when compared to that of hens and lovebirds egg.(Table no.4 and Graph 3). From the above results its been found that hens egg has more cholesterol than other birds. Earlier studies has showed that quails egg has good cholesterol than hens egg where the further work can be carried out in this respect.

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# STUDY OF VEIN PATTERN VARIATIONS IN WINGS OF MALE AND FEMALE DROSOPHILA MELANOGASTER MUTANTS AND WILD TYPE

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## ABSTRACT

A study was conducted on the vein pattern variation in the wings of Drosophila melanogaster mutants under light compound microscope. The physical characteristics of veins such as number of veins, veins junction, number of notches and wing area were analysed in both male and female Drosophila melanogaster mutants and were recorded. Thus a conclusion was drawn that in all the mutants such as white eye, sepia eye, vestigial wing , curly wings, ebony body , yellow body, bar eye and wild type showed variations in veins junctions and wing area but showed similarity in number of notches and number of veins.

## INTRODUCTION

Drosophila melanogaster is a small fly belonging to order Diptera which means two winged organisms. They are often called as fruit flies. Insects wings are adult outgrowth of insect exoskeleton that enable insects to fly , found on the second and third thoracic segment. The wings are strengthened by a number of longitudinal veins, which often have cross connection that form closed cells in the membranes. The wings of insect had originated only once in the Arthropod lineage and have suffered considerable variation in shape ,size and patterns of cell differentiation (Kukalova-Peck,1978; Kristeresen, 1981).]

The wings of different insects present many modification in shape ,size & adaptation to variety of functions such as locomotion, defence, melanism and regulation of body temperature(Imms, 1964).The wings are strengthened by a number of longitudinal veins, which often have cross connections that form closed cells in the membranes.

The veins are most characteristic structure of the wings which serve to strengthen the wing and also enclose conducts in which the haemolymph can circulate and may carry trachea and axons (waddinngton, 1940).

Uniform nomenclature of the wing vein is based on homologies and applicable to all order (Comstock and Needham, 1898). The important veins from anterior to posterior are costa(C),Subcosta (Sc), Radius (R),Media (M), Cubitus(Cu) and Anal (A) veins. Pattern of six main veins constituted the ancestral one and other patterns can be derived either by addition or more frequently by reduction of particular vein branches (Comstock and Needham, 1899).

Some reports are also available that in Drosophila, variation pattern is relatively simple when compared with other insects and consists of four longitudinal veins & two short transversal cross veins.

There is no documentary evidence at present regarding the study of veins pattern variation in Drosophila melanogaster mutants male and female flies. Therefore, number of veins, vein junction may be used as a tool to establish a phylogenetic relationship between different species in evolutionary lineage.

## MATERIALS AND METHODS

Drosophila melanogaster mutant flies were procured from Department of Zoology & Genetics, Mysore University, Mysuru and these mutants flies such as white eye, sepia eye, vestigial wings, curly wings, ebony body ,yellow body, bar eye and wild type were reared under the standard laboratory conditions of temperature and humidity. The wings (Right and left) of each mutant flies were clipped off and was observed under camera fixed compound microscope and were later analysed for the various characteristic features such as vein junction's, number of veins, no. of notches by simple counting method.The wing area was calculated by knowing the area of microscopic field in the photograph i.e. $\pi r^2$

## RESULT

The analysis of all the mutant wing (Right and left ) of both male and female flies showed only 1 notches (Graph.1 & Table.1). However, the veins junction in mutant flies showed variations from number 6 to 9 whereas the constant number of 9 vein junction were observed in wild type flies and 6 vein junction in yellow body of right left wings of both male and female flies (Graph .2 & Table.2)

The no. of veins in mutant flies showed no variations in number and found to be the constant number of 5 were observed in both wild type flies and mutant flies of right left wings of both male and female flies (Graph .3 & Table.3)

Similarly, the area of the mutant wings showed variation between 1.31$mm^2$ to 0.98$mm^2$ (Graph.4 & Table.4 )

## DISCUSSION

At present majority of the work has been related to understand the developmental basis for vein pattern variations in other insect wings and a few work has been reported in Drosophila melanogaster mutant and it is mainly restricted to the genetic basis of wing development in D.melanogaster (Blair, 1935).

A remarkable characteristic of venation pattern diversity among both male and female (Right and Left) of the same order and within families were observed as reported by (IMMS, 1964).

Thus modifications during development in wings can be used as a tool for different evolutionary lineages and also for identification to the family or even genus level in many orders of insects.

