☎ 9153549620
✉ dumkalcollege@gmail.com

DUMKAL COLLEGE

P.O-Basantapur,P.S-Dumkal,Dist.-Murshidabad,WestBengal, PIN-742406
(Govt.Aided, Affiliated to the: University of Kalyani Included under section 2(f) & 12 (B) of UGC Act.)

2nd CYCLE NAAC ACCREDITATION PROCESS-2024

CRITERIA: 3 – Research, Innovations and Extension

Key Indicator: 3.3- Research Publications and Awards

Metric: 3.3.1: Number of research papers published per teacher in the Journals notified on UGC care list during the last five years

Peer Reviewed ISSN Approved | Impact Factor: 7.17

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS

International Peer Reviewed & Refereed Journals, Open Access Journal
E-ISSN 2348-1269, P- ISSN 2349-5138

Scholarly open access journals, Peer-reviewed, and Refereed Journals, Impact factor 7.17 (Calculate by google scholar and Semantic Scholar | AI-Powered Research Tool), Multidisciplinary, Monthly, Indexing in all major database & Metadata, Citation Generator, Digital Object Identifier (DOI), UGC Approved Journal NO: 43602(19)

Publisher and managed by: IJ Publication

Website: www.ijrar.org | E-mail: editor@ijrar.org

An Empirical Study to Understand the Impact of Crude Oil Prices on Indian Stock Market.

Amritendu Roy
Assistant Professor of Economics,
Dumkal College, Murshidabad,W.B, India

Abstract

India is the 3rd largest oil importing nation and world 7th largest economy. Around 80% of crude requirements are imported. Nearly 60% of its imports constitute crude oil. This makes it at least 2% of its India's full year GDP. Rising crude affects India's balance of payments. It also affect rupee negatively as more money flows out of the system to buy dollars to pay crude payment. Global crude oil price change on the back of geo-political fierce like war etc or over a potential demand supply disruption or any policy stance taken by the OPEC countries. It is important to study the impact of oil price movements and stock market prices because the emerging economies like India continue to grow and prosper and are anticipated to ply larger influence over the world economy.

This study aims to find out whether there is any long term correlation between stock price movements with respect to changes in crude price. Our study used monthly data from April 2001 to April 2019. Unit root test, Johansen co integration test, Granger causality test have been applied to study long term relationship between them. Empirical results have found that there is no correlation between the variables.

Keywords: Crude price, Co-integration, Stock Market

Introduction

Integration of international markets and Liberalization of emerging economies characterized with international investments and increased level of capital flows have made the global investments more vulnerable to emerging stock markets with respect to oil price fluctuation. Economic variables are affected by small changes in oil prices.

Rise in oil prices may have adverse effects depending on whether the increase in crude oil prices is driven by supply shocks or demand shocks. Further rises in oil price may have negative effects on emerging market economies that has no oil producing facilities and positive effect on the oil producing countries. Crude price movement plays a crucial role in the development of an economy. The recent rise in price is due to production cut by oil producing countries and improvements in global demand as the food is rolled out across the world. Brent crude price crossed US dollar 60 per barrel after over a year. In January 2019 the West Texas Intermediate (WTI) crude slipped below zero for the first time in history to a negative US dollar 40.32 per Barrel. A large number of oil producing countries cut oil production previous year due to a sharp fall in demand caused by lack of food. Saudi Arabia decided along with other major oil production countries of the world to decrease oil production, Saudi Arabia alone decrease oil production by one million barrels each day to increase crude prices.

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Ref No : IJRAR/Vol 6 / Issue 2/ 536

To,
Amritendu Roy
Publication Date 2019-05-07 23:15:04

Subject: Publication of paper at International Journal of Research and Analytical Reviews (IJRAR).

Dear Author,

With Greetings we are informing you that your paper has been successfully published in the International Journal of Research and Analytical Reviews (IJRAR) - IJRAR (E-ISSN 2348-1269, P- ISSN 2349-5138). Thank you very much for your patience and cooperation during the submission of paper to final publication Process. It gives me immense pleasure to send the certificate of publication in our Journal. Following are the details regarding the published paper.

About IJRAR	: UGC and ISSN Approved - International Peer Reviewed Journal, Refereed Journal, Indexed Journal, Impact Factor: 7.17, E-ISSN 2348-1269, P- ISSN 2349-5138
UGC Approval	: UGC Approved Journal No: 43602
Registration ID	: IJRAR_248989
Paper ID	: IJRAR19K9536
Title of Paper	: AN EMPIRICAL STUDY TO UNDERSTAND THE IMPACT OF CRUDE OIL PRICES ON INDIAN STOCK MARKET.
Impact Factor	: 7.17 (Calculate by Google Scholar) | License by Creative Common 3.0
DOI	:
Published in	: Volume 6 | Issue 2 | May 2019
Publication Date:	2019-05-07 23:15:04
Page No	: 37-44
Published URL	: http://www.ijrar.org/viewfull.php?&p_id=IJRAR19K9536
Authors	: Amritendu Roy

Thank you very much for publishing your article in IJRAR. We would appreciate if you continue your support and keep sharing your knowledge by writing for our journal IJRAR.

R.B. Joshi

Editor In Chief
International Journal of Research and Analytical Reviews - IJRAR
(E-ISSN 2348-1269, P- ISSN 2349-5138)

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

E-ISSN: 2348-1269, P-ISSN: 2349-5138

Certificate of Publication

The Board of

International Journal of Research and Analytical Reviews (IJRAR)

Is hereby awarding this certificate to

Amritendu Roy

In recognition of the publication of the paper entitled

AN EMPIRICAL STUDY TO UNDERSTAND THE IMPACT OF CRUDE OIL PRICES ON INDIAN STOCK MARKET.

Published In IJRAR (www.ijrar.org) UGC Approved - Journal No : 43602 & 7.17 Impact Factor

Volume 6 Issue 2 May 2019, Date of Publication: 07-May-2019

PAPER ID : IJRAR19K9536

Registration ID : 248989

R.B.Joshi

EDITOR IN CHIEF

UGC and ISSN Approved - Scholarly open access journals, Peer-reviewed, and Refereed Journals, Impact factor 7.17 (Calculate by google scholar and Semantic Scholar | AI-Powered Research Tool) , Multidisciplinary, Monthly Journal

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS | IJRAR

An International Scholarly, Open Access, Multi-disciplinary, Indexed Journal

Website: www.ijrar.org | Email: editor@ijrar.org | ESTD: 2014

Manage By: IJPUBLICATION Website: www.ijrar.org | Email ID: editor@ijrar.org

IJRAR | E-ISSN: 2348-1269, P-ISSN: 2349-5138

BHASAPATH

Essays In Philosophy

ISSN : 2455 9512

Vol : IV, Issue No. 2

June - August 2018

Chief Editor : Abhijit Bandyopadhyaya

Guest Editor : Anupam Jash

Cover by Sanjay Lokhande

BHASAPATH

Essays in Philosophy

Chief Editor
Abhijit Bandyopadhyaya

Guest Editor
Anupam Jash

BHASAPATH

A Peer Reviewed Journal
Special Philosophy Issue
Essays in Indian and Western Philosophy

ISSN: 2455-9512
Regd. No. WBBEN/2015/64674
Vol-IV, Issue No.-2
June -August 2018

Date of Publication
30 June 2018

Chief Editor
Abhijit Bandyopadhyaya

Guest Editor
Anupam Jash

Editorial Board
Siddheswar Acharya, Sanat Banerjee, Biswajit Guin, Subha Roychowdhury
Amitava Chakraborty, Arup Banerjee, Anupam Jash, Koushik De
Sankar Palit, Shyamacharan Karmakar, Subhadip Sen Sharma

In Collaboration With Department of Philosophy
Bankura Christian College, Bankura

Composed by
Aditya Singha [9333205761]

Printed at
Aksharbinyas, Katwa, Purba Bardhaman

Published by
Indrani Banerjee

Editorial House
Nirjhar Smriti, Kalitala, Madhuban
Kalna, Purba Bardhaman, 713409
Contact : 9434573352 / 9932250071
Email : bhasapath@gmail.com

Website : www.bhasapath.com

Price : 1200.00 [for this special issue]

BHASAPATH
A Peer Reviewed Journal
Special Philosophy Issue
Essays in Indian and Western Philosophy

ISSN: 2455-9512
Regd. No. WBBEN/2015/64674
Vol-IV, Issue No.-2
June -August 2018

Date of Publication
30 June 2018

Chief Editor
Abhijit Bandyopadhyaya

Guest Editor
Anupam Jash

In Collaboration With Department of Philosophy
Bankura Christian College, Bankura

Composed by
Aditya Singha [9333205761]

Printed at
Aksharbinyas, Katwa, Purba Bardhaman

Published by
Indrani Banerjee

Editorial House
Nirjhar Smriti, Kalitala, Madhuban
Kalna, Purba Bardhaman, 713409
Contact : 9434573352 / 9932250071
Email : bhasapath@gmail.com

Website : www.bhasapath.com

Price : 1200.00 [for this special issue]

সূচিপত্র

রবীন্দ্রনাথের মননে গৌতম বুদ্ধের দার্শনিক চিন্তা

আব্দুল আলীম সেখ

এম.ফিল গবেষক, দর্শন বিভাগ, রামকৃষ্ণ মিশন বিদ্যামন্দির

ভারতীয় মহামানবের ঐতিহাসিক আলোচনার পরিমণ্ডলে গৌতম বুদ্ধ ও রবীন্দ্রনাথ দু'জন উজ্জ্বল জ্যোতিষ্ক স্বরূপ প্রতীয়মান। গৌতম বুদ্ধকে যদি আমরা দুঃখ নামক রোগের মহাঔষধীর আবিষ্কারক ভাবি তাহলে সাহিত্যের মাধ্যমে বাঙালি ঘরে পৌঁছে দেওয়ার যথেষ্ট চেষ্টা রবীন্দ্রনাথ ঠাকুর করেছিলেন সে বিষয়ে সন্দেহের কোন অবকাশ থাকে না। উনবিংশ শতকে বাঙালি জাতির নবজাগরণের সূচনা স্বরূপ সাহিত্য-সংস্কৃতির উপলব্ধি এবং তার পাশাপাশি ধর্মচিন্তা ও দার্শনিক উপলব্ধির একটি অসম্ভব সংযোগ গড়ে উঠেছিল। দ্বিজেন্দ্রনাথ ঠাকুর, সত্যেন্দ্রনাথ ঠাকুর, হরপ্রসাদ শাস্ত্রী, রামদাস সেন, রাজকৃষ্ণ মুখোপাধ্যায়, কেশবচন্দ্র সেন, রাজা রাজেন্দ্রলাল মিত্র, রমেশচন্দ্র দত্ত, চারুচন্দ্র বসু, অঘোরনাথ গুপ্ত, নবীনচন্দ্র সেন, শরচ্চন্দ্র দেব, সতীশচন্দ্র বিদ্যাভূষণ প্রমুখ মনীষীতুল্য ব্যক্তিগণ বুদ্ধদেবের জীবন ও দর্শন নিয়ে বিভিন্ন গ্রন্থাদি রচনা করেছিলেন। এই সমস্ত মহামনীষীদের লেখনী রবীন্দ্রমানস গঠনে যথেষ্ট প্রভাব ফেলেছিল। রবীন্দ্রনাথ ছিলেন ভারতীয় উপমহাদেশীয় সাহিত্যচিন্তার জগতে এক উজ্জ্বল রত্ন বিশেষ। তাছাড়া তৎকালীন ঠাকুর পরিবার ছিল বাংলা সাহিত্য-সংস্কৃতিচর্চার একটি উন্নত পীঠস্থান। তাই স্বাভাবিকভাবেই রবীন্দ্রনাথের পারিবারিক আবহেও ছিল ভগবান বুদ্ধের দর্শনের চর্চার এক অতি মূল্যবান আয়তন। তাঁর সহোদর দ্বিজেন্দ্রনাথ ঠাকুর 'আর্যধর্ম এবং বৌদ্ধধর্মের পরস্পর ঘাতপ্রতিঘাত ও সঙ্ঘাত' (১৮৯৯) এবং সত্যেন্দ্রনাথ ঠাকুর রচিত 'বৌদ্ধধর্ম' (১৯০১) গ্রন্থদুটিই তার প্রমাণ বহন করে। এছাড়াও রাজেন্দ্রলাল মিত্রের 'The Sanskrit Buddhist Literature of Nepal' (১৮৮২), গিরিশচন্দ্র ঘোষের 'বুদ্ধচরিত' (১২৯২) নাটক এবং নবীনচন্দ্র সেনের 'আমিতাভ' (১৩০২) কাব্যের দ্বারা রবীন্দ্রনাথের মননে গৌতম বুদ্ধের মহত্ব প্রকাশে সহায়তা করেছিল। এছাড়া ইংরেজ কবি এডুইন আর্নল্ডের 'Light of Asis' (১৮৭৯) গ্রন্থটিও রবিঠাকুরের মনে গৌতম বুদ্ধের দর্শন চিন্তা একটি গভীর রেখাপাত টেনেছিল। অবনীন্দ্রনাথ প্রমুখ শিল্পীগণ বুদ্ধদেব ও বৌদ্ধসংস্কৃতির এক একটা মূল্যবান দিক উন্মোচন করে গেছেন। বেদ, উপনিষদ, ইসলাম ধর্ম, খ্রিস্ট ধর্ম, বৌদ্ধ ধর্ম, বৈষ্ণব ধর্ম, বাউল, সাধু, সন্ত, সহজিয়া প্রভৃতি ধর্ম ও দর্শন রবীন্দ্রনাথ ঠাকুরের সাহিত্য সম্পদে যে প্রভাব রেখেছিলো তার মধ্যে নিঃসন্দেহে বৌদ্ধ ধর্ম ও দর্শনের প্রভাব অগ্রগণ্য। এছাড়া রবীন্দ্রমানসে ভারতীয় দর্শনের বিভিন্ন সম্প্রদায়ের ভূমিকা অবশ্য স্বীকার্য। বৌদ্ধ ধর্ম ও

Eur. Phys. J. Plus (2019) **134**: 462
DOI 10.1140/epjp/i2019-12824-6

THE EUROPEAN PHYSICAL JOURNAL PLUS

Regular Article

Study of strongly nonlinear oscillators using the Aboodh transform and the homotopy perturbation method

K. Manimegalai[1], Sagar Zephania C F[1], P.K. Bera[2], P. Bera[3], S.K. Das[4], and Tapas Sil[1,a]

[1] Department of Physics, Indian Institute of Information Technology Design and Manufacturing Kancheepuram, Chennai - 600127, Tamil Nadu, India
[2] Department of Physics, Dumkal College, Basantapur, Dumkal, Murshidabad - 742303, West Bengal, India
[3] School of Electronics Engineering, VIT University, Vellore - 623014, Tamil Nadu, India
[4] Department of Mechanical Engineering, IIT Ropar, Rupnagar - 140001, Punjab, India

Received: 9 May 2019 / Revised: 10 June 2019
Published online: 25 September 2019

Abstract. A generalized equation is constructed for a class of classical oscillators with strong anharmonicity which are not exactly solvable. The Aboodh transform-based homotopy perturbation method (ATHPM) is applied to get the approximate analytical solution for the generalized equation and hence some physically relevant anharmonic oscillators are studied as the special cases of this solution. ATHPM provides the approximate analytical solution of the generalized equation in a simple way. The solution from this simple method not only shows excellent agreement with the numerical results but is also found to be of better accuracy in comparison to the solutions obtained from other established approximation methods whenever compared for physically relevant special cases.

1 Introduction

Most of the physical systems are nonlinear in nature and hence they are mostly not exactly solvable [1–3]. Although, getting numerical solution for the differential equations representing systems involving nonlinearity are sometimes easy, one desires to get the analytic solution of such problems as they carry more information and hence give a better insight into the system. The perturbation method is a widely used method for finding an approximate solution to complex nonlinear systems, especially with the nonlinear term appears as an additional term of small order to an exactly solvable problem. As the equations for many nonlinear systems do not have small parameter, application of perturbation technique is highly restricted. There are many techniques for solving nonlinear oscillator problems analytically such as the harmonic balance method [4], the Krylov-Bogolyubov-Mitropolsky method [5], weighted linearization method [6], perturbation procedure for limit cycle analysis [7], modified Lindstedt-Poincaré method [8], Adomain decomposition method [9], artificial parameter method [10], Homotopy Analysis method (HAM) [11,12], Laplace transform based variational iteration method [13] and so on. Most of these methods are not only involved the calculational rigor but also failed to handle problems with strong nonlinearity properly. Recently, a new technique is proposed to obtain an analytical solution to the dynamic model of a wind-power system which found to yield very good results without any higher-order approximation [14]. Energy balance method (EBM) proposed by He [15] based on the variational principle, is one of the commonly used non-perturbative techniques. This heuristic approach is found to be working well for several strongly nonlinear systems [16–18]. There exists another non-perturbative analytic method due to He [19] known as frequency-amplitude-formulation (FAF) method, which finds a lot of successful applications [16,20,21]. FAF does not require a small parameter and a linear term in the differential equation. Recently, Nofal *et al.* [22] employed FAF followed by EBM, to study some physically relevant anharmonic oscillators with strong anharmonicities and concluded that this FAF-EBM method has given much better accuracy in comparison to that obtained by using EBM alone.

He developed the homotopy perturbation method (HPM) for solving linear, nonlinear, initial and boundary value problems [23,24]. In this method, the solution is given in an infinite series usually converging to an accurate solution [25,26]. HPM is found to be very efficient in solving problems with strong nonlinearity in classical [23,24,27] as well as quantum mechanical domain [28].

[a] e-mail: tapassil@iiitdm.ac.in

Table 1. Important Aboodh transforms of some functions.

$f(t)$	1	t	t^n	e^{at}	$\sin(at)$	$\cos(at)$	$t\sin(at)$	$\sinh(at)$	$\cosh(at)$
$A[f(t)]$	$\frac{1}{\nu^2}$	$\frac{1}{\nu^3}$	$\frac{n!}{\nu^{n+2}}$	$\frac{1}{\nu^2-a\nu}$	$\frac{a}{\nu(\nu^2+a^2)}$	$\frac{1}{(\nu^2+a^2)}$	$\frac{2a}{(\nu^2+a^2)^2}$	$\frac{a}{\nu(\nu^2-a^2)}$	$\frac{1}{(\nu^2-a^2)}$

Aboodh introduced a transform [29] derived from the classical Fourier integral for solving ordinary and partial differential equations easily in the time (t) domain. Aboodh transform (AT) has been applied for different types of problems and is found to be a very simple technique to solve differential equations.

We construct a generalized nonlinear differential equation which, under certain approximation, reduces to different physically relevant problems, such as vibration of tapered beam, motion of a particle in arranged parabola, Mathews-Lakshmanan oscillator, etc. The Aboodh transform-based homotopy perturbation method (ATHPM) is applied to find out a generalized solution to these problems and hence to get the displacement (x) and the frequency oscillation (ω) for the special cases. We compare ATHPM results to those obtained from FAF-EBM and numerical calculations (RK4) to check its accuracy.

This paper is organized as follows. In sect. 2, we demonstrate briefly the formulation of ATHPM. Applications of ATHPM to study some physically relevant anharmonic oscillators have been shown in sect. 3. Finally, in sect. 4, we provide a brief discussion and our conclusions.

2 Formalism

If $f(t)$ is the piecewise continuous function of t, the corresponding Aboodh transform is defined as [29]

$$A[f(t)] = f(\nu) = \frac{1}{\nu}\int_0^\infty f(t)e^{-\nu t}\mathrm{d}t, \quad t \geq 0,\ k_1 \leq \nu \leq k_2, \tag{1}$$

where k_1, $k_2 > 0$ and may be finite or infinite. In order to make sure that this integrand diminishes rapidly for the convergence, or $f(t)$ does not grow rapidly, it is assumed that $f(t)$ is a function of exponential order. The Aboodh transform of some functions, useful for this article, are presented in table 1. The inverse Aboodh transform of a function can also be obtained from table 1. The Aboodh transform of the first- and the second-order time derivative of $x(t)$ is given as follows:

$$\begin{aligned} A[f'(t)] &= \nu f(\nu) - \frac{f(0)}{\nu}, \\ A[f''(t)] &= \nu^2 f(\nu) - \frac{f'(0)}{\nu} - f(0). \end{aligned} \tag{2}$$

Let us consider a nonlinear inhomogeneous differential equation as

$$Lx(t) + \omega^2 x(t) + Rx(t) + Nx(t) = g(t), \tag{3}$$

with the initial conditions at $t = 0, x(0) = a$ and $x'(0) = 0$ Here, L is the second-order linear differential operator ($L \equiv \frac{\mathrm{d}^2}{\mathrm{d}t^2}$), R is the linear operator having an order less than L, N is the nonlinear operator, $g(t)$ is the inhomogeneous term and ω is a parameter. Now, taking the Aboodh transform on both sides of eq. (3), we get

$$A[Lx(t)] + \omega^2 A[x(t)] + A[Rx(t)] + A[Nx(t)] = A[g(t)]. \tag{4}$$

Using the differential properties of the Aboodh transform (AT) as mentioned above and the initial conditions, eq. (4) can be written as

$$x(\nu) = \left(\frac{1}{\nu^2+\omega^2}\right)x(0) + \frac{x'(0)}{\nu(\nu^2+\omega^2)} - \left(\frac{1}{\nu^2+\omega^2}\right)A[Rx(t)] - \left(\frac{1}{\nu^2+\omega^2}\right)A[Nx(t)] - \left(\frac{1}{\nu^2+\omega^2}\right)A[g(t)]. \tag{5}$$

Taking the inverse Aboodh transform on both sides of eq. (5), we get

$$x(t) = X_0(t) - A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[Rx(t)]\right] - A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[Nx(t)]\right] - A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[g(t)]\right], \tag{6}$$

where

$$X_0(t) = A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)x(0) + \frac{x'(0)}{\nu(\nu^2+\omega^2)}\right]. \tag{7}$$

According to the homotopy perturbation method [23,19,28], we may expand $x(t)$ in power of an embedded parameter p $(0 \leq p \leq 1)$ as, $x(t) = \sum_{n=0}^{\infty} p^n x_n(t)$ and nonlinear term $Nx(t) = \sum_{n=0}^{\infty} p^n H_n(x)$, where He's polynomial $H_n(x)$ can be written as

$$H_n(x) = \frac{1}{n!}\frac{\mathrm{d}^n}{\mathrm{d}p^n}\left[N\sum_{n=0}^{\infty} p^n x_n(t)\right], \quad n = 0, 1, 2, 3, \ldots. \tag{8}$$

By the construction of homotopy, here we get an exactly solvable problem for $p = 0$ whereas $p = 1$ corresponds to the nonliear problem for which we are trying to find the solution. Applying HPM and substituting the value of $x(t)$ and $Nx(t)$ in eq. (6) in terms of the power series of p and $H_n(x)$, we get,

$$\begin{aligned}\sum_{n=0}^{\infty} p^n x_n(t) = X_0(t) - p\Bigg(&A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A\left[R\sum_{n=0}^{\infty} p^n x_n(t)\right]\right] \\ &+ A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A\left[\sum_{n=0}^{\infty} p^n H_n(t)\right]\right] + A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[g(t)]\right]\Bigg).\end{aligned} \tag{9}$$

Comparing the coefficient of like power of p on both sides, we get the following relations from eq. (9),

$$p^0 : x_0(t) = X_0(t), \tag{10}$$

$$p^1 : x_1(t) = -A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A\left[Rx_0(t)\right]\right] - A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[H_0(x_0(t))]\right] - A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[g(t)]\right], \tag{11}$$

$$p^2 : x_2(t) = -A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[Rx_1(t)]\right] - A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[H_1(x_1(t))]\right] - A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[g(t)]\right]. \tag{12}$$

The approximate solution, as $p \to 1$, is

$$x(t) = \lim_{p\to 1}\sum_{n=0}^{\infty} p^n x_n(t) = x_0(t) + x_1(t) + x_2(t) + x_3(t) + \ldots. \tag{13}$$

Here, $x_0(t)$ is the zeroth-order term which corresponds to the solution $p = 0$ homotopy, *i.e.*, the exactly solvable part of the equation. The first order correction is represented by x_1 and x_2 is the second order term and so on. It is to be noted that the approximate solution of $x(t)$ in eq. (13) is independent of the expansion parameter p or any other perturbative parameter. The HPM solution not only converges very fast but it also gives the exact solution with the certain assumption [26,30].

3 Applications

We construct the following differential equation representing the general form of a group of nonlinear oscillators which are profusely used for describing physical systems [18,22,31–33] encountered in science and engineering:

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \frac{\lambda x + a_1 x(\frac{\mathrm{d}x}{\mathrm{d}t})^2 + a_2x^3\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2 + a_3x^3 + a_4x^5}{1 + b_1x^2 + b_2x^4} = 0, \tag{14}$$

where λ, a_1, a_2, a_3, a_4, b_1 and b_2 are arbitrary parameters. Let us rewrite eq. (14) as

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \omega^2 x = (\omega^2 - \lambda)x - b_1x^2\frac{\mathrm{d}^2x}{\mathrm{d}t^2} - b_2x^4\frac{\mathrm{d}^2x}{\mathrm{d}t^2} - a_1x\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2 - a_2x^3\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2 - a_3x^3 - a_4x^5, \tag{15}$$

where ω is the frequency of oscillation of the system. We apply AT on both sides of eq. (15) to get

$$\begin{aligned}x(\nu) = &\left(\frac{1}{\nu^2+\omega^2}\right)x(0) + \frac{x'(0)}{\nu(\nu^2+\omega^2)} + (\omega^2-\lambda)\left(\frac{1}{\nu^2+\omega^2}\right)A[x] \\ &- b_1\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x^2\frac{\mathrm{d}^2x}{\mathrm{d}t^2}\right] - b_2\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x^4\frac{\mathrm{d}^2x}{\mathrm{d}t^2}\right] \\ &- a_1\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2\right] - a_2\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x^3\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2\right] \\ &- a_3\left(\frac{1}{\nu^2+\omega^2}\right)A[x^3] - a_4\left(\frac{1}{\nu^2+\omega^2}\right)A[x^5].\end{aligned} \tag{16}$$

With help of the properties of inverse Aboodh transform, as given in table 1, and applying the initial conditions, $x(0) = a$ and $x'(0) = 0$, we obtain $x(t)$ from eq. (16) as follows:

$$\begin{aligned} x(t) = {} & a\cos\omega t + (\omega^2 - \lambda)A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[x]\right] \\ & - b_1 A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x^2\frac{\mathrm{d}^2x}{\mathrm{d}t^2}\right]\right] - b_2 A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x^4\frac{\mathrm{d}^2x}{\mathrm{d}t^2}\right]\right] \\ & - a_1 A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2\right]\right] - a_2 A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A\left[x^3\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2\right]\right] \\ & - a_3 A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[x^3]\right] - a_4 A^{-1}\left[\left(\frac{1}{\nu^2+\omega^2}\right)A[x^5]\right]. \end{aligned} \tag{17}$$

With the help of the properties of AT and inverse AT, we obtain the coefficients of p^0 and p^1 from eq. (10) as follows:

$$\begin{aligned} & p^0 : x_0(t) = a\cos(\omega t), \\ & p^1 : x_1(t) = \frac{1}{2\omega}\left[a(\omega^2-\lambda) + \frac{3}{4}b_1a^3\omega^2 + \frac{5}{8}b_2a^5\omega^2 - \frac{1}{4}a_1a^3\omega^2 - \frac{1}{8}a_2a^5\omega^2 - \frac{3}{4}a_3a^3 - \frac{5}{8}a_4a^5\right]t\sin\omega t \\ & \quad + \frac{1}{8\omega^2}\left[\frac{1}{4}(a_1+b_1)a^3\omega^2 + \frac{1}{16}(a_2+5b_2)a^5\omega^2 - \frac{1}{4}a_3a^3 - \frac{5}{16}a_4a^5\right](\cos\omega t - \cos 3\omega t) \\ & \quad + \frac{1}{24\omega^2}\left[\frac{1}{16}(a_2+b_2)a^5\omega^2 - \frac{1}{16}a_4a^5\right](\cos\omega t - \cos 5\omega t). \end{aligned} \tag{18}$$

To avoid the secular term, we put the coefficient of $t\sin\omega t$ equal to zero, *i.e.*,

$$a(\omega^2-\lambda) + \frac{3}{4}b_1a^3\omega^2 + \frac{5}{8}b_2a^5\omega^2 - \frac{1}{4}a_1a^3\omega^2 - \frac{1}{8}a_2a^5\omega^2 - \frac{3}{4}a_3a^3 - \frac{5}{8}a_4a^5 = 0, \tag{19}$$

which gives the angular frequency of nonlinear oscillation as

$$\omega = \sqrt{\frac{8\lambda + 6a_3a^2 + 5a_4a^4}{8 + 2a^2(3b_1 - a_1) + (5b_2 - a_2)a^4}}. \tag{20}$$

Using eq. (19) in eq. (18), we get the analytic solution from eq. (17) to the generalized equation (14), considering the first order approximation as

$$\begin{aligned} x_{ATHPM}(t) = {} & a\cos\omega t \\ & + \frac{1}{8\omega^2}\left[\frac{1}{4}(a_1+b_1)a^3\omega^2 + \frac{1}{16}(a_2+5b_2)a^5\omega^2 - \frac{1}{4}a_3a^3 - \frac{5}{16}a_4a^5\right](\cos\omega t - \cos 3\omega t) \\ & + \frac{1}{24\omega^2}\left[\frac{1}{16}(a_2+b_2)a^5\omega^2 - \frac{1}{16}a_4a^5\right](\cos\omega t - \cos 5\omega t). \end{aligned} \tag{21}$$

We shall study different physically relevant cases considering different sets of force parameters in eq. (14).

3.1 Case 1: Motion of a particle on a rotating parabola

We consider the equation of motion of a particle sliding down freely on a parabola which is rotating about its axis [4, 34],

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \frac{\omega_0^2x + 4q^2x(\frac{\mathrm{d}x}{\mathrm{d}t})^2}{1+4q^2x^2} = 0, \tag{22}$$

which also represents the movement of the double-slider mechanism [35]. This may be obtained from the generalized equation (14) by choosing, $\lambda = \omega_0^2$, $a_1 = 4q^2$, $a_2 = a_3 = a_4 = 0$, $b_1 = 4q^2$ and $b_2 = 0$. The frequency of this nonlinear oscillator by employing ATHPM may be obtained from eq. (20) substituting the parameters as mentioned above and can be written as

$$\omega = \frac{\omega_0}{\sqrt{1+2q^2a^2}}, \tag{23}$$

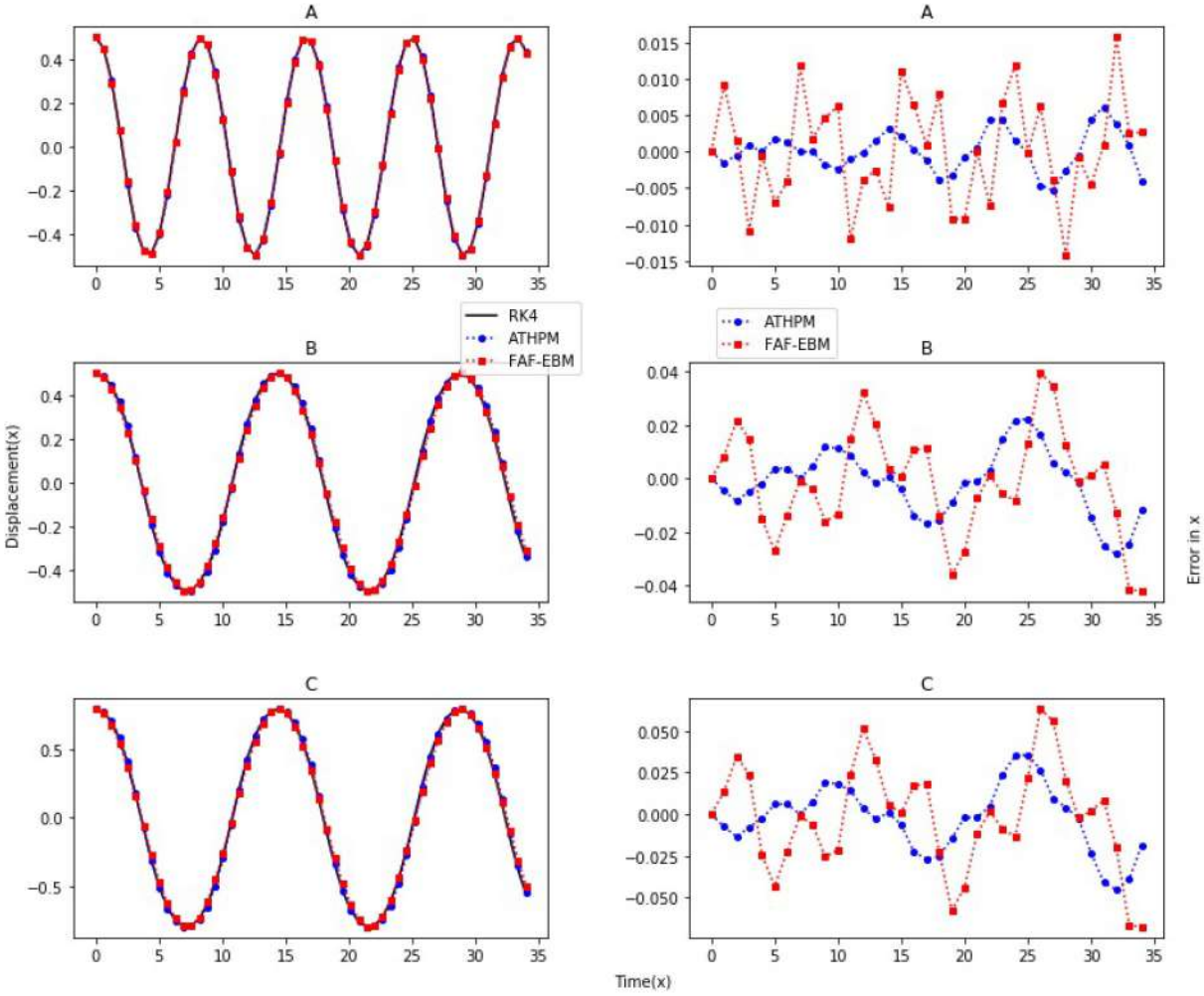


Fig. 1. Plot of variation of displacements $x_{RK4}(t)$ (black solid line), $x_{ATHPM}(t)$ (blue circles), and $x_{FAF-EBM}(t)$ (red squares) with time (t) are shown in the three panels of the left column for three parameter sets A, B, C in the top panel, middle panel, and bottom panel, respectively. Errors in approximate calculations with respect to RK4, ϵ_{xA} and ϵ_{xF} for the same parameter sets are displayed in the right column.

which is the same as that given by Davodi *et al.* [32] obtained using the amplitude frequency formulation and also the same as that given by Nofal *et al.* [22] employing frequency amplitude formulation based energy balance method (FAF-EBM). The approximate solution of eq. (22) is obtained by ATHPM from eq. (21) as

$$x_{ATHPM}(t) = a\cos\omega t + \frac{1}{4}q^2a^3\left(\cos\omega t - \cos 3\omega t\right). \tag{24}$$

Also, the approximate result by the FAF-EBM is

$$x_{FAF-EBM}(t) = a\cos\left(\frac{\omega_0}{\sqrt{1+2q^2a^2}}t\right). \tag{25}$$

We plot the displacement obtained from ATHPM $x_{ATHPM}(t)$ (blue circles) eq. (24) with increasing time t for three sets of values of parameters (a, ω_0, q) in the left column of fig. 1 and compared with the same given by FAF-EBM method $x_{FAF-EBM}(t)$ (red squares) eq. (25) and also that obtained by numerical solution of eq. (22) employing forth-order Runge-Kutta (RK4) method $x_{RK4}(t)$ (black solid line). It is seen that for all the parameter sets (A:(0.5,0.8,0.5) for top panel, B:(0.5,0.5,0.8) middle panel and C:(0.8,0.5,0.5) in the bottom panel), approximate displacements match extremely well with the x_{RK4}.

The error in approximate solutions of displacement with respect to its values calculated using RK4, $\epsilon_{xA}(= x_{RK4} - x_{ATHPM},$ blue circles) and $\epsilon_{xF}(= x_{RK4} - x_{FAF-EBM},$ red squares) are displayed in the right column for the same

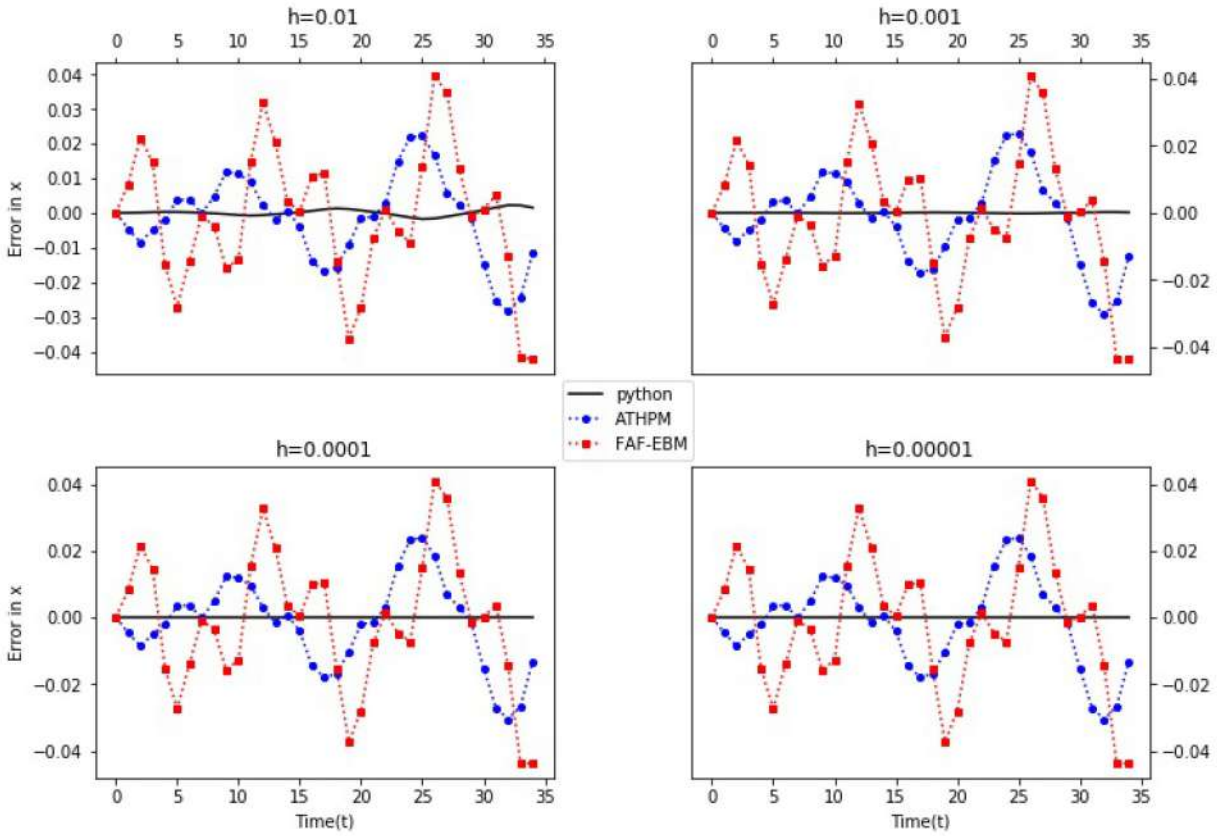


Fig. 2. Plot of error in displacement obtained from Python function odeint ϵ_{xP} (black solid line), eq. (24) ϵ_{xA} (blue circles) and eq. (25) ϵ_{xF} (red squares) with respect to those calculated from RK4 *versus* time for different values of the mesh size (h) of time t.

parameter sets. Errors involved in both of the approximate solutions of $x(t)$ are small (maximum value ϵ_{xA} 0.045 and ϵ_{xF} 0.074) within the ranges of the time t and for the parameters considered. All three panels in the right column show that accuracy of $x_{ATHPM}(t)$ is much improved in comparison to $x_{FAF-EBM}(t)$.

In fig. 1, a comparison of the results obtained from ATHPM and FAF-EBM is done considering those from RK4 method as the reference. In order to check the reliability of RK4 results, we compute the displacement (x_{PY}) by solving eq. (22) using Python (function "`odeint`") for the parameter set B. We plot, in fig. 2, the error $\epsilon_{xP}(= x_{RK4} - x_{PY})$, along with ϵ_{xA} and ϵ_{xF} as a function of time t for different values of mesh size (h 0.01, 0.001, 0.0001 and 0.00001) of time t. It is observed that ϵ_{xP} (black solid line) remains very close to zero, through out the span of time considered here, whereas ϵ_{xA} (blue circles) and ϵ_{xF} (red squares) having maximum error 0.028 and 0.046, respectively. The errors ϵ_{xA} and ϵ_{xF} remains the same for all values of h. This gives the confidence about the accuracy of the numerical solutions using RK4 which is taken as the reference when we compare solutions from two approximation methods such as ATHPM and FAF-EBM.

In table 2, we display, the maximum error $\epsilon_{xA}^{\max}$ in displacement obtained from ATHPM in the second column, the occurrence of maximum error at the time ($t_A^{\max}$) in the fourth column and the values of the displacement $x_A^{\max}$ at $t_A^{\max}$ in the fifth column for a range of values of the force parameters. We have also displayed the values of the same quantities obtained from FAF-EBM $\epsilon_{xF}^{\max}$, $t_F^{\max}$, and $x_F^{\max}$ in the third, sixth and seventh columns, respectively, to compare the corresponding ATHPM results. We see, the order of magnitude of the error are same in the displacement obtained from both the approximate methods although the ATHPM results are found to give better numerical accuracy than FAF-EBM specially at larger values of the force parameters.

3.2 Case 2: Tapered beam

Tapered members are increasingly used in the construction industry because of their unique ability to combine efficiency, economy and aesthetics —the three corner stones of structural art [36]. Tapered beam is an important model for engineering structures having variable stiffness along the length such as tree-branches, turbine blades, bridges, etc. The fundamental vibration mode of a tapered beam can be expressed as the following nonlinear differential

Table 2. Comparison of maximum error in calculation of displacement ($x(t)$) in ATHPM ($\epsilon_{xA}^{\max}$) and FAF-EBM ($\epsilon_{xF}^{\max}$) methods for different values of the force parameters. The locations of occurrence of maximum errors for both models are displayed in last four columns.

Parameters	$\epsilon_{xA}^{\max}$	$\epsilon_{xF}^{\max}$	$t_A^{\max}$	$x_A^{\max}$	$t_F^{\max}$	$x_F^{\max}$
$a = 0.5$, $\omega_0 = 0.5$						
$q = 0.2$	0.0011	0.0003	20.0	−0.4451	19.6	−0.4803
0.5	0.0025	0.0025	9.4	−0.0011	9.4	−0.0012
0.8	−0.0033	−0.0296	20.0	−0.4038	20.0	−0.4038
1.0	−0.0259	−0.0603	20.0	−0.2114	20.0	−0.2114
1.5	0.08643	0.1031	12.0	−0.2980	14.7	0.2747
$a = 0.5$, $q = 0.5$						
$\omega_0 = 0.2$	0.0026	−0.0061	20.0	−0.4108	20.0	−0.4107
0.5	0.0025	0.0025	9.4	−0.0012	9.4	−0.0012
0.8	−0.0039	−0.0127	20.0	−0.4166	20.0	−0.4166
1.0	0.0119	0.0207	18.2	−0.0313	18.8	0.2575
1.5	0.0002	0.0002	20.0	−0.4997	20.0	0.4997
$\omega_0 = 0.5$, $q = 0.5$						
$a = 0.2$	0.0004	0.0001	20.0	−0.1780	19.6	−0.1921
0.5	0.0025	0.0025	9.4	−0.0012	9.4	−0.0012
0.8	−0.0052	−0.0473	20.0	−0.6461	20.0	−0.6461
1.0	−0.0518	−0.1205	20.0	−0.4228	20.0	−0.4228
1.5	0.2593	0.3095	12.0	−0.8942	14.7	0.8243

equation [37–39]:

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \frac{x + \varepsilon x\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2 + \beta x^3}{1 + \varepsilon x^2} = 0. \tag{26}$$

The same equation may be obtained by choosing the arbitrary parameters in eq. (14) as $\lambda = 1$, $a_1 = \varepsilon$, $a_2 = 0$, $a_3 = \beta$, $a_4 = 0$, $b_1 = \varepsilon$, $b_2 = 0$. The ATHPM frequency can be obtained from eq. (20) as

$$\omega = \sqrt{\frac{4 + 3\beta a^2}{4 + 2\varepsilon a^2}}\,, \tag{27}$$

which is the same as that given by FAF-EBM method [22]. The approximate solution by ATHPM (x_{ATHPM}) to eq. (26) is obtained from eq. (21) is as follows:

$$x_{ATHPM}(t) = a\cos\omega t + \frac{1}{8\omega^2}\left[\frac{1}{2}\varepsilon a^2\omega^2 - \frac{1}{4}\beta a^3\right](\cos\omega t - \cos 3\omega t), \tag{28}$$

where the same as that given by FAF-EBM [22] is

$$x_{FAF-EBM}(t) = a\cos\left(\sqrt{\frac{4 + 3\beta a^2}{4 + 2\varepsilon a^2}}\,t\right). \tag{29}$$

In fig. 3, we plot the exact displacement from numerical solution x_{RK4} (solid line), $x_{FAF-EBM}$ (squares) and x_{ATHPM} (circles) for two different parameter sets U ($a = 1$, $\varepsilon = 0.1$, $\beta = 1$, in the upper left panel) and V ($a = 1$, $\varepsilon = 1$, $\beta = 1$, in the upper right panel). We have also compared the variation of errors ϵ_{xA} and ϵ_{xF} with time for the aforementioned parameter set in corresponding bottom panels.

It is found, from the top panels of fig. 3, that the approximate solutions for the displacement of tapered beam mimic with those obtained from the RK4 very well for the range of time and parameter sets considered for this study. In this case, the accuracies of the solutions obtained by ATHPM and FAF-EBM are similar. A close look at the error-graphs $\epsilon_{xA}(= x_{RK4} - x_{ATHPM},$ solid line) and $\epsilon_{xF}(= x_{RK4} - x_{FAF-EBM},$ squares) *versus* time t, displayed in the bottom panels of the figure corroborates the conclusion made from the plots presented in the top panels.

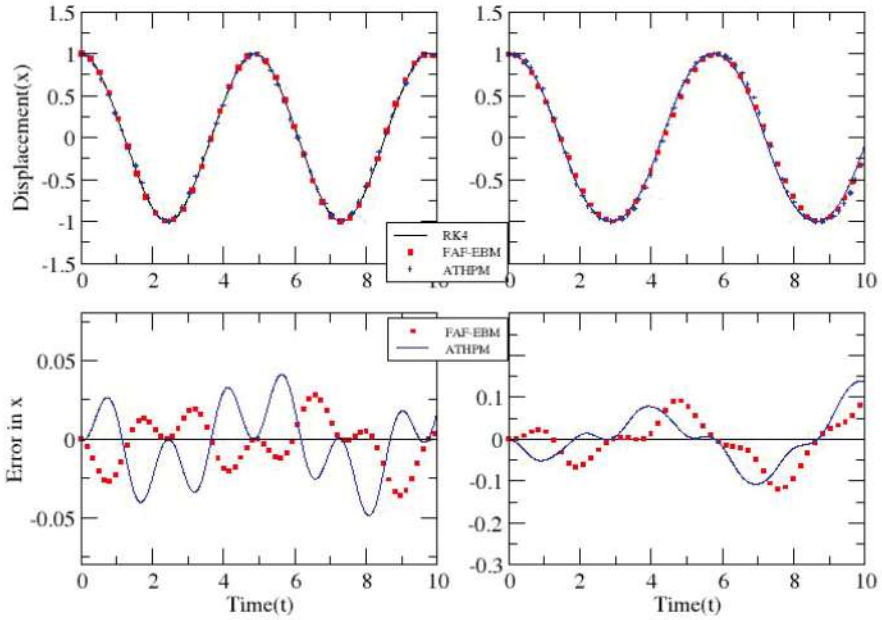


Fig. 3. Plot of variation of displacements $x_{RK4}(t)$ (solid line), $x_{ATHPM}(t)$ (circles), and $x_{FAF-EBM}(t)$ (squares) with time t are shown in the top row for two parameter sets U, and V in the left panel, and the right panel, respectively. Errors in approximate calculations ϵ_{xA} and ϵ_{xF} for the same parameter sets are displayed in the bottom panels.

3.3 Case 3: Autonomous conservative oscillator

Let us consider the force parameters, $a_1 = \varepsilon$, $a_2 = 2\alpha$, $a_3 = \beta$, $a_4 = \gamma$, $b_1 = \varepsilon$ and $b_2 = \alpha$. From eq. (15) we obtained the equation of motion as

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \frac{\lambda x + \varepsilon x\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2 + 2\alpha x^3\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2 + \beta x^3 + \gamma x^5}{1 + \varepsilon x^2 + \alpha x^4} = 0, \tag{30}$$

which represents the free vibrations of an autonomous conservative oscillator with fifth order nonlinearities [18,40,41]. Here motion is assumed to start from the position of maximum displacement with zero initial velocity. The parameter λ is an integer which may take values from -1, 0, 1 and ε, α, β, γ are positive parameters. The solution to the above equation may be readily obtained from the generalized solutions equations (20) and (21) with the help of ATHPM. The approximate frequency as a function of amplitude is obtained as

$$\omega = \sqrt{\frac{8\lambda + 6\beta a^2 + 5\gamma a^4}{8 + 4\varepsilon a^2 + 3\alpha a^4}}\,, \tag{31}$$

which is the same as that given by the FAF-EBM method [22] but differs from the expression of frequency reported by Mehdipour *et al.* [18], using EBM,

$$\omega_{EBM} = \frac{1}{\sqrt{3}}\sqrt{\frac{12\lambda + 9\beta a^2 + 7\gamma a^4}{8 + 4\varepsilon a^2 + \alpha a^4}}\,. \tag{32}$$

The ATHPM solution of eq. (30) is

$$\begin{aligned} x_{ATHPM}(t) = a\cos\omega t &+ \frac{1}{8\omega^2}\left[\frac{1}{2}\varepsilon a^3\omega^2 + \frac{7}{16}\alpha a^5\omega^2 - \frac{1}{4}\beta a^3 - \frac{5}{16}\gamma a^5\right](\cos\omega t - \cos 3\omega t) \\ &+ \frac{1}{24\omega^2}\left[\frac{3}{16}\alpha a^5\omega^2 - \frac{1}{16}\gamma a^5\right](\cos\omega t - \cos 5\omega t), \end{aligned} \tag{33}$$

where the same is given by FAF-EBM as

$$x_{FAF-EBM}(t) = a\cos\omega t. \tag{34}$$

It is noted that, unlike $x_{FAF-EBM}$, x_{ATHPM} contains terms from higher harmonics (3ω and 5ω).

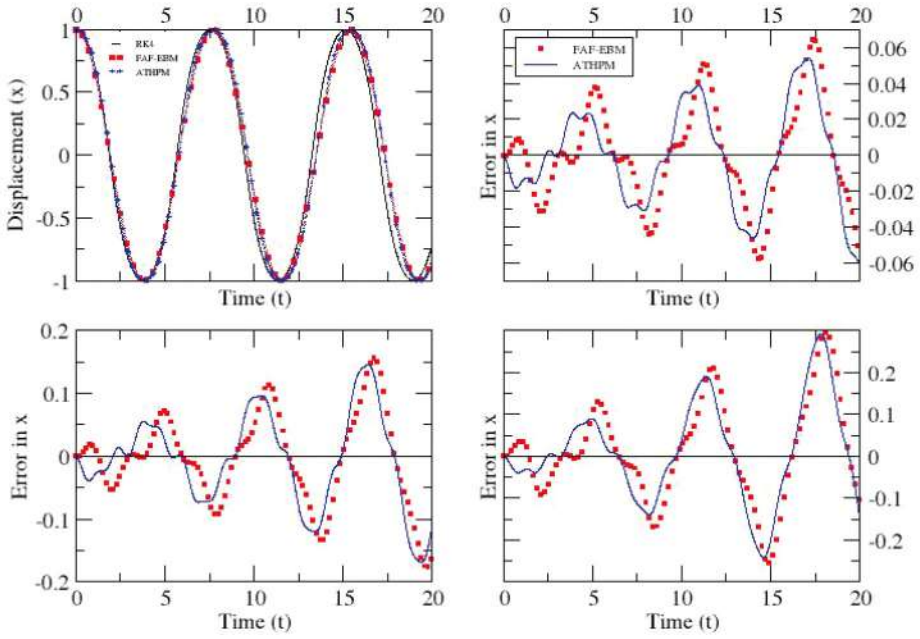


Fig. 4. The plots of displacements $x_{ATHPM}(t)$ (circles), $x_{FAF-EBM}(t)$ (squares), and $x_{RK4}(t)$ (solid line) as a function of time t for parameter set P is displayed in the left top panel. Comparison of errors ϵ_{xA} (solid line) and ϵ_{xF} (squares) are given for parameter sets Q (right top panel), R (left bottom panel) and S (right bottom panel).

The variation of displacement obtained from ATHPM, $x_{ATHPM}(t)$ (circles) with time t for of values of parameter set P $(a = 1, \epsilon = 0.2, \alpha = 0.2, \beta = 0.1, \gamma = 0.1)$ in the left top panel of fig. 4 and compared with the same given by FAF-EBM method $x_{FAF-EBM}(t)$ (squares) eq. (25) and also that obtained by numerical solution of eq. (22) employing fourth-order Runge-Kutta (RK4) method $x_{RK4}(t)$ (solid line). We have also compared the variation of errors ϵ_{xA} (solid line) and ϵ_{xF} (squares) within the time range 0 to 20, for the parameter sets Q $(1.0, 0.5, 0.5, 0.3, 0.2)$ right top panel, R $(1.0, 1.0, 0.5, 0.3, 0.2)$ left bottom panel and S $(1.0, 1.5, 0.2, 0.2, 0.1)$ right bottom panel.

It is seen, from the left top panel, that all three curves match very well at initial stage the approximate solutions start deviating slowly from the corresponding exact values $x_{RK4}(t)$ as the time increases. The same is observed in error graphs shown in the other three panels.

3.4 Case 4: Mathews and Lakshmanan oscillator

Mathews and Lakshmanan [42] presented a nonlinear system which obeys equation of motion as follows:

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \frac{\alpha^2 x \mp kx\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2}{1 + kx^2} = 0. \tag{35}$$

This equation of motion was obtained from the Lagrangian density for a relativistic scalar field which arises in the context of the theory of elementary particle. Equation (35) is a simpler form of the general equation in eq. (14). Considering the arbitrary parameters as $\lambda = \alpha^2$, $a_1 = \pm k$, $a_2 = a_3 = a_4 = 0$, $b_1 = \mp k$ and $b_2 = 0$ one can arrive at eq. (35). The frequency of the nonlinear oscillator, which is obtained by ATHPM from eq. (20) as

$$\omega_{ATHPM} = \frac{\alpha}{\sqrt{1 \pm ka^2}}, \tag{36}$$

which is the same as the exact frequency [42]. We obtain first-order correction term as, $x_1 = 0$. Thus, the displacement in ATHPM is

$$x_{ATHPM} = a\cos\left[\frac{\alpha}{\sqrt{1 \pm ka^2}}t\right]. \tag{37}$$

Therefore, we get the exact solution by ATHPM of the Mathews and Lakshmanan nonlinear oscillator.

4 Conclusion

A generalized equation is constructed which reduces to strongly nonlinear equations corresponding to physically relevant systems such as the motion of a particle in a rotating parabola, the vibration of a tapered beam, autonomous conservative oscillator, etc., for particular choices of the parameters of the restoring force. Aboodh transform based homotopy perturbation method is applied to find an approximate analytical solution to this equation giving rise to both the displacement and frequency of the oscillation for free vibration of strongly nonlinear oscillators as mentioned above. It was observed that the solution converges very fast, even first-order correction is sufficient for getting results with high accuracy. This method not only gives very accurate numerical values of displacement and frequency but also gives an idea about the contributions from different harmonics to it. It is to conclude that the solution for the generalized equation enables us to study various nonlinear physically relevant systems easily in the same footing. The merit of ATHPM is its simplicity and ability to give the solutions to the nonlinear systems with high accuracy. This study also reveals that the ATHPM gives better accuracy in calculating oscillation-variables in comparison to those obtained from FAF-EBM for the systems considered.

References

1. R.A. Bonham, L.S. Su, J. Chem. Phys. **45**, 2827 (1966).
2. Carl M. Bender, Tai Tsun Wu, Phys. Rev. Lett. **21**, 406 (1968).
3. A. Nayfeh, *Perturbation Methods* (Willey-Interscience, New York, 1973).
4. A.H. Nayfeh, D. Mook, *Nonlinear Oscillations* (John Willey and Sons, New York, 1979).
5. N.N. Bogoliubov, Y.A. Mitropolsky, *Asymptotic Methods in the Theory of Non-Linear Oscillations* (CRC Press, 1961).
6. V. Agrwal, H. Denman, J. Sound Vib. **99**, 463 (1985).
7. S. Chen, Y. Cheung, S. Lau, Int. J. Nonlinear Mech. **26**, 125 (1991).
8. Y. Cheung, S. Chen, S. Lau, Int. J. Nonlinear Mech. **26**, 367 (1991).
9. G. Adomian, J. Math. Anal. Appl. **135**, 501 (1988).
10. G. Liu, in *Conference of 7th Modern Mathematics and Mechanics, Shanghai* (Scirp, 1997) pp. 47–53.
11. S.J. Liao, *The proposed homotopy analysis technique for the solution of nonlinear problems*, PhD Thesis, Shanghai Jiao Tong University Shanghai (1992).
12. Y.P. Liu, S.J. Liao, Z.B. Li, J. Symb. Comput. **55**, 72 (2013).
13. N. Anjum, J.-H. He, Appl. Math. Lett. **92**, 134 (2019).
14. N. Herisanu, V. Marinca, G. Madescu, F. Dragan, Energies **12**, 915 (2019).
15. J.-H. He, Mech. Res. Commun. **29**, 107 (2002).
16. S. Ganji, D.D. Ganji, Z. Ganji, S. Karimpour, Acta Appl. Math. **106**, 79 (2009).
17. J.-H. He, Phys. Rev. Lett. **90**, 174301 (2003).
18. I. Mehdipour, D.D. Ganji, M. Mozaffari, Curr. Appl. Phys. **10**, 104 (2010).
19. J.-H. He, Int. J. Nonlinear Mech. Num. Simul. **9**, 211 (2008).
20. J. Langari, M. Akbarzade, Adv. Stud. Theor. Phys. **5**, 343 (2011).
21. A. El-Naggar, G. Ismail, Appl. Math. Sci. **6**, 2071 (2012).
22. T.A. Nofal, G.M. Ismail, A.A.M. Mady, S. Abdel-Khalek, J. Electromagn. Anal. Appl. **5**, 388 (2013).
23. J.-H. He, Comput. Methods Appl. Mech. Eng. **178**, 257 (1999).
24. J.-H. He, Int. J. Nonlinear Mech. **35**, 37 (2000).
25. A. Yıldırım, J. Math. Phys. **50**, 023510 (2009).
26. Z. Ayati, J. Biazar, J. Egypt. Math. Soc. **23**, 424 (2015).
27. J. Biazar, M. Eslami, Comput. Math. Appl. **62**, 225 (2011).
28. P. Bera, T. Sil, Appl. Math. Comput. **219**, 3272 (2012).
29. K.S. Aboodh, Global J. Pure Appl. Math. **9**, 35 (2013).
30. A. Ghorbani, Chaos, Solitons Fractals **39**, 1486 (2009).
31. J.-H. He, Eur. J. Phys. **29**, L19 (2008).
32. A.G. Davodi, D.D. Ganji, R. Azami, H. Babazadeh, Mod. Phys. Lett. B **23**, 3427 (2009).
33. H.-L. Zhang, Comput. Math. Appl. **58**, 2480 (2009).
34. V. Marinca, N. Herisanu, J. Sound Vib. **329**, 1450 (2010).
35. D.D. Ganji, M. Azimi, M. Mostofi, Indian. J. Pure Appl. Phys. **50**, 670 (2012).
36. D.P. Billington, *The Tower and the Bridge: The New Art of Structural Engineering* (Princeton University Press, 1985).
37. M. Akbarzade, Y. Khan, Math. Comput. Model. **55**, 480 (2012).
38. S.H. Hoseini, T. Pirbodaghi, M.T. Ahmadian, G.H. Farrahi, Mech. Res. Commun. **36**, 892 (2009).
39. Daniel J. Gorman, *Free Vibration Analysis of Beams and Shafts* (John Wiley & Sons, 1975).
40. M.Nv. Hamdan, N.H. Shabaneh, J. Sound Vib. **199**, 711 (1997).
41. S.-S. Chen *et al.*, Nonlinear Anal. Real World Appl. **10**, 881 (2009).
42. P.M. Mathews, M. Lakshmanan, Q. Appl. Math. **32**, 215 (1974).

Application of Homotopy Perturbation Method to an Eco-epidemic Model

Article · October 2014

Source: arXiv

CITATIONS
0

READS
189

3 authors:

Pulak Bera
Zonal Adaptive Research Station, Jalpaiguri, Govt of WB
79 PUBLICATIONS **548** CITATIONS
SEE PROFILE

Sahabuddin Sarwardi
Aliah University
50 PUBLICATIONS **666** CITATIONS
SEE PROFILE

Md. Abdul Khan
Aliah University
60 PUBLICATIONS **151** CITATIONS
SEE PROFILE

Application of Homotopy Perturbation Method to an Eco-epidemic Model

P. K. Bera[(1)], S. Sarwardi[(2)*] and Md. A. Khan[(3)]
[(1)] Department of Physics, Dumkal College, Basantapur, Dumkal Murshidabad - 742 303, West Bengal, India
[(2)] Department of Mathematics, Aliah University, Salt Lake City, Sector-V, Kolkata - 700 091, West Bengal, India.
email: **s.sarwardi@gmail.com**
[(3)] Department of Physics, Aliah University, Salt Lake City, Sector-V, Kolkata - 700 091, West Bengal, India.

Abstract

In this article, we apply Homotopy Perturbation Method (HPM) for solving three coupled non-linear equations which play an important role in biosystems. To illustrate the capability and reliability of this method. Numerical example is given which confirms our analytical findings.

Keywords: Homotopy Perturbation Method; Eco-epidemic model; Application

1 Introduction

There exist a wide class of literature dealing with the problem of approximate solutions to nonlinear equations with various different methodologies, called the perturbation methods. But almost all perturbation methods are based on small parameters so that the approximate solutions can be expanded in series of small parameters. Its basic idea is to transform by means of small parameters, a nonlinear problem of an infinite number of linear subproblems into an infinite number of simpler ones. The small parameter determines not only the accuracy of the perturbation approximations but also the validity of the perturbation method.

There exists some analytical approaches, such as the harmonic balance method [1], the Krylov-Bogolyubov-Mitropolsky method [2], weighted linearization method [3], perturbation procedure for limit cycle analysis [4], modified Lindstedt-Poincare method [5], artificial parameter method [6] and so on.

*Author to whom all correspondence should be addressed

In science and engineering, there exists many nonlinear problems, which do not contain any small parameters, especially those with strong nonlinearity. He [7, 8] developed the Homotopy Perturbation Method (HPM) for solving linear, nonlinear, initial and boundary value problems by merging the standard homotopy and the perturbation. The HPM was formulated by taking full advantage of the standard homotopy and perturbation methods. In this method the solution is given in an infinite series usually converging to an accurate solution.

Inspired and motivated by the ongoing research in the area of bioscience involving mainly ecological and eco-epidemiological systems, we apply HPM for solving three coupled nonlinear equations representing a prey-predator model system with disease in prey species only.

This paper is organized as follows: In Section 2, HPM has been illustrated. Based on the HPM, the approximate solutions of three coupled nonlinear equations are obtained in section 3. Finally, we have drawn the conclusion in section 4.

2 Analysis of the Homotopy Perturbation Method (HPM)

To illustrate the basic ideas of HPM for solving nonlinear differential equations, He[7, 8] considered the following nonlinear differential equation:

$$A(u) - f(r) = 0, \ r \in \Omega, \tag{2.1}$$

with the boundary conditions

$$B\left(u, \frac{\partial}{\partial n}\right) = 0, \ r \in \Gamma, \tag{2.2}$$

where A is a general differential operator, B is a boundary operator, $f(r)$ is known anaclitic function, Γ is the boundary of the domain Ω and $\frac{\partial}{\partial n}$ denotes differentiation along the normal vector drawn outwards from Ω. The operator A can generally be divided into two parts L and N, where L is linear and N is nonlinear. Therefore, Eq. (2.1) can be written as

$$L(u) + N(u) - f(r) = 0, r\epsilon\Omega. \tag{2.3}$$

He [7, 8] constructed a homotopy as follows:

$$H(v,p) = (1-p)\Big(L(v) - L(u_0)\Big) + p\Big(A(v) - f(r)\Big) = 0 \tag{2.4}$$

or,

$$H_i(v,p) = L_i(v,p) - L_i(v_0,p) + p\Big(L_i(v_0,p) + N_i(v,p)\Big) = 0. \tag{2.5}$$

where $v(r,p) : \Omega \times [0,1] \to R$. In Eq. (2.4), $p \in [0,1]$ is an embedding parameter and u_0 is the first approximation that satisfies the boundary condition. The changing

process of p from zero to unity is just that of $H(v,p)$ from $L(v)-L(u_0)$ to $A(v)-f(r)$. In topology, this is called deformation. The terms $L(v)-L(u_0)$ and $A(v)-f(r)$ are called homotopy. According to the homotopy perturbation method, the parameter p is used as a small parameter and the solution of Eq. (2.4) can be expressed as a series in p in the form

$$v = v_0 + pv_1 + p^2v_2 + p^3v_3 + \cdots\cdots\cdots \tag{2.6}$$

when $p \to 1$, Eq. (2.4) corresponds to the original one, Eq. (2.5) the approximate solution of Eq. (2.1) , i.e.

$$u = \lim_{p\to 1} v = v_0 + v_1 + v_2 + v_3 + \cdots\cdots\cdots \tag{2.7}$$

The convergence of the series in Eq. (2.6) has been discussed by He[7, 8].

3 Homotopy perturbation method for three coupled system

We consider three coupled nonlinear equations which describe a prey-predator model, consisting with two prey and a predator species. We also consider an infectious disease, which is transmissible among the prey species only to give the model realism, interested readers are referred to [9-11]. Let us assume $S(t)$ denotes susceptible prey population, $I(t)$ denotes infected prey population, and $P(t)$ denotes predator population at any time. The model under consideration is given by the following system of ordinary nonlinear differential equations

$$\frac{dS}{dt} = rS\left(1-\frac{S+I}{K}\right) - c_1SP - \delta SI, \tag{3.1}$$

$$\frac{dI}{dt} = \delta SI - c_2IP - d_1I, \tag{3.2}$$

$$\frac{dP}{dt} = e(c_1S + c_2I)P - d_2P, \tag{3.3}$$

where $S(0) > 0, I(0) > 0, P(0) > 0$ and $\dot{S}_0 = 0, \dot{I}_0 = 0$ and $\dot{P}_0 = 0$. Here r is the growth rate of the prey population, c_1 and c_2 are the searching efficiency of the predators for the susceptible prey and infected prey respectively, similarly ec_1 and ec_2 are the conversion factors for the susceptible prey and infected prey respectively consumed by the predators. K is the carrying capacity of the environment for the total (susceptible + infected) prey population, the disease spreads horizontally with mass action incidence rate δSI. d_1 is the mortality rate of infected prey population including disease related death, d_2 is the mortality rate of the predator population. All the parameters are non negative. The predators eat both susceptible and infected prey at different rates, since the susceptible prey more likely escapes from an attack, thus $c_1 < c_2$. It is to be noted that the value

of the system parameter 'e' is a proper fraction for most of the realistic prey-predator interactions. For application of HPM, now we write Eqs. (3.1)-(3.3) as

$$H_i(S,P,I,p) = L_i(S,I,P,p) - L_i(S_0,I_0,P_0,p) + p\left(L_i(S,I,P,p) + N_i(S,I,P,p)\right) \quad (3.4)$$

where $i = 1, 2, 3$ and we also consider

$$S = S_0 + pS_1 + p^2S_2 + p^3S_3 + \cdots\cdots\cdots \quad (3.5)$$

$$I = I_0 + pI_1 + p^2I_2 + p^3I_3 + \cdots\cdots\cdots \quad (3.6)$$

$$P = P_0 + pP_1 + p^2P_2 + p^3P_3 + \cdots\cdots\cdots \quad (3.7)$$

when $p \to 1$, Eqs. (3.5)-(3.7) become the approximate solution of Eqs. (3.8)-(3.10), i.e.,

$$S_{approx} = \lim_{p\to 1} S = S_0 + S_1 + S_2 + S_3 + \cdots\cdots\cdots \quad (3.8)$$

$$I_{approx} = \lim_{p\to 1} I = I_0 + I_1 + I_2 + I_3 + \cdots\cdots\cdots \quad (3.9)$$

$$P_{approx} = \lim_{p\to 1} P = P_0 + P_1 + P_2 + P_3 + \cdots\cdots\cdots \quad (3.10)$$

Here, boundary conditions are $S_0 > 0, I_0 > 0, P_0 > 0$ and $\dot{S}_0 = \dot{I}_0 = \dot{P}_0 = 0$.

For without perturbation, the Eqs. (3.1)-(3.3) can be written as

$$\frac{dS_0(t)}{dt} = rS_0 \quad (3.11)$$

$$\frac{dI_0}{dt} = -d_1I_0 \quad (3.12)$$

$$\frac{dP_0}{dt} = -d_2P_0 \quad (3.13)$$

whose solutions are $S_0(t) = S(0)e^{rt}, I_0(t) = I(0)e^{-d_1t}, P_0(t) = P(0)e^{-d_2t}$.

With the help of Eq. (3.4), one can write the Eqs. (3.1)-(3.3) as follows:

$$\frac{dS}{dt} - rS = p\left(-rS\left(\frac{S+I}{K}\right) - c_1SP - \delta SI\right), \quad (3.14)$$

$$\frac{dI}{dt} + d_1I = p\left(\delta SI - c_2IP\right), \quad (3.15)$$

$$\frac{dP}{dt} + d_2P = p\left(ec_1S + ec_2IP\right). \quad (3.16)$$

Substituting the values of $S(t), I(t)$ and $P(t)$ from Eqs. (3.5)-(3.7) and equating the coefficients of embedding parameter p, we get coefficient of p^0 as

$$\begin{aligned}
\frac{dS_0(t)}{dt} - rS_0 &= 0, && (3.17)\\
\frac{dI_0}{dt} + d_1 I_0 &= 0, && (3.18)\\
\frac{dP_0}{dt} + d_2 P_0 &= 0. && (3.19)
\end{aligned}$$

Equating the coefficient of p, we have

$$\begin{aligned}
\frac{dS_1}{dt} - rS_1 &= -\frac{r}{K}S_0^2 - \frac{r}{k}S_0 I_0 - c_1 S_0 P_0 - \delta S_0 I_0, && (3.20)\\
\frac{dI_1}{dt} + d_1 I_1 &= \delta S_0 I_0 - c_2 I_0 P_0, && (3.21)\\
\frac{dP_1}{dt} + d_2 P_1 &= ec_1 S_0 P_0 + ec_2 I_0) P_0, && (3.22)
\end{aligned}$$

and coefficient of p^2 as

$$\begin{aligned}
\frac{dS_2}{dt} - rS_2 &= -\frac{2r}{K}S_0 S_1 - \frac{r}{k}(I_0 S_1 + S_0 I_1) - c_1(P_0 S_1 + S_0 P_1)\\
&\quad -\delta(S_1 I_0 + S_0 I_1), && (3.23)\\
\frac{dI_2}{dt} + d_1 I_2 &= \delta\Big(S_1 I_0 + S_0 I_1) - c_2(I_1 P_0 + I_0 P_1\Big), && (3.24)\\
\frac{dP_2}{dt} + d_2 P_2 &= ec_1\Big(S_1 P_0 + S_0 P_1\Big) + ec_2\Big(I_1 P_0 + I_0 P_1\Big), && (3.25)
\end{aligned}$$

etc. Eqs. (3.1)-(3.3) can easily determine the components S_k, I_k and P_k and $k \geq 0$. So, it is possible to calculate more components in the decomposition series to enhance the approximation. Consequently, one can recursively determine every term of the series $\Sigma_{k=0}^{\infty} S_k(t)$, $\Sigma_{k=0}^{\infty} I_k(t)$ and $\Sigma_{k=0}^{\infty} P_k(t)$ and hence the solutions $S(t)$, $I(t)$ and $P(t)$ is readily obtained in the form of a series like

$$\begin{aligned}
S_{approx.} &= S_0 e^{rt} + A_1 e^{2rt} + A_2 e^{(r-d_1)t} + A_3 e^{(r-d_2)t} + A_4 e^{3rt} + A_5 e^{(r-d_1-d_2)t}\\
&\quad + A_6 e^{(r-2d_1)t} + A_7 e^{(r-2d_2)t} + A_8 e^{(2r-d_1)t} + A_9 e^{(2r-d_2)t}, && (3.26)\\
I_{approx.} &= I_0 e^{-d_1 t} + B_1 e^{(r-d_1)t} + B_2 e^{-(d_1+d_2)t} + B_3 e^{(r-d_1-d_2)t} + B_4 e^{(r-2d_1)t}\\
&\quad + B_5 e^{(2r-d_1)t} + B_6 e^{-(2d_1+d_2)t} + B_7 e^{-(d_1+2d_2)t}, && (3.27)\\
P_{approx.} &= P_0 e^{-d_2 t} + C_1 e^{(r-d_2)t} + C_2 e^{-(d_1+d_2)t} + C_3 e^{(r-d_1-d_2)t} + C_4 e^{(r-2d_2)t}\\
&\quad + C_5 e^{(2r-d_2)t} + C_6 e^{-(2d_2+d_1)t} + C_7 e^{-(d_2+2d_1)t}, && (3.28)
\end{aligned}$$

where the constants $A_i,\ i = 1$ to 9 are given by

$$\begin{aligned}
A_1 &= -\frac{S^2(0)}{K},\ A_2 = \frac{1}{d_1}\left(\frac{r}{K}+\delta\right)S(0)I(0),\ A_3 = \frac{c_1}{d_2}S(0)P(0),\\
A_4 &= \frac{S^3(0)}{K^2},\ A_5 = \frac{1}{d_1+d_2}\left(\left(\frac{r}{K}+\delta\right)\left(\frac{2c_2}{d_1}+\frac{c_1}{d_2}\right)-\frac{ec_2^2}{d_2}\right)S(0)I(0)P(0),\\
A_6 &= \frac{rc_1}{2Kd_1d_2}I(0)S(0)P(0)+\frac{\delta}{2d_1^2}\left(\frac{r}{K}+\delta\right)I^2(0)S(0),\\
A_7 &= \frac{c_1^2}{d_2^2}S(0)P^2(0),\ A_8 = -\frac{1}{r-d_1}\left(\frac{\delta}{r}+\frac{1}{K}\right)\left(\frac{2r^2}{Kd_1}-\frac{r}{K}+\delta\right)S^2(0)I(0),\\
A_9 &= -\frac{1}{r-d_2}\left(\frac{2rc_1}{Kd_2}-\frac{ec_1^2}{r}-\frac{c_1}{K}\right)S^2(0)P(0),
\end{aligned}$$

the constants $B_i,\ i = 1$ to 7 are given by

$$\begin{aligned}
B_1 &= \frac{\delta}{r}S(0)I(0),\ B_2 = \frac{c_2}{d_1}I(0)P(0),\ B_3 = \frac{1}{r-d_2}\left(\delta\left(\frac{c_1}{d_2}+\frac{c_2}{d_1}\right)\right.\\
&\quad \left.-c_2\left(\frac{ec_1+\delta}{r}\right)\right)S(0)I(0)P(0),\\
B_4 &= \frac{\delta c_1}{d_2(r-d_1)}S(0)I(0)P(0), B_5 = \frac{\delta}{2r}\left(\frac{\delta}{r}-\frac{1}{K}\right)S^2(0)I(0),\\
B_6 &= -\frac{ec_2^2}{d_2(d_1+d_2)}I^2(0)P(0), B_7 = \frac{c_2^2}{2d_2d_1}P^2(0)I(0),
\end{aligned}$$

and the constants $C_i,\ i = 1$ to 7 are given by

$$\begin{aligned}
C_1 &= \frac{ec_1}{r}S(0)P(0),\ C_2 = -\frac{ec_2}{d_2}I(0)P(0),\\
C_3 &= \frac{1}{r-d_1}\left(\left(\frac{e^2c_1c_2}{r}+\frac{ec_2\delta}{r}-\frac{e^2c_1c_2}{d_2}\right)S(0)I(0)P(0)+\frac{ec_1^2}{d_2}S(0)P^2(0)\right),\\
C_4 &= \frac{ec_1^2}{d_2(r-d_2)}S(0)P^2(0),\ C_5 = \frac{ec_1}{2r}\left(\frac{ec_1}{r}-\frac{1}{K}\right)S^2(0)P(0),\\
C_6 &= -\frac{ec_2^2}{d_1(d_1+d_2)}P^2(0)I(0),\ C_7 = \frac{e^2c_2^2}{2d_2d_1}I^2(0)P(0).
\end{aligned}$$

Putting the different values of parameters $r, k, c_1, c_2, \delta, e, d_1, d_2$, we obtained the approximate solutions of Eqs. (3.1)-(3.3). To explain our results, we have drawn figures of $S(t), I(t)$ and $P(t)$ versus time for different parameters and initial condition values. From these figures, we see that the exact numerical results and the results obtained using HPM are nearly same.

4 Conclusion

This system of three coupled differential equations (3.1)–(3.3) plays an important role in biosystems. The basic goal of this paper is to study this model using HPM. The goal has been achieved by deriving solutions using few iterations only. The qualitative results of the present studies have been compared with the results obtained by numerical computation using $r = 0.1, k = 0.3, c_1 = 0.1, c_2 = 0.2, \delta = 0.1, e = 0.1, d_1 = 0.2, d_2 = 0.2$ as evident from the Fig. 1 and reveal that HPM is very effective and convenient for solving non-linear differential equations. Hope that with the help of these solutions, one can study qualitative and quantitative behaviors of realistic prey-predator interactions. The HPM introduces a significant improvement in this field. This makes the proposed scheme more powerful and gives a wider applicability.

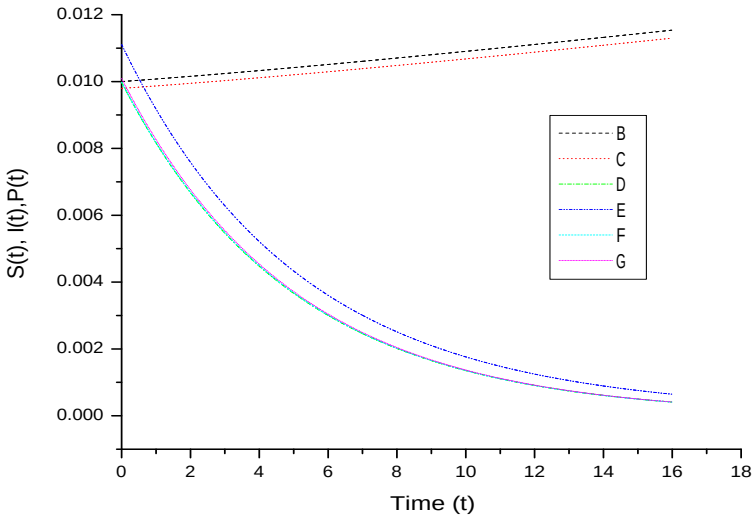


Figure 1: The $S(t), I(t), P(t)$ versus time for the different values of parameters $r = 0.1, k = 0.3, c_1 = 0.1, c_2 = 0.2, \delta = 0.1, e = 0.1, d_1 = 0.2, d_2 = 0.2$ and initial conditions $S_0(0) = 0.01, I_0(0) = 0.01$ and $P_0(0) = 0.01$. B-, D-, F-line represent the numerical solutions $S(t), I(t)$ and $P(t)$ respectively and C-, E-, G-line represent the approximate solutions of $S(t), I(t)$ and $P(t)$ respectively which have been obtained using HPM.