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# A STUDY OF ECOLOGY OF A LENTIC WATER BODY IN RELATION TO BACTERIAL POPULATION

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**Abstract**

Physico-chemical analysis and study of bacterial population were carried out on water samples of Kavalkere pond in Bannerghatta Biological Park, Bangalore. The bacterial population abundance largely depend on the physico-chebmical conditions prevailing in the water of the pond. The study shows the importance of heterotrophic food chain in the trophic characteristics of a lentic water system.

**Key words**: Physico-chemical, Analysis, Characteristics, Bacteria, Coliforms, population, trophic.

This paper was presented at the UGC sponsored national conference on Environment and Pollution, held on 23-24 March 2017, at National College, Basavanagudi, Bangalore.

## 1. Introduction

Bacteria act as decomposers in a heterotrophic food chain of an aquatic system. Therefore it is important to study different bacterial population of a water body to understand the ecological status of the water body. Several workers have studied bacterial characteristics of drinking water bodies. Few like Ayyappan, Manoharachary have contributed to bacteriological analysis of ponds and lakes in India.

Bannerghatta National Park located 22 km south of Bangalore, was declared as National Park in 1971 by Government of Karnataka for the conservation of wildlife. Bannerghatta National Park has several perennial water bodies, amongst them Kavalkere which is situated in the Zoo area was selected for the present study.

Research on habitat and ecology is essential to a National Park to monitor ecological changes and human impact in order to provide crucial data for continuous planning and management of the National Park. Research may also help in providing valuable insights for ecosystem conservation and management of protected areas.

This is a rare study as it involves habitat of a National Park or a Wildlife spot contributing a bit in developing strategies for the proper management of National Parks and conservation of wildlife in the country.

## 2. Material and Methods

Water samples were collected in sterilized glass bottles at monthly intervals for one and a half year. Physico-chemical analysis and bacterial enumeration were undertaken following standard methods of APHA.

Bacterial enumeration was done by 'serial dilution and plating technique' and 'most probable number (MPN)' method. Dilutions of water samples used were $10^{-1}$ and $10^{-2}$.

Sterile petri plates with respective agar media for different types of bacteria inoculated with diluted water samples were incubated in a bacteriological incubator at 37°C for 24 hr and then colony forming units were counted.

For MPN method sterile tubes containing liquid broth media inoculated with diluted samples were incubated in incubator for 48hr to 72hr and MPN were estimated using standard MPN table.

## 3. Results and discussion

### 3.1 Physico-chemical Analysis

Physico-chemical characters like temperature, pH, alkalinity, free carbon dioxide, dissolved oxygen, phosphate, nitrate, silica, iron etc., are very important biotic factors of an aquatic ecosystem which play major role in productivity and sustaining of organisms in the system. Many of them like phosphate, nitrate act as limiting factors in the growth of organisms.

The findings of physico-chemical characteristics of water are given in Table 1 in the form of ranges of parameters.

**Table 1.Physico-chemical characteristics**

| Parameters | Values (range) |
|---|---|
| Water temperature(°C) | 20.0 – 27.2 |
| pH | 7.4 – 8.6 |
| Free $CO_2$ ( mg $l^{-1}$) | 0.0 – 8.2 |
| Conductivity (µ mho $cm^{-1}$) | 115.28 – 426.39 |
| Total alkalinity (mg $CaCO_3$ $l^{-1}$) | 48 – 152 |
| Nitrate-nitrogen ( mg $l^{-1}$) | |
| Phosphate ( mg $l^{-1}$) | Traces – 0.26 |
| Silica ( mg $l^{-1}$) | Traces to 0.29 |
| Total iron ( mg $l^{-1}$) | 0.01 – 1.3<br>0.02 Traces to 0.9 |
| Dissolved $O_2$ ( mg $l^{-1}$) | 6.8 – 10.83 |
| Dissolved organic matter | 2.3 – 8.9 |

*Water temperature*: The range of water temperature recorded was 20.0 – 27.2°C. The minimum temperature was recorded in December and the maximum in March.

*pH*: Water was found to be slightly alkaline throughout the study period with pH ranging from 7.4 to 8.6. The pH was slightly lesser in June and September probably due to rain.

*Conductivity*: Conductivity ranged from 115.28 to 426.39µ mhocm$^{-1}$. It also remained low during rainy season.

*Free Carbon dioxide*: The free $CO_2$ content of water ranged from 0.0 to 8.2 mg per litre. The higher $CO_2$ level was observed in winter months which may be due to decreased photosynthetic activity by lower density of planktons.

*Total Alkalinity*: The total alkalinity due to both carbonate and bicarbonate ions ranged between 48 to 152mg per litre.

*Nitrate-nitrogen*: It ranged from traces to 0.26 mg per litre, minimum during January and maximum in September. Nitrate is an important factor for all aquatic organisms which may also act as a limiting factor.