Acknowledgement: This work is supported by University Grants Commission(UGC), Government of India (Project No.PSW-63/12-13(ERO)). Dr. S. Sarwardi is thankful to the Department of Mathematics, Aliah University for extending opportunities to perform the present work.

References

[1] A. H. Nayfeh and D. T. Mook, Nonlinear Oscillations, John Willey and Sons., New York, 1979.

[2] N. N. Bogolyubov and IU. A. Mitropolsky, Asymptotic methods in theory of nonlinear Vibrations, Moskva, 1974.

[3] V. P. Agrwal and H. Denman, Weighted linearrization technique for period approximation technique for period approximation in large amplitude Nonlinear Oscillations, J. Sound Vib. **57**, 463–473, 1985.

[4] S. H. Chen , Y. K. Cheung, S. L. Lau, On Perturbation Procedure for limit cycle analysis, Int. J. Nonl. Mech., **26**, 125–133, 1991.

[5] Y. K. Cheung, S. H. Chen, and S. L. Lau, A modified Lindstedt-Pioncare method for certain strong sonlinear oscilations, Int. J. Nonl. Mech. **26**, 367–378, 1991.

[6] G. L. Lau, New research direction in singular perturbation theory, artificial parametrer approach and inverse-perturbation technique, National Conf. on 7th Modern Mathematics and Mechanics, 47–53, Shanghai 1997.

[7] J. H. He, Homotopy perturbation technique, Comp. Meth. Appl. Mech. Eng. **178**, 257–262, 1999.

[8] J. H. He, A coupling method of a homotopy technique and a perturbation technique for nonlinear problems, Int. J. Nonl. Mech. **35**, 37–43, 2000.

[9] M. Haque, J. Zhen, and E. Venturino, An ecoepidemiological predator-prey model with standard disease incidence, Math. Meth. Appl. Sci., **32(7)**, 875–898, 2009.

[10] O. Arino, J. Mikram, J. Chattopadhyay, Infection in prey population may act as a biological control in ratio-dependent predator-prey models. Nonlinearity, **17**, 1101–1116, 2004.

[11] S. Sarwardi, M. Haque, and E. Venturino, A Leslie-Gower Holling-type II ecoepidemic model, J. Appl. Math. Comput., **35**, 263– 280, 2009.

Volume 8, Issue 16, November 2019 ISSN: 2278-9545

EDULIGHT

Multi-disciplinary, Peer Reviewed Print Research Journal

Editor: Dr. Ajit Mondal

Referred Journal since 2012

COUNCIL OF EDULIGHT
KALYANI, DISTRICT – NADIA, WEST BENGAL,
INDIA -741235
E-mail: mondalajit.edn@gmail.com
www.edulightjournal.in

Date of Publication
15th November, 2019

CONTENT

Crime, Society and Politics in Hariharpara Block of Murshidabad District, 1984-2011

Arnav Debnath
Assistant Professor, Department of Political Science,
Dumkal College, Murshidabad, West Bengal, E-mail: arnav121206@gmail.com

ABSTRACT

Politics in a local area occurs both in particular context and following certain rules no matter how small its arena is. The movement of politics from 1984 to 2011 in the Hariharpara block of the district of Murshidabad is a case in point. Like any democratic political orientation, it was based on the principle of distinction between friend and enemy among the political parties worked in the block, yet their ground-level activities were shaped by some of the major socio-political factors that existed there. The political rivalry between parties mixed with increasing crime tended to develop a discrete kind of political atmosphere that involved state, people and society of Hariharpara. This article tries to focus on the nature of local politics of Hariharpara block in terms of such features it maintained, and to have an overview of how it influenced by those factors and influenced them in turn during the said time-span.

Kew words: ***Hariharpara block, local politics, crime, society, state, political party.***

> ***No one is immune from political violence, whether living in a wealthy Western democracy, or in a country undergoing late economic development.*** - Vittorio Bufacchi[1]

1.1. Social Context and Political Dynamics

Politics within a society whatsoever, national, sub-national or local, tends to assume a certain kind of relationship between more than one entity, namely, groups or individuals. This relationship does not, as it is perceived, emerge from mere opposition between groups or individuals. But it is not mere opposition that is key to the definition of politics; it is something more essential that defines it. 'An opponent', Ben Shalit explains, 'stands in our way, passively. The effects of an opponent are felt in proportion to the extent of our actions on it, when we act on it.' (Shalit, 1988:84) This relationship with one's opponent is, therefore, 'either zero - or nonzero-sum game'. Politics rather comes into being with another sort of relationship which denotes 'a nonzero-sum game'. The relationship that qualifies politics is of friend and enemy where an enemy is 'an opponent perceived to be behaving in a mode that actually threatens our aims. An enemy actively challenges our desired state or action, and his gain is perceived as our loss.' (Shalit, 1988:84)

The notion that politics rests upon a distinction between friend and enemy elucidated by Carl Schmitt in his incisive yet controversial work *The Concept of the Political* is 'actively and passionately discussed throughout the world' (Bernstein, 2013:12). The distinction being an essential element of politics stands apart from

A Bengali Peer-Reviewed Journal

ISSN : 2454-4884

24544884

সংশপ্তক

।। বিশেষ সংখ্যা ।।

ঈশ্বরচন্দ্র বিদ্যাসাগর

ও

বিভূতিভূষণ বন্দ্যোপাধ্যায়

এবং

।। অন্যান্য প্রবন্ধ ।।

পঞ্চম বর্ষ ।। দ্বিতীয় সংখ্যা

জুন, ২০২০ ইং

সম্পাদক : উত্তম দাস

সংশপ্তক

SAMSAPTAK

Peer- Reviewed Journal

A bi annual journal based on research social ,literary and cultural discourse

সমাজ, সাহিত্য ও সংস্কৃতি বিষয়ক ষাণ্মাসিক পত্রিকা

২০20 ,জুন

2020 ,June

Vol.5, Issue-2

পঞ্চম বর্ষ ।।দ্বিতীয় সংখ্যা

ISSN-2454-4884

Title of the magazine - Samsaptak

পত্রিকার নাম - সংশপ্তক

The language in which Published - Bengali

যে ভাষায় প্রকাশিত - বাংলা

Periodicity of Publication - Six monthly

ব্যবধান - ষাণ্মাসিক

Magazine Director - Dr. Utpal Mandal

পত্রিকা অধিকর্তা

ড. উৎপল মণ্ডল

Name of the editor - Uttam Das

সম্পাদকের নাম - উত্তম দাস

সহকারী সম্পাদক

সুব্রত দাস,জিতেন্দ্র নাথ ভট্টাচার্য , উজ্জ্বল শীল , প্রসেনজিৎ দাস , তুফান রায় ,ইউনুস মিঞা, শান্তনু মণ্ডল ,(সহকারী অধ্যাপক কল্যাণী বিশ্ববিদ্যালয়) , তাপস সোরেন , সহকারী অধ্যাপক ,(বীরভূম মহাবিদ্যালয়) গৌতম দাস ,সহকারী অধ্যাপক ,(বাঁকুড়া বিশ্ববিদ্যালয়) , এহেসানুল্লা হক, অমিত বিশ্বাস

প্রচ্ছদ ও অলঙ্করণ - উত্তম দাস

মুদ্রণ ও প্রকাশকের নাম - মা প্রেস , তুফানগঞ্জ , কোচবিহার

মূল্য - ১৯৫/-

অন্যান্য বিষয়ে

 ISSN-2454-4884

গান্ধির 'হিন্দ স্বরাজ' প্রসঙ্গে

অর্ণব দেবনাথ

১ ভূমিকা

Anthony J. Parel তাঁর সম্পাদিত 'Hind Swaraj and Other Writings' (২০০৯) বইয়ের সম্পাদকীয় অংশে বলেছেন যে, '*Hind Swraj* is Gandhi's seminal work' (Parel xiii)। মোহনদাস করমচাঁদ গান্ধির (১৮৬৯-১৯৪৮) 'হিন্দ স্বরাজ' লিখেছিলেন প্রথমে মাতৃভাষা গুজরাটিতে, এবং পরে ইংরাজিতে। এটি ছিল একটি আসামান্য লেখা: 'S.S. Kildonan Castle' জাহাজে ইংল্যান্ড থেকে দক্ষিণ আফ্রিকায় ফেরার পথে ১৯০৯ সালের ১৩ থেকে ২২ নভেম্বরের মধ্যে, মাত্র দশ দিনে বইটি লেখা হয়েছিল।ডান হাত ক্লান্ত হয়ে পরলে গান্ধি বাঁ হাতে একটানা লিখেছেন; মোট ২৭৫ পাতার, এবং প্রায় ৩০,০০০ শব্দের পাণ্ডুলিপির মধ্য চল্লিশ পাতাই ছিল বাঁ হাতে লেখা।সমগ্র পাণ্ডুলিপির কয়েকটি মাত্র শব্দ তিনি পরিবর্তন, আর মাত্র ষোলটি লাইন কাটাকাটি করেছিলেন।হিন্দ স্বরাজ একইসঙ্গে ব্রিটিশ ঔপনিবেশিক শাসক, জাতীয় কংগ্রেসের নেতৃত্ব, সহিংস বিপ্লবী আর সধারণ ভারতবাসীদের উদ্দেশ্য লেখা।এর আর কয়েকটি গুরুত্বপূর্ণ উদ্দেশ্য ছিল: প্রথমত, 'স্বরাজ'-এর প্রকৃত অর্থকে উজাগর করা। স্বরাজের মূল ধরানাই এই বইয়ের তাত্ত্বিক আধার নির্মাণ করেছিল, তাকে যুক্তিসিদ্ধ কাঠামো প্রদান করেছিল।দ্বিতীয় উদ্দেশ্যটি ছিল এই যে, সশস্ত্র বিপ্লবী আন্দোলন স্বরাজ আর স্বাধীনতা অর্জনের পক্ষে সঠিক পথ নয়, এই পন্থা যে এক কিসিমের 'suicidal policy', তাকে দেখানোর চেষ্টা করা।আর, তৃতীয়তা 'আধুনিক সভ্যতা' (Modern Civilization) উপনিবেশবাদ ও সাম্রাজ্যবাদের চেয়েও কতটা বেশি বিপজ্জনক আর ভয়াবহ, তা উপলব্ধি করানোর প্রয়াস।১৯০৯ সালে 'Indian Opinion' পত্রিকার গুজরাটি সংস্করণে দু'টি কিস্তিতে দক্ষিণ আফ্রিকা থেকে লেখাটি প্রথম প্রকাশিত হয়।১৯০১০ সালে প্রথমে গুজরাটি ভাষায় পুস্তিকা আকারে, ও পরে ইংরাজি অনুবাদে প্রকাশ পায়। উল্লেখ্য যে, 'হিন্দ স্বরাজ' হলো একমাত্র বই যেটি গান্ধি নিজে লিখেছিলেন, এবং তর্জমা করেছিলেন। পরে মোট কুড়িটি আধ্যায়ে বিভক্ত হিন্দ স্বরাজ - বঙ্গভঙ্গ, স্বরাজ, সভ্যতা, হিন্দু-মুসলিম সম্পর্ক, পাশব শক্তি, নিষ্ক্রিয় প্রতিরোধ, শিক্ষা'র মতো জাতীয় ও ঐতিহাসিকভাবে জরুরী বিশয়গুলি ছাড়াও রেলপথ, আইনজীবী, চিকিৎসক, যন্ত্রপাতি'র মতো ব্যবহারিক বিষয়, অথবা *'ভারত কেন পরাজিত হলো?* ও *'ভারত কি করে স্বাধীন হতে পারে?'*র সমাজ-রাজনৈতিক বিষয়ও এর প্রতিপাদ্য হয়ে উঠেছিল।এই প্রবন্ধে মোহনদাস করমচাঁদ গান্ধির দেড়শতম জন্ম জয়ন্তী উপলক্ষে তাঁর অন্যতম প্রধান

GLOCALISM
Journal of culture, politics and innovation
OPEN ACCESS

Global Bauls, Local Bauls: Community, Violence and Everyday Life

Arnav Debnath
Dumkal College (India)

DOI: https://doi.org/10.12893/gjcpi.2020.3.7

Keywords: globalization, local, bauls, community, everyday, violence

ABSTRACT

The enormous power of globalization

পঁচিশ টাকা

"উত্তিষ্ঠত জাগ্রত প্রাপ্য বরান্ নিবোধত"

উদ্বোধন

॥১২২॥

বৈশাখ ১৪২৭ • চতুর্থ সংখ্যা • ১২২তম বর্ষ • উদ্বোধন কার্যালয় • কলকাতা

"উত্তিষ্ঠত জাগ্রত প্রাপ্য বরান্ নিবোধত"

উদ্বোধন

॥ ১২২ ॥

১২২তম বর্ষ ● ৪র্থ সংখ্যা
বৈশাখ ১৪২৭ ● এপ্রিল ২০২০

সূ চি প ত্র

সম্পাদক : স্বামী শিবার্চনানন্দ

ব্যবস্থাপক সম্পাদক : স্বামী নিত্যমুক্তানন্দ

স্বপ্না প্রিন্টিং ওয়ার্কস (প্রাঃ) লিমিটেড, ৫২ রাজা রামমোহন রায় সরণি, কলকাতা-৭০০ ০০৯ থেকে বেলুড় রামকৃষ্ণ মঠের ট্রাস্টিগণের পক্ষে স্বামী নিত্যমুক্তানন্দ কর্তৃক মুদ্রিত ও ১ উদ্বোধন লেন, কলকাতা-৭০০ ০০৩ থেকে প্রকাশিত।
ডিটিপি-তে অক্ষরবিন্যাস ও পৃষ্ঠা অলঙ্করণ : সম্পাদকীয় বিভাগ, 'উদ্বোধন'
বার্ষিক গ্রাহকমূল্য ♦ ব্যক্তিগত সংগ্রহ ১৩০ টাকা; সডাক: ১৬০ টাকা ♦ প্রতি সংখ্যার মূল্য: ২৫ টাকা

বাংলায় লোকায়ত দর্শনচর্চা ও দেবীপ্রসাদ চট্টোপাধ্যায়

আব্দুল আলীম শেখ
অতিথি প্রভাষক, দর্শন বিভাগ, ডোমকল কলেজ

সমাজবিকাশের পটভূমিতে বিশ্বসংস্কৃতির উৎক্ষেপণ-অবক্ষেপণের মানদণ্ড হিসাবে যেসমস্ত শাস্ত্র সাক্ষ্যবহন করে, তার মধ্যে নিঃসন্দেহে দর্শনশাস্ত্র অগ্রগণ্য। আর সেই দর্শন যদি বৈজ্ঞানিক ভিত্তিভূমিতে গড়ে ওঠে, তাহলে সেই দর্শন যে সমাজের একটি মুক্ত চিন্তাধারার প্রকাশ করবে সে নিয়ে সন্দেহের অবকাশ থাকে না। বৈজ্ঞানিক দৃষ্টি বলতে এমন এক বস্তুবাদী চিন্তাকে বোঝায়, যার মূল ভিত্তি হবে—প্রত্যক্ষ ও পরীক্ষণ। ভারতীয় দর্শনে এমন একটি সম্প্রদায়ের খোঁজ পাওয়া যায়—যে-সম্প্রদায় অতি প্রাচীনকালে বৈজ্ঞানিক দৃষ্টিভঙ্গিকেই তাঁদের দর্শন আলোচনার পদ্ধতি হিসাবে গ্রহণ করেছিলেন; সেই সম্প্রদায়টি হলো লোকায়ত দর্শন[১] সম্প্রদায় বা চার্বাক সম্প্রদায়। কথাটি শ্রুতিকটু মনে হলেও গভীরভাবে চিন্তা করলে বোঝা যায় যে, সর্বপ্রথম ভারতভূমিতে বিজ্ঞানচেতনার বিজয়মশাল তাঁদের হাতেই আমরা লক্ষ্য করেছিলাম—হোক না সেটা অপরিণত বৈজ্ঞানিক চিন্তা। সেই বৈজ্ঞানিক চিন্তা আমাদের সেই প্রাচীনকাল থেকে ধর্মের সঙ্গে কুসংস্কারের পার্থক্য করা শিখিয়েছে।

আমাদের ভারতীয় দর্শন সম্প্রদায়ের মধ্যে বস্তুবাদী চিন্তার একমাত্র ধারক-বাহক হলো চার্বাক দর্শন সম্প্রদায়।[২] ভারতীয় উপমহাদেশে এই দর্শনের আবির্ভাবের বিষয়টি পণ্ডিতদের যথেষ্ট ভাবিয়ে তোলে। ভাবিয়ে তোলে—কিভাবে সেই বৈদিক ব্রাহ্মণ্য যুগে চার্বাকগণ দুঃসাহসের সঙ্গে জড়বাদের কথা বলেছেন।

দুঃখের বিষয় এই যে, আস্তিক সমাজে চার্বাকদের জড়বাদী/বস্তুবাদী চিন্তার বিষয়টি ইতিহাস ঠিকভাবে সংরক্ষণের ব্যবস্থা করতে পারেনি। এই কারণে চার্বাক সম্প্রদায় সম্পর্কে জানার জন্য কোন নির্ভরযোগ্য প্রামাণ্য গ্রন্থ পাওয়া যায় না। যা পাওয়া যায় সেগুলি সবই চার্বাক-প্রতিপক্ষের লেখা বিকৃত তথ্য। যার ফলে সেই আলো-আঁধারি তথ্যের ভিত্তিতে চার্বাক দর্শন সম্পর্কে কিছু বলা, বিশেষ করে এই আধুনিক যুগে দাঁড়িয়ে সেই হারিয়ে যাওয়া দর্শন সম্পর্কে একাধিক গবেষণামূলক গ্রন্থ লেখা শুধুমাত্র প্রশংসার দাবি রাখে তাই নয়, একধরনের দুঃসাহসিক মন ও প্রগতিবাদী চিন্তার সাক্ষ্য বহন করে। এই দুঃসাহসিক কাজে হাত দিয়েছিলেন বাঙালি বস্তুবাদী দার্শনিক প্রয়াত দেবীপ্রসাদ চট্টোপাধ্যায়। তিনি আজকের বাঙালি সুধীসমাজের সামনে সেই প্রাচীনকালের সাধারণ মানুষের দর্শন (লোকায়ত দর্শন)-এর পরিচয় তুলে ধরার চেষ্টা করেছেন। উল্লেখ্য, বিংশ শতাব্দীতে পাশ্চাত্যের মাটিতে যৌক্তিক প্রত্যক্ষবাদের কথা দিকে দিকে ছড়িয়ে পড়েছে, সেই চিন্তার মূল সুর সেই প্রাচীন যুগ থেকে আমাদের ভারতবর্ষের মাটিতে লোকায়ত দর্শনমতের মধ্যে লুক্কায়িত ছিল।

একটা সময় ছিল যখন পশ্চিমবঙ্গের কোন বিশ্ববিদ্যালয়/কলেজ স্তরে অনার্স/পাস কোর্সে নাস্তিক দর্শন (চার্বাক, বৌদ্ধ ও জৈন) পড়ানো হতো না। স্বাভাবিকভাবে সেই সময়ে মুক্তমনা নাস্তিক দর্শন সম্পর্কে কোন যুক্তিযুক্ত গবেষণামূলক গ্রন্থ পাঠকের হাতে পৌঁছাতে পারেনি। এই সমস্যা দূর করতে দার্শনিক দেবীপ্রসাদ চট্টোপাধ্যায় তাঁর ক্ষুরধার বুদ্ধিমত্তা, অকাট্য যুক্তি, পাহাড়সম তথ্য নিয়ে আবির্ভূত হয়েছিলেন বাঙালি মুক্তমনা তথা সাধারণ দর্শনপ্রেমী মানুষের কাছে। প্রসঙ্গত উল্লেখ্য যে, একসময় কলকাতা বিশ্ববিদ্যালয়ের মতো দেশের স্বনামধন্য বিশ্ববিদ্যালয়ে লোকায়ত দর্শন পাঠ্যসূচির বহির্ভূত ছিল, আর এখন সেই লোকায়ত দর্শনের ওপর গবেষক আহ্বান করা হয় যাদবপুর বিশ্ববিদ্যালয়ের মতো এশিয়া মহাদেশের অন্যতম সেরা বিশ্ববিদ্যালয় থেকে। এই কৃতিত্বের কিছু অংশ যে দেবীপ্রসাদ চট্টোপাধ্যায়ের মতো

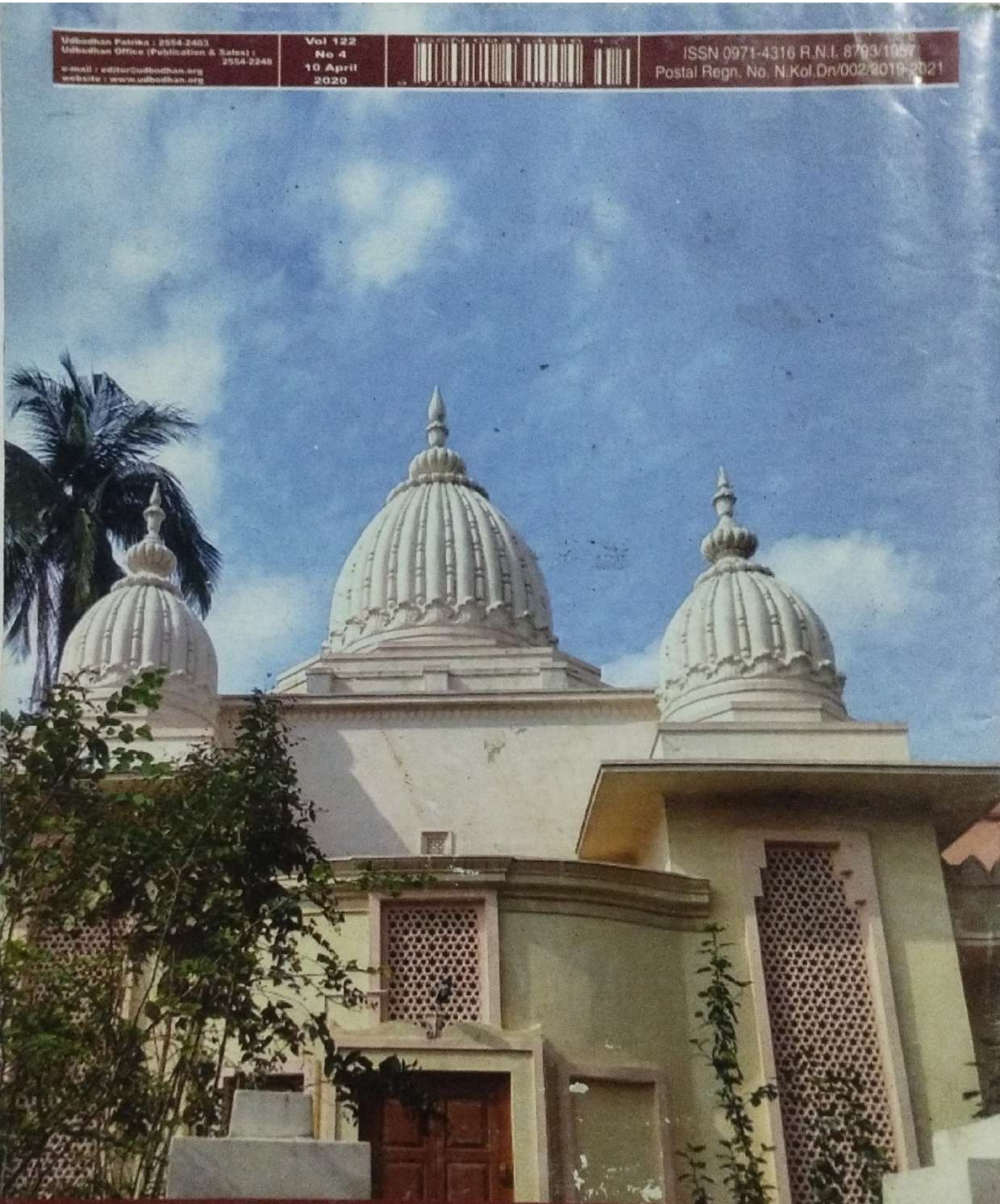
---

১ এই দর্শন সম্প্রদায়টি একাধিক নামে পরিচিত। যথা—নাস্তিক, লোকায়ত, বাহস্পত্য, স্বাভাববাদী, ভূতবাদী, হৈতুক, কাপালিক দর্শন, ইচ্ছান্তিক প্রভৃতি।
২ ভারতীয় দর্শনে চার্বাক সম্প্রদায় ছাড়াও ন্যায়-বৈশেষিক, সৌত্রান্তিক, বৈভাষিক প্রভৃতি সম্প্রদায় একটা বিশেষ দৃষ্টিভঙ্গি থেকে নিজেদের বস্তুবাদী বলে দাবি করলেও এই সমস্ত দর্শন সম্প্রদায় গভীরভাবে পাঠ করলে দেখা যায়—প্রকৃতপক্ষে এই সম্প্রদায়গুলি প্রত্যক্ষ বা পরোক্ষভাবে ভাববাদের প্রাধান্য স্বীকার করে নিয়েছেন।

Udbodhan Patrika : 2554-2403
Udbodhan Office (Publication & Sales) : 2554-2248
e-mail : editor@udbodhan.org
website : www.udbodhan.org

Vol 122
No 4
10 April
2020

ISSN 0971-4316 R.N.I. 8793/1957
Postal Regn. No. N.Kol.Dn/002/2019-2021



Printed by Swami Nityamuktananda, Adhyaksha, Ramakrishna Math, 1 Udbodhan Lane, Baghbazar, Kolkata-700003 and published by him on behalf of the Board of Trustees of the Ramakrishna Math, Belur and Printed at Swapna Printing Works Pvt. Ltd., 52 Raja Rammohan Roy Sarani, Kolkata-700009 and Published from Ramakrishna Math, 1 Udbodhan Lane, Baghbazar, Kolkata-700003. Editor : Swami Shivarchanananda.

A Bengali Peer-Reviewed Journal

ISSN : 2454-4884

সংশপ্তক

।। বিশেষ সংখ্যা ।।

ঈশ্বরচন্দ্র বিদ্যাসাগর

ও

বিভূতিভূষণ বন্দ্যোপাধ্যায়

এবং

।। অন্যান্য প্রবন্ধ ।।

পঞ্চম বর্ষ ।। দ্বিতীয় সংখ্যা

জুন, ২০২০ ইং

সম্পাদক : উত্তম দাস

সংশপ্তক , SAMSAPTAK

Peer- Reviewed Journal

২০20 ,জুন

2020 June

Vol.5, Issue-2

পঞ্চম বর্ষ ।।দ্বিতীয় সংখ্যা

ISSN-2454-4884

=====

পরবর্তী সংখ্যার বিষয়

'ছোটগল্প ও অন্যান্য প্রবন্ধ '

অভ্রতে কালপুরুষ ফন্ট এ লিখে সফটকপি uttamnbu@gmail.com এ পাঠান

অক্টোবর ১৫ ২০২০এরমধ্যে । পিডিএফ করবেন না, 9734518427

সূচীপত্র ⟹

 ISSN-2454-4884

ঈশ্বরচন্দ্র বিদ্যাসাগরের নারীবাদী দর্শন : তত্ত্ব ও প্রয়োগ

আব্দুল আলীম শেখ

বীরসিংহের সিংহশিশু[i] ঈশ্বরচন্দ্র বিদ্যাসাগর আমাদের সমাজে দেবতার চেয়ে অনেক বেশি দুর্লভ[ii], অক্ষয় মনুষ্যত্ব, কর্তব্যে নির্ভয়, দৃঢ়তায় হিমগিরি, নিরন্নের অন্নদাতা, অনন্যতন্ত্র করুণারসাগর ছিলেন নারী ও পুরুষের সাম্য ও সমাধিকারে বিশ্বাসী একজন মানুষ। যথার্থ অর্থে তিনিই পুরুষ যিনি নারীপুরুষের ভেদ স্বীকার না করে উভয়ের সাম্য ও স্বাধীনতায় বিশ্বাস করেন, বিশ্বাস অনুসারে বাস্তবে চর্যা করেন। তাই, রবীন্দ্রনাথ ঠাকুর বিদ্যাসাগর সম্বন্ধে বলেছিলেন, '৪০ কোটি ভারতবাসীর মধ্যে একমাত্র পুরুষ'।নারীকে শাসন, শোষণ, নিপীড়নের সঙ্গে পৌরুষের কোন সম্পর্ক নেই। পুরুষ তিনিই যিনি বিপদে নারীকে রক্ষা করেন, ভালো ভাবে বাঁচতে সাহায্য করেন, উপযুক্ত শিক্ষার ব্যবস্থা করেন এবংসামাজিক স্বাধীনতা অর্জনে সাহায্য করেন। তাই তিনি মনে প্রাণে'পুত্রের ন্যায় কন্যাকেও যত্ন করতে ও শিক্ষা দিতে হবে'[iii]- এমন বাণী সর্বদা হৃদমাঝারে লালন করেছেন।নারী সম্পর্কে তাঁর স্বাতন্ত্র্যবোধ ছিল তীব্র। যুগোপযোগী ভাবনায় আদলে তিনি তাঁর মনন গঠন করেছিলেন বলেই জীবনের প্রতিটি সিদ্ধান্তে দৃঢ় মেরুদণ্ডের পরিচয় দিয়েছেন। লোকাচার বা ধর্ম যখন নারীর পরাধীনতাকে সম্মতি দেয় ঠিক তখন বিদ্যাসাগর মাথা উঁচু করে দৃঢ়টার সঙ্গে রুখে দাঁড়িয়েছিলেন নারীর অবিচারের বিরুদ্ধে। সমাজের অযৌক্তিক কাঠামোর প্রতি সজোরে আঘাতের মধ্যদিয়ে যুগের প্রচলিত ভাবনাকে পরিবর্তিত হতে বাধ্য করেছিলেন।

ঈশ্বরচন্দ্র বিদ্যাসাগর প্রাচীন শাস্ত্র পাঠ করে জেনে ছিলেন, সে যুগের প্রথমদিকে নারীর অধিকার পুরুষের চেয়ে কোন অংশে কম ছিল না। বৈদিক যুগে শিক্ষায় নারীর অধিকার ছিল, পরিণত বয়সে বিবাহ থেকে শুরু করে স্বয়ম্বর সভা বা গান্ধর্ব মতে বিয়ে করার অধিকার ছিল। সে যুগে দেখা যায় অপালা, বিশ্ববরার মতো নারীগণ বৈদিক শ্লোক রচনারঅধিকারপেয়ে ছিলেন। উপনিষদের যুগে দেখা যায় গার্গীর মতো মহিলা দার্শনিকেরদৃষ্টান্ত। দময়ন্তী, গৌতমী, শিখণ্ডী, শিবা, বিদুলা, মৈত্রেয়ী, অরুন্ধতী, আত্রেয়ী, শকুন্তলা, লোপামুদ্রার প্রমুখ ব্যক্তির উপাখ্যানও লক্ষ্য করা যায়।যুদ্ধেরময়দানে লক্ষ্য করা যায় মুদগলিনী, বিশপলা, শশিয়সী প্রমুখ মহীয়সীনারীকে। কিন্তু পরবর্তীসময়ে(অথর্ববেদ) নারীর জীবনেনেমে আসে সতীদাহের মতো করুণ অবস্থা। সতীদাহের মতো কুৎসিতপ্রথা থেকে রাজারামমোহন রায় আইনত মুক্তি দিলেও বিদ্যাসাগরের সময়ে নারী অবস্থা যথেষ্ট করুণ ছিল।পরবর্তীবৈদিক যুগে শূদ্রএবং নারীর জন্য বেদপাঠ নিষিদ্ধ করা হয়। পতিতা ছাড়া আর কোন নারীশিক্ষিতা এবং স্বাধীন ছিল না। প্রসঙ্গতউল্লেখ্য, হিন্দু ধর্মে যখন নারীর অবস্থা খুবইশোচনীয় ঠিক তখন বৌদ্ধ ও জৈন ধর্মাবলম্বী পরিবারের মেয়েদের উচ্চশিক্ষায় অংশ গ্রহণ বেশচোখেপড়ার মতো। বৌদ্ধ শাস্ত্রে নারীদেরতিরস্কারএবং মারধোর করাকে নিন্দার চোখে দেখানো হয়েছে। কিন্তু হিন্দু নারীর মুক্তি কোথায়? হিন্দু নারীর দার্শনিক, কবি, সাহিত্যিক, যুদ্ধেঅংশ গ্রহণ করার সমস্ত অধিকার ধ্বংসের চরমতম দৃষ্টান্ত লক্ষ্য করা যায় উনবিংশশতকে। নারীর করুণ অবস্থার পরিবর্তন ঘটাতে এগিয়ে এলেন পণ্ডিত ঈশ্বরচন্দ্র বিদ্যাসাগর। সে সময়ে প্রচলিত বাল্যবিবাহ, বিধবার করুণ অবস্থা, বহুবিবাহ প্রভৃতি ছিল নারীর প্রধান সমস্যা। তাই তিনি কখনও বাস্তব যুক্তি-বুদ্ধি নিরিখে, আবার কখনও শাস্ত্রের সাহায্যে প্রচলিত কুপ্রথার গুলির বিরুদ্ধে গর্জে উঠেছিলেন।

বিজ্ঞানভিত্তিক যুক্তির মধ্যদিয়ে বিদ্যাসাগর বাল্যবিবাহের বিরোধিতা করে ১৮৫০ সালে 'সর্ব শুভঙ্করী' পত্রিকায় লিখেছিলেন 'বাল্যবিবাহের দোষ' শীর্ষক প্রবন্ধ। তিনি শাস্ত্রের যুক্তিতর্কে না গিয়ে বাস্তবিক দৃষ্টিতে বলেছিলেন- "বাল্যকালে বিবাহ করিয়া আমরা সর্বতোভাবে বিব্রত ও ব্যতিব্যস্ত হই। কারণ প্রথমত বিবাহ ঘটিত আমোদ-প্রমোদে ও কেলিকৌতুকে বিদ্যাশিক্ষার মুখ্যকাল যে বাল্যকাল, তাহা ব্যয় হইয়া যায়।"[iv] অর্থাৎ, বাল্যবিবাহ কোনভাবেই বাস্তব সম্মত নয়। বাল্যবিবাহে স্বামী-স্ত্রী

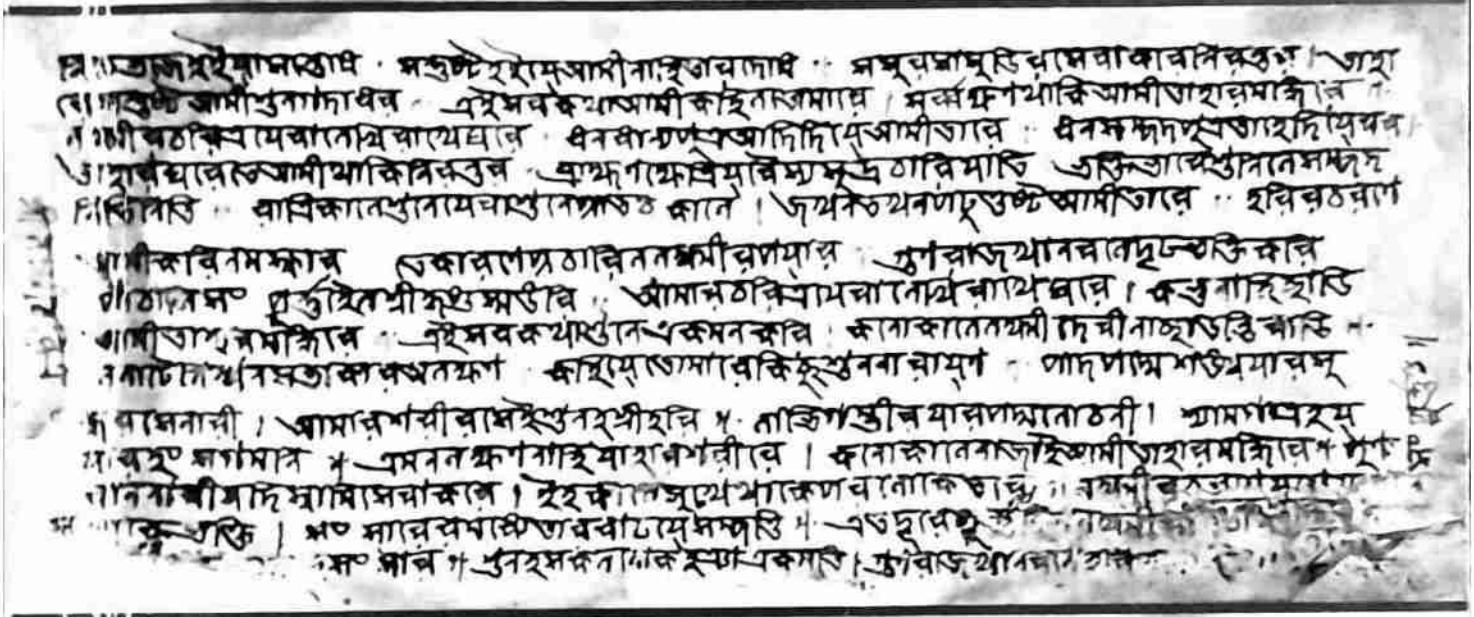
ISSN 2320-6160

হিমেল
১৪২৬

সাহিত্যলোক

লেখক-পাঠক যোগাযোগ

বাংলা সাহিত্য-বিষয়ক গবেষণাধর্মী রেফার্ড ও পিয়ার-রিভিউড ষাণ্মাসিক পত্রিকা



প্রাগাধুনিক বাংলা সাহিত্য :
বহুমাত্রিক অভিনিবেশ

সম্পাদক : উদয় রতন মুখার্জী

সাহিত্যতক্কো :

লেখক-পাঠক যোগাযোগ

বাংলা সাহিত্য-বিষয়ক গবেষণাধর্মী রেফার্ড ও পিয়ার-রিভিউড ষাণ্মাসিক পত্রিকা

ISSN 2320-6160

অষ্টম বর্ষ, পঞ্চদশ সংখ্যা

হিমেল ১৪২৬, ডিসেম্বর ২০১৯

বিষয়

প্রাগাধুনিক বাংলা সাহিত্য : বহুমাত্রিক অভিনিবেশ

সম্পাদক

উদয় রতন মুখার্জী

সম্পাদকীয় দপ্তর

অস্মি ভ্যালি আবাসন, ফ্ল্যাট নং-৩ জি, দেশবন্ধুপাড়া, জলপাইগুড়ি-৭৩৫১০১

১৬২/ডি/১, কুতুল শাহী রোড, বারাসাত, কোলকাতা-৭০০১২৪

যোগাযোগ

৯৪৩৩৮০৯০২০, ৯৪৩৩৭২১২৩৮

sahityatakko@gmail.com

●

প্রচ্ছদ

প্রথম ছবিটি ইন্টারনেট সূত্রে প্রাপ্ত এবং দ্বিতীয় ছবিটি দীনেশচন্দ্র সেন সম্পাদিত

'বঙ্গ সাহিত্য পরিচয়', কলিকাতা বিশ্ববিদ্যালয় প্রকাশিত, ১৯১৪ সংস্করণ থেকে গৃহীত

ভিতরের ছবি

বিভিন্ন প্রাচীন গ্রন্থ এবং ইন্টারনেট সূত্রে প্রাপ্ত

অক্ষরবিন্যাস

উদয় রতন মুখার্জী

সামগ্রিক বিন্যাস

এল. আর. ইনফোটেক

৫৮ শ্রীরামপুর রোড (নর্থ), গড়িয়া, কোলকাতা-৭০০০৮৪

মুদ্রক

মিলেনিয়াম প্রিন্টার্স, দক্ষিণপাড়া, বারাসাত, কোলকাতা-৭০০১২৪

মূল্য

২৮০ টাকা

মঙ্গলকাব্য

কবিচতুষ্টয়

নানা প্রসঙ্গ

ISSN 2320-6160

হিমেল ১৪২৬

ডিসেম্বর ২০১৯

প্রাগাধুনিক বাংলা সাহিত্য : বহুমাত্রিক অভিনিবেশ

সাহিত্য রূপ

লেখক-পাঠক যোগাযোগ...

অন্নদামঙ্গল থেকে কবিওয়ালা : গীতিকবিতার এক সন্ধান

অচিন্ত্যকুমার গঙ্গোপাধ্যায়

গীতিকবিতার পরিসর প্রায় এক হাজার বছর বা তারও বেশি সময় ধরে বাংলা কবিতায় রয়ে গেছে। সুদূর চর্যাপদের রচনায় যেখানে আত্মপ্রকাশের ক্ষেত্রে আবেগময়ী একটি স্বতঃস্ফূর্ত বাণীরূপকে আমরা লাভ করি, সেখানেই চমৎকৃত উপলব্ধি এই গীতিকবিতার জন্ম দেয়। তাই কবিমনে উদাত্ত সেই আহ্বান ডোম্বী নারীকে উদ্দেশ করে চর্যার যুগে ঘনীভূত হয়েছে,—

আলো ডোম্বী তোরে পুছসি সদভাবে।
আছসি যাস ডোম্বী কাহাবি নাবে।। [ডোম্বীপাদ]

এখানে স্পষ্টতই ডোম্বী নাম্নী নারীটির জীবনে একজন পুরুষ আছে, নিভৃতে গোপন কাহিনি হয়ে এই পুরুষটির সঙ্গে সে মিলিত হয়। অন্য এক পরিচিত পুরুষ তাকে উদ্দেশ করে উপরের দু'টি কাব্যময় পংক্তি উচ্চারণ করেছে। এই সম্বোধনরীতিটি অনেকটাই 'Ode' বা গাথাজাতীয় কাব্যের অন্তর্গত হয়ে ওঠে। 'আলো' শব্দটি মধ্যযুগীয় বাংলা সাহিত্যে অনেকবার ব্যবহৃত হলেও তার দৈনন্দিন ব্যবহার লেখার মধ্যে উঠে আসে না। কিন্তু নারীর নিজস্ব জগতের ভাষার এক আশ্চর্য সুন্দর প্রতিফলন বেশ সচেতনভাবেই আমাদের নন্দিত করে।

প্রাচীন যুগ থেকে প্রায় প্রাগাধুনিক যুগ পর্যন্ত গীতিকিবিতার সেই প্রবহমানতাকে স্পর্শ করবার চেষ্টা এই ক্ষুদ্র পরিসরে সম্ভব নয়। তাই আমাদের উদ্দিষ্ট অভিযাত্রা এই ক্ষেত্রে আঠারো শতকের মাঝামাঝি থেকে প্রায় উনিশ শতকের সূচনালগ্ন পর্যন্ত। এই কালপর্বে দাঁড়িয়ে এই চমৎকার গানের ক্ষেত্রটি কীভাবে পল্লবিত ও বিকশিত হয়েছে তারই একটি পূর্ণত্বের স্বরূপকে আমরা আলোচনায় নিয়ে আসতে চাইছি। মধ্যযুগের সর্বত্রই গেয়সাহিত্য বা মৌখিক সাহিত্যের ধারা বহমান। কিন্তু বস্তুনিরপেক্ষ এক আত্মপ্রক্ষেপণের ছাপ গীতিকবিতায় যেমন জীবন্ত হয়ে ধরা দেয়, তেমনি নানান রূপ-রূপান্তরের সারণি বেয়ে গীতিকবিতার অমেয় এক সুরমূর্ছনা আধুনিকতার দরজায় দাঁড়িয়ে কীভাবে কবিওয়ালারা লাভ করেন তারও আভাস এখানে পাওয়া সম্ভব হবে।

ঐতিহাসিক এক ক্রান্তিলগ্নে লেখা হয়েছে ভারতচন্দ্রর অন্নদামঙ্গল কাব্যের বিদ্যাসুন্দর কাহিনি। মঙ্গলকাব্যে গেয় উপাদানের পরিমাণ বেশি থাকায় অনায়াসে নারীর রূপ বর্ণনা থেকে শুরু করে চৌত্রিশার মতো বিবরণধর্মী ক্ষেত্রগুলিকে ছুঁয়ে গেছে সাধারণ পাঠক ও শ্রোতার মনোজগৎ। আরবি ও ফার্সি ভাষার পাশাপাশি সংস্কৃত, দেশীয় নানান উপভাষা সহ ওড়িয়া ভাষার সঙ্গে কবি ভারতচন্দ্রর পরিচয় ছিলো। তাই তিনি নির্দ্বিধায় বলতে পেরেছেন,—

যে হোউক সে হোউক ভাষা কাব্যরস লয়ে।

অর্থাৎ কবিত্বের মৌলিক উপাচার যে কাব্যরস অবলম্বনেই নির্মিত হয় সে সম্পর্কে ভারতকবি সচেতন।

এছাড়া ছান্দসিকের মতো লৌকিক বাংলা শব্দের বিন্যাস যেমন তিনি নিয়ে আসতে সমর্থ হয়েছেন, তেমনি ধ্রুপদি রীতি মেনে একাবলী, ভুজঙ্গপ্রয়াত, তোনক, তূটক জাতীয় ছন্দ বৈশিষ্ট্যেরও প্রয়োগ করতে তিনি সমর্থ হন। ফলশ্রুতিস্বরূপ বিভিন্ন ভাষার শব্দভাণ্ডার ব্যবহার করে ভারতচন্দ্র বাংলা

ভাষার প্রকাশ ক্ষমতাকেও বাড়িয়ে দিয়েছেন অনেকটাই—যা তাঁকে উত্তরকালে স্মরণীয় করেছে। অন্নদামঙ্গলের নানান স্থলে দেখা পাওয়া সম্ভব গীতিকবিতার উচ্ছ্বাসের স্বরূপটি,—

ওহে বিনোদ রায় ধীরে যাও হে
অধরে মধুর হাসি বাঁশীটি বাজাও হে।।
নবজলধরতনু শিখিপুচ্ছ শক্রধনু
পীতধরা বিজলীতে ময়ূরে নাচাও হে।

প্রায় একশো বছর অতিক্রম করে এর অনুরণন প্রকাশ পায় মধুকবির ব্রজাঙ্গনার নায়িকা রাধার আকুতিপূর্ণ স্বরে। বস্তুত সনেটে ভারতকবিকে এই মধুসূদন রাখালিয়া কবি বা Pastoral Poet-এর তকমা দিতে চেয়েছেন। সমালোচক ড. আশুতোষ ভট্টাচার্য সার্থকভাবেই ভারতকবিকে আধুনিককালের কাব্য নির্মাতাদের প্রথম উদ্গাতার ভূমিকা দিতে চান,—

> "এই বিশেষত্বগুলি তাহার ঐহিক প্রীতির নিদর্শন রূপে গণ্য হইবার মর্যাদা লাভ করিয়া তাঁহাকে আধুনিক যুগের অগ্রদূত বলিয়া নির্দিষ্ট হইবার যোগ্যতা দান করিয়াছে।"[১]

দুই

মধ্যযুগীয় বা প্রাচীন বাংলার বারো বা চোদ্দোটি চরণে বিন্যস্ত গীতিকবিতার মধ্যে একালের গীতিকবিতার যে বৈশিষ্ট্যগুলি অটুট থাকবে তা হলফ করে বলা সম্ভব নয়। গীতিকবিতায় অবশ্যই একটি সুরের স্বতঃপ্রণোদিত প্রবহমানতা থাকে। যে কোনো মঙ্গলকাব্যের ধারায় তার সংযোগ বর্তমান। এছাড়াও গীতিকবিতায় আছে দৃশ্যরূপের এক ধারাবাহিক জীবন্ত উপস্থিতি। দু'টির একটি বিশেষ সঞ্চারপথ তৈরি করে দেয় লিরিক বা গীতিকবিতা নির্মাণের উপাদানের দিক থেকে।

শব্দবিন্যাসের দক্ষতাতেই একজন কবি তাঁর কল্পনা বৈভবকে মেলে ধরতে সক্ষম হন। সাধারণভাবে সম্বোধন করবার রীতিটি সেকালের প্রচলিত গাথাকবিতাকে মনে করিয়ে দেয়। নিশ্চিতভাবে শব্দ সংযোজনের কারুকৃতির উপর ওই গীতিকবিতার সার্থকতা বা ব্যর্থতা বহুলাংশেই নির্ভর করে। শব্দগুলি মুখ্যত নরম বা কোমল প্রকৃতির হয়। এক ধরনের ব্যঞ্জনাবাহী ও মার্মিক হৃদয়স্পন্দন এতে ধ্বনিত হয়। আবার প্রাকৃতিক নানাবিধ অনুষঙ্গ থেকে চমৎকার এক প্রাণোচ্ছলতা প্রকাশ পায় আমাদের চোখে।

একথা অবশ্যই স্বীকার্য যে, মনস্তাত্ত্বিকভাবেই কবিমনের একটি বিশেষ ভাবনা কেবল আবদ্ধ হয়ে থাকে না। তাঁর পরিক্রমার পরিসর ছুটে চলে একটি উপাদান থেকে অন্য উপাদানকে আশ্রয় করে। ভারতচন্দ্রর রচনার মধ্যে এই অন্তরস্থিত উপলব্ধি চমৎকার আবেগঘন এক বা একাধিক মুহূর্ত যেন তৈরি করে চলে। যেমন মদনভস্মের পর স্ত্রী হিসেবে রতির বিলাপের মধ্যে আশাভঙ্গের বেদনার স্বর ঘনিয়ে আসে,—

একের কপালে রহে আর এক কপালে দহে
আগুনের কপালে আগুন।[২]

ঠিক একইভাবে বেশ কয়েকটি প্রবাদপ্রতিম বাক্যাংশের মধ্যেও সংগীতহিল্লোল সৃষ্টির অপরূপ বিস্তারিত হতে চায়,—

১. খুন হয়েছিনু বাছা চুন চেয়ে চেয়ে।[৩]

২. আধপনে আধসের কিনিয়াছি চিনি।
অনা লোকে ভুরা দেয় ভাগ্যে আমি চিনি।।[৪]

৩. কে বলে শরদশশি সে মুখের তুলা।
পড়ে আছে পদনখে তাঁর কতগুলা।।[৫]

গভীর প্রজ্ঞাদীপ্ত একটি উচ্চারণ ভারতকবির সৃষ্টিকে অম্লান করে দেয়। 'নগর পুড়িলে দেবালয় কি এড়ায়'—এই পংক্তিটির মধ্যে নিহিত আছে মানবিক হৃদয়স্পর্শী আবেদনের মগ্নতার ছাপ। সরল যুক্তবাঞ্জনহীন অক্ষরের এই রচনাটি অত্যন্ত অভিজ্ঞতার নির্যাসকে সংকলিত করে তোলে।

বৈষ্ণব পদাবলী থেকেও উঠে এসেছে কিছু বিশেষ প্রবচনমূলক বাক্যসমূহ (যেমন হাভাতে যে দিকে চায় সাগর শুকায়ে যায়) কিংবা ঈশ্বরী পাটনীর চোখে পার্বতী বা মহেশ্বরীর অলৌকিক ক্ষমতা জানার পর যেভাবে বর্ণনাধর্মী বিবরণ বা Narrative-এর উপস্থাপন ঘটে, সেখানে সাংকেতিক ভাষার শ্রুতিমাধুর্যের খুব একটা বাহুল্য নেই,—

সেঁউতিতে পদ দেবী রাখিতে রাখিতে।
সেঁউতি হইল সোনা দেখিতে দেখিতে।।[৬]

এই দুটি পয়ার নিবন্ধন চরণের দিকে তাকালে যে কোনো সচেতন পাঠক বলতেই পারেন,—'বিস্ময়ে তাই জাগে, জাগে আমার গান।' অবশ্যই মনে রাখতে হয়, বাস্তবিক বেদনাবিদ্ধ চিত্তের উদ্ভাসনই কবিতা হয়ে ওঠে। পশ্চিমী ভাবনায় বলা হয়,—'Our sweetest songs are those, that tells us saddest thought'। একালের কবি জীবনানন্দ দাশ-এর লেখায় জীবন্ত হয়ে ওঠে,—

হায় চিল, সোনালি ডানার চিল
খুঁজে তুমি ফিরো নাকো ধানসিঁড়ি নদীটির তীরে।

কিংবা,—

থাকে শুধু অন্ধকার—মুখোমুখি বসিবার বনলতা সেন।

বাস্তব থেকে পরাবাস্তবের পথে হাঁটছে কবি ও পাঠকের মন, এই বিমূর্ত এক সৌন্দর্যের নান্দনিক বৈভবকে সঙ্গী করে। প্রকৃতপক্ষে এই অভিযাত্রাই হয়ে পড়েছে শিল্পের গভীর ব্যঞ্জনাদায়ী একটি অনুভবের প্রকাশ। অন্নদামঙ্গলের কবি 'বহুযুগের ওপার থেকে' গীতিকবিতার মধ্যে যে তন্ময়তা বা আত্মলীনতা বোধের দরকার তা ব্যক্তিগত সেই 'আমিত্ব' বা অহং থেকে জন্ম নেয়। বৈষ্ণব পদাবলীর বিদ্যাপতিকৃত প্রার্থনা-বিষয়ক পদের সঙ্গে এই অংশের যোগও সামান্যই আছে।

মধ্যযুগের কবিদের অধিকাংশ লেখা ধর্মীয় বিষয়কে আশ্রয় করে প্রকাশ পেয়েছে। এজন্য দেখা যায়, ভারতচন্দ্র কমবেশি এগারোটির কাছাকাছি শিবপ্রসঙ্গ নিয়ে গান রচনা করেন। সম্ভবত ব্যক্তিজীবনে ক্ষতবিক্ষত হয়ে ওঠা ভারতকবির লেখায় অমোঘ হয়ে উঠেছিলো এই শিব। কারণ স্বয়ং কবিও নিজের জীবনে বিষপানে নীলকণ্ঠ ছিলেন। তাই দেখি ব্যাসকাশি নির্মাণের ক্ষেত্রে কবির গান,—

ভুল না রে ওরে নর শংকর সার কর
শমনেরে কেন ডর।[৭]

ভয় বা দুর্ভোগের শঙ্কা থেকেই হোক, এই স্বর যথেষ্ট আন্তরিক হয়ে ওঠে। আবার কোথাও কবি লৌকিক গাথার অনুসরণে মেয়েমহলের হাস্যরসকে গানে রূপদানের চেষ্টা করছেন,—

আই আই ওই বুড়ো কি
এই গৌরীর বর লো।
বিয়ের বেলা এয়োর মাঝে
হই দিগম্বর লো।।[৮]

সমকালের সমাজ ও অর্থনৈতিক চাপে সাধারণ শিল্পীমন সর্বদা এক গভীর অস্থিরতা ও অনিশ্চয়তার মধ্যে অবস্থান করেছে। সমাজ গবেষকেরা একে অধিকাংশ ক্ষেত্রে নিজস্ব দৃষ্টিভঙ্গি দিয়ে বিচারও করেন,—

> "কাজে কোনো স্থানেই হৃদয়ের ব্যাকুলতা নাই; হৃদয়ের মর্মস্পর্শী দুঃখ কি স্নিগ্ধমুখধারা তাঁহার কাজের কোন অংশকে পবিত্র করে নাই।"[৯]

তিন

সহজাত কবিপ্রতিভা নিয়ে এসেছিলেন আঠারো শতকের দ্বিতীয়ার্ধ থেকে উনিশ শতকের প্রায় মাঝামাঝি পর্যন্ত কবিগানের শিল্পীরা। স্মরণীয় যে, চিরস্থায়ী বন্দোবস্তের পর মধ্যবিত্ত বাঙালিসমাজ জাগ্রত হয়ে উঠেছিলো নতুন গ্রামীণ অর্থনীতির সর্বোত্তম বিকাশের (Optimal Development) হাত ধরে। সদ্য গড়ে ওঠা কোলকাতার নাগরিক জীবনের বিনোদনকে মেটাতে প্রয়োজন হলো গ্রামের কবিওয়ালাদের। তাই দেখা যায় একশো কুড়ি থেকে দেড়শো মাইলের মধ্যে থাকা কবিগানের শিল্পীরাই উপস্থিত হলেন এই বাবুসমাজের মনোরঞ্জনের জন্য।

বর্তমান প্রবন্ধে আমরা দু'জনের রচনাকে অবলম্বন করে নানান দিকের আলোচনায় প্রবৃত্ত হবো। প্রথমটি ঈশ্বর গুপ্তর লেখা 'কবিজীবনী' এবং দ্বিতীয়টি রবীন্দ্রনাথের লেখা 'কবিওয়ালা' প্রবন্ধ। প্রথম ক্ষেত্রে কবিগান বা কবির লড়াইয়ের যে জীবন্ত পটভূমি জন্ম দিয়েছিলো ঈশ্বর গুপ্তর কবিতাগুলিকে, একটু তলিয়ে দেখলে আধুনিক মানসিকতার নেপথ্যে সেই চালচিত্রের মতো নাগরিক গতানুগতিক শব্দ ও ভাষার নিজস্ব শৈলীর মধ্যে শাস্ত্রজ্ঞানের পটুত্ব, কেউ বা গীতিকবিতার সহজাত কবিত্ব নিয়ে এই লড়াই এর আঙিনায় এসেছেন,—

বালিকা ছিলাম, ছিলাম ভাল সই
ছিল না মুখ অভিলাষ
পতি চিনতাম না, ও রস জানতাম না,
হৃদপদ্ম ছিল অপ্রকাশ।
এখন সেই শতদল মুদ্রিত কমল
কাল পেয়ে ফুটিল।[১০]

[রূপচাঁদ পক্ষী দলের গান]

বিদ্যা ও সুন্দরের যৌবনের প্রথম পরিস্ফুটনের ধরনের মলয়জ এই গীতের মাধ্যমে অনেকটাই প্রকাশ পেয়েছে।

আবার স্বয়ং রবীন্দ্রনাথ কবিওয়ালাদের লেখা রাধা-কৃষ্ণ বিষয়ক মানাভিমানের পালাকে রসরুচির গভীরতর দৃষ্টি বা ক্ষত হিসেবে চিহ্নিত করতে চেয়েছেন। তাই তাঁর দ্বিধাহীন কণ্ঠ থেকে উচ্চারিত হয়,—

শ্যাম কাল মান করে গেছে
কেমন আছে দূতী,
দেখে আয়।
করে আমারে বঞ্চিতে, গেল কার কুঞ্জে বঞ্চিত,
হয়ে খণ্ডিতে, মরি প্রেমের দায়।[১১]

[একজন দাঁড়াকবির গান]

খণ্ডিতা, মান, কলহান্তরিতা কিংবা আক্ষেপানুরাগ এই ধরনের কবিসৃষ্টির আধ্যাত্মিক ভাবগরিমা যাই হোক না কেন; আসলে অনুশোচনাক্লিষ্ট এক বাস্তব নায়িকার স্বরূপ উন্মোচিত হয়। গঠনগত দিক থেকে এইসব গানগুলির মধ্যে নানান স্তরবিন্যাস প্রত্যক্ষগোচর হয়ে থাকে—যেমন মহড়া, খাদ, মেলতা, চিতেন, অন্তরা, পাড়ন, ফুকা প্রভৃতি বিভিন্ন পর্যায়ে ফিরে ফিরে আসে চরণদ্বয়ের মিল নিয়ে।

শিক্ষা ও রুচিতে খুব একটা কৃতীমান নন এঁরা কেউই, থাকলেও পুরুষানুক্রমিকভাবে গায়কি বা ছন্দময়তা তাঁদের কবিত্ব সৃষ্টির মধ্যে তা প্রকাশ পেতো না। সেই সঙ্গে একই Pattern বা ছকে বাঁধা নির্মাণশৈলীর মধ্যেই এঁরা সবাই গতায়াত করেছেন। তবে কয়েকজন বিশিষ্ট কবিওয়ালা সমসময়ের কূপমণ্ডুকতার বাইরে এই কবিগান বা মৌখিক ঐতিহ্যটিকে (Oral Tradition) তাঁদের প্রতিভা বা নির্মাণদক্ষতায় উচ্চ পর্যায়ে উন্নতিকরণে বিশেষ উৎসাহ দেখান। এঁদের মধ্যে উল্লেখযোগ্য নাম 'নিধুবাবু' (যিনি নিধিরাম গুপ্ত নামে পরিচিত)। একই সঙ্গে হরু ঠাকুর, গোঁজলা গুই, যজ্ঞেশ্বরী, অ্যান্টনি কবিয়াল, ভোলা ময়রা প্রমুখর নাম সবিশেষ উচ্চারিত।

রামনিধি গুপ্ত, শোরী মিঞার কাছে সংগীতের তালিম নেন। অবশ্য নিধুবাবু হিন্দুস্তানি ঘরনার সংগীতকে বাঙালি সমাজের কাছে তেমনভাবে হাজির করতে চাননি। বরং সুর তাল ও ভাবের এক অনন্য অনুভূতিকে তিনি গানে স্থাপন করতে চেয়েছেন। অবশ্যই যে গানের মূল ভাবরস বাংলা টপ্পা জাতীয় মেজাজি শিল্পরুচিকে মনে করিয়ে দেয়। তাঁর সৃষ্ট দু'-একটি সংগীতের নমুনা,—

নয়নেরে দোষো কেন,
সে কি করিতে পারে
না ঘটিলে মনোমিলন।[১২]

[রামনিধি গুপ্তর গান]

তাঁর বেশ কয়েকটি গানে আবার কিছুটা আদিরসাত্মক হলেও 'কামগন্ধ নাহি তায়' এই অনুভবের সাক্ষ্য পাওয়া যায়, যেমন—

ভালোবাসিবে বলে ভালোবাসিনে
আমার স্বভাব এই তোমা বই আর
কারো জানিনে।
শ্রী মুখে মধুর হাসি, দেখিতে বড় ভালোবাসি
তাই দেখি আসি, দেখা দিতে আসিনে।।[১৩]

[রামনিধি গুপ্তর গান]

যদিও উপরিউক্ত গানটি শ্রীধর কথকের রচনা বলে স্বীকৃতি পেয়েছে তবে অনেক সাহিত্যবিশারদের কাছে এটি নিধুবাবুর টপ্পা নামেই চিহ্নিত। টপ্পা গায়কির শব্দটিকে বিশ্লেষণ করলে পাওয়া যায়—দ্রুতগতিতে ছুটে চলা বা লাফিয়ে এগোনোর চেষ্টা করা।

আবেগের মাধুর্যে এই আমির বিহ্বলতায় মুগ্ধ করে দিতো শ্রোতাদের। সেই সময় প্রবলতম আবেগ কাজ করেছে,—

যখন হাসি হাসি সে আসি বলে
তার হাসি দেখে ভাসি নয়নের জলে।
মন চায় রে ধরিতে
লজ্জা বলে ছি ছি ধরোনা।।

[রামনিধি গুপ্তর গান]

চার

বৈষ্ণব পদাবলীর গৌরবোজ্জ্বল দিগন্তই অষ্টাদশ শতাব্দীর শেষভাগে বাঙালির সংগীতময় রসরুচিকে ধারণ বা লালন করেছে তা নিঃসন্দেহে বলা যায় না। এর সঙ্গে অবশ্যই যুক্ত হওয়া দরকার শাক্ত সংগীতের অনুভবস্পর্শী অভিজ্ঞতার শিহরণ। প্রসাদী সংগীতের মধ্যে গুঞ্জরিত হয়ে উঠেছে গীতিকাব্যের সঞ্চারী আবেগ। কারণ সেযুগের যন্ত্রণাবিদ্ধ বাঙালিমনে সখেদে শোনা গেলো বিশ্বজননীকে আশ্রয় করে আশ্রয়চ্যুত এক শিশুর সারল্যমাখা আর্জি—

মা আমায় ঘুরাবি কত
চোখ বাঁধা কলুর বলদের মতো। [ভক্তের আকুতি : রামপ্রসাদ সেন]

কিংবা নিজের মাকে লক্ষ করে স্বয়ং ভুবনবন্দিতা জগজ্জননীকে উদ্দেশ করে কবি বলেন,—

মা গো তারা ও শংকরী
কোন অবিচারে আমার উপরে করলে দুখের ডিগ্রি জারি?

[ভক্তের আকুতি : রামপ্রসাদ সেন]

খাজাঞ্চিখানার সেরেস্তার কাজের দায়িত্ব একদা দেওয়া হয়েছিলো রামপ্রসাদকে। তাঁর অর্থবিভাগে তছরুপ করবার প্রবৃত্তি না থাকায় জমিদারমশাই তাঁর এই কর্মচারীটির প্রতি যে আদৌ সন্তোষ প্রকাশ করতে পারেননি, তা স্পষ্টতই ফুটে উঠলো একটি গানে,—

আমায় দেও মা তবিলদারী
আমি নিমকহারামি নই শংকরী। [ভক্তের আকুতি : রামপ্রসাদ সেন]

রামপ্রসাদের আগমনী পর্যায়ের পদে আন্তরিক হৃদয়বেদনা গভীরভাবে ধ্বনিত হয়ে ওঠে। কিছু ক্ষেত্রে নাটকীয়তার ছাপ এই ধরনের পদগুলিতে পড়েছে, যেমন—

আমার উমা এলো বলে রানী এলোকেশে ধায়
যত নগর নাগরী সারি সারি সারি দৌড়ি গৌরী মুখপানে চায়।

[কমলাকান্ত ভট্টাচার্য : আগমনী]

দেবী সিংহ ও রেজা খাঁ অষ্টাদশ শতাব্দীর মন্বন্তর জর্জরিত বাংলার বুকে শোষক ও নিপীড়ক হিসেবেই চিহ্নিত হয়ে রয়েছেন। সেযুগে কেন্দ্রীয় শক্তির অভাবে বাংলার প্রাদেশিক শাসনকর্তারা নিজেদের আধিপত্যের বিস্তার ঘটাতে চাইছিলেন। লক্ষণীয় যে এর পরবর্তী শতাব্দীর সূচনায় রামমোহন রায় যেমন হিসেব কষে দেখাতে উদ্যোগী হন যে, একটি জমি বা ভূখণ্ডের উপর প্রায় পঁয়ত্রিশ জন রায়ত বা জমির মালিকানা (সংক্ষেপে অংশীদারিত্ব) প্রসারিত ছিলো। ফলে কৃষিকার্যের মাধ্যমেও জীবিকা নির্ধারণ করা সহজ ছিলো না।

এর প্রায় দু'দশকের মধ্যেই অক্ষয় কুমার দত্ত তত্ত্ববোধিনী পত্রিকার পাতায় লেখেন 'পল্লীগ্রামস্থ প্রজাদের দুরবস্থা বর্ণন'—যেখানে সুস্পষ্টভাবে প্রকাশ পেলো পত্তনিদার, ইজারাদার, দরইজারাদার প্রভৃতি নানা শ্রেণির মানুষের অবস্থান। ক্রমশ কোলকাতা ও তার সংলগ্ন এলাকাগুলোতে দেখা গেলো, ১৭৯৩-তে চিরস্থায়ী বন্দোবস্তের ফলে এই শতাব্দীতেই জমিদারি ব্যবস্থার পাশে সাহেবের মতো মধ্যবিত্ত সম্প্রদায়ের বিকাশ ও সমৃদ্ধির পরিচয় ফুটে উঠলো। ঈশ্বর গুপ্তর বিবরণ থেকে পাওয়া যায় যে, পরিশীলিত বা উন্নত নাগরিক বৈদগ্ধ্যের প্রকাশভঙ্গি কবিওয়ালাদের না থাকলেও মৌখিক ছড়া রচনার বিশেষ দক্ষতা স্বভাবকবিত্বের শ্রেণিতে এঁদের উন্নীত করে দেয়।

সালতামামি নিলে বলা চলে যে, ভারতচন্দ্রর মৃত্যুর পর যে গায়কবৃন্দ জমিদারি বদান্যতায় বা বাবুসমাজের দাক্ষিণ্যে (সংগীতশিল্পীরা শব্দ ও অর্থালঙ্কারপূর্ণ ভাবনা ও রূপের পরিচয়কে) তাঁদের গানে স্থাপনা করতে চাইলেন, যেখানে কবিত্বের স্বভাবসিদ্ধ চটকদারি ব্যাপারটা জৌলুসপূর্ণভাবে ধরা দিলেও গভীরতা তেমনভাবে দাগ কেটে যাওয়ার কোনো ক্ষমতা দেখায়নি। তাই শ্রীকৃষ্ণকীর্তনের মাধ্যমে যেমন বৈষ্ণব পদাবলীর অভিযাত্রা শুরু হয়, ঠিক সেভাবেই এই কবিওয়ালাদের কবিগান উত্তর-পর্বে বাংলা গীতিকবিতার পথটিকে প্রশস্ত করে দেয়।।

উদ্ধৃতি ও তথ্যসূত্র :

১. শ্রীশচন্দ্র মজুমদার, সাহিত্য সন্দর্শন, চতুর্থ সংস্করণ, পৃষ্ঠা-২১।
২. জয়িতা ভট্টাচার্য সম্পাদিত, রায়গুণাকর ভারতচন্দ্র প্রণীত, অন্নদামঙ্গল কাব্য, পৃষ্ঠা-১১৮।
৩. তদেব, পৃষ্ঠা-১২২।
৪. তদেব।
৫. তদেব, পৃষ্ঠা-১২৩।
৬. তদেব।
৭. অন্নদামঙ্গল কাব্যের মধ্যখণ্ডে ব্যাসদেব কর্তৃক ব্যাসকাশী নির্মাণের অংশবিশেষ।
৮. অন্নদামঙ্গল কাব্যের মধ্যখণ্ডে শিবরূপ দর্শন করে নারীদের বিলাপ।
৯. দীনেশচন্দ্র সেন, বঙ্গভাষা ও সাহিত্য, তৃতীয় সংস্করণ, পৃষ্ঠা-১১৪।
১০. অসিতকুমার বন্দ্যোপাধ্যায়, বাংলা সাহিত্যের ইতিবৃত্ত, চতুর্থ খণ্ড, পৃষ্ঠা-১২৯।
১১. তদেব।
১২. নিধুবাবুর (যিনি রামনিধি গুপ্ত প্রকৃত নামে সুবিদিত) একটি টপ্পাগান থেকে পাওয়া গীতিকবিতা।
১৩. অসিতকুমার বন্দ্যোপাধ্যায়, বাংলা সাহিত্যের ইতিবৃত্ত, চতুর্থ খণ্ড, পৃষ্ঠা-১৫৮।

Quick search

SSRSMI
- About
- Editorial Advisory Board
- Issues [30]
- Peer Review
- Authors Instructions
- Browse
- Search
- Contact

Journals
- MOCM
- SCSCC6
- SCSSM
- TSTM
- CP
- SCSB
- INTERSTUDIA
- GYMNASIUM
- JESR
- SSRSMI
- JIPED
- PLUMEE
- SCECO
- SCS

Browse abstracts
- Browse by keywords
- Browse by authors
- Browse by titles

Scientific Studies and Research. Series Mathematics and Informatics

Issue: SSRSMI - Volume 30, Number 2 (2020)

SSRSMI - Volume 30, Number 2
Abstracts: 9 records

Module updated: 29-09-2021
Abstracts: 4837; Visits: 0
Generated: 0.006s

"Vasile Alecsandri" University of Bacău
Faculty of Sciences
Scientific Studies and Research
Series Mathematics and Informatics
Vol. 30 (2020), No. 2, 71 - 84

ON THE DISTRIBUTION OF ZEROS OF BICOMPLEX VALUED ENTIRE FUNCTIONS IN A CERTAIN DOMAIN

SANJIB KUMAR DATTA, TANCHAR MOLLA, JAYANTA SAHA, TANDRA SARKAR

Abstract. Bicomplex algebra is a modern developed area which is a generalization of the field of complex numbers. In this paper we derive some results related to the distribution of zeros of bicomplex valued entire functions in a certain domain. A few examples with related figures are given here to justify the results obtained.

1. Introduction

Bicomplex numbers which are the commutative generalization of complex numbers were first introduced by Segre (cf, [5]). Standard definitions, notations and many more properties of bicomplex numbers are available in [2] and [6]. A bicomplex entire function $f(z)$ is also represented by an everywhere convergent power series as $f(z) = \sum_{j=0}^{\infty} \alpha_j z^j$, where α_j's and z are bicomplex numbers. Thus, bicomplex entire functions can be thought of the natural generalization of bicomplex polynomials. The aim of the paper is to establish some results concerning the distribution of zeros of bicomplex entire functions in a certain domain.

Keywords and phrases: Bicomplex valued entire function, domain, zero free region.
(2010) Mathematics Subject Classification: 30C10, 30C15, 30D10, 30D20, 30G35.

Bharata Ganita Parisad

search this site...

- Home
- History of BGP
- Constitution of BGP
- Publications
- Important Links
- Contact
- Member
- Events

Ganita – Volume – 70(2)

Volume 70(2)

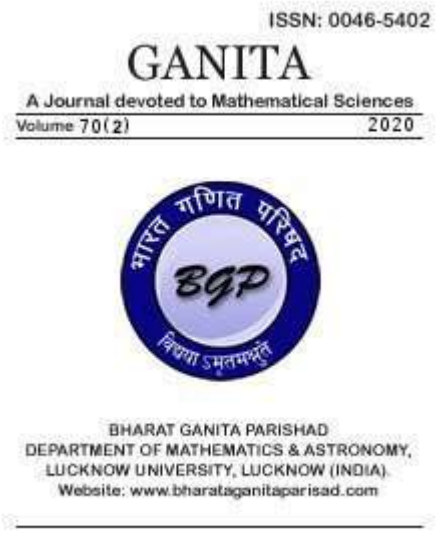


Table of Content
You can download publication. Click on topic to download.

3. **Jenifer Arulmani**
Coefficient Bounds For New Subclasses Defined
Using Frasin Di□erential Operator

4. **Shivangi Asthana and Madan Mohan Singh**
On the Diophantine Equation 3x + 117y = z2

5. **D Dhiman, A Kumar, A Kumar & L N Mishra**
Existence and controllability of Hilfer fractional di□erential inclusions

6. **Y. J. Bagul, S. B. Thool & R. M. Dhaigude**
On new inequalities involving circular, inverse circular,
inverse hyperbolic and exponential functions

7. **Vivek Joseph and Manju Agarwal**
Mathematical Modelling on the Effect of Chemical Reaction
on the Air Pollutant under Mesoscale Wind

8. **P K Shukla, Geeta Verma and V N Pathak**
Semi Symmetric non-metric connection on a Hsu
r-contact metric structure manifold

9. **Vineet K Verma and Sanjeeva K Singh**
Analytical Solution of Flow in a Composite Cylindrical
Channel using Brinkman model

10. **U S Rajput and Naval Kishore Gupta**
Hall Current And Radiation Effects on a Natural
Convection MHD Flow Through Porous Media In A Rotating
System With Inclined Magnetic Field

11. **Safiqul Islam**
A Study on Ideal of Classical Linear Algebra

12. **Dhanesh Kumar, Anand B. Joshi and Abdul Gaffar**
Double color-image encryption based on 2D fractional
discrete Fourier transform and Arnold cat map

13. **M. Murugan, P. Sriraman and M. Suriya**
One Point Union of Paths of Cycles and their k-Numbers

14. **Arun Kumar and Ashish Verma**
Examples of Simple Wavelet Sets for Matrix Dilation in R2

15. **Roshan Lal**
Generalisation of a Theorem of Ankeny and Rivlin

16. **S K Datta, C Ghosh and J Saha**
On The Ring Of Hyperbolic Valued Functions

17. **S K Datta, T Molla, Mukul Sk & J Saha**
On the location of zeros of transcendental entire functions

18. **K K Dixit, A L Pathak, S N Mishra and A Singh**
On a new class of fractional operator associated with k-uniformly convex functions with negative coefficients

19. **Dipen Ganguly and Arindam Bhattacharyya**
A study on conformal Ricci solitons in the framework of (LCS)n-manifolds

20. **P L Powar, Rishabh Tiwari & L N Mishra**
Wedge Functions for Degree-n Approximation over Pentagonal Discretization

21. **Rajeev Kumar Singh & B.Prasad**
On an extended recurrent Riemannian manifold

22. **Tanmay Biswas & Chinmay Biswas**
Some results on generalized relative order (Alpha, Beta↟) and generalized relative type (Alpha, Beta) of meromorphic function with respect to an entire function

23. **K G Mirajkar, A Morajkar & B Doddamani**
Correlation of Some Molecular Descriptors with Polycyclic Aromatic Hydrocarbons and Topological Indices of Fullerenes

24. **A S Shinde, Rajkumar N Ingle & P T Reddy**
Subclass of Meromorphic Univalent Functions with
Positive Coefficients Defined by Linear Operator

25. **B Joshi, M C Singh, A Kumari & N K Pandey**
Fixed Point Results and Weak Orbital Continuity

26. **N Shaikh, V K Gupta & V H Badshah**
Combinatorial Problem in North Indian Music System
with 16- Musical Tone

27. **G K Singh & A K Thakur**
Matrix Summability of the Conjugate Series of Derived Fourier Series

28. **I B Bapna & R S Prajapat**
Properties of k-Riemann-Liouville Fractional Integral Operator
with Mittag-Leffler functions

29. **Garima Saxena, R. K. Sharma and Ankit Agrawal**Global Dynamics of an SIQR Epidemic Model With Specific Non-Linear Incidence Rate

70th ANNUAL CONFERENCE OF BHARATA GANITA PARISAD

"RECENT ADVANCES IN MATHEMATICS AND APPLICATIONS"

AN INTERNATIONAL MEET

December 2 & 3, 2023

Download Brochure

Registration Form

- Home
- Constitution of BGP
- Ganita
- Important Links
- Contact

On the location of zeros of transcendental entire functions

Sanjib Kumar Datta [1a], **Tanchar Molla** [2], **Mukul Sk** [3b], **Jayanta Saha** [4c]

[1,3,4] *Department of Mathematics, University of Kalyani, P.O.:Kalyani, Dist.:Nadia, Pin:741235, West Bengal, India.*
[a]*sanjibdatta05@gmail.com,* [b]*m.sk211094@gmail.com,* [c]*jayantas324@gmail.com*

[2] *Department of Mathematics, Dumkal College, P.O: Basantapur, P.S: Dumkal, Dist.: Murshidabad, Pin: 742406, West Bengal, India.*
email:tanumath786@gmail.com

Abstract

The aim of this paper is to establish some results focusing on the location of zeros of transcendental entire functions. A few examples with related figures are given here to justify the results obtained.

Subject Classification: Primary: 30D20; Secondary: 30C10, 30C15, 30D10.
Keywords: Transcendental entire function, order, zero free region .

1 Introduction, Definitions and Notations.

The study of the location of zeros of polynomials has a long history. The earliest contributors to this area of subject were Gauss, Cauchy and Enström-Kakeya {cf.[6]} and consequently a lot of papers devoted in this branch can be found in the literature{cf.[1],[4],[5],[7] & [8]}. A function of one complex variable analytic in the finite complex plane $\mathbb{C}$ is called an entire function and whenever it has an essential singularity at point at infinity it will be transcendental. If a function $f(z)$ is entire then it can be represented by an every where convergent power series like

$$f(z) = a_0 + a_1 z + ... + a_n z^n + ...$$

Thus the entire functions form natural generalization of polynomials.

The prime purpose of this paper is to derive zero free region for some transcendental entire functions of finite order under various conditions using the coefficients a_n's. We do not explain the standard theories, notations and definitions of entire functions as those are available in [9] & [10].