*Phosphate*: Phosphate is also a limiting factor for aquatic plants and microbes. It ranged between traces to 0.29 mg per litre.

*Silica*: Silica content varied from 0.01 to 1.3 mg per litre.

*Total iron*: It ranged from traces to 0.9 mg per litre. Iron is an important factor for phytoplankton.

Dissolved$O_2$: The dissolved oxygen concentration ranged from 6.8 to 10.83mg per litre, minimum during summer and maximum during winter. Comparatively high oxygen level may be due to lower water temperature. Water temperature was the controlling factor for dissolved oxygen content.

Physico-chemical analysis reveals that water of the pond is not polluted.

### 3.2 Bacterial Analysis

The bacterial properties are given in Table 3 in the form of range of values and discussed in detail below;

**Table 3. Bacteriological properties** (No. in the bracket indicate maximum)

| Sl.No. | Type of Bacteria | Counts (No. $ml^{-1}$) - range |
|---|---|---|
| 1 | Total Coliforrms | 65 – 250 (950) |
| 2 | Aerobic heterotrophic bacteria | 250 – 630 (2000) |
| 3 | Nitrogen fixing bacteria<br>– Aerobic<br>- Anaerobic | <br>18 – 93<br>10 – 45 |
| 4 | Ammonifying bacteria | 220 – 450 (1240) |
| 5 | Nitrifying bacteria | 8 – 30 (140) |
| 6 | Ureolytic bacteria | 130 – 360 (850) |
| 7 | Phospholytic bacteria | 6 – 36 (185) |
| 8 | Methanogenic bacteria | 3 – 32 |
| 9 | Iron bacteria | 3 - 28 |

Total coliforms

Coliforms are generally estimated from a water body to check its potability as it is an indicator of contamination of water by faecal matter. Water of Kavalkere pond shows Coliforms in the range between 65 – 250 per ml of water with a maximum of 950 in July. It is higher due to the washings of Zoo area that contain animal faecal matter is lead tothe pond. Further, in the rainy season it is maximum.

Aerobic heterotrophic bacteria

Aerobic heterotrophic bacteria numbers varied in a range of 250 – 630 per ml. During rainy season hetrotrophic bacteria number increased with a maximum 2000 per ml in August. This may be due to more dissolved oxygen content of water during rainy season.

Ureolytic bacteria

Number varied from 130 – 360 per ml with a maximum 850 per ml observed in June. The number was higher during summer season when water temperature was high. The higher number of ureolytic bacteria were also coinciding with the higher number of ammonifyingbacteria , both actively engaged in decomposing activity.

Phospholytic bacteria

They varied between 6 – 36 per ml with a maximum of 122 noticed in July. These are the bacteria that are responsible for solubilising inorganic phosphate. Their presence also corresponds to the phosphate content of water.

Iron bacteria

The number of iron bacteria were low ranging from 3 – 28 per ml.

Methanogenic bacteria

Methanogenic bacteria numbers range from3 – 32 per ml. Their presence may be due to animal faecal matter coming with washings from zoo area, which provide substrate for their activity.

## 4. Conclusion

The physico- chemical analysis of water showed that water of Kavalkere is not polluted even though washings of Zoo area carry animal faecal matter adding to the organic content in the pond. This is mainly because of the activities of ammonifying bacteria, ureolytic bacteria and methanogenic bacteria which cause the decomposition of organic matter leading to satisfactorily good water quality. From this it is also evident that most of the coliforms present in the water are not of faecal origin.

If the release of Zoo area washings to the pond is avoided the water can be used to feed the animals.

| Month | Rainfall (mm) | Relative humidity(%) | Atmospheric temperature (°C) |
|---|---|---|---|
| September 2013 | 352.6 | 78 | 24.8 |
| October | 100.2 | 72 | 24.0 |
| November | 143.7 | 71 | 23.0 |
| December | 0.3 | 63 | 21.7 |
| January 2014 | 0.0 | 51 | 22.3 |
| February | 0.2 | 51 | 24.6 |
| March | 0.6 | 43 | 27.3 |
| April | 15.0 | 52 | 29.2 |
| May | 74.6 | 61 | 28.0 |
| June | 189.6 | 73 | 24.4 |
| July | 196.7 | 71 | 24.6 |
| August | 96.3 | 76 | 23.8 |
| September | 68.4 | 69 | 24.7 |
| October | 83.2 | 71 | 24.1 |
| November | 25.0 | 63 | 22.9 |
| December | 0.7 | 64 | 19.8 |
| January 2015 | 0.2 | 52 | 22.3 |
| February | 0.3 | 54 | 24.6 |

**Table2. Monthly rainfall (mm), relative humidity (%) and mean average atmospheric temperature (°C)**

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