The following definitions are well known:

ISSN : 0976-9463
Issue 25, Vol. 40

তরুপল্লব ৪০

UGC Approved Peer-Reviewed Research Journal on Arts and Humanities

সমাজ

সংস্কৃতি

সাহিত্য

ক্রোড়পত্র ১। দেবেশ রায়

ক্রোড়পত্র ২। আনিসুজ্জামান

দি গৌরী কালচারাল এন্ড এডুকেশনাল অ্যাসোসিয়েশন

৪০

TABU EKOLABYA
ISSN 0976-9463

তবু একলব্য

ভাষা-সাহিত্য-সংস্কৃতি বিষয়ক গবেষণা পত্রিকা

২৫ বর্ষ • ৪০ সংখ্যা • ২০২০

TABU EKALABYA

UGC Approved International Peer-Reviewed (Refereed)
Research Journal on Arts & Humanities

UGC-CARE LISTED JOURNAL, SL. NO. 16

সমাজ-সংস্কৃতি-সাহিত্য

বিশেষ সংখ্যা

ক্রোড়পত্র/১ : দেবেশ রায়
ক্রোড়পত্র/২ : আনিসুজ্জমান

দি গৌরী কালচারাল এন্ড এডুকেশনাল অ্যাসোসিয়েশন
সমাজ-সংস্কৃতি-সাহিত্য গবেষণাকেন্দ্র

TABU EKALAVYA

UGC Approved International Peer-Reviewed (Refereed) Research Journal on Arts & Humanities

ISSUE 25, Vol. 40 ● July - September, 2020

ISSN : **0976-9463**

প্রথম প্রকাশ : ২৩ সেপ্টেম্বর, ২০২০

দ্বিতীয় মুদ্রণ : ডিসেম্বর ২০২০

প্রাপ্তিস্থান : দে'জ, দিয়া, দে বুক স্টোর (দীপু), পাতিরাম, ধ্যানবিন্দু, পাতাবাহার

মূল্য : ৩৫০ টাকা

প্রাচীন ভারতের ভাষাদর্শনের আলোকে শক্তির স্বরূপ বিষয়ে সংক্ষিপ্ত আলোচনা

আব্দুল আলীম শেখ

যে-কোনো ভাষায় বাক্যগঠনের ক্ষেত্রে পদের গুরুত্ব অপরিসীম। একটি বাক্য গঠিত হয় এক বা একাধিক পদ দিয়ে। তাই প্রাচীন ঋষিগণ পদসমূহকে বাক্য বলে অভিহিত করেছেন। এই প্রসঙ্গে উল্লেখ করা যায় যে, নব্য নৈয়ায়িক অন্নংভট্ট তাঁর দীপিকা টীকায় বলেছেন—'বাক্যই পদসমূহঃ'[১]। একটি বাক্যের বিভিন্ন অংশকে বলা হয় তার অবয়ব। তাই পদমাত্রই বাক্যের অবয়ব। অন্যভাবে বলা যায়, বাক্যে ব্যবহৃত শব্দগুলিকে পদ বলা যায়। বিভিন্ন ব্যাকরণ শাস্ত্রে পদ বলতে বোঝায় বাক্যস্থিত বিভক্তিযুক্ত শব্দ। বৈয়াকরণিক তথা কবি পাণিনি তাঁর 'অষ্টাধ্যায়ী' গ্রন্থে 'সু', 'উ', 'জস', 'তি', 'তস' প্রভৃতি[২] সর্বমোট ২১ টি বিভক্তির কথা বলেছেন, যার দ্বারা পদ গঠিত হয়।[৩] দার্শনিক অন্নংভট্ট তাঁর দীপিকায় পদের সংজ্ঞা দিতে গিয়ে বলেন—'যা শক্তিবিশিষ্ট তাই পদ'।[৪] প্রশ্ন হলো শক্তি কী? উত্তরে বলা যায়, একটি পদ শ্রবণ করলে একটি বিশেষ পদার্থের জ্ঞান উৎপাদন ঘটে, এই জ্ঞান উৎপাদনের সামর্থকে শক্তি বলা হয়। সাধারণত আমরা হাতি শব্দ শুনলে একটি দীর্ঘকায় শুঁড় বিশিষ্ট বন্য প্রাণীর চেহারা আমাদের মানসপটে ভেসে ওঠে। এখানে 'হাতি' শব্দটি হলো পদ এবং 'দীর্ঘকায় শুঁড়বিশিষ্ট বন্য প্রাণীটি হলো পদার্থ। এই পদ ও পদার্থের পারস্পারিক বলা হয় সম্বন্ধকে শক্তি। কিন্তু অন্নংভট্ট তাঁর দীপিকা টীকায় বলেন, 'শক্তি হলো পদ ও পদার্থের সম্বন্ধ যা পদার্থ স্মরণের সহায়ক'[৫]।

উদ্দেশ্য : উদ্দেশ্যবিহীনভাবে কোনো কাজ বস্তুজগতে সম্ভবপর হয় না। প্রতিটি কাজ করার পশ্চাতে একটা সুদৃঢ় উদ্দেশ্যে থাকাটা বাঞ্ছনীয়। আর সে কাজ যদি কোনোরূপভাবে গবেষণামূলক হয়, তাহলে তার একটা স্বচ্ছ উদ্দেশ্য থাকা এবং সেটি উল্লেখ করাও আবশ্যক হয়ে দাঁড়ায়। আমার এই প্রবন্ধেও বেশ কয়েকটি উদ্দেশ্য নিশ্চয় রয়েছে। সেগুলি হলো—প্রথমত, প্রাচীন ভাষাদর্শনের অনেক গুরুত্বপূর্ণ দিক রয়েছে যা আজকের দিনে সমানভাবে প্রাসঙ্গিক সেগুলি সম্পর্কে পাঠককে সজাগ ঘটানো। দ্বিতীয়ত, শক্তি কী? শক্তির গুরুত্বই বা কী সেই বিষয়টিকে স্পষ্ট করা আর একটি গুরুত্বপূর্ণ উদ্দেশ্য। তৃতীয়ত, ভাষারও যে দার্শনিক ভিত্তি হতে পারে সেটি সম্পর্কে পাঠককে অবগত করানো। চতুর্থত, পাশ্চাত্যের দার্শনিকগণ প্রায়ই অভিযোগ করেন যে, ভারতীয় দর্শন মূলত জীবনবিমুখ, আধিবিদ্যক সমস্যা নিয়েই ব্যস্ত থাকেন; বস্তু জগতের বৈচিত্র্যময় দিকগুলি নিয়ে ভারতীয় চিন্তাবিদগণ তেমন গুরুত্ব

ISSN 2454-5694

Volume 6 Number 2 December 2020

JOURNAL OF KOLKATA SOCIETY FOR ASIAN STUDIES

An International Bilingual Journal of
Social Science (UGC CARE)

KSAS

Kolkata Society for Asian Studies

JOURNAL OF
KOLKATA SOCIETY FOR ASIAN STUDIES
Office: 3/25/1, R.K. Chatterjee Road, Kolkata-700042
Phone: +91 9432490361
Email: ksasianstudies@gmail.com
kspublication1@gmail.com

General Information

Journal of Kolkata Society for Asian Studies is a double blind peer reviewed publication. It is an International Journal dedicated to the development of all branches of Social Sciences with special reference to Asian Studies. The journal accepts theoretical and empirical papers on interdisciplinary studies. The journal occasionally publishes special issues which meditate on a single topic. It also publishes research notes, reports, book reviews, etc.

JKSAS is a half –yearly (June and December) and bilingual (English and Bangla) journal. Only original unpublished papers are accepted. Papers submitted for consideration must not be under consideration elsewhere. The copyright of the accepted papers will lie with Kolkata Society for Asian Studies. Decisions of the Editorial Board are final.

Subscription and Business Affairs

	Annual Subscription	
Countries	**Institutional Subscribers**	**Individual**
India	**INR 1200.00**	**INR 1000.00**
Foreign Countries	**US $ 100.00**	**US $ 90.00**

All correspondences relating to subscription, advertisements and other business matters should be addressed to the SECRETARY, Kolkata Society for Asian Studies. Remittance should be payable to KOLKATA SOCIETY FOR ASIAN STUDIE

Idea and Practice of Fearlessness: Gandhi's Noakhali Experiment

Arnav Debnath

Abstract: *M.K.Gandhi's (1869-1948) use of "ahimsa", i.e. nonviolence as a "political weapon" as to the question of "Hindu-Muslim relation" in particular in pre-independence India faced one of its hardest challenges in Noakhali of the undivided Bengal (now in Bangladesh) in 1946-1947. The organised violence unleashed by the majority Muslims on the minority Hindus created the point of no return - a "Do or Die" condition for Gandhi which made him set up an experiment upon nonviolence heavily armed with the idea and practice of "fearlessness", another primal observance in Gandhi's thought. This paper attempts to spell out the categories relating to the understanding of the idea of 'fearlessness' which he propelled with an eye to restore the communal trust along with nonviolence to the people of both communities and how the idea, in its varied forms, had been put into effect by the satyagrahi exemplars, including Gandhi himself, in Noakhali. The practice of fearlessness in Noakhali adds further importance to it for its being 'political' by nature as specific for Muslim League's anti-national politics of disintegration (of Indian nation) against the larger context at that juncture of historical time.*

Keywords: Fearlessness, Nonviolence, Hindu-Muslim relation, Satyagrahi, Violence of the strong, Violence of the weak.

Introduction: "Nonviolence", the supremely enabling virtue, as a "means" tends to serve an ineffable master as its "end" - the "truth" - in the M. K. Gandhi's political thought sometimes seems dormant if put into effect insular. Gandhi's notion of nonviolence, being a "pure means", was to invigorate its end, i.e. "satya", was conductive to solving moral and practical problems "supplied Gandhism with a theory of politics, enabling it to become the ideology of a national political movement" (Chatterjee, 1999:107) in colonial India. Yet, to walk down along the path of ahimsa was like, to Gandhi, "balancing oneself on the edge of a sword" for it requires "ceaseless striving", for an act of ahimsa is "not a mechanical performance". The use of the analogy, though unusual, if not contradictory, may dumbfound a heedful student or an ardent reader of Gandhian philosophy of non-violence at first, seems to tease out, inter alia, a certain lineament having been indwelt in the concept itself that to be willing to walk on the sharp edge of a sword of politics in any form demands as much mental strength and high-spiritedness as bodily niftiness in maintaining balance for an accident may cause the walker, the "satyagrahi" or a common person believing in ahimsa, so to say, to bleed or, even worst, to risk of having more fatal consequences at any point of the edge of this deadly political weapon. Thus, the Gandhian gnome that to be a nonviolent satyagrahi or a true believer of ahimsa is to be of a courageous mind comes to reveal one of the most fundamental correlate of the principle of ahimsha: "fearlessness". This article attempts to understand the nature and practice of this idea of fearlessness carried out by Gandhi himself, his fellow "satyagrahies" (who practises the ideal of "satyagraha", i.e. literally "holding on to truth") and the laypersons in a specific context – a historical juncture where a colonial nation was about to be cut off, and communal hatred went to its highest peak as a result on the eve of "transfer of power" in the Indian sub-continent and, from a certain perspective - a "hostile environment" of post-carnage Noakhali in between the late 1946 and early 1947, programmed to be in retaliation of the "Great Calcutta Killing" occurred in the month of August, 1946. Moreover, if it is taken to be true that politics is by no means an "apodictic science" and it "proceeds by experimenting, groping in the dark" (Deluze and Guattari, 1987:461), then Gandhi's experiment in Noakhali with his idea of fearlessness as complementary to nonviolence is well worth considering.

Background: the darkest ditch: "Gandhi was an odd kind of pacifist", wrote Jawaharlal Nehru, "for he was an activist full of dynamic energy. ... he was full of resistance, though this was peaceful and courteous." (Nehru, 1989:361) The peaceful yet resistant character of Gandhi seems to represent ahimsha and fearlessness – two complementary means at once. It goes on to carry Gandhi's very own kind of language of politics and actions in a colonized sub-continent where fear after his homecoming in 1915:

ISSN: 2395-3160 (Print)
ISSN: 2455-2445 (Online)

Volume 07 (01) DOI Prefix: 10.46587/JGR January 2021

Biannual International Refereed/ Peer-Reviewed Journal

JOURNAL OF GLOBAL RESOURCES

Institute of Sustainable Development, Environmental & Scientific Research
ISDESR

Journal of Global Resources
Biannual International Peer-Reviewed Journal
ISSN: 2395-3160 (Print)/2455-2445 (Online)
DOI: 10.46587/JGR.2021.v07i01.015
January 2021
Volume 07 (01)
Crossref DOI 10.46587

15

SOCIO-ECONOMIC SCENARIO OF THE RURAL STONE CRUSHERS OF SILIGURI BALASON RIVER BASIN

Arindom Biswas
Assistant Professor, Department of Geography,
Dumkal College, Murshidabad, West Bengal, India
Email-biswas.arindom@gmail.com

Abstract: *The present study attempts to find out the socio-economic condition of the rural stone crushers of Siliguri Balason river basin. The river Balason near Siliguri transmits the natural resources like stone, sand and boulders. People live on the water's edge and are involved in work like collection of stones and sand, crushing the stones into different shapes and sizes and loading them into vehicles. While most of the rural inhabitants make their way to the fields as expected in the countryside, residents in Balason river colony, welcome every day of the year trekking uphill the Balason stone quarry. Men, women with children on their backs, start and end their entire day extracting, lifting and crushing stones; using easy handmade tools to quench the insatiable construction industry in the rapidly urbanising city. As one of the units of informal sector, the stone crushers has been significantly contributing in strengthen the small scale economic sector. But the study extremely found that the Stone crushing industry have a regressive and insignificant impact on socio-economic conditions of workers due to low wages, lack of working and welfare measures and environment. Accordingly, the study intended some policy implications to balance the existence of Stone Crushing Units, employee's welfare and environment protection.*

Key words: Stone Crushers, Construction and Crushing industry, Environment protection.

Introduction

Agricultural activities and mineral extraction are playing a vital role in rural livelihood improvement thereby helping to alleviate rural poverty. In developing countries like India many people are engage in occupations such as small-scale surface mining and quarrying for their survival. Mining plays a significant role in the development of human societies. The mining of minerals, stones and coal etc. have provided a foundation for local economies in many parts of our country. Stone crushing industry in India is an unorganized small-scale sector and basically a labor intensive small scale industry, where most of the procedures are performed manually. Most of the plant and machinery has been conventional type in nature and made-up locally. It is one of the sources of earning for uneducated poor unskilled rural people. In this economic sector many people are engaged in producing crushed stone of various sizes depending upon the local demand which acts as raw material use for various construction activities like as construction of houses, roads, National Highways, Bridges, Office Buildings, and multipurpose water canals etc.

As one of the units of informal sector, the stone crushers has been significantly contributing in strengthen the small scale economic sector. Stone quarrying is one of the key economic activities in the Siliguri Balason river basin area, supplying the bulk of stone of varying aggregates to the construction industry within the district and beyond. It has been proved very efficient in strengthening the local economic condition. As per records of to the Survey of India Topographical Map the stone crushing activities along the Balason River

A relationship between magnetizability and chemical potential

Article *in* Chemical Papers · January 2021

DOI: 10.1007/s11696-020-01458-x

4 authors, including:

Hiteshi Tandon
Manipal University Jaipur
18 PUBLICATIONS **45** CITATIONS
SEE PROFILE

Tanmoy Chakraborty
Sharda University
79 PUBLICATIONS **273** CITATIONS
SEE PROFILE

Vandana Suhag
BML MUNJAL UNIVERSITY
17 PUBLICATIONS **38** CITATIONS
SEE PROFILE

A relationship between magnetizability and chemical potential

Hiteshi Tandon, Sandip Kumar Rajak, Tanmoy Chakraborty & Vandana Suhag

Chemical Papers

ISSN 2585-7290

Chem. Pap.
DOI 10.1007/s11696-020-01458-x

Springer

Chemical Papers
https://doi.org/10.1007/s11696-020-01458-x

ORIGINAL PAPER

A relationship between magnetizability and chemical potential

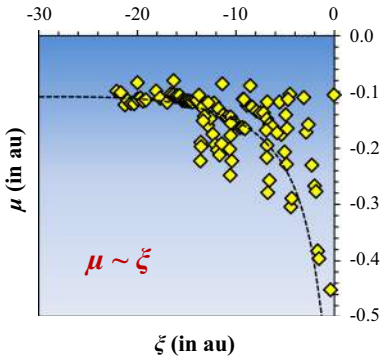
Hiteshi Tandon[1] · Sandip Kumar Rajak[2] · Tanmoy Chakraborty[3] · Vandana Suhag[4]

Received: 15 August 2020 / Accepted: 27 November 2020

Abstract

Magnetizability (ξ) and chemical potential (μ) are two valuable atomic and molecular descriptors of reactivity. They play a valuable role in studying chemical/magnetic interactions and deducing the fate of a species/reaction. In view of this, a connection has been explored between these properties employing polarizability (α) as a reference. It is expected that the relation amongst these descriptors would assist in gaining more specific and advanced knowledge about the reactivity and stability of almost every species and their associated interactions. According to the present study, atoms and molecules with high chemical potential will have high magnetizability and vice versa, similar to polarizability. The proposed relationship is in accordance with the Minimum Magnetizability Principle as well, since chemical potential also prefers a minimum value like magnetizability.

Graphic abstract



Keywords Chemical potential · Polarizability · Periodic descriptor · Density functional theory (DFT) · Reactivity descriptor · Minimum magnetizability principle (MMP)

✉ Hiteshi Tandon
hiteshitandon@yahoo.co.in

✉ Tanmoy Chakraborty
tanmoychem@gmail.com; tanmoy.chakraborty@sharda.ac.in

[1] Department of Chemistry, Manipal University Jaipur, Jaipur 303007, India

[2] Department of Chemistry, Dumkal College, Murshidabad 742406, India

[3] Department of Chemistry and Biochemistry, School of Basic Sciences and Research, Sharda University, Greater Noida 201310, India

[4] Department of Applied Sciences, BML Munjal University, Gurugram 122413, India

Introduction

The aim of the present study is to establish a connection between two important concepts — magnetizability (ξ) and chemical potential (μ). Both of these quantities are significant in predicting and understanding numerous physico-chemical or magnetic properties and associated interactions in atoms as well as molecules (Pearson 1992a, b; Bader and Keith 1993; Toro-Labbé 1999; Olejniczak et al. 2017; Janda and Foroutan-Nejad 2018; Conradie et al. 2019). Apparently, a great deal of work has been carried out for/using these properties (Boudart 1952; Wilson

Published online: 05 January 2021

et al. 1999; Franco-Pérez et al. 2015; Szmytkowski and G. Łukasik 2016; Valiev et al. 2017). This makes it crucial to study both the quantities extensively to gain ample information regarding their relationships with several other quantities and their effects in species. Magnetizability (ξ) is understood as the linear response of an atom, molecule or ion's electron cloud towards an external magnetic field, alike polarizability (α) which is response in the presence of an electric field (Dahle et al. 1999).

$$m = \xi B,\ \xi = -\left(\frac{\partial^2 E(B)}{\partial B^2}\right)\Bigg|_{B=0} \tag{1}$$

$$d = \alpha \in,\ \alpha = -\left(\frac{\partial^2 E(\in)}{\partial \in^2}\right)\Bigg|_{\in=0} \tag{2}$$

In Eq. (1), m and B denote induced magnetic moment and external magnetic field while in Eq. (2), d and ϵ signify induced dipole moment and external electric field, respectively. E refers to energy. The descriptor has been considerably employed to predict the aromaticity of diverse species (Badri et al. 2013; Foroutan-Nejad 2015; Janda and Foroutan-Nejad 2018; Conradie et al. 2019). As transparent from their relationships, magnetizability is more or less similar to polarizability. Accordingly it is expected that magnetizability would follow principles and present relationships with other descriptors identical to that of polarizability. On the basis of this notion, a Minimum Magnetizability Principle (MMP) was proposed analogous to Minimum Polarizability Principle (MPP) (Tanwar et al. 2006). A relation of softness with magnetizability was also explored in terms of Hard–Soft Acid–Base (HSAB) principle (Chattaraj et al. 2007). A commonly used term while describing magnetizability is magnetic susceptibility. Although both physical quantities are related and convertible to each other, practically they are different. While former refers to the molecular property, latter is an experimentally calculable bulk quantity (Ruud et al. 1994). Laplacian of the charge density (ρ) is another quantity which helps in providing additional insight towards the reactivity patterns (Bader and MacDougall 1985). It offers sharp peaks and valleys in various regions corresponding to electrophilic and nucleophilic regions of the system under study.

Since 1960s chemical potential has been an admired concept. Its significance in predicting and explaining the reactivity patterns is clearly evident from its history. Although, the theoretical framework for the electronic chemical potential based on Density Functional Theory (DFT) was developed in 1980. In the DFT formalism (Parr and Yang 1989; Geerlings et al. 2003), an electronic chemical potential is recognized as the variation of the electronic energy (E) of a system about the number of electrons (N) at fixed external potential (v(r)) (Geerlings et al. 2003).

$$\mu = \left(\frac{\partial E}{\partial N}\right)_{v(r)} \tag{3}$$

Whenever a species undergoes any change due to a chemical reaction or any other factor, such as electronic movement, it always tends to move towards a point which has a lower chemical potential. Lower the value of chemical potential, higher is the stability of that species and vice versa. Since it is a form of energy, it gives a good amount of information about the direction of a chemical reaction and the stability of the products to be formed. It can also give an idea about the feasibility of the given reaction conditions with respect to the compounds concerning that reaction. For modeling an electron transfer reaction between two species, two descriptors are very crucial. While one provides the tendency of the species to resist donation of electrons, another assesses the propensity of the species to accept electrons. These two descriptors can be recognized as the ionization potential (IP) and electron affinity (EA) or, to some extent more instinctively, as an electronic chemical potential that determines the gain or loss in energy on acquiring or losing electrons (Parr et al. 1978). In general, the chemical potential is described directly in terms of electron affinity (EA) and ionization potential (IP) (Parr et al. 1978; Parr and Pearson 1983).

$$\mu(N) = -\frac{1}{2}(\mathrm{IP}(N) + \mathrm{EA}(N)) \tag{4}$$

Moreover, from a DFT perspective, a system's chemical potential (μ) is described as "the escaping tendency of an electronic cloud" making electronegativity as its negative counterpart (Parr and Yang 1989; Parr et al. 1978; Kohn et al. 1996). In a similar manner, chemical potential is directly or indirectly associated with several other properties too (Tandon et al. 2019a, b, 2020). Since it is the first energy derivative which is significantly related to other properties, it is useful in explaining reactivity and stability of different species, compounds and reaction pathways. In view of this fact, we have tried to explore the link between the two significant atomic/molecular quantities, viz. chemical potential and magnetizability, which can be helpful in predicting and elucidating a plethora of chemical and magnetic interactions and phenomenon in the area of magnetochemistry. Owing to the inverse relationship of electronegativity with chemical potential (Parr et al. 1978; Iczkowski and Margrave 1961) as well as polarizability (Tandon et al. 2019a), a direct association between chemical potential and polarizability follows, viz. $\mu \sim \alpha$. Also, since magnetizability shows similar behaviour as polarizability ($\xi \sim \alpha$) (Tanwar et al. 2006; Chattaraj

et al. 2007), it is expected that a large chemical potential of a species is associated with its high polarizability and high magnetizability as well.

Theory and methodology

In a chemical process, the reactants distort the electron cloud and alter each other's electronic surroundings. In case of a species with higher chemical potential, the distortion is rather easier than a species with lower potential. It is a well-known fact that species with higher energy (or chemical potential) are more reactive (or prone to electron cloud distortion) and less stable than the ones with lower energy. Polarizability assesses the ease of electron cloud distortion when a species is under the influence of an electric field. Moreover, as mentioned above, a species with a higher chemical potential has more polarizing power, viz. $\mu \sim \alpha$.

Under normal circumstances, all the reactant molecules experience a field due to other reactant molecules. An external electromagnetic field can simulate this field when any of the reactants, whether atoms or molecules, are placed in it. To account for the magnetic properties of atoms and molecules, magnetizability is a suitable descriptor which in conjunction with polarizability can be employed in getting insights into reactivity as well as stability. With an intention of expanding this connection, we are exploring whether the species with a larger chemical potential will possess high magnetizability as well.

In the present analysis, we have compared the association of chemical potential with polarizability and magnetizability utilizing the data from Cárdenas et al. (2016) , Haynes (2017) and Fraga et al. (1973) work, respectively, for atoms with $Z = 2$–96. Similar comparisons are also made for several saturated and unsaturated hydrocarbons comprising open-chain as well as cyclic systems employing experimental data to justify the connections amongst the properties. The comparison is performed by taking molecular chemical potentials from Schäfer and Lax (1961) and molecular polarizabilities as well as molecular magnetizabilities from Haynes (2017). Further, atomic magnetizability (Fraga et al. 1973) values are plotted against atomic numbers to study the periodicity.

Results and discussion

The variation of chemical potential (Cárdenas et al. 2016) of atoms with $Z = 2$–96 with the corresponding polarizabilities (Haynes 2017) and magnetizabilities (Fraga et al. 1973) is presented in Fig. 1. A look at Fig. 1 clearly reveals the similar connection of chemical potential with polarizability as well as magnetizability. It is apparent that a higher value of chemical potential, in general, relates to a high polarizing and magnetizing power.

On observing Fig. 1, it appears that the relations between chemical potential (μ) and polarizability (α) as well as between chemical potential (μ) and magnetizability (ξ) for atoms may be described through a simple empirical formula (Eq. 5):

$$\mu = \frac{c_1}{x} + c_2 \tag{5}$$

where $x = \alpha$, ξ and c_1 and c_2 are adjustable parameters. Using the least square fit approach for the data presented in Fig. 1a, b, we have obtained empirical fits for chemical potential (μ) – polarizability (α) and chemical potential (μ) – magnetizability (ξ) as depicted by Eq. (6) and Eq. (7), respectively:

$$\mu = \frac{0.102}{\alpha} - 0.086 \tag{6}$$

$$\mu = \frac{0.486}{\xi} - 0.095 \tag{7}$$

Based on the above result (Eq. (6) and (7)), a reasonable relation between polarizability (α) and magnetizability (ξ) has been deduced (Eq. 8):

$$\alpha = \frac{0.102\xi}{0.486 + 0.009\xi} \approx 1.13\xi \tag{8}$$

Empirical curves for the fitted equations, viz. Eq. (6), Eq. (7) and Eq. (8), are illustrated using continuous lines in Fig. 1a, b and c, respectively.

Further, Fig. 2 provides the plots for some alkane molecules (see Table 1) presenting the association between the above three properties using experimental data. It is evident from the plots that an outstanding relation is present between chemical potential and magnetizability ($R^2 = 0.929$), almost same as polarizability ($R^2 = 0.935$). Another fact noted is enhanced correlation between the properties in case of molecules in comparison to mere atoms. On a practical note, this is a better result since most of the studies are performed on molecules and almost everything in general is in the form of a molecule or compound. Thus, the following relationship (Eq. 9) may be considered to exist between chemical potential (μ) and magnetizability (ξ):

$$\mu \sim \xi \tag{9}$$

It is important to note from the figures that the chemical potential–polarizability trend displays very close resemblance to the chemical potential–magnetizability trend data because of the likeness in their concepts.

Since chemical potential and magnetizability have been established to be almost directly related, when one property

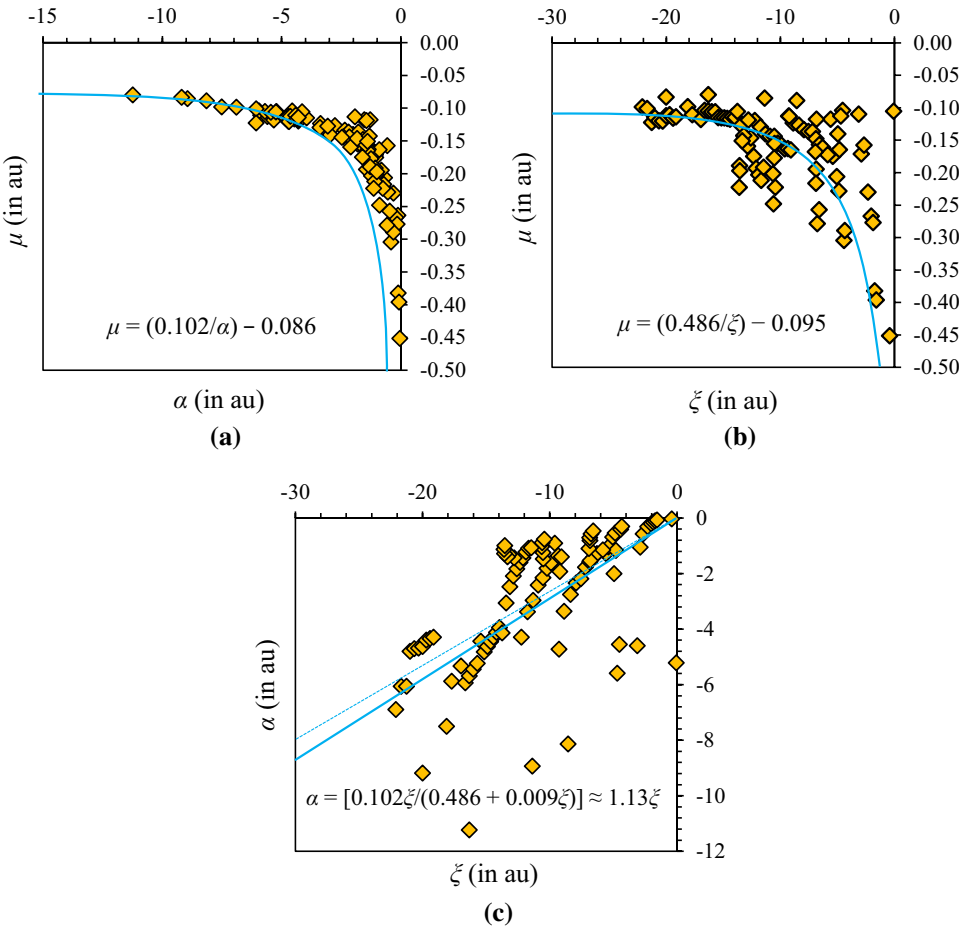


Fig. 1 Plots depicting variation of **a** chemical potential (μ) (Cárdenas et al. (2016)) (in au) with polarizability (α) (Haynes 2017) (in -10^{-1} au), **b** chemical potential (μ) (Cárdenas et al. 2016) (in au) with magnetizability (ξ) (Fraga et al. 1973) (in au) and **c** polarizability (α) (Haynes 2017) (in -10^{-1} au) with magnetizability (ξ) (Fraga et al. 1973) (in au) for atoms with $Z=2$–96

decreases, the other should also decrease and vice versa. Likewise, as chemical potential favours lower value to gain stability, magnetizability should also favour a smaller value. This outcome is in accordance with the Minimum Magnetizability Principle (MMP) which states "a stable configuration/conformation of a molecule or a favourable chemical process is associated with a minimum value of the magnetizability" (Tanwar et al. 2006). The validity of this principle has been recently demonstrated in case of several chemical reactions further strengthening the concept (Tandon et al. 2021). This result as well indicates the appropriateness of our suggested relation.

A graph is plotted for atomic magnetizability (Fraga et al. 1973) ($Z=2$–96) as a function of atomic number (Fig. 3). It is apparent from the plot that alkali metals and alkaline earth metals possess the largest magnetizabilities in a period while the noble gases the least. In accordance with the chemical potential (Cárdenas et al. 2016) and polarizability plots (Tandon et al. 2019a), atomic magnetizability too shows a declining trend across the period while increasing within a group. Maximum values of magnetizability are evident for the elements present at the end of each row of the periodic table. For the atoms having closed shells or sub-shells, the values of chemical potential, polarizability and magnetizability are expected to be small. It must be noted that polarizability as well as magnetizability displays an explicit minima for closed-shell systems having ns^2np^6 configuration. On the other hand, excluding some elements, the sub-shell structure in polarizability and magnetizability is not very pronounced. For instance, the behaviour of chemical potential in case of the Group IIA elements is a lot more systematic than that of polarizability or magnetizability. It is promising to note that there is an increment in the values of chemical potential, polarizability and magnetizability from He to Rn, highlighting the characteristic direct behaviour between chemical potential and polarizability as well as chemical potential and magnetizability.

Further, in case of heavy and super-heavy elements, such as Pb, Au, Hg, Cn, Fl, the ns^2 and $np_{1/2}{}^2$ shells present inertness due to relativistic mass–velocity stabilization of the ns and np orbitals (Balasubramanian 1997, 2001, 2002a, b). In fact, it is observed that the ionization potential of Fl is very high since both $7s^27p_{1/2}{}^2$ shells become inert pair (Balasubramanian 2001, 2002a) and the spin–orbit splitting of $7p_{1/2}-7p_{3/2}$ becomes almost 1/3rd of the ionization potential of hydrogen atom (Balasubramanian 2001). On the basis

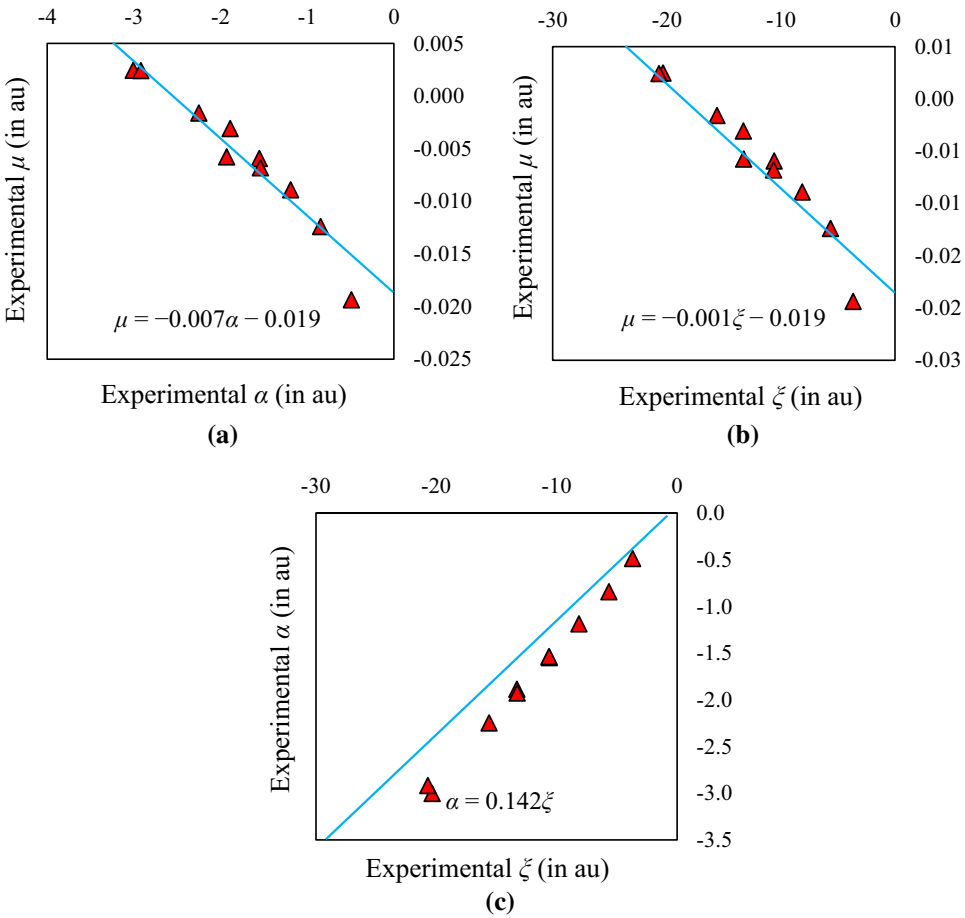


Fig. 2 Plots depicting experimental variation of **a** chemical potential (μ) (Schäfer and Lax 1961) (in au) with polarizability (α) (Haynes 2017) (in -10^{-1} au), **b** chemical potential (μ) (Schäfer and Lax 1961) (in au) with magnetizability (ξ) (Haynes 2017) (in au) and **c** polarizability (α) (Haynes 2017) (in -10^{-1} au) with magnetizability (ξ) (Haynes 2017) (in au) for some alkanes

Table 1 Experimental values of chemical potential (μ) (in au), polarizability (α) (in -10^{-1} au) and magnetizability (ξ) (in au) for selected alkanes

Molecule	μ^a	α^b	ξ^b
Methane	−0.0194	−0.4901	−3.6615
Ethane	−0.0124	−0.8448	−5.6396
Propane	−0.0089	−1.1888	−8.1227
Butane	−0.0059	−1.5498	−10.5848
Pentane	−0.0031	−1.8881	−13.2784
Hexane	−0.0016	−2.2491	−15.5931
Octane	0.0024	−3.0051	−20.3279
2-Methylpropane	−0.0068	−1.5385	−10.6269
2,2-Dimethylpropane	−0.0058	−1.9278	−13.2573
2,2,4-Trimethylpentane	0.0024	−2.9182	−20.6856

[a]Values obtained from Schäfer and Lax (1961)

[b]Values obtained from Haynes (2017)

of MMP (Tanwar et al. 2006), it is suggested that when an electronic configuration of a system is completed, it becomes inert and achieves its minimal energy and magnetizability state. Accordingly, a minimum value of magnetizability is observed for such closed-shell systems.

Hence, magnetizability can be identified as a descriptor for understanding the reactivity and stability of numerous species and various magnetic interactions together with polarizability and related parameters. Overall, a lower value of chemical potential and magnetizability appears to be linked with a stable state, viz. minimum energy configuration, while a higher value of chemical potential and magnetizability is associated with an excited or transition state, viz. high or maximum energy configuration.

Conclusion

In the present work, we have tried to explore the link between atomic/molecular reactivity descriptors—chemical potential and magnetizability. It is observed that similar to polarizability, magnetizability is also associated with chemical potential and thus it can be used to provide insights into the reactivity and stability of species and various magnetic interactions. It is a well-known fact that lower chemical potential signifies higher stability of a species. Similarly, a lower magnetizability is also related to stability. Hence, the suggested relationship is clearly in line with the Minimum Magnetizability Principle as well. It is also observed

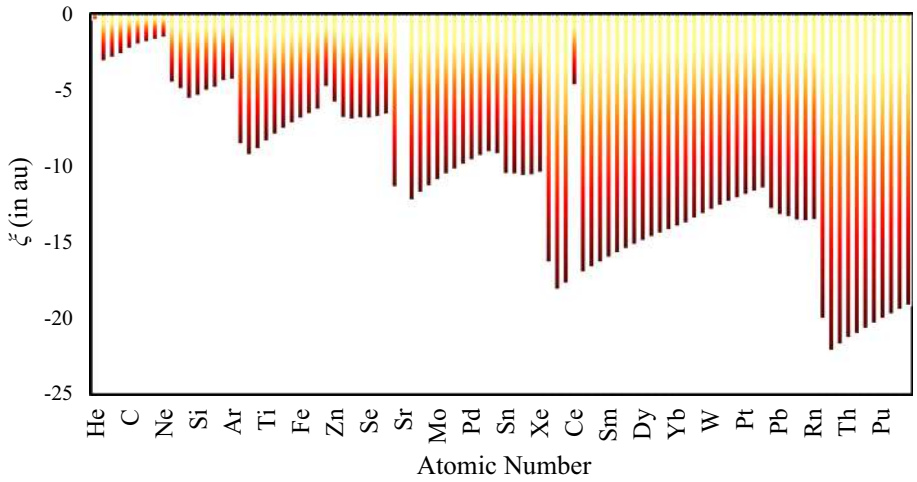


Fig. 3 Plot of magnetizability (ξ) (Fraga et al. 1973) as a function of atomic number ($Z=2$–96) (in au)

that within the periodic table, magnetizability displays an expected periodic behaviour.

Acknowledgements Dr. Tanmoy Chakraborty is thankful to Sharda University and Dr. Hiteshi Tandon is thankful to Manipal University Jaipur for providing computational resources and research facility.

Author contribution HT: Conceptualization, Methodology, Formal analysis, Investigation, Validation, Writing—Original Draft, Visualization. SKR: Resources. TC: Conceptualization, Supervision, Writing—Review and Editing. VS: Supervision, Writing—Review and Editing.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Compliance with ethical standards

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Bader RFW, Keith TA (1993) Properties of atoms in molecules: magnetic susceptibilities. J Chem Phys 99:3683–3693. https://doi.org/10.1063/1.466166

Bader RFW, MacDougall PJ (1985) Toward a theory of chemical reactivity based on the charge density. J Am Chem Soc 107:6788–6795. https://doi.org/10.1021/ja00310a007

Badri Z, Pathak S, Fliegl H, Rashidi-Ranjbar P, Bast R, Marek R, Foroutan-Nejad C, Ruud K (2013) All-metal aromaticity: revisiting the ring current model among transition metal clusters. J Chem Theory Comput 9:4789–4796. https://doi.org/10.1021/ct4007184

Balasubramanian K (1997) Relativistic effects in chemistry: part A theory and techniques. John Wiley & Sons, New York

Balasubramanian K (2001) Relativistic computations of the electronic states of the superheavy element 114 and 114^+. Chem Phys Lett 341:601–607. https://doi.org/10.1016/S0009-2614(01)00413-4

Balasubramanian K (2002a) Breakdown of the singlet and triplet nature of electronic states of the superheavy element 114 dihydride ($114H_2$). J Chem Phys 117:7426–7432. https://doi.org/10.1063/1.1508371

Balasubramanian K (2002b) Electronic states of the superheavy element 113 and (113)H. Chem Phys Lett 361:397–404. https://doi.org/10.1016/S0009-2614(02)00888-6

Boudart M (1952) Electronic chemical potential in chemisorption and catalysis. J Am Chem Soc 74:1531–1535. https://doi.org/10.1021/ja01126a055

Cárdenas C, Heidar-Zadeh F, Ayers PW (2016) Benchmark values of chemical potential and chemical hardness for atoms and atomic ions (including unstable anions) from the energies of isoelectronic series. Phys Chem Chem Phys 18:25721–25734. https://doi.org/10.1039/C6CP04533B

Chattaraj PK, Murthy TA, Giri S, Roy DR (2007) A connection between softness and magnetizability. J Mol Struct THEOCHEM 813:63–65. https://doi.org/10.1016/j.theochem.2007.02.035

Conradie J, Foroutan-Nejad C, Ghosh A (2019) Norcorrole as a Delocalized, Antiaromatic system. Sci Rep 9:1–6. https://doi.org/10.1038/s41598-019-39972-y

Dahle P, Ruud K, Helgaker T, Taylor PR (1999) Molecular polarizabilities and magnetizabilities. In: Maksid ZB, Orville-Thomas WJ (eds) Pauling's legacy: modern modelling of the chemical bond, theoretical and computational chemistry, vol 6. Elsevier, Amsterdam, pp 147–188

Foroutan-Nejad C (2015) Is NICS a reliable aromaticity index for transition metal clusters? Theor Chem Acc 134:8. https://doi.org/10.1007/s00214-015-1617-7

Fraga S, Karwowski J, Saxena KMS (1973) Hartree-Fock values of coupling constants, polarizabilities, susceptibilities, and radii for the neutral atoms, helium to nobelium. Atomic Data Nucl Data Tables 12:467–477. https://doi.org/10.1016/0092-640X(73)90003-X

Franco-Pérez M, Gázquez JL, Ayers PW, Vela A (2015) Revisiting the definition of the electronic chemical potential, chemical hardness, and softness at finite temperatures. J Chem Phys 143:154103. https://doi.org/10.1063/1.4932539

Geerlings P, De Proft F, Langenaeker W (2003) Conceptual density functional theory. Chem Rev 103:1793–1874. https://doi.org/10.1021/cr990029p

Haynes WM (2017) CRC handbook of chemistry and physics, 97th edn. CRC Press, Boca Raton, FL

Iczkowski RP, Margrave JL (1961) Electronegativity. J Am Chem Soc 83:3547–3551. https://doi.org/10.1021/ja01478a001

Janda T, Foroutan-Nejad C (2018) Why is benzene unique? Screening magnetic properties of C6H6 isomers. ChemPhysChem 19:2357–2363. https://doi.org/10.1002/cphc.201800364

Kohn W, Becke AD, Parr RG (1996) Density functional theory of electronic structure. J Phys Chem 100:12974–12980. https://doi.org/10.1021/jp960669l

Olejniczak M, Bast R, Gomes AS (2017) On the calculation of second-order magnetic properties using subsystem approaches in a relativistic framework. Phys Chem Chem Phys 19:8400–8415. https://doi.org/10.1039/C6CP08561J

Parr RG, Pearson RG (1983) Absolute hardness: companion parameter to absolute electronegativity. J Am Chem Soc 105:7512–7516. https://doi.org/10.1021/ja00364a005

Parr RG, Yang W (1989) Density functional theory of atoms and molecules. Oxford University Press, Oxford

Parr RG, Donnelly RA, Levy M, Palke WE (1978) Electronegativity: the density functional viewpoint. J Chem Phys 68:3801–3807. https://doi.org/10.1063/1.436185

Pearson RG (1992a) Chemical hardness and the electronic chemical potential. Inorg Chim Acta 198:781–786. https://doi.org/10.1016/S0020-1693(00)92423-X

Pearson RG (1992b) The electronic chemical potential and chemical hardness. J Mol Struct THEOCHEM 255:261–270. https://doi.org/10.1016/0166-1280(92)85014-C

Ruud K, Skaane H, Helgaker T, Bak KL, Jørgensen P (1994) Magnetizability of hydrocarbons. J Am Chem Soc 116:10135–10140. https://doi.org/10.1021/ja00101a036

Schäfer K, Lax E (1961) Landolt-Börnstein: Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik, 6th ed., Vol. 2, Part 4. Springer-Verlag, Berlin-Göttingen-Heidelberg

Szmytkowski R, Łukasik G (2016) Static electric and magnetic multipole susceptibilities for Dirac one-electron atoms in the ground state. Atomic Data Nucl Data Tables 111:41–66. https://doi.org/10.1016/j.adt.2016.02.002

Tandon H, Chakraborty T, Suhag V (2019a) A new scale of atomic static dipole polarizability invoking other periodic descriptors. J Math Chem 57:2142–2153. https://doi.org/10.1007/s10910-019-01055-8

Tandon H, Chakraborty T, Suhag V (2019b) A new scale of the electrophilicity index invoking the force concept and its application in computing the internuclear bond distance. J Struct Chem 60:1725–1734. https://doi.org/10.1134/S0022476619110040

Tandon H, Chakraborty T, Suhag V (2020) A scale of atomic electronegativity in terms of atomic nucleophilicity index. Found Chem 22:335–346. https://doi.org/10.1007/s10698-020-09358-4

Tandon H, Chakraborty T, Suhag V (2021) On the validity of minimum magnetizability principle in chemical reactions. Acta Chim Slov. https://doi.org/10.17344/acsi.2020.6305

Tanwar A, Pal S, Roy DR, Chattaraj PK (2006) Minimum magnetizability principle. J Chem Phys 125:056101. https://doi.org/10.1063/1.2227381

Toro-Labbé A (1999) Characterization of chemical reactions from the profiles of energy, chemical potential, and hardness. J Phys Chem A 103:4398–4403. https://doi.org/10.1021/jp984187g

Valiev RR, Fliegl H, Sundholm D (2017) Closed-shell paramagnetic porphyrinoids. Chem Commun 53:9866–9869. https://doi.org/10.1039/C7CC05232D

Wilson PJ, Amos RD, Handy NC (1999) Density functional predictions for magnetizabilities and nuclear shielding constants. Mol Phys 97:757–768. https://doi.org/10.1080/00268979909482876

J. Indian Chem. Soc.,
Vol. 97, No. 11b, November 2020, pp. 2391-2396

Probing the reactive center for site selective protonation in carbonyl sulphide in terms of conceptual density functional based site selectivity descriptors

Sandip Kumar Rajak

Department of Chemistry, Dumkal College, Basantapur, Murshidabad-742 406, West Bengal, India

E-mail: sandip1ku@gmail.com

Manuscript received online 12 October 2020, revised and accepted 27 November 2020

In the investigation of sufficient number of molecule species from the interstellar and circumstellar media with almost 80% of these cations are protonated molecules. The carbonyl sulphide (OCS) molecule being the interstellar molecule has three possible protonation sites (either O, S, or C). So, the investigation is performed to determine the best site for the protonation of carbonyl sulphide (OCS) theoretically. The physico-chemical process of protonation is allied with the energy lowering phenomenon. For ambivalent molecules having more than one lone pairs at different sites, the protonation occurs preferentially. Preferred site of protonation is an important physico-chemical input in suggesting and modeling reaction mechanism involving such molecules. Locating the preferred site of protonation in ambivalent molecules is a fascinating problem of experiment as well as theoretical chemistry. The present study has invoked local density functional descriptors governing electrophilic attack for Fukui function (f^-), local softness function (s^-) and local philicity function (ω^-) theoretically locating the preferred site of protonation, an electrophilic reaction, of the chosen of ambidentate molecule whose preferred site of protonation are known experimentally. It is found that theoretically prediction in terms of computed theoretical descriptor values regarding the preferred sites of protonation in carbonyl sulphide (OCS) molecules have one to one correspondence with the experimental findings.

Keywords: Protonation, DFT, Fukui function.

Introduction

The protonation reactions or the physico-chemical process of protonation are ubiquitous in almost all the areas of chemistry and biochemistry[1–5]. The chemical method of protonation is basic of many chemical rearrangements, and enzymatic reactions[4]. The resulting protonated molecule is frequently an essential intermediate that guides the succeeding steps of the overall process. The knowledge of the intrinsic basicity and the site of protonation of a compound are central for the understanding of the mechanism of chemical reactions. The legend proton affinity is defined as the negative of the enthalpy change of a protonation reaction at the standard conditions. The gas-phase proton affinities are a quantitative measure of the intrinsic basicity of a molecule[6]. The study of thermochemistry of the proton transfer reaction in the gas phase is well-known experiment of acid-base reaction[7]. Dynamics of proton transfer is also important for ionization processes in mass spectroscopy[8].

In the investigation of ample number of molecule species from the interstellar and circumstellar media with about 10% being cations and almost 80% of these cations are protonated molecules[9–16]. Jefferts *et al.*[17] during their study, first detected the carbonyl sulphide (OCS) as a recognized interstellar molecule within the giant molecular Sagittarius B2 and was further confirmed in about ten interstellar sources[18–20].This interstellar molecule OCS participate an significant role in the global cycling of sulphur[21] and it forms the major source of stratospheric aerosol[22] due to its high abundance (about 500 ppm) in the troposphere.

Since, the OCS molecule has three possible protonation sites (either O, S, or C) so the purpose of this work was to determine the best site for the protonation of OCS theoretically which correspond with the experimental result[23–28].

In the physico-chemical process of protonation, when a proton dynamically approaches towards a nucleophile from a long distance, it is attracted by the electron cloud of the molecule. Thus a proton acting as an electrophile starts soaking the electron density from the entire skeleton of the nu-

cleophile[29] and as a result, the electron cloud of the nucleophile is redistributed and remains under the influence of nucleus of the electrophile. Ultimately the proton fixes at a site of lone pair – the site of protonation, of the molecule. However, if there is no lone pair in the structure of the molecule, the proton remains weakly attached to the sphere of the charge cloud of the molecule. The polarizing power of the proton induces a physical process of structural and energetic changes in the molecule. This phenomenon is, in particular, at the origin of the site of protonation, has considerable effect on the strength and length of the bonds[5]. The structural and energetic changes induced by the polarizing power of the proton are expected to be at its maximum at the gas phase of the molecule. Thus, the gas-phase basicity is certainly the ideal revelator of the structural and energetic characteristics of the molecular protonation process.

If a molecule has more than one donor sites i.e. lone pairs and if a proton approaches such a molecule, the proton will not find all the donor sites to be attacked equally likely. The proton will select the most preferred site in the structure of the molecule. In the dynamic process of protonation reaction, the preferred site may be identified by the attaching proton in a kinetic and thermodynamic process. But the selection of preferred site will be decided by the thermodynamically controlled process. When the proton is fixed at the preferred site, the enthalpy change is more and when the proton fixes at non-preferred site liberation of energy is less. The procedure follows the hierarchical steps: (i) calculate energy of the molecule first, and (ii) then attach proton at different probable sites to generated protonated species one after another, and (iii) then compute the energy of the protonated species theoretically and/or experimentally.

The preferred site of protonation in ambidentate molecules can also predicted from the charge densities on atomic sites and also the hybridization of the lone pair that binds the proton[5,29,30]. Introduction of Conceptual Density Functional Theory based global and local descriptors by Parr and coworkers[31–34] made DFT more popularize and initiated a new arena of scientific research. Although, the global descriptors like electronegativity, hardness and electrophilicity index are hypothetical concepts[35–47], these descriptors are successfully used to predict several physico-chemical properties of molecules as well as the reaction surfaces[45,47] and to probe the site of chemical reaction of molecules[48]. It is worth mentioning that the local descriptors are evolved from the global descriptors. Global quantities like hardness, softness deal with the stability and reactivity of different interacting fragments as a whole.

If a proton approaches dynamically towards a donor, what direction will be preferred from among several directions that can produce the same type of chemical bond between the proton and the donor? Since the purpose of this work here is to correlate the known site selectivity in terms of local density functional descriptors, so it is pertinent to discuss the local reactivity descriptors in brief.

The most popular method for predicting how and whether a reaction will take place is the frontier molecular orbital theory (FMO)[49]. This method uses the shapes and symmetries of the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) to indicate whether a reaction will occur or not. If the HOMO of the electron donor and the LUMO of the electron acceptor have the same shape (symmetry) and phase, then electron transfer from the HOMO of the first molecule to the LUMO of the second can occur, often forming a bond between the reagents[50]. This motivated the definition of a function in the context of density functional theory (DFT) that encapsulates the essence of FMO[31,51–53] but, in principle, includes both electron correlation[31,54]. This function is known as the "Fukui function" $f(r)$. The quantity $f(r)$ is a local property depending on position, r and hence it possesses different value at different position in the chemical species. The Fukui function, $f^-(r)$, is defined as the change in density that one observes when one goes from N to $N - 1$ electrons (with the nuclear positions fixed) and within the frozen core approximation this is analogous to the density of the HOMO orbital. A similar function, $f^+(r)$, can be defined as the difference between the electron densities of the $N + 1$ and N electron systems; this is analogous to the LUMO orbital density. The Fukui function is labeled according to whether the system is acting as an electron acceptor or an electron donor. The $f^+(r)$ says where an electron will add to the molecule. The $f^-(r)$ says where an electron given to an electron acceptor will come from. Electron donors tend to attack the molecule where $f^+(r)$ is large because this is where the molecule "wants electrons". The essence of the theoretical development is that the numerical

values of $f^+(r)$ and $f^-(r)$ in molecules predict the preferred sites for electrophilic or nucleophilic attack in the molecules. Electron acceptors tend to attack the molecule where $f^-(r)$ is large because this is where the molecule has electrons that it is "willing to give up"[31,51]. .

Notwithstanding some workers reported the failure of Fukui functions to predict the reaction site of a molecule[30], still the Fukui functions are used in several works as good descriptor of site selectivity[48,51,55–60].

Parr and Yang[31,33], on the basis of DFT, further introduced a new local DFT descriptor – the local softness (s) which have been found potentially useful to identifying the preferred sites of molecules prone to chemical reaction. The local softness can be considered as "local abundance" or "concentration" of their corresponding global properties. The conceptual structure and the necessary algorithm for this descriptor have crystallized a distinct branch of conceptual chemistry – the local Hard-Soft Acid-Base (HSAB) principle.

In order to provide a unified treatment of chemical reactivity and selectivity concept of philicity is introduced[30] through a resolution of identity.

Theoretical background

There is a paradigm shift in the realm of conceptual chemistry due to the density functional underpinning of Parr *et al.*[31,32,52,61]. The useful qualitative entities like hardness, electronegativity and electrophilicity index which were abstract semiotic representations are now considered as theoretical quantities of cognitive representations. According to DFT, given the electron density function $\rho(r)$ of a chemical system and the ground state energy and everything can be determined. The chemical potential, μ of that system in equilibrium has been defined as the derivative of the energy functional $E(\rho)$ with respect to the electron density at fixed molecular geometry.

The chemical potential, μ, is given by[62]

$$\mu = -\chi = [\delta E(\rho)/\delta\rho]_v \quad (1)$$

where v is the external potential acting on an electron due to the presence of nucleus.

The differential definition more appropriate to atomic system is on the basis that for a system of N electrons with ground state energy $E[N,v]$,

$$\mu = -\chi = [\partial E/\partial N]_v \quad (2)$$

The absolute hardness is defined[63] as

$$\eta = \tfrac{1}{2}\,[\partial\ \mu/\partial N]_v = \tfrac{1}{2}\,[(\partial^2 E/\partial N^2)]_v \quad (3)$$

The ansatz for hardness is mathematically difficult because the numerical method is required to be invoked to solve it[64]. However, Parr and Pearson[63], invoking finite difference approximation, suggested an approximate formula for the evaluation of hardness and electronegativity as

$$\eta = \tfrac{1}{2}\,(I - A) \quad (4)$$

$$\chi = \tfrac{1}{2}\,(I + A) \quad (5)$$

where I is the ionization energy and A is the electron affinity of the chemical species. Pearson[65] proceeded further to evaluate 'I' and 'A' in terms of orbital energies of the highest occupied molecular orbital, HOMO and the lowest unoccupied molecular orbital, LUMO by connecting it with Hartree - Fock SCF theory and invoking Koopmans' theorem the hardness and electronegativity are reformulated as

$$\eta = \tfrac{1}{2}\,(-\varepsilon_{HOMO} + \varepsilon_{LUMO}) \quad (6)$$

$$\text{and } \chi = -\mu = -\tfrac{1}{2}\,(\varepsilon_{LUMO} + \varepsilon_{HOMO}) \quad (7)$$

where $I = -\varepsilon_{HOMO}$, and $A = -\varepsilon_{LUMO}$.

The inverse of hardness is defined as softness[31,33].

$$S = \tfrac{1}{2}\eta = (\partial N/\partial\mu)_v = 1/(I - A) \quad (8)$$

Parr *et al.*[34] defined another global parameter, the electrophilicity index (ω) as

$$\omega = (\mu)^2/(2\eta) \quad (9)$$

or,

$$\omega = \{(I + A)^2\}/8(I - A) \quad (10)$$

The Fukui function is defined as

$$f(r) = [\delta\mu/\delta v(r)]_N = [\partial\rho(r)/\partial N]_v \quad (11)$$

The Fukui function can give three predictions:

(i) governing electrophilic attack: $f^-(r) = [\partial\rho(r)/\partial N]^-_v$ (12)

(ii) governing nucleophilic attack: $f^+(r) = [\partial\rho(r)/\partial N]^+_v$ (13)

(iii) governing neutral (radical) attack:

$$f^0(r) = [\partial\rho(r)/\partial N]^0_v \quad (14)$$

The three cases have $\mu_S > \mu_R$, $\mu_S < \mu_R$ and $\mu_S \sim \mu_R$.

A "frozen core" approximation now gives $d\rho = d\rho_{valence}$ in each case, and therefore,

(a) governing electrophilic attack: $f^-(r) = \rho_{HOMO}(r)$ (15)

(b) governing nucleophilic attack: $f^{+}(r) = \rho_{LUMO}(r)$ (16)

(c) governing neutral (radical) attack:

$f^{0}(r) \approx ½ [\rho_{HOMO}(r) + \rho_{LUMO}(r)]$ (17)

where $\rho(r)$ is the electron density.

Local softness, $s(r)$, can be written by the formula

$s(r) = S f(r) = (\partial\rho(r)/\partial\mu)_{T,v(r)}$ (18)

There are three local softness functions:

(a) governing electrophilic attack: $s^{-}(r) = S f^{-}(r)$ (19)

(b) governing nucleophilic attack: $s^{+}(r) = S f^{+}(r)$ (20)

(c) governing neutral (radical) attack: $s^{0}(r) = S f^{0}(r)$ (21)

Here $s^{-}(r)$, $s^{+}(r)$ and $s^{0}(r)$ are the local softnesses corresponding to electrophilic attack, nucleophilic attack and radical attack respectively[66]. The local philicity index[30] is given as

$\omega(r) = \omega f(r)$ (22)

There are three local philicity functions:

(a) governing electrophilic attack: $\omega^{-}(r) = \omega f^{-}$ (23)

(b) governing nucleophilic attack: $\omega^{+}(r) = \omega f^{+}$ (24)

(c) governing neutral (radical) attack: $\omega^{+}(r) = \omega f^{+}$ (25)

Propose of this study to locate the reactive centers for the chemico-physical process of protonation of representative molecule in terms of the computed values of local density functional descriptors.

Method of computation

Computational study is performed within *ab initio* framework and descriptors have been calculated using conceptual density functional theory. All the modeling and structural optimization of compounds have been performed using Gaussian 09 software package[67]. For optimization purpose, Hartree-Fock with basis set 6-311G has been adopted.

The optimized structure for carbonyl sulfide are presented in Fig. 1.

All the global descriptor such as global hardness (η), chemical potential (μ), electronegativity (χ), global softness (S), and global electrophilicity index (ω) are computed for the molecules stated above using eq. (6), eq. (7), eq. (8) and eq. (10) respectively and are given in the Table 1.

The global descriptors are used to compute the local

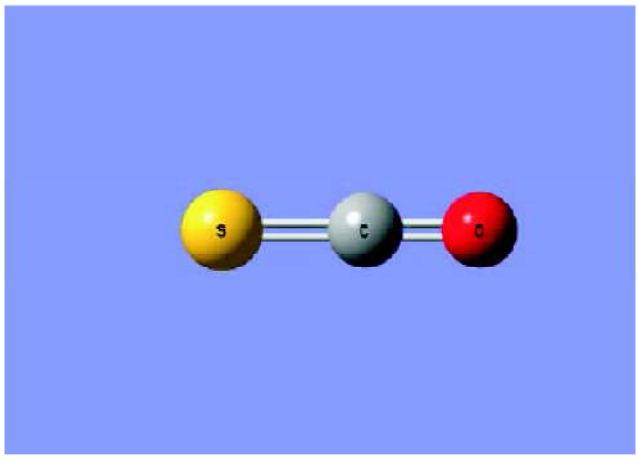


Fig. 1. Optimized structure of carbonyl sulfide.

Table 1. Global hardness (η), global softness (S), chemical potential (μ), and global electrophilicity index (ω) in eV

Molecules	η (eV)	μ (eV)	χ (eV)	ω (eV)	S (eV)
OCS	6.90112	–4.8611	4.8611	1.71207	0.1449

descriptors. Since proton is an electrophile and the site selectivity of the instant reactions will be decided by f^{-}, s^{-} and ω^{-}, so computation has done to calculate the values of Fukui function (f^{-}), local softness (s^{-}), local philicity index (ω^{-}) only using eq. (15), eq. (19) and eq. (23) respectively for all the probable donor centers of the chosen molecule and are given in the Table 2.

Table 2. The computed Fukui function (f^{-}), local softness (s^{-}), local philicity index (ω^{-}) in eV for different donor centers of carbonyl sulfide (OCS)

Center	f^{-}	s^{-}	ω^{-}
O	0.30078	0.043584	0.51495
C	0.03277	0.004748	0.0561
S	0.84815	0.122901	1.4521

Results and discussion

The structural formula shows that the molecule has three probable sites, 'O' ,'S' and 'C' of protonation. The evaluated Fukui functions (f^{-}), the local softness (s^{-}) and local philicity (ω^{-}) for the three different donor centers O, S and C of the molecule OCS are presented in Table 2. It is the intrinsic characteristics of Fukui function that the numerical value of f^{-} measures the reactivity (nucleophilicity) of a particular

atomic site of a donor center towards an electrophile, the proton. Looking at Table 2, it can be seen that the f^- values of the different donor centers in the donor, OCS follows the order S > O > C which clearly indicates that the S-center in OCS molecule is the more reactive center towards an electrophile.

In prediction based upon the calculated atomic charges, on the other hand, would be seriously in error. In OCS, the most negative atomic charge are found to be on O, S and C, –0.4404, 0.197, 0.24338 respectively, followed inconsistent with the experimental fact[23,24–28] that S is the most attractive site of protonation attack.

So, the experiment[23,24–28] and theory proceed hand in hand in the matter of selecting the preferred site of protonation in multi dented molecule like OCS and the theoretical tour is some local DFT descriptor.

Conclusion

Molecules may have more than one site having lone pair of electrons in its structure in terms of valence bond description. The lone pairs are the centre where an electrophile usually attaches during the course of chemical reactions between a nucleophilic and electrophile. Proton is an electrophile. It approaches kinetically towards a molecule and soaks electron density from the molecule. In the process energy lowering takes place. It is also quite expected that proton will prefer more polarizable site in the molecule for binding. The local Hard-Soft Acid-Base (HSAB) principle has introduced a cluster of local theoretical descriptors namely the Fukui functions, local softnesses and the local electrophilicity indices. The thermodynamic mechanism of protonation can be rationalized in terms of the local Hard-Soft Acid-Base (HSAB) descriptors. The gamut of the theory is that the site selectivity in the physico-chemical process of protonation can be predicted in terms of these theoretical descriptors.

In the present study, determined the preferred site of electrophilic reactions/protonation of such molecules in terms of the local descriptors discussed above and the result is 1 to 1 correspondence between the theoretical prediction and experimental finding. In other words, the preferred site of protonation can be rationalized in terms of the local density functional descriptors. The experiment and theory proceed hand in hand in the matter of selecting the preferred site of protonation in multidented compounds and the theoretical tour is some local DFT descriptor. But prediction based upon the calculated atomic charges, on the other hand, would be seriously in error.

References

1. R. Stewart, "The Proton: Appellation to Organic Chemistry", Academic Press, New York, 1985.
2. F. A. Carrol, "Perspectives on Structure and Mechanism in Organic Chemistry", Brooks-Cole, New York, 1998.
3. J. Zhao and R. Zhang, *Atmospheric Environment*, 2004, **38**, 2177.
4. R. A. Kennedy, Ch. A. Mayhew, R. Thomas and P. Watts, *Int. J. Mass Spectrom.*, 2003, **627**, 223.
5. G. Bouchoux, *Mass Spectrometry Reviews*, 2007, **26**, 775.
6. C. A. Deakyne, *Int. J. Mass Spectrom.*, 2003, **227**, 601.
7. S. G. Lias, J. F. Liebman and R. D. Levine, *J. Phys. Chem. Ref. Data*, 1984, **13**, 695.
8. A. Hansel, N. Oberhofer, W. Lindinger, V. A. Zenevich and G. B. Billing, *Int. J. Mass Spectrom.,* 1999*,* **559**, 185.
9. H. J. Fraser, M. R. S. McCoustra and D. A. Williams, *Aston. Geophys*, 2002, **43**, 2.10-2.18.
10. A. G. G. M. Tielens, *Rev. Mod. Phys*., 2013, **85**, 1021.
11. E. E. Etim and E. Arunan, *Planex Newslett,* 2015, **5**, 16.
12. E. E. Etim, P. Gorai, A. Das, S. K. Chakrabarti and E. Arunan, *Astrophys. J.,* 2016, **832(2)**, 10.3847/0004-637X/832/2/144.
13. E. E. Etim and E. Arunan, *Eur. Phys. J. Plus*, 2016, **131**, 10.1140/epjp/i2016-16448-0.
14. E. E. Etim and E. Arunan, *Adv. Space Res.*, 2017, **59**, 1161.
15. E. E. Etim, E. Arunan, *Astrophys. Space Sci.*, 2017, **362**, 1.
16. E. E. Etim, P. Gorai, A. Das and E. Arunan, *Eur. Phys. J. D*, 2017, **71**, 10.1140/epjd/e2017-70611-3.
17. K. B. Jefferts, A. A. Penzias, R. W. Wilson and P. M. Solomon, *Astrophys. J.,* 1971, **168**, L111-L113.
18. P. F. Goldsmith and R. K. Linke, *Astrophys. J.,* 1981, **245**, 482.
19. W. Fock and T. McAllister, *Astrophys. J.,* 1982, **257**, L99-L101.
20. M. E. Palumbo, T. R. Geballe and A. G. Tielens, *Astrophys. J.,* 1997, **479**, 839.
21. D. C. Thornton, A. R. Bandy, B. W. Blomquist and B. E. Anderson, *J. Geophys. Res.: Atmos.,* 1996, **101**, 1873.
22. K. Hiraoka, K. Fujita, M. Ishida, K. Hiizumi and F. Nakagawa, *J. Am. Soc. Mass Spectrom.*, 2005, **16**, 1760.
23. S. Saebo, M. M. Sanz and S. C. Foster, *Theoret. Chem. Accounts*, 1997, **97**, 271.
24. S. E. Wheeler, Y. Yamaguchi and H. F. Schaefer III, *Chem.*

Phys., 2006, **124**, 10.1063/1.2150819.

25 . R. C. Fortenberry, X. Huang, J. S. Francisco, T. D. Crawford and T. J. Lee, *J. Phys. Chem. A,* 2012, **116**, 9582.

26. T. McAllister, P. R. Taylor and M. Scarlett, *Org. Mass Spectrom*., 1986, **21**, 157.

27. P. R. Taylor and M. Scarlett, *Astrophys. J.,* 1985, **293**, L49.

28. J. Liu, B. van Devener and S. L. Anderson, *J. Chem. Phys*., 2002, **117**, 8292.

29. D. C. Ghosh, "A theoretical study of some selected molecules and their protonation by the application of CNDO method", Premchand Roychand Research Studentship Award, University of Calcutta, Calcutta, 1976.

30. J. Melin, F. Aparicio, V. Subramanian, M. Galván and P. K. Chattaraj, *J. Phys. Chem. A*, 2004, **108**, 2487.

31. R. G. Parr and W. Yang, *J. Am. Chem. Soc*., 1984, **106**, 4049.

32. R. G. Parr and W. Yang, "Density Functional Theory of Atoms and Molecules", Oxford, University Press, 1989.

33. W. Yang and R. G. Parr, *Proc. Natl. Acad. Sci. USA*, 1985, **82**, 6723.

34. R. G.Parr, L, V. Szentpaly and S. Liu, Electrophilicity Index, *J. Am. Chem. Soc*., 1999, **121**, 1922.

35. D. C. Ghosh and N. Islam, *Int. J. Quantum Chem*., 2011, **111**, 2802.

36. D. C. Ghosh and N. Islam, *Int. J. Quantum Chem*., 2011, **111**, 2811.

37. D. C. Ghosh and N. Islam, *Int. J. Quantum Chem*., 2011, **111**, 1942.

38. D. C. Ghosh and N. Islam, *Int. J. Quantum Chem*., 2009, **110**, 1206.

39. D. C. Ghosh, N. Islam and S. K. Rajak, *Int. J. Chem. Model*, 2009, **2**, 361.

40. D. C. Ghosh, N. Islam and S. K. Rajak, *Int. J. Chem. Model*, 2009, **2**, 375.

41. D. C. Ghosh and N. Islam, *Int. J. Quantum Chem*., 2011, **111**, 1931.

42. D. C. Ghosh and N. Islam, *Int J. Quantum Chem*., 2010, **111**, 1961.

43. D. C. Ghosh and N. Islam*, Int J. Quantum Chem*., 2011, **111**, 40.

44. N. Islam and D. C.Ghosh, *Mole Phys*., 2011, **109**, 917.

45. N. Islam and D. C. Ghosh, *European Physical Journal D*., 2011, **61**, 341.

46. N. Islam and D. C. Ghosh, *Int. J. Quantum Chem.*, 2011, **111**, 3556.

47. N. Islam and D. C. Ghosh, *Eur. J. Chem.*, 2010, **1**, 83.

48. D. C. Ghosh and S. Bhattacharyya, "DFT Correlation of the Site Selectivity of Donor–Acceptor Chemical Interaction, Nanoscience and Advancing Computational Methods in Chemistry: Research Progress", Apple Academic Press, Canada, 2011.

49. T. A. Albright, J. K. Burdett and M. H. Whangbo, "Orbital Interactions in Chemistry", Wiley-Interscience, New York, 1985.

50. J. S. M.Anderson, J. Melin and P. W. Ayers, *J. Chem. Theory Comput*., 2007, **3**, 358.

51. P. W. Ayers and M. Levy, *Theor. Chem. Acc*., 2000, **103**, 353.

52. W. Yang, R. G. Parr and R. Pucci, *J. Chem. Phys*., 1984, **81**, 2862.

53. P. W. Ayers and R. G. Parr, *J. Am. Chem. Soc*., 2000, **122**, 2010.

54. J. Melin, P. W. Ayers and J. V. Ortiz, *J. Chem. Sci*., 2005, **117**, 387.

55. P. Fuentealba and R. Contreras, in: "Reviews of Modern Quantum Chemistry: A Celebration of the Contributions of Robert G. Parr, K. D. Sen", World Scientific, Singapore, 2002.

56. E. Chamorro, R. Contreras and P. Fuentealba*, J. Chem. Phys*., 2000, **113**, 10861.

57. P. Geerlings, F. De Proft and W. Langenaeker, *Chem. Rev.,* 2003, **103**, 1793.

58. P. Pérez, Y. Simón-Manso, A. Aizman, P. Fuentealba and R. Contreras, *J. Am. Chem. Soc*., 2000, **122**, 4756.

59. L. T. Nguyen, T. N. Le, F. De. Proft, A. K. Chandra, W. Langenaeker, M. T. Nguyen and P. Geerlings, *J. Am. Chem. Soc*., 1999, **121**, 5992.

60. S. Pal and K. R. S. Chandrakumar, *J. Am. Chem. Soc*., 2000, **122**, 4145.

61. R. G. Parr, R. A. Donnelly, M. Levy and W. E. Palke, *J. Chem. Phys*., 1978, **68**, 3801.

62. E. P. Gyftopoulos and G. N. Hatsopoulos, *Proc. Natl. Acad. Sci*., 1968, **60**, 786.

63. R. G. Parr and R. G. Pearson, *J. Am. Chem. Soc.*, 1983, **105**, 7512.

64. K. D. Sen and S. C. Vinayagam, *Chem. Phys. Lett*., 1988, **114**, 178.

65. R. G. Pearson, *Proc. Natl. Acad. Sci*., 1986, **83**, 8440.

66. D. C. Ghosh and J. Jana, *Int. J. Quantum Chem*., 2003, **92**, 484.

67. M. J. Frisch, G. W. Toucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Baron, B. Mennucci and G. A. Peterson, Gaussian 09, revision D.01, Gaussian, Inc., Wallingfort, CT, 2009.

সমকালের জিয়ন কাঠি

ISSN: 2249-4782
UGC Care Listed
International Peer Reviewed Research Journal

দ্বি-শতবর্ষে

বিদ্যাসাগর স্মরণ সংখ্যা

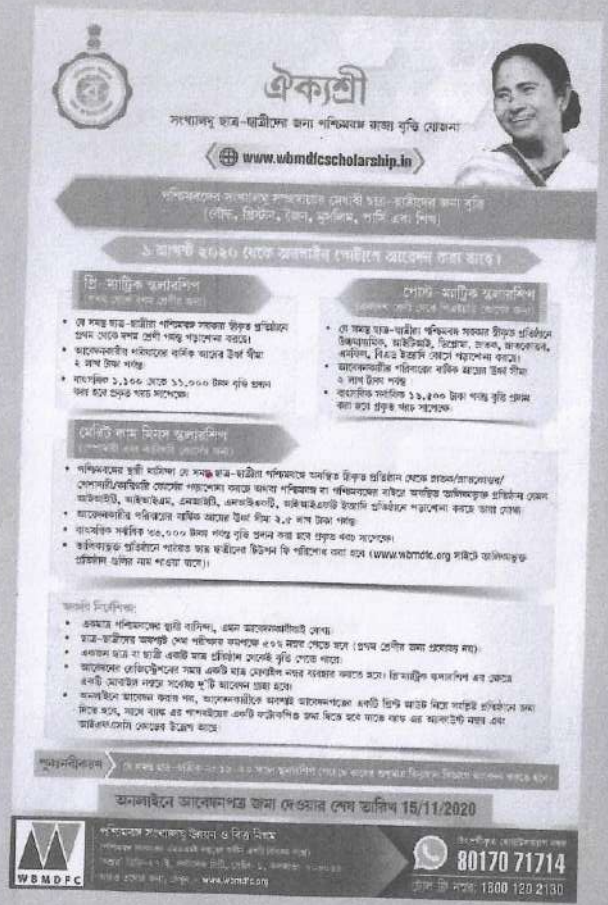
এবং বিবিধ

জুলাই-ডিসেম্বর ২০২০,যুগ্ম

সম্পাদক

নাজিবুল ইসলাম মণ্ডল

Samakaler Jiyonkathi July - December (Jt.) DL No. 11
04.02.2004



Owner & Publisher : Nazibul Islam Mondal, Jiban Mondal Hat,
P.O. - Mayahowri, P.S. - Bakultala,South 24 Parganas, WB, India
Pin - 743337 / E-mail : nazibulislammondal@rediffmail.com
Mob. - 7699456832 / 9932567161
Printer : Jayasree Press- 91/1A, Baithakkhana Road, Kolkata - 700009

Rs. -₹ 300.00

Vidyasagar Smaran Sankhya
Samakaler Jiyonkathi Sahitya Patrika
Edited by Nazibul Islam Mondal

প্রথম প্রকাশ : জুলাই-ডিসেম্বর ২০২০ (যুগ্ম)

মুদ্রণ ঃ জয়শ্রী প্রেস
৯১/১বি, বৈঠকখানা রোড, কলকাতা-৯

অক্ষরবিন্যাস ঃ এল টি এম গ্রাফিক্স
বারুইপুর, কলকাতা-১৪৪

সম্পাদকীয় দপ্তর ঃ নাজিবুল ইসলাম মণ্ডল
সমকালের জিয়নকাঠি প্রকাশন
জীবন মণ্ডল হাট
ডাকঘর : মায়াহাউড়ি, দক্ষিণ চব্বিশ পরগনা, সূচক-৭৪৩৩৩৭

শহর অফিস ঃ সমকালের জিয়নকাঠি প্রকাশন
মণিমালা অ্যাপার্টমেন্ট
অরূপ ভদ্র সরণি, কলকাতা-১৪৪
চলভাষ : ৭৬৯৯৪৫৬৮৩২/৯৯৩২৫৬৭১৬১
e-mail : nazibulislammondal@rediffmail.com

প্রাপ্তিস্থান ঃ
● দে জ পাবলিশিং
১৩ বঙ্কিম চ্যাটার্জি স্ট্রিট, কল-৭৩
● দে বুক স্টোর (দীপুদা)
১৩ বঙ্কিম চ্যাটার্জি স্ট্রিট, কল-৭৩
● ফার্মা কে.এল.এম
২৫৭ বি.বি.গাঙ্গুলী স্ট্রিট, কল-১২

বিনিময় ঃ ৩০০.০০ টাকা

ISSN : 2249-4782

সম্পাদনা
শুভদীপ সরকার
ও
ভবানী কর

SOPAN সোপান

দ্বন্দ্ব ও সমন্বয়ে বর্ণপরিচয়

তমাল কান্তি পাল

আমাদের বাংলাদেশ ও সাহিত্য, সবক্ষেত্রে যিনি বিশাল বনস্পতি হয়ে রয়েছেন, যাঁর সমাজ সংস্কারের সুদূরপ্রসারী ফলভোগ করে বাঙালি জাতির উত্থান হয়েছিল জ্ঞানে, কর্মসৃষ্টির কাজে অগ্রণী এক জাতি সত্তায় পরিণত হয়েছিল। 'বিদ্যাসাগর' বাঙালির শিক্ষারীতিকে কার্যকরী রূপ দেবার জন্য বালক পাঠ্যপুস্তক পুস্তিকা রচনায় অগ্রসর হয়েছিলেন। 'বর্ণপরিচয়' থেকে 'আখ্যানমঞ্জরী' পর্যন্ত শিশু-বালক- কিশোরদের জন্য অনেকগুলি পাঠ্যপুস্তক রচনা করে বাঙালি জাতিকে 'জ্ঞানচক্ষু' খুলে দিতে সচেষ্ট হয়েছেন। শিশুদের বর্ণবোধের কথা ভেবে তাদের উপযোগী পুস্তক রচনার কথা অনুভব করেছিলেন। আবার শিশুরা যাতে নীরস রচনার দ্বারা বিরস বদনে গ্রন্থবিমুখ হয়ে না পড়ে সেদিকে নজর রেখেছিলেন। শিশুচিত্তের অনুসারী গ্রন্থ রচনায় আন্তরিক প্রয়াস চালিয়েছিলেন। অন্যদিকে পঠন-পাঠন যাতে বৈজ্ঞানিক ভিত্তির উপর গড়ে ওঠে সেদিকেও যথেষ্ট সচেতন ছিলেন। শিশুশিক্ষার বুনিয়াদ সুগঠিত না হলে কোন জাতি উন্নত জাতিতে উন্নীত হতে পারে না। তাই বিদ্যাসাগর শিক্ষা প্রচার ও প্রসারে ব্রতী হয়ে শিশু শিক্ষার প্রতি নিজেকে উজাড় করেছিলেন। এই বই প্রকাশের সঙ্গে সঙ্গে আদর্শ শিশু পাঠ্যপুস্তক রূপে বাঙালির ঘরে ঘরে তা ছোটদের হাতে পৌঁছে গিয়েছিল।[১]

'শিশু শিক্ষা' ও 'কিশোর শিক্ষার' উপযোগী আখ্যান নির্মাণ, তাদের রসবোধের চূড়ান্ত বিকাশের পথটি তিনি দেখাতে কোনো কার্পণ্য করেননি। শিশু শিক্ষার পাঠ পর্বের প্রথম চাহিদা হল—শিশু প্রথম থেকেই মানব সমাজের স্নেহে লালিত হোক, মানবিক সম্পর্কগুলি দৃঢ় হোক, সামাজিক দায়বদ্ধতা জাগ্রত হোক আজকের নানা ছেদ চিহ্ন ব্যবহার করে মনের সব রকম ভাব প্রকাশের উপযোগী গদ্যই বিদ্যাসাগরের এক অমর সৃষ্টি। এই সুন্দর ভাবনাগুলি 'বর্ণপরিচয়'-এ আছে। বিদ্যাসাগর মহাশয়ের 'বর্ণপরিচয়'-এ প্রথম ভাগ ও দ্বিতীয় ভাগ ১৮৫৫ খ্রিস্টাব্দে (সং বৎসর ১৯১২, সাল ১২৬২) এপ্রিল-জুনে প্রকাশিত হয়। বর্ণপরিচয় সেযুগের সার্থক শিশুপাঠ্য পুস্তক এবং এ যুগের সর্বশ্রেষ্ঠ শিশুপাঠ্য গ্রন্থ। বর্ণপরিচয়ে প্রকাশের পূর্বে ও পরে বিদ্যাসাগর

Journal of Mathematical Chemistry (2021) 59:1014–1028
https://doi.org/10.1007/s10910-021-01224-8

ORIGINAL PAPER

Theoretical computation of normalised radii, density and global hardness as a function of orbital exponent

Shalini Chaudhary[1,2] · Abhay Chaudhary[3] · Sandip Kumar Rajak[4] · Savaş Kaya[5] · Mustafa Elik[6] · Tanmoy Chakraborty[7]

Received: 27 December 2020 / Accepted: 1 February 2021 / Published online: 21 February 2021

Abstract

The recent work has an aim to establish a pivotal role of orbital exponent in the normalized atomic radii, atomic density and atomic hardness. These three periodic descriptors help to understand the real scenario of an element. Concerning the effective nuclear charge, screening constant and effective principal quantum number, we have developed a new relation between these periodic properties and invoked a new formula by which we can compute the normalized radii, density and global atomic hardness in terms of the orbital exponent. With comparison to the existing famous formulae originating from different concepts, we can conclude that our empirical computation has an inherent efficacy to predict periodicity.

Keywords Orbital exponent · Atomic density · Atomic hardness · Effective nuclear charge

✉ Tanmoy Chakraborty
tanmoychem@gmail.com; tanmoy.chakraborty@sharda.ac.in

[1] Department of Chemistry, Alankar P.G. Girls College, Jaipur, Rajasthan 302034, India

[2] Department of Chemistry, Manipal University Jaipur, Jaipur, Rajasthan 303007, India

[3] Department of Computer Science Engineering, Vellore Institute of Technology, Amaravati, Andhra Pradesh 522237, India

[4] Department of Chemistry, Dumkal College, Murshidabad, West Bengal 742406, India

[5] Department of Pharmacy Health Services Vocational School, Sivas Cumhuriyet University, Sivas 58140, Turkey

[6] Faculty of Education, Sivas Cumhuriyet University, Sivas 58140, Turkey

[7] Department of Chemistry and Biochemistry, School of Basic Sciences and Research, Sharda University, Uttar Pradesh, Knowledge Park III, Greater Noida 201310, India

1 Introduction

Atomic radius is an important periodic descriptor which can govern many physico-chemical properties. It is a function of the molecular environment [1]. It is well noted that atomic radii cannot be defined in precession. The size of the molecule relies upon the particle weight. The atomic size is considered as non-observable. Theoretical research on various properties such as the structure of electrons in an atom and a molecule are carried out depending upon a vast domain, i.e., wave mechanics. Quantum mechanics portrays the image of an atom as a separate group of electrons around the centre of an atom, and every group reaches out to the core. Similarly, the electrons of an atom come beneath the direct sway of the nucleus of an atom. There is a finite possibility of determining the location of an electron in the vast space, leading to a gradual increase in the radial distance with the diminishing of electron density ($\rho_{(r)}$) and becomes zero at infinity [2].

The radii categorised as the radii of an atom or an ion irrespective of whether it is bonded or nonbonded having covalent, and van der Waals forces amongst each other [3–15]. Though the additivity of atomic and ionic radii was reported in the early history of size calculation [16–19], it was established later that the interatomic and interionic distance are a function of the crystal type, allotropic nature and coordination number [20–23].

Determination of atomic and molecular size has paramount importance in chemical sciences. Whereas theoretical models have a preference in predicting absolute atomic and ionic radii, innovative techniques are useful to compute relative size [24]. Theoretical calculation of atomic and ionic size has evolved from the empirical model and reached up to Self-Consistent Field theory [25–27]. Empirical relationship gained popularity in terms of the minimum requirement of computational resources, whereas SCF has inherent importance of its accurate prediction of atomic and ionic size. Empirical ionic radii, as well as atomic radii, correlate to the wave functions of an ion and atom similar to the maximum charge density in a valence shell of an atom [7, 10, 28–45]. Recently Chakraborty et al. [46] have discovered a new set of atomic radii through empirical calculations considering the relationship between atomic size with various periodic descriptors, such as ionisation potential (IP) and effective nuclear charge. Slater [47] propounded a new analytical form of the radial part of one electron function with the fruitful scope of calculation of normalised radii of atoms. Based on the versatile suggestions given by Slater, we suggest a new and transit form of formula of normalised radii and density by which we can calculate these properties for 103 atoms.

2 Methodology of computation

2.1 Computation of normalized radii and atomic density

The radii have been categorised as the radii of an atom or an ion irrespective of whether it is bonded or nonbonded having covalent, and van der Waals forces amongst each other [3, 5–7, 7–12, 14, 16–18, 48, 49]. Though the additivity of atomic and ionic radii was reported in the early history of size calculation, it was established later that the interatomic and interionic distance are a function of the crystal type, allotropic nature and coordination number [19–21, 23, 24, 50].

Determination of atomic and molecular size has paramount importance in chemical sciences. Several researchers had been trying to define atomic/molecule/ionic scope invoking different experimental and theoretical methods the trend is going on till today. Whereas theoretical models have a preference in predicting absolute atomic and ionic radii, innovative techniques are useful to compute relative size [51]. The concept of quantum mechanics has put a hindrance to visualise the rigid size of atom and ion. However, still, atom or ion can approach only up to a particular distance under the influence of a force during a chemical reaction. Basis of the empirical approach to evaluate a periodic descriptor is by taking in mind the conjoint actions of auxiliary periodic descriptors. Periodic law is fundamental, and the following periodicity is regarded as a validation of periodic descriptors. An analytical relation for the radial part of an atom as one electron function called slater-type orbitals (STO) [47] is as under

$$R_{nl}(r) = (2\xi)^{n+1/2}[(2n)!]^{-1/2} r^{n-1} exp(-\xi r) \tag{1}$$

where R_{nl} (r) = Radial part of atomic orbital, n = the principal quantum number of the electron, r = distance from the nucleus, ξ = orbital exponent = $\frac{(Z-S)}{n^*}$, Z = atomic number, S = screening constant, n^* = effective principal quantum number

$$\mathrm{Z} - \mathrm{S} = Z^* \tag{2}$$

Z^* = effective nuclear charge.

Radial charge density pronounces the behaviour of an electron in a province of space called an atomic orbital. Radial part of atom changes with distance from the nucleus due to the shape of the orbital. Radial charge density distribution function (()) can be defined [52] as follows

$$\rho(r) = 4\pi r^2 R^2 \tag{3}$$

From Eqs. (1) and (3), it may be written as

$$\begin{aligned} \rho(r) &= 4\pi r^2 (2\xi)^{2n+1}[(2n)!]^{-1} r^{2n-2} exp(-2\xi r) \\ \rho(r) &= 4\pi r^{2n} (2\xi)^{2n+1}[(2n)!]^{-1} exp(-2\xi r) \end{aligned} \tag{4}$$

Differentiating Eq. (4) concerning r

$$\frac{d\rho(r)}{dr} = [4\pi(2\xi)^{2n+1}[(2n)!]^{-1}exp(-2\xi r)][2nr^{2n-1} - 2\xi r^{2n}] \tag{5}$$

In terms of slater orbitals theoretical atomic radii ($r_{max=\frac{n}{\xi}}$), equating the right-hand side of Eq. (5) equal to zero and replacing r_{max} by r

$$r_{max} = \frac{n}{\xi} = r \tag{6}$$

The relationship [52] of an induced dipole with the applied electric field is given by

$$d = \alpha F \tag{7}$$

where d = induced dipole moment, α = polarizability, F = the applied electric field.

The polarizability can be defined by [53]as under

$$\alpha = r^3 \tag{8}$$

$$\alpha = \frac{3V}{4\pi} \tag{9}$$

$$V = \frac{4}{3}\pi r^3 \tag{10}$$

$$\alpha = Kr^3 \tag{11}$$

K = proportionality constant.

In the actual formula, K has used due to the inhomogeneity of the electron cloud [54]. Purcell [55] calculated the exact quantum mechanical calculation of polarizability of the hydrogen atom as under

$$\alpha = \frac{9}{2}a_0^3 \tag{12}$$

$$a_0 = Bohr\ radius$$

On comparing Eqs. (11) and (12), K is equal to the 4.5.

By putting the value of orbital exponent and the value of r in terms of volume in Eq. (1) we get a new formula as under

$$R_{nl}(r) = \left(2\frac{(Z-S)}{n^*}\right)^{n+1/2}[(2n)!]^{-1/2}\left[\left(\frac{3m}{4\pi d}\right)^{\frac{n-1}{6}}exp\left[\left(\frac{(Z-S)}{n^*}\right)\left(\frac{3m}{4\pi d}\right)^{\frac{1}{6}}\right]\right. \tag{13}$$

where d is density.

On considering Eq. (3) with Eq. (1)

$$r_{\max} = \frac{n}{\xi}$$

Hence

$$R_{nl}(r) = \left(2\frac{(n)}{r_{max}}\right)^{n+1/2} [(2n)!]^{-1/2}[(r_{max})^{n-1} exp[-n] \tag{14}$$

2.2 Computation of Atomic Density

Compare Eqs. (13) and (14) and considering the exponential value

$$exp^{-n} = exp\left[\left(-\frac{Z-S}{n^*}\right)\left(\frac{3m}{4\pi d}\right)^{\frac{1}{6}}\right] \tag{15}$$

and

$$-\mathrm{n} = [(-\frac{Z-S}{n^*})(\frac{3m}{4\pi d})^{\frac{1}{6}}] \tag{16}$$

On raising both the side by to power 6 in Eq. (16)

$$\begin{aligned}(-\mathrm{n})^6 &= \left[\left(-\frac{Z-S}{n^*}\right)^6\left(\frac{3m}{4\pi d}\right)\right] \\ (\mathrm{n})^6 &= \left[\left(\frac{Z-S}{n^*}\right)^6\left(\frac{3m}{4\pi d}\right)\right] \\ \mathrm{d} &= \left[\left(\frac{Z-S}{n^*}\right)^6\left(\frac{3m}{4\pi(\mathrm{n})^6}\right)\right]\end{aligned} \tag{17}$$

By use of Eq. (17), we can calculate the exact values of density of atoms which is computed with the use of orbital exponent for specification, as all the orbitals have different types of shapes.

R. Onofrio [56] pronounced that electroweak scale gravitational constant has roughly 1033 times to the Newtonian gravitational constant. Sesvatharam et al. [57] noticed that

$$\frac{G_w}{G_N} \cong (\frac{m_p}{m_e})^{10} \tag{18}$$

Considering an atom, the total mass of an atom is the sum of the product of the total number of proton and mass of the proton and the product of the total number of neutrons and mass of neutrons. Hence, we can replace the value of m_p by m_n

$$\frac{G_w}{G_N} \cong \left(\frac{m_n}{m_e}\right)^{10} \tag{19}$$

$$(m_p)^{10} = \frac{G_w}{G_N}(m_e)^{10} \tag{20}$$

where G_w = Weak Gravitational constant, G_e = Electromagnetic Gravitational Constant, G_N = Newtonian Gravitational Constant.

We can replace m in Eq. (17) as the mass of an atom is equal to the sum of the mass of protons and neutrons

$$\mathrm{d} = \left[\left(\frac{Z-S}{n^*}\right)^6\left(\frac{3\left(a*m_n+b*m_p\right)}{4\pi(\mathrm{n})^6}\right)\right] \tag{21}$$

where a represents the number of neutrons and b is used for a number of protons.

2.3 Computation of Atomic Hardness (η)

The strength of an element is the force of an atom in which the electrons attract to themselves when they are part of a compound. The chemical hardness of the atom can signify the resistance of an atom towards its the deformation or polarisation of its under a minute perturbation (***V***) by the chemical reaction. However, the exact value of this critical quantity is still at large [58–60]. Atomic hardness can be observed as an essential periodic descriptor for atoms which are useful in correlation, prediction and modelling of various many Physico- chemical qualities of an atom or a molecule. The correct values of atomic hardness are the foremost importance as they are required for modulation and understanding various biochemical syntheses as well as the structure of condensed matter. The hardness is a conceptual property of an atom, and it cannot be observed physically. Therefore, we cannot evaluate it experimentally. In fact, the probability of quantum mechanical calculation of hardness is eliminated in accordance with the rules of quantum mechanics. [61]. Ayers et al. [62] suggested that the atomic radius to be inversely proportional to the strength and vice versa. Geerlings et al. [63] to verify the Eqs. (14) and (17), let's consider the physical quantity, i.e. η (global hardness). According to the DFT [64–66] (Density Functional Theory), the operational definition for the hardness is as under

$$\eta = \frac{I-A}{2} \tag{22}$$

where I defined as the ionization potential of atoms and molecules and A is as the electron affinity of atoms and molecules.

Feynman et al. [67] suggested that the electric field around a charged particle as

$$E_{(q)} = \frac{q^2}{4\pi\varepsilon_0 2R} \tag{23}$$

where q used for charge and R = r used for radius

$$I = \frac{(q+e)^2}{2r} - \frac{q^2}{2r} \qquad (24)$$
$$A = -I$$

Hence

$$\eta = \frac{e^2}{2r} \qquad (25)$$

As $r = r_{max}$

$$\eta = \frac{e^2}{2n}\xi \qquad (26)$$

where n represents the principal quantum number of orbital, e is the electronic charge, $\xi represents the orbital exponent, and \eta$ represents the global hardness.

Hence

$$\eta \propto \xi$$

So, it is clear that global hardness is directly proportional to the orbital exponent. The global hardness can be calculated by Eq. (26), and it must be considered as a new scale of global hardness. By Eq. (26), We have computed the global hardness of 103 atoms of the periodic table and found a very nice correlation as global hardness is a periodic descriptor. We have achieved the atomic hardness of 103 atoms as a function of orbital exponent in Fig. 4.

3 Results and discussion

Periodicity is an essential chemical construct which has been defined through experimental and theoretical techniques. Many scientists have used theoretical, empirical methods to explain the qualitative description of periodic descriptors.

The terms atomic size is very prevalent in chemical research, and the notion has been principally active in explaining several physico-chemical properties of chemical species and is a beneficial parameter of electronic structure related concept. We have explored a simple method of computing the normalized size of atoms and brought together the 103 elements to expose how many diverse properties correlate with orbital exponent.

In this series, we have developed a new scale or formula to compute normalized radii (13,14), density (21) and global hardness (26) of 103 elements of the periodic table.

We have strained the size of atoms as a function of orbital exponent in two different fashions in Figs. 1 and 2 by using Eqs. (13) and (14), respectively.

To inspect the efficacy of the current method, well-known d-block and f-block screening effect in the periodic table are revealed through our computed data. The computed normalized radii of transition element of 3d, 4d, 4f and 5f are shown as a function of the orbital exponent in Figs. 3 and 4, respectively. The methods of

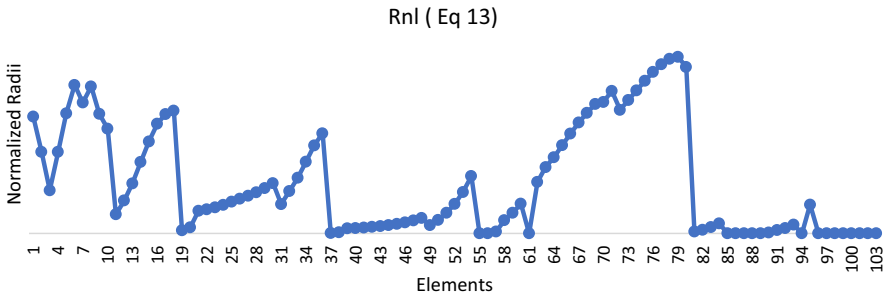


Fig. 1 The plot of computed normalized radii (R_{nl}) as a function of orbital exponent [70] using equation number 13

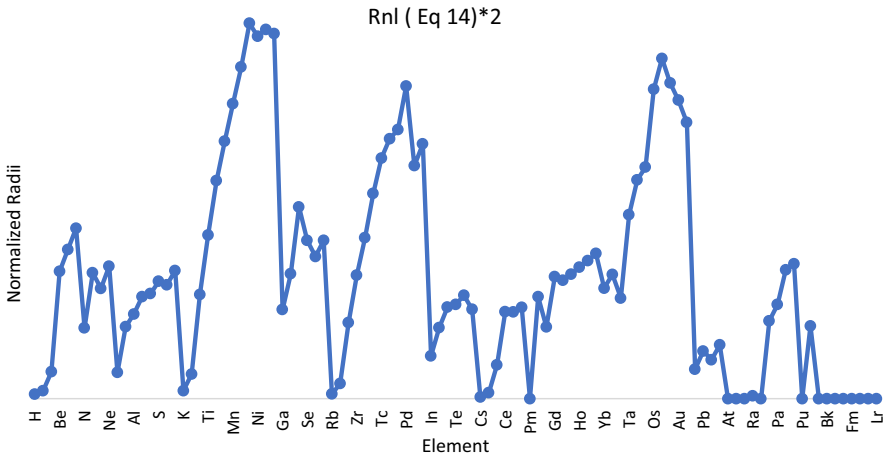


Fig. 2 The plot of computed normalized radii (R_{nl}) as a function of orbital exponent [70] computed using equation number 14

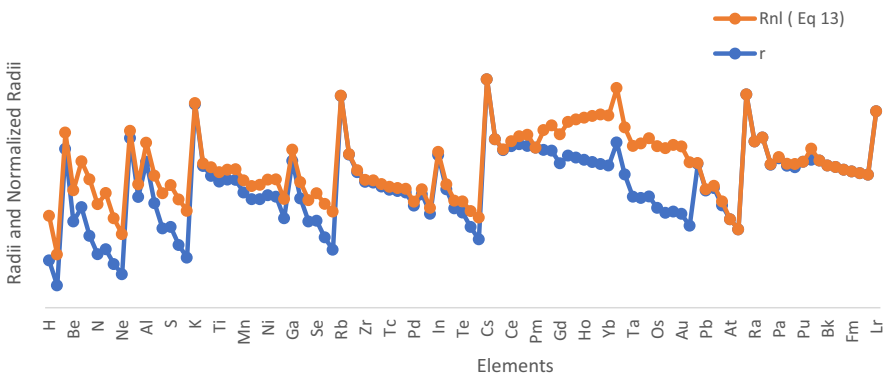


Fig. 3 Comparative study of computed normalized radii (R_{nl}) by equation number 13 and radii [46]

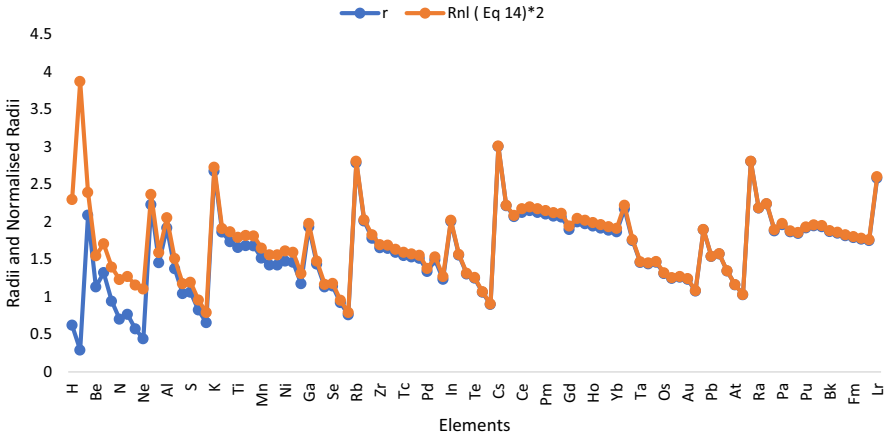


Fig. 4 Comparative study of computed normalized radii (R_{nl}) by equation number 14 and radii [46]

computation of normalized atomic radii have been revealed by the physical properties like:

(A) the principal quantum number of the electron (B) distance from the nucleus (C) orbital exponent (D) atomic number (E) screening constant (F) effective principal quantum number. Our calculated normalised radii of 103 elements have to be followed in a row and group of the periodic table in a generalized way like.

i) Normalized radii decrease along the row in the periodic table.
ii) Normalized radii increase down the group in the periodic table.
iii) d–block (lanthanides) contraction is clearly shown in Figs. 1 and 2.
iv) f–block atoms (actinides) contraction, also viewed in Figs. 1 and 2.
v) The periodicity of atomic size should be isomorphic with the periodicity of the orbital exponent.
vi) The periodicity of normalized radii should be harmonized with the periodicity of atomic radii [46] in Fig. 3.

Horizontally rightward movement and vertically downward will be candid if the sizes of the atoms are generalized as a function of atomic number.

Slater suggested that the principle maxima of the radial charge density distribution function on the periphery of the atom may be measured as its theoretical orbital exponent. The observations transpire from a comparative study [68] of the sizes of atoms.

We have plotted the computed density of atoms as a function of orbital exponent in Fig. 5. The universal advent of the plot of atomic density, as revealed in Fig. 5, is periodic in nature.

In Fig. 6, a comparative study has been shown for the element with atomic number 1 to 18. A similar trend for both of the plot validates our study. The alkali metals have the smallest density, and the ideal gas atoms have the most significant atomic density, and the density increases harmonically horizontally in a period. Hence, it is

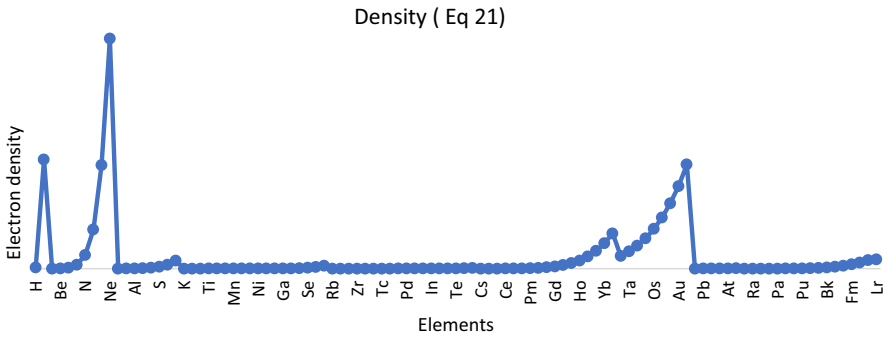


Fig. 5 The plot of Atomic electron density using Eq. 21 as a function of orbital exponent [70]

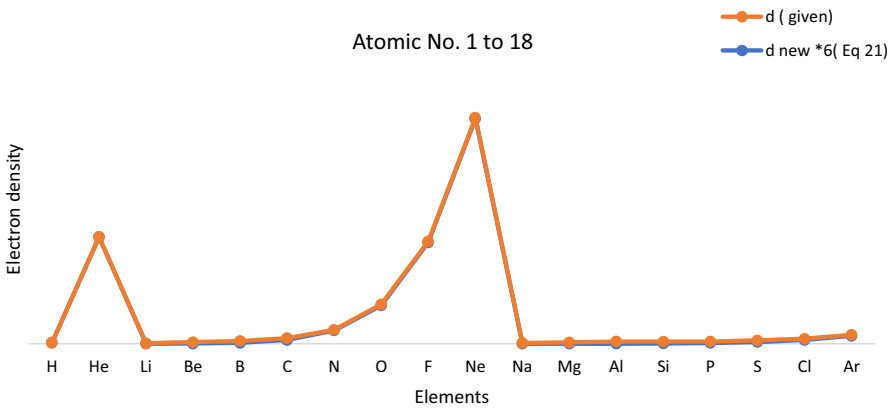


Fig. 6 Comparative study of computed atomic electron density of atomic number 1 to 18 and density [68]

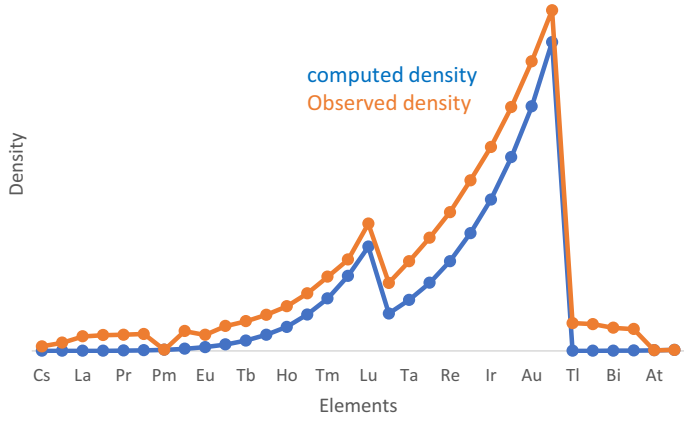


Fig. 7 Comparative study of computed atomic density of atomic number 55 to 85 and density [68]

clear that the computed atomic density in terms of the orbital exponent of the present work expressively exhibits its qualitative periodicity.

Through a comparison between the computed data of atomic density of current calculation *vis-à-vis* already reported data [68] in Fig. 7, we propose that the theoretically computed values of atomic density of elements from Cs atomic number 55 to Lr atomic number 103 have a good correlation with observed data. Thus we conclude that the result is encouraging both extensively and intensively.

Invoking the Eq. 21, we would be able to compute the actual density of 103 atoms because we are considering the physical factor which affects the density at various conditions. A notable characteristic is observed when we reduce the temperature to 4 K and retain helium inside it, helium turns into a liquid. It acts against the gravitational rules, the viscosity gets increased, and helium flows without any outflow of its kinetic energy. The main reason for such effect is the variation of density at such temperature (Fig. 8).

Even though the atomic hardness is an atomic property and depends upon the atomic size, it is not an unswervingly quantifiable experimental quantity of an isolated atom, and it has no quantum mechanical operator. From an analysis of the manifest common inter-relationship between atomic hardness (η), Ionisation energy and electron affinity and their relation with atomic radii, the direct relationship between atomic hardness and the orbital exponent is self-evident. It seems from Fig. 9 that the profile for atomic hardness and the profile for orbital exponent are both periodic and reciprocally homomorphic.

From the Eq. 26, we can conclude that the global hardness turns up to be directly proportional to orbital exponent which we only used to consider as merely a physical quantity with no significance while deducing the characteristic of an atom. But from now we should consider it as a periodic descriptor since we would be able to differentiate atoms with just knowing it orbital exponent.

Hence, it is evident from the Fig. 10 that the computed atomic hardness in terms of the orbital exponent of the 103 atoms has a good correlation with the effective principal

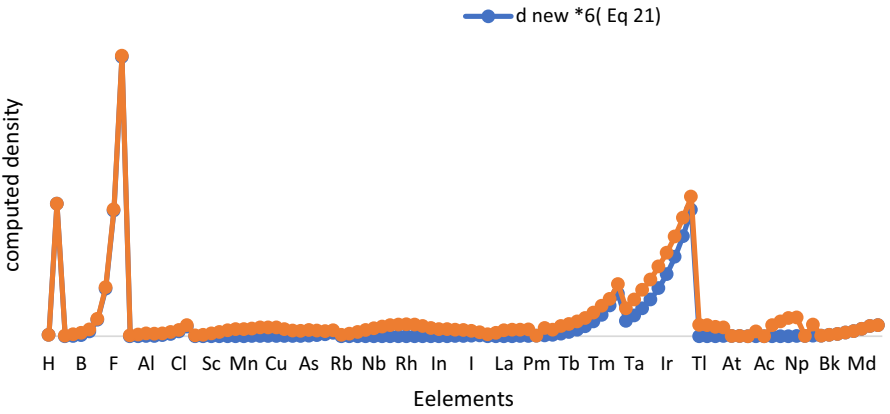


Fig. 8 Comparative study of computed atomic electron density of 103 elements of the periodic table and density [67]

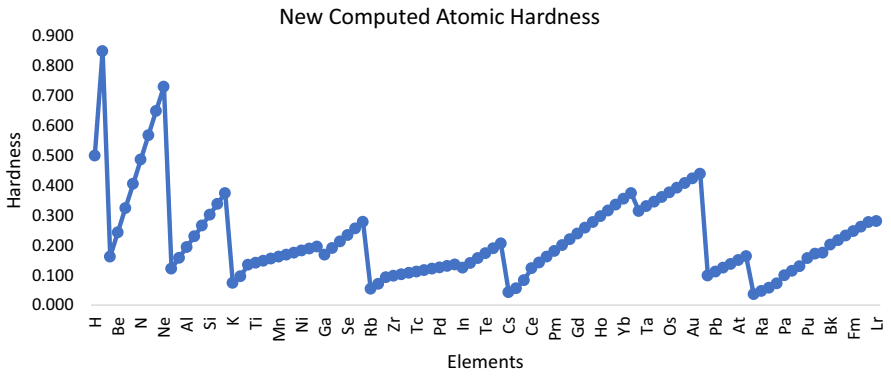


Fig. 9 A plot of Atomic Hardness (η) as a function of orbital exponent [70]

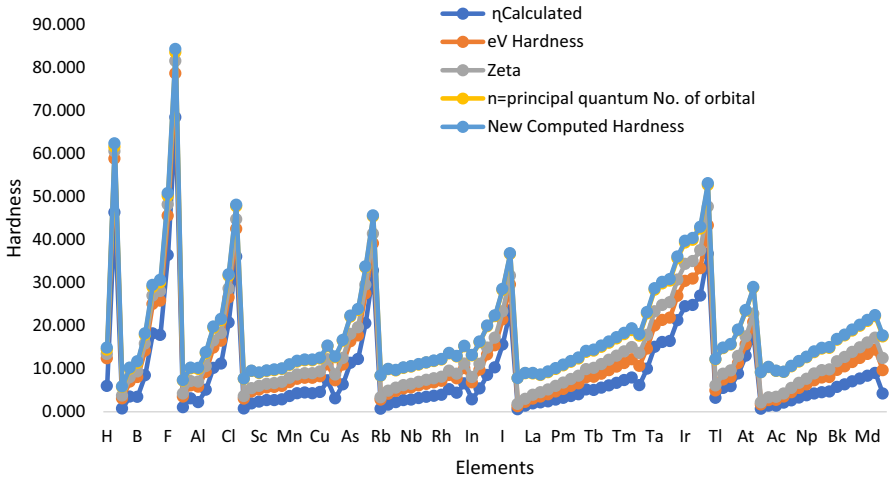


Fig. 10 Comparative study of computed hardness and different calculated hardness [47, 69, 70]

quantum number, the theoretically calculated atomic hardness in terms of energy [69] and computed hardness invoking force model [70].

The normalized atomic radii of current calculation have a reasonable correlation with other available theoretical radii computed through the more erudite methods. Thus, the present approach of computing the size of atoms, density and atomic hardness modestly seems to be a definite scheme.

4 Conclusion

A new theoretical approach is suggested to define the normalized radii, density and atomic hardness of 103 elements in the periodic table. Our computed data significantly exhibits the periodicity. Semi and Full filled shell structures are also distinct in our results. A successful comparative analysis between our computed data vis-à-vis existing experimental / theoretical results establishes our model.

Acknowledgements Dr. Tanmoy Chakraborty is thankful to Sharda University for providing computational resources and research facility.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

References

1. D. Ghosh, R. Biswas, Theoretical calculation of absolute radii of atoms and ions. Part 1. The atomic radii. Int. J. Mol. Sci. **3**(2), 87–113 (2002)
2. S.T.K. Gazi, D.C. Ghosh, Computation of the atomic radii through the conjoint action of the effective nuclear charge and the ionisation energy. Mol. Phys. **108**(16), 2081–2092 (2010)
3. L. Pauling, *The Nature of the Chemical Bond*, vol. 260 (Cornell University Press, Ithaca, 1960), pp. 3175–3187
4. B. Cordero, V. Gómez, A.E. Platero-Prats, M. Revés, J. Echeverría, E. Cremades, S. Alvarez, Covalent radii revisited. Dalton Trans. **21**, 2832–2838 (2008)
5. R.T. Shannon, C.T. Prewitt, Effective ionic radii in oxides and fluorides. Acta Crystallogr. Sect. B Struct. Crystallogr. Cryst. Chem. **25**(5), 925–946 (1969)
6. R.D. Shannon, Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides. Acta Crystallogr. Section A Cryst. Phys. Diffract. Theor. General Crystallogr **32**(5), 751–767 (1976)
7. J.T. Waber, D.T. Cromer, Orbital radii of atoms and ions. J. Chem. Phys. **42**(12), 4116–4123 (1965)
8. P. Politzer, R.G. Parr, D.R. Murphy, Relationships between atomic, chemical potentials, electrostatic potentials, and covalent radii. J. Chem. Phys. **79**(8), 3859–3861 (1983)
9. B.M. Deb, P.K. Chattaraj, New quadratic nondifferential Thomas-Fermi-Dirac-type equation for atoms. Phys. Rev. A **37**(10), 4030 (1988)
10. S. Nath, S. Bhattacharya, P.K. Chattaraj, Density functional calculation of a characteristic atomic radius. J. Mol. Struct. (Thoechem) **331**(3), 267–279 (1995)
11. J.E. Huheey, E.A. Keiter, R.L. Keiter, O.K. Medhi, *Inorganic Chemistry: Principles of Structure and Reactivity* (Pearson Education, India, 2006).
12. R.T. Sanderson, The covalent radius of xenon. Inorg. Chem. **2**(3), 660–661 (1963)
13. R.T. Sanderson, The covalent radius of radon and the electronegativities of gold, mercury, thallium, lead, and bismuth. J. Inorg. Nuclear Chem. **7**, 288 (1958)
14. T.L. Meek, Electronegativities of the noble gases. J. Chem. Educ. **72**(1), 17 (1995)
15. A. Bondi, van der Waals volumes and radii. J. Phys. Chem. **68**(3), 441–451 (1964)
16. P.G. Ashmore, R.M. Noyes, L. Valentine, N. Miller, G.C. Bond, J.S. Rowlinson, F.S. Dainton, General and physical chemistry. Ann. Rep. Progress Chem. **52**, 7–92 (1955)
17. V.M. Goldschmidt, T. Barth, G. Lunde, W.H. Zachariasen, Geochemical distribution law of the elements. VII. Summary of the chemistry of crystals. Skr. Nor. Vidensk. Akad **1**, 1–117 (1926)
18. V.M. Goldschmidt, Crystal structure and chemical correlation. Ber. Deut. Chem. Ges. **60**, 1263–1296 (1927)
19. V.M. Goldschmidt, The distribution of the chemical elements 1. Nature **124**, 15–17 (1929)

20. L.H. Ahrens, The significance of the chemical bond for controlling the geochemical distribution of the elements-part 1. Phys. Chem. Earth **5**, 1–54 (1964)
21. D. Robert Hay, P.D. Parikh, Valence bond interpretation of elastic anisotropy in BCC transition metals. Phil. Mag. **20**(166), 753–758 (1969)
22. W.H. Zachariasen, A set of empirical crystal radii for ions with inert gas configuration. Zeitschrift für Kristallographie-Cryst. Mater. **80**(1–6), 137–153 (1931)
23. W.H. Zachariasen, Crystal radii of the heavy elements. Phys. Rev. **73**(9), 1104 (1948)
24. W.L. Bragg, XVIII The arrangement of atoms in crystals. Lond. Edinburgh Dublin Philos. Mag. J. Sci. **40**(236), 169–189 (1920)
25. J.K. Nagle, Atomic polarizability and electronegativity. J. Am. Chem. Soc. **112**(12), 4741–4747 (1990)
26. J.C. Slater, Atomic radii in crystals. J. Chem. Phys. **41**(10), 3199–3204 (1964)
27. J.C. Slater, *Quantum Theory of Molecules and Solids: Symmetry and Energy Bands in Crystals*, vol. 2 (McGraw-Hill, New York, 1963).
28. D.R. Hartree, The calculation of atomic structures (1957).
29. E. Clementi, D.L. Raimondi, Atomic screening constants from SCF functions. J. Chem. Phys. **38**(11), 2686–2689 (1963)
30. D. Liberman, J.T. Waber, D.T. Cromer, Self-consistent-field Dirac-Slater wave Functions for atoms and ions. I. Comparison with previous calculations. Phys. Rev. **137**(1), A27 (1965)
31. C. Froese, Hartree—Fock parameters for the atoms helium to radon. J. Chem. Phys. **45**(5), 1417–1420 (1966)
32. E. Clementi, D.L. Raimondi, W.P. Reinhardt, Atomic screening constants from SCF functions. II. Atoms with 37 to 86 electrons. J. Chem. Phys. **47**(4), 1300–1307 (1967)
33. C. Fisk, S. Fraga, Atomic Radii. In *Anales de fisica* . Facultad de fisica quimica ciudad univ, 3 Madrid, vol. 65, (Real Soc Espan Quimica, Spain), p. 135 (1969).
34. A. C. Larson, J. T. Waber. *Self-consistent field Hartree Calculations for Atoms and Ions (No. LA-4297)*. Los Alamos Scientific Lab., N. Mex (1969).
35. C.F. Fischer, Average-energy-of-configuration Hartree-Fock results for the atoms helium to radon charlotte Froese Fischer. Atom. Data Nucl. Data Tabl. **12**, 301–399 (1972)
36. C.W. Kammeyer, D.R. Whitman, Quantum mechanical calculation of molecular radii. I. Hydrides of elements of periodic groups IV through VII. J. Chem. Phys. **56**(9), 4419–4421 (1972)
37. S. Fraga, J. Karwowski, K.M.S. Saxena, Hartree-Fock values of coupling constants, polarizabilities, susceptibilities, and radii for the neutral atoms, helium to nobelium. At. Data Nucl. Data Tables **12**(5), 467–477 (1973)
38. C.F. Fischer. Atom. Data 4 (1972) 301. Atom. Data Nucl. Data, **12**, 87 (1973).
39. J.P. Desclaux, Atomic Data Nucl. Data Tables **12**(4), 311 (1973)
40. R.J. Boyd, The relative sizes of atoms. J. Phys. B At. Mol. Phys. **10**(12), 2283 (1977)
41. B.M. Deb, R. Singh, N. Sukumar, A universal density criterion for correlating the radii and other properties of atoms and ions. J. Mol. Struct. (Thoechem) **259**, 121–139 (1992)
42. D. Ghosh, R. Biswas, Theoretical calculation of absolute radii of atoms and ions. Part 1. The atomic radii. Int. J. Mol. Sci. **3**(2), 87–113 (2002)
43. M.V. Putz, N. Russo, E. Sicilia, Atomic radii scale and related size properties from density functional electronegativity formulation. J. Phys. Chem. A **107**(28), 5461–5465 (2003)
44. P. Pyykko, S. Riedel, M. Patzschke, Chem. Eur. J.11: 3511 (2005).
45. D.C. Ghosh, R. Biswas, T. Chakraborty, N. Islam, S.K. Rajak, J. Mol. Struct. (Theochem) **865**, 60 (2008)
46. T. Chakraborty, K. Gazi, D.C. Ghosh, Computation of the atomic radii through the conjoint action of the effective nuclear charge and the ionisation energy. Mol. Phys. **108**(16), 2081–2092 (2010)
47. J.C. Slater, Atomic shielding constants. Phys. Rev. **36**(1), 57 (1930)
48. R.T. Sanderson, The covalent radius of radon and the electronegativities of gold, mercury, thallium, lead, and bismuth. J. Inorg. Nucl. Chem. **7**, 288 (1958)
49. A. Bondi, Vander Waals volumes and radii. J. Phys. Chem. **68**(3), 441–451 (1964)
50. W.H. Zachariasen, A set of empirical crystal radii for ions with inert gas configuration. Zeitschrift-für Kristallographie-Crystall. Mater. **80**(1–6), 137–153 (1931)
51. P.W. Atkins, R.S. Friedman, *Molecular Quantum Mechanics*, 3rd edn. (Oxford University Press, Oxford, 1997).
52. T. Brinck, J.S. Murray, P. Politzer, J. Chem. Phys. **98**, 4305 (1993)
53. S. Hati, D. Dutta, J. Phys. Chem. **98**, 10451 (1994)

54. E.M. Purcell, Berkley Physics Course, TMH Edition, Vol. 2, (Tata McGraw-Hill Publishing Company, Bombay) (1963).
55. O. Roberto, On weak interactions as short-distance manifestations of gravity. Mod. Phys. Lett. A **28**, 1350022 (2013)
56. U.V.S. Seshavatharam, S. Lakshminarayana, Role of four gravitational constants in nuclear structure. Mapana J. Sci. **18**(1), 21–46 (2019)
57. R.S. Mulliken, Electronic population analysis on LCAO–MO molecular wave functions I. J. Chem. Phys. **23**(10), 1833–1840 (1955)
58. R.G. Parr, R.G. Pearson, Absolute hardness: companion parameter to absolute Electronegativity. J. Am. Chem. Soc. **105**(26), 7512–7516 (1983)
59. G. Klopman, Chemical reactivity and the concept of charge-and frontier-controlled Reactions. J. Am. Chem. Soc. **90**(2), 223–234 (1968)
60. D.C. Ghosh, T. Chakraborty, Gordy's electrostatic scale of electronegativity revisited. J. Mol. Struct. (Thoechem) **906**(1–3), 87–93 (2009)
61. P.W. Ayers, The physical basis of the hard/soft acid/base principle. Faraday Discuss. **135**, 161–190 (2007)
62. P. Geerlings, F. De Proft, W. Langenaeker, Conceptual density functional theory. Chem. Rev. **103**(5), 1793–1874 (2003)
63. R.G. Parr, R.G. Pearson, J. Am. Chem. Soc. **105**, 7512 (1983)
64. R.G. Pearson, J. Chem. Educ. **64**, 561 (1987)
65. R.G. Parr, W. Yang, *Density Functional Theory of Atoms and Molecules* (Oxford University Press, New York, 1989).
66. R.P. Feynman, R.B. Leighton, M. Sands, The Feynman Lecture on Physics, Addison– Wesley: Mass., Vol. II., (1964).
67. P.B. Janardhan, B. Sivasankar, *A Text-Book of Inorganic Chemistry* (Oxford and IBH, New Delhi, 1978).
68. D.C. Ghosh, N. Islam, Semiempirical evaluation of the global hardness of the atoms of 103 elements of the periodic table using the most probable radii as their size descriptors. Int. J. Quantum Chem. **110**(6), 1206–1213 (2010)
69. D.C. Ghosh, R. Biswas, Theoretical calculation of absolute radii of atoms and ions. Part 1. The atomic radii. Int. J. Mol. Sci **3**(2), 87–113 (2002)
70. R.P. Shalini, T. Chakraborty, Theoretical Computation of Periodic Descriptors Invoking Periodic Properties, in *Chemical Science and Engineering Technology*. ed. by C.A. Suresh, C. Tanmoy (Apple Academic Press, Waretown, 2019), pp. 31–40

Theoretical Chemistry Accounts (2021) 140:59
https://doi.org/10.1007/s00214-021-02772-7

REGULAR ARTICLE

Structure and electronic properties of $[Au_nV]^{\lambda}$ ($n = 1–9; \lambda = 0, \pm 1$) nanoalloy clusters within density functional theory framework

Prabhat Ranjan[1] · Shayeri Das[1] · Poonam Yadav[2] · Hiteshi Tandon[2] · Shalini Chaudhary[2] · Babita Malik[2] · Sandip Kumar Rajak[3] · Vandana Suhag[4] · Tanmoy Chakraborty[5]

Received: 10 January 2021 / Accepted: 29 April 2021

Abstract

The structure and physico-chemical properties of vanadium-doped gold nanoalloy clusters $[Au_nV]^{\lambda}$ ($n = 1–9$; $\lambda = 0, \pm 1$) are reported within density functional theory framework. The ground state configurations reveal that neutral and anionic clusters favour planar structures for $n = 1–9$, whereas cationic clusters show three-dimensional geometries for $n = 7–9$. Our computed results show that the highest occupied molecular orbital (HOMO)–lowest unoccupied molecular orbital (LUMO) energy gap of neutral, cationic and anionic nanoalloy clusters is in the range of 1.41 eV to 2.50 eV, 1.04 eV to 2.37 eV and 1.25 eV to 2.24 eV, respectively. It justifies the applications of $[Au_nV]$ clusters in optoelectronic, photovoltaic and nonlinear optical devices. The HOMO–LUMO energy gap and molecular hardness reveal a fascinating odd–even alteration as a function of cluster size. The electronegativity, electrophilicity index and dipole moment of cationic clusters are more as compared to neutral and anionic clusters. The computed dipole polarizability has a linear relationship with the cluster size. Calculated bond length, dissociation energy and vibrational frequency for species $[Au_2]^{\lambda}$ and $[AuV]^{\lambda}$ ($\lambda = 0, \pm 1$) are in agreement with the experimental results.

Keywords Gold–vanadium nanoalloy cluster · DFT · HOMO–LUMO energy gap · Molecular hardness · Electronegativity

1 Introduction

Since last few decades, gold and impurity-doped gold nanoalloy clusters have been gaining a lot of interest due to significant technological applications in fabrication of nanoscale devices, material science, bio-science, medical science and catalysis [1–4]. Gold nanoalloy clusters display a unique structural, electronic, optical and magnetic properties which is different from other coin-age metals like copper and silver [5, 6]. The distinctive physico-chemical properties of gold clusters are due to significant relativistic effects [7, 8]. It is well established through theory as well as experiment that physico-chemical properties of nanoalloy clusters can be noticeably altered by incorporating suitable impurity [9, 10]. It is reported that physico-chemical properties of gold clusters can be tuned through proper doping of transition metal atoms in gold clusters [11, 12]. These bimetallic nanoalloy clusters show distinct physical and chemical

Published as part of the special collection of articles "Festschrift in honour of Prof. Ramon Carbó-Dorca".

✉ Tanmoy Chakraborty
tanmoychem@gmail.com; tanmoy.chakraborty@sharda.ac.in

Prabhat Ranjan
prabhat.ranjan@jaipur.manipal.edu;
prabhat23887@gmail.com

[1] Department of Mechatronics Engineering, Manipal University Jaipur, Dehmi Kalan 303007, India

[2] Department of Chemistry, Manipal University Jaipur, Dehmi Kalan 303007, India

[3] Department of Chemistry, Dumkal College, Murshidabad 742406, India

[4] DIT University, Dehradun 248009, India

[5] Department of Chemistry and Biochemistry, School of Basic Sciences and Research, Sharda University, Greater Noida 201310, India

properties different from pure and mono-metallic clusters. It specifies that impurity of atoms plays an important role in enhancing the physico-chemical properties and structure of bimetallic clusters [13, 14]. These clusters are suitable candidates for applications in nanoscience, semiconductors and life sciences [15, 16].

Among the transition metals of the periodic table, vanadium is considered as one of the important transition metals due to its applications in memory and sensing devices [17]. Creveling et al. [18] investigated the gold–vanadium alloys by using heat treatment method. They revealed that molecular system Au_4V displays interesting ferromagnetic properties at 60° K. Jaque et al. [19] investigated Cu clusters by using conceptual density functional theory (CDFT) approach. They reported that CDFT method is very helpful in computing the physical and chemical properties of metallic clusters. Poater et al. [20] have performed a detailed investigation on Cu clusters and Cu monocarbonyls cluster by using CDFT methodology. Seminario et al. [21] studied small gold clusters Au_n ($n = 1$–4) by using DFT technique. Authors reported that tetrahedral structure with the lowest spin multiplicity is not the ideal geometry for neutral Au_4 however this structure is preferred for charged clusters. Paz-Borbon et al. [22] studied gold clusters supported on pristine and MgO surface with the help of DFT technique. Yan et al. [23] reported the electron transport characteristic in Au–Si interface by using DFT method. Authors stated that Au–Si junctions can be suitable for chemical sensors and switching devices. Yang et al. [24] investigated transition metal-doped gold clusters MAu_{24} (M = V, Cr, Mn, Fe, Co and Ni) by using DFT approach. They found that these atoms can be doped steadily into Au_{24} cluster without making any significant change in the atomic and electronic geometry of the parent cluster. Du et al. [25] performed extensive study for the structure of transition metal-doped gold clusters MAu_{12} (M = 3d–5d) by using DFT methodology. They found that Mo- and W-doped gold clusters display a perfect icosahedron cage geometry. Ben-Xia et al. [26] studied structural, electronic and magnetic properties of transition metal-doped gold clusters Au_5M (M = Sc–Zn) by using DFT technique. The ground state configuration of these clusters reveals that M atom prefers to be placed at the highly coordinated site. Torres et al. [27] studied $[Au_nM]^+$ ($n \leq 9$; M = Sc, Ti, V, Cr, Mn, Fe, Au) clusters by using Density Functional Theory (DFT) methodology. They found the lowest energy structure as $n = 6$ for Sc, $n = 5$ for Ti, $n = 5$, 7 for V, Cr, Mn and Fe. Li et al. [28] investigated $[MAu_6]^-$ (M = Ti, V, Cr) clusters by using photoelectron spectroscopy and DFT technique. The result shows that neutral and anionic clusters favour planar geometry in which transition metal is placed at the centre and it also displays large magnetic moment. Doping of transition metals in gold clusters enhances the physico-chemical properties and bond strength of bimetallic clusters [14, 29]. Blades et al. [30] investigated the geometries, stabilities and magnetic properties of $[VCu_x]^+$, $[VAg_x]^+$ and $[VAu_x]^+$ clusters by using DFT method. They stated that atomic configuration of the host cluster is very crucial in influencing the bonding properties of an impure atom with a localized spin magnetic moment. Hua et al. [31] reported that stabilities and binding energies of aluminium clusters are enhanced after doping of vanadium in aluminium clusters. Medel et al. [32] reported that stability of neutral and cationic vanadium-doped silver cluster depends on the shape of the cluster. Furthermore, they pointed out that for larger clusters, the lowest energy structure is transit from planar to 3-d structure whereas the second lowest energy structure of $[Ag_7V]^+$ is occupied with 1S and 1P shells. Nhat et al. [33] studied neutral and anionic vanadium-doped gold clusters by using DFT technique. The study shows that neutral clusters with even number of atoms favour a high spin state. Recently, Die et al. [10] reported vanadium-doped copper clusters by using DFT methodology. They revealed that doping of vanadium atom in copper clusters enhanced the chemical stability, binding energy and other physical and chemical properties of host clusters.

In this report, structure and Physico-chemical properties of $[Au_nV]^\lambda$ ($n = 1$–9; $\lambda = 0, +1, -1$) nanoalloy clusters are systematically investigated by using DFT methodology. The ground state configurations and low-lying isomers of neutral, cationic and anionic Au_nV nanoalloy clusters are studied. In addition, we have also investigated DFT-based global descriptors HOMO–LUMO energy gap, molecular hardness, softness, electronegativity, electrophilicity index, dipole moment and dipole polarizability of $[Au_nV]^\lambda$ nanoalloy clusters. Our data reveal an interesting relationship between HOMO–LUMO energy gap and DFT-based descriptors of Au_nV nanoalloy clusters.

2 Computational details

Among several computational techniques, DFT has emerged as one of the most successful approaches to deal with physical and chemical properties of nanoalloy clusters. DFT methods have provided a new dimension in the field of nanoscience, electronics, physics, chemistry, material science, life sciences and even earth sciences [34]. In this report, nanoalloy clusters of $[Au_nV]^\lambda$ ($n = 1$–9; $\lambda = 0, \pm 1$) are investigated within density functional theory framework. Geometry optimization and modelling have been performed using computational software Gaussian 16 [35]. For optimization, we have used hybrid functional Becke three-parameter Lee–Yang–Parr exchange correlation functional (B3LYP) and basis set LANL2DZ. The hybrid functional B3LYP has been proven very efficient

for bimetallic clusters especially for impurity-doped gold clusters [36]. In recent years, B3LYP/LANL2DZ is widely used to compute physico-chemical properties of bimetallic clusters [10, 14, 15, 37].

With the help of Koopmans' Approximation, Ionization Energy (IE) and Electron Affinity (EA) of $[Au_nV]^{\lambda}$ nanoalloy clusters are calculated by using the following approach [38]

$$I = -\varepsilon_{\mathrm{HOMO}} \tag{1}$$

$$A = -\varepsilon_{\mathrm{LUMO}}. \tag{2}$$

The conceptual density functional theory (CDFT)-based global descriptors viz. HOMO–LUMO energy gap, molecular hardness (η), softness (S), electronegativity (χ) and electrophilicity index (ω) are also computed by using the following equations

$$\chi = -\mu = \frac{I + A}{2} \tag{3}$$

where μ represents the chemical potential of the system.

$$\eta = \frac{I - A}{2} \tag{4}$$

$$S = \frac{1}{2\eta} \tag{5}$$

$$\omega = \frac{\mu^2}{2\eta}. \tag{6}$$

3 Results and discussion

3.1 Geometrical structures of V-doped Au nanoalloy clusters, $[Au_nV]^{\lambda}$ ($n = 1$–9; $\lambda = 0, +1, -1$)

The ground state configurations and low-lying isomers of vanadium-doped gold clusters are discussed in this section. Several isomers are optimized during the quest for the lowest energy structure of Au_nV nanoalloy clusters, however only the four most stable structures for each cluster are depicted in Figs. 1, 2 and 3 for neutral, cationic and anionic state, respectively. The isomers are placed in low to high energy order.

3.2 Neutral Au_nV nanoalloy clusters ($n = 1$–9)

The lowest energy structure and low-lying isomers of neutral vanadium-doped gold nanoalloy clusters are shown in Fig. 1. The low-lying isomers are arranged in the format of N–A–X, where N is the neutral cluster, A is total number of gold atoms and X represents the position of the lowest energy structure of each cluster. Furthermore, symmetry, spin multiplicity state and energy difference between ground state configuration and isomers for each cluster are also presented in Fig. 1. The optimized results show that ground state configurations of neutral Au_nV ($n = 1$–9) nanoalloy clusters evidently favour planar structure. The lowest energy structure for AuV nanoalloy cluster shows singlet spin with bond length between Au and V is 2.514 Å, whereas the bond length between Au–Au for Au_2 cluster is computed as 2.49 Å. It shows that bond length of AuV is larger than that of Au_2. The computed bond lengths for Au_2 and AuV are in agreement with the previous reports [33]. The most stable structure (N-2–1) of Au_2V nanoalloy cluster is of symmetry group C_{2V} with spin multiplicity sextet. The average distance between Au–V is 2.686 Å and the angle between Au–V–Au is 62.35°. The second most stable structure (N-2–2) with symmetry form $C_{\infty V}$ is a linear structure with spin state doublet. It is energetically 1.567 eV higher than the most stable structure (N-2–1). The isomer N-2–3 with spin state quartet and point group C_{2V} is of triangular structure and it is energetically less stable than N-2–1 and N-2–2 by 1.604 eV and 0.037 eV, respectively.

The lowest energy structure of Au_3V nanoalloy cluster is N-3–1 isomer with symmetry group C_s and singlet spin state. The isomer N-3–1 with Y-shape geometry is obtained by adding one gold atom to isomer N-2–3. The isomer N-3–2 with singlet spin state and symmetry group D_{3h} is energetically very close to the ground state configuration N-3–1. Nhat et al. [33] found the isomer N-3–2 as the most stable structure for Au_3V cluster, whereas, our optimization result suggests that structure N-3–2 is energetically less stable than N-3–1 by 0.006 eV. The isomer N-3–3 is a rectangular structure with point group C_{2V} and singlet spin state. The isomer N-3–3 is less stable by 0.057 eV and 0.051 eV from isomers N-3–1 and N-3–2, respectively. Isomer N-3–4 is obtained by exchanging the position of gold and vanadium atoms in the lowest energy structure N-3–1. The isomer N-3–4 with symmetry group C_1 and singlet spin is 1.26 eV less stable than the ground state configuration N-3–1.

The most stable structure of Au_4V nanoalloy cluster is isomer N-4–1 with point group C_{2V} and doublet spin state. It is obtained by adding two gold atoms on opposite sides of isomer N-2–3. The structure N-4–1 is in agreement with the previous result reported by Nhat et al. [33]. The isomer N-4–2 with symmetry group C_s and spin multiplicity state doublet, is optimized from structure N-3–3 by addition of a gold atom. It is energetically less stable by 0.644 eV than the most stable isomer N-4–1. Isomer N-4–3 with symmetry group C_{2V} and doublet spin state is higher in energy than the most stable structure by 0.715 eV. The optimized

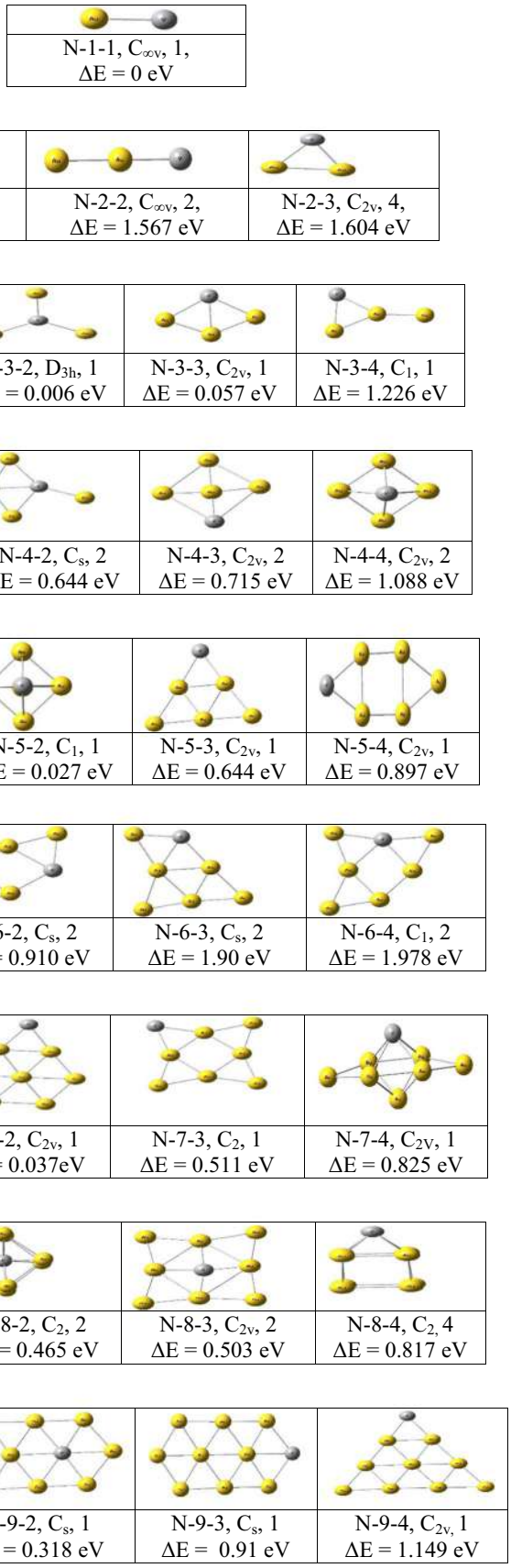
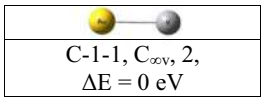
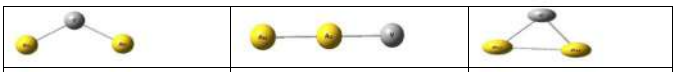


Fig. 1 The ground state configuration and low-lying isomers of neutral Au_nV nanoalloy clusters ($n = 1$–9)

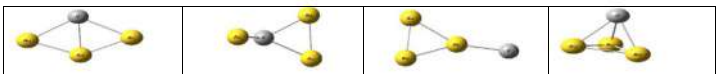
Fig. 2 The ground state configuration and low-lying isomers of cationic $[Au_nV]^+$ nanoalloy clusters ($n = 1$–9)



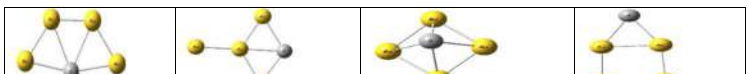
C-1-1, $C_{\infty v}$, 2,
ΔE = 0 eV



C-2-1, C_{2v}, 1, ΔE = 0 eV	C-2-2, $C_{\infty v}$, 1, ΔE = 0.916 eV	C-2-3, C_{2v}, 1, ΔE = 1.281 eV



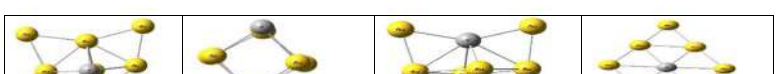
C-3-1, C_{2v}, 2 ΔE = 0 eV	C-3-2, C_{2v}, 2 ΔE = 0.027 eV	C-3-3, C_2, 2 ΔE = 0.104 eV	C-3-4, C_{2v}, 2 ΔE = 0.690 eV



C-4-1, C_{2v}, 1 ΔE = 0 eV	C-4-2, C_{2v}, 1 ΔE = 0.323 eV	C-4-3, C_{2v}, 1 ΔE = 0.538 eV	C-4-4, C_{2v}, 1 ΔE = 1.107 eV

C-5-1, C_{2v}, 2 ΔE = 0 eV	C-5-2, C_{2v}, 2 ΔE = 0.411 eV	C-5-3, C_{2v}, 2 ΔE = 0.530 eV	C-5-4, C_1, 2 ΔE = 1.017 eV

C-6-1, C_1, 1 ΔE = 0 eV	C-6-2, D_{2h}, 1 ΔE = 0.138 eV	C-6-3, C_1, 1 ΔE = 0.532 eV	C-6-4, C_s, 1 ΔE = 0.975 eV

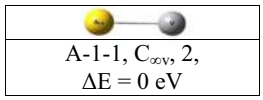


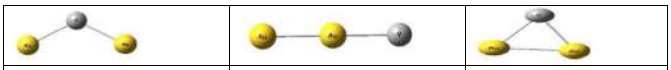
C-7-1, C_2, 2 ΔE = 0 eV	C-7-2, C_{2v}, 4 ΔE = 0.365 eV	C-7-3, C_2, 2 ΔE = 0.762 eV	C-7-4, C_2, 2 ΔE = 1.210 eV

C-8-1, C_2, 1 ΔE = 0 eV	C-8-2, C_2, 1 ΔE = 0.106 eV	C-8-3, C_1, 1 ΔE = 0.391 eV	C-8-4, $C_{2v,}$ 1 ΔE = 0.687 eV

C-9-1, C_{2v}, 2 ΔE = 0 eV	C-9-2, C_{2v}, 2 ΔE = 0.067 eV	C-9-3, C_{2v}, 2 ΔE = 0.296 eV	C-9-4, $C_{2v,}$ 2 ΔE = 0.714 eV

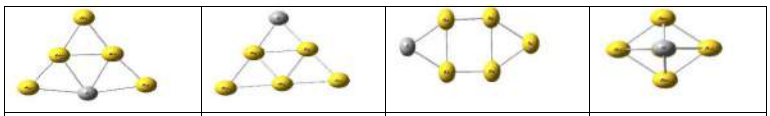
Fig. 3 The ground state configuration and low-lying isomers of anionic $[Au_nV]^-$ nanoalloy clusters ($n = 1$–9)

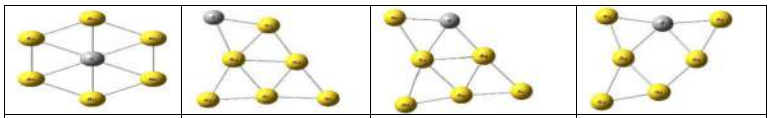

A-1-1, $C_{\infty v}$, 2, ΔE = 0 eV

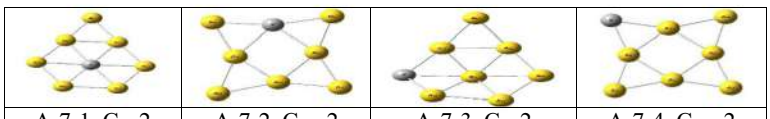

A-2-1, C_{2v}, 1, ΔE = 0 eV | A-2-2, $C_{\infty v}$, 1, ΔE = 0.110 eV | A-2-3, C_{2v}, 1, ΔE = 0.362 eV

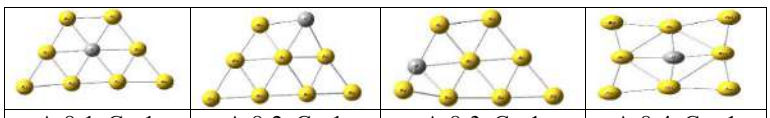

A-3-1, D_{3h}, 2 ΔE = 0 eV | A-3-2, C_s, 2 ΔE = 0.133 eV | A-3-3, C_1, 2 ΔE = 0.353 eV | A-3-4, C_{2v}, 2 ΔE = 0.416 eV

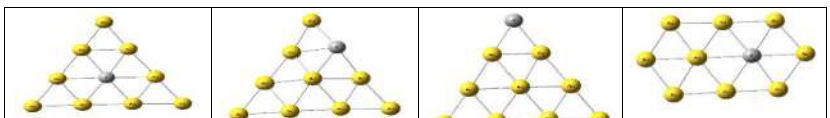

A-4-1, C_{2v}, 1 ΔE = 0 eV | A-4-2, C_s, 1 ΔE = 0.095 eV | A-4-3, C_{2v}, 1 ΔE = 0.138 eV | A-4-4, C_{2v}, 1 ΔE = 0.301 eV


A-5-1, C_{2v}, 2 ΔE = 0 eV | A-5-2, C_{2v}, 2 ΔE = 0.421 eV | A-5-3, C_{2v}, 2 ΔE = 0.597 eV | A-5-4, C_1, 2 ΔE = 1.013 eV


A-6-1, D_{2h}, 1 ΔE = 0 eV | A-6-2, C_s, 1 ΔE = 0.291 eV | A-6-3, C_s, 1 ΔE = 0.560 eV | A-6-4, C_1, 1 ΔE = 0.883 eV


A-7-1, C_2, 2 ΔE = 0 eV | A-7-2, C_{2v}, 2 ΔE = 0.109 eV | A-7-3, C_2, 2 ΔE = 0.311 eV | A-7-4, C_{2V}, 2 ΔE = 0.517 eV


A-8-1, C_1, 1 ΔE = 0 eV | A-8-2, C_1, 1 ΔE = 0.190 eV | A-8-3, C_1, 1 ΔE = 0.206 eV | A-8-4, $C_{2v,}$ 1 ΔE = 0.315 eV


A-9-1, C_{2v}, 2 ΔE = 0 eV | A-9-2, C_{2v}, 2 ΔE = 0.098 eV | A-9-3, C_{2v}, 2 ΔE = 0.125 eV | A-9-4, $C_{s,}$ 2 ΔE = 0.361 eV

isomers of Au_4V nanoalloy clusters show that isomers N-4–3 and N-4–2 are energetically close and have energy difference of 0.071 eV. The isomer N-4–4 is optimized from N-4–3 by shifting the position of gold and vanadium atoms. Isomer N-4–4 with point group C_{2V} and doublet spin state is less stable by 1.088 eV than the ground state configuration N-4–1.

The optimized geometries of Au_5V nanoalloy cluster reveal that planar structure is more preferable than the three-dimensional structure. The most stable structure (N-5–1) with point group C_{2V} and singlet spin state is a planar structure which is obtained from N-4–1. The isomer N-5–2 is a three-dimensional structure with point group C_1 and singlet spin state. It is less stable by 0.027 eV than the lowest energy structure N-5–1. Isomer N-5–3 is obtained from most stable structure N-5–1 by changing the position of gold and vanadium atom. Isomer N-5–3 with symmetry group C_{2V} and singlet spin is less stable by 0.644 eV than N-5–1. Isomer N-5–4 is a planar structure with point group C_{2V} with singlet spin. It is obtained from N-5–2 by capping with gold and vanadium atom from opposite sides of rhombus. The energy difference between N-5–4 and N-5–1 is 0.897 eV.

The ground state configuration of Au_6V nanoalloy cluster (N-6–1) is a ring-type structure in which vanadium atom positioned at the centre. The optimized structure is in agreement with the previous results [28, 33, 39]. The isomer N-6–1 with symmetry configuration D_{6h} and spin multiplicity state doublet is found from N-4–1 by addition of two gold atoms. The isomer N-6–2 with point group C_S and doublet spin is a rhombus-shape structure capped with three gold atoms from sides. Energetically it is less favourable by 0.910 eV than the lowest energy structure N-6–1. Isomer N-6–3 is obtained from N-5–3 by adding one Au atom. It has symmetry configuration C_S with spin multiplicity doublet and energetically less favourable by 0.99 eV and 1.90 eV than the isomers N-6–2 and N-6–1, respectively. The isomer N-6–4 with symmetry group C_1 with doublet spin state is 1.978 eV less stable than the isomer N-6–1.

After optimization of several planar and three-dimensional structures, isomer N-7–1 is found as the most stable structure. It is optimized from N-6–1 with symmetry configuration C_2 and spin state singlet. The isomer N-7–2 is a ring structure formed by Au atoms and capped with vanadium atom from one side of the ring. Isomer N-7–2 is found from N-7–1 by substituting Au atom in place of V atom at the centre of the ring. The second lowest energy structure with point group C_{2V} and singlet spin state is only 0.037 eV higher in energy than the ground state configuration N-7–1. The isomer N-7–3 is a rhombus-type structure capped with vanadium and gold atoms from sides. Structure N-7–3 with point group C_2 and singlet spin state is energetically less favourable than isomers N-7–1 and N-7–2 by 0.511 eV and 0.474 eV, respectively. The isomer N-7–4 with symmetry group C_{2V} and singlet spin state is three-dimensional structure and higher in energy by 0.825 eV than the ground state configuration N-7–1.

The ground state configuration N-8–1 of Au_8V nanoalloy cluster with point group C_1 and doublet spin is a planar structure which obtained after incorporation of two gold atoms to isomer N-6–1. The isomer N-8–2 is a three-dimensional geometry with two layers of rhombus structure and vanadium atom is placed at the centre. The isomer N-8–2 with spin multiplicity doublet and symmetry group C_2 is energetically less favourable than the planar structure (N-8–1) by 0.465 eV. The isomer N-8–3 with point group C_{2V} and doublet spin state is obtained from N-7–3 in which vanadium atom placed at the centre. It is only 0.038 eV higher in energy than the 3-d isomer N-8–2 and 0.503 eV higher than the isomer N-8–1. The isomer N-8–4 is obtained from N-8–2 in which two layers of rhombus are capped by vanadium atom from one end. Isomer N-8–4 with configuration C_2 and quartet spin state is 0.817 eV higher in energy than the most stable structure N-8–1.

The ground state configuration N-9–1 with symmetry group C_{2V} and spin multiplicity singlet is obtained from isomer N-6–1. The structure N-9–2 with symmetry group C_2 and singlet spin state is found from isomer N-3–3 by adding more number of Au atoms on both sides of rectangle. The isomer N-9–2 is 0.318 eV higher in energy than the most stable structure N-9–1. Isomer N-9–3 is obtained from N-9–2 after swapping the position of vanadium and gold atom. The structure N-9–3 with point group C_S and singlet spin is energetically higher in energy by 0.91 eV than the lowest energy structure N-9–1. The isomer N-9–4 is optimized from most stable structure N-9–1 after exchanging the position of Au and V atom. The structure N-9–4 with symmetry group C_{2V} and singlet spin state is energetically less favourable by 1.191 eV than the isomer N-9–1.

3.3 Cationic $[Au_nV]^+$ nanoalloy clusters ($n = 1–9$)

The ground state configuration and low-lying isomers of cationic vanadium-doped gold nanoalloy clusters $[Au_nV]^+$ are presented in Fig. 2. The low-lying isomers are arranged in the format of C–A–X, where C is the representation of cationic cluster, A is total number of gold atoms and X represents the position of the lowest energy structure of each cluster. Moreover, symmetry, spin multiplicity state and energy difference between ground state configuration and isomers for each cluster are also presented in Fig. 2. The result shows that the most stable structure for cationic nanoalloy clusters $[Au_nV]^+$ ($n = 1$ to 6) is having planar structure, whereas three-dimensional structure is observed for clusters, $n = 7$ to

9. The ground state configurations of cationic $[Au_nV]^+$ are in line with the geometries reported by Torres et al. [27]. The optimized structure of AuV reveals that formation of cationic $[AuV]^+$ nanoalloy cluster is responsible to decrease the bond length between Au and V by 0.118 Å, which is in agreement with the previous result reported by Torres et al. [27]. The result shows that ground state configuration of nanoalloy clusters $[Au_2V]^+$, $[Au_4V]^+$ and $[Au_5V]^+$ have identical structure with respect to their corresponding neutral clusters. The most stable structure of $[Au3V]^+$ is rectangular structure (C-3–1) with point group C_{2V} and doublet spin. The second lowest energy structure (C-3–2) which is only 0.027 eV higher in energy than isomer C-3–1, is not planar but distorted a bit with symmetry configuration C_{2V} and doublet spin multiplicity. For $[Au_6V]^+$, lowest energy structure C-6–1 with point group C_1 and singlet spin multiplicity is obtained from C-5–1. Isomer C-6–2 with ring-type structure in which vanadium atom is placed at the centre, is less stable by 0.138 eV than the most stable structure. Isomer C-6–2 with symmetry configuration D_{2h} is having singlet spin multiplicity state.

For $[Au_7V]^+$ nanoalloy cluster, ground state configuration C-7–1 with symmetry group C_2 and spin multiplicity doublet is a three-dimensional geometry, where a rhombus structure is capped by vanadium and gold atoms from opposite faces and with gold atoms from two sides. The second lowest energy structure C-7–2 with spin multiplicity quartet and point group C_{2V} is of double layer of rhombus structure, which is connected back to back. Isomer C-7–2 is 0.365 eV higher in energy than the most stable structure C-7–1. The isomer C-7–3 is obtained from C-7–1 after swapping the position of vanadium and gold atom. It is energetically less stable than isomers C-7–1 and C-7–2 by 0.762 eV and 0.397 eV, respectively. The isomer C-7–4 is a planar structure with symmetry configuration C_2 and doublet spin state. It is obtained from isomer C-6–2 and energetically less stable by 1.210 eV than the most stable isomer C-7–1.

The ground state configuration (C-8–1) of $[Au_8V]^+$ nanoalloy cluster with symmetry group C_2 and singlet spin multiplicity is a rhombus structure capped by gold atoms from top and sides. The isomer C-8–2 is obtained from C-8–1 by swapping vanadium and gold atom. The isomer C-8–2 with point group C_2 and singlet spin is energetically less favourable than the isomer C-8–1 by 0.106 eV. The isomer C-8–3, a planar structure with symmetry group C_1 and singlet spin is obtained from isomer C-6–2. It is 0.391 eV higher in energy than the most stable structure C-8–1. Isomer C-8–4 with symmetry group C_{2V} and singlet spin is obtained from structure C-5–1, it is less stable than the ground state configuration, C-8–1 by 0.687 eV.

The lowest energy structure (C-9–1) and second most stable structure (C-9–2) is obtained from isomer C-8–4 by addition of one Au atom and exchanging the position of vanadium with gold atom. Isomer C-9–2 is less stable than the most stable structure C-9–1 by only 0.067 eV. Isomer C-9–3 is a double layer of pentavalent geometry with symmetry group C_{2V} and doublet spin multiplicity. Isomer C-9–3 is higher in energies than the isomers C-9–1 and C-9–2 by 0.296 eV and 0.229 eV, respectively. Isomer C-9–4 with symmetry group C_{2V} and doublet spin is a planar structure obtained from C-8–2. It is 0.714 eV higher in energy than the most stable structure C-9–1.

3.4 Anionic $[Au_nV]^-$ nanoalloy clusters ($n = 1–9$)

The lowest energy structure and low-lying isomers of anionic vanadium-doped gold nanoalloy clusters $[Au_nV]^-$ are presented in Fig. 3. The low-lying isomers are arranged in the format of A–B–X, where A is representing anionic cluster, B is total number of gold atoms and X represents the position of the lowest energy structure of each cluster. Moreover, symmetry, spin multiplicity state and energy difference between the most stable structure and isomers for each cluster are also presented in Fig. 3. The result reveals that the lowest energy structures for anionic clusters $[Au_nV]^-$ are identical to neutral clusters, except $[Au_3V]^-$ nanoalloy cluster. The optimized structures are in agreement with the previous result reported by Nhat et al. [33]. The optimized structure of anionic $[AuV]^-$ cluster shows that bond length between Au and V is increased by 0.186 Å as compared to the bond length formed between Au and V in neutral cluster. The most stable structure of $[Au_3V]^-$ nanoalloy cluster is A-3–1 isomer with a symmetry configuration D_{3h} and doublet spin multiplicity. The second lowest energy structure (A-3–2) with point group C_S and doublet spin state is higher in energy than the isomer A-3–1 by 0.133 eV. The isomer A-3–3 with point group C_1 and doublet spin is less stable than A-3–1 by 0.353 eV. Isomer A-3–4 with configuration C_{2V} and doublet spin multiplicity is energetically less favourable than the most stable structure by 0.416 eV. The energy difference between isomers A-3–3 and A-3–4 is only 0.053 eV.

3.5 Electronic properties and DFT-based descriptors of $[Au_nV]^\lambda$ ($n = 1–9$; $\lambda = 0, \pm 1$)

In this section, we have studied the electronic properties and DFT-based global descriptors—molecular hardness, softness, electronegativity, electrophilicity index, dipole moment and dipole polarizability of $[Au_nV]^\lambda$ ($n = 1–9$; $\lambda = 0, \pm 1$) nanoalloy clusters. The frontier orbitals, the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) are significant parameters to investigate the electronic properties of clusters at nanoscale. The energy difference between these two orbitals specifies the minimum energy required for a charge carrier to move from occupied orbital to unoccupied orbital,

due to which conduction occurs in any cluster. It is also established that HOMO and LUMO play an important role in transfer of charge and bonding during the development of donor–acceptor interaction in any molecule [40–44]. The HOMO–LUMO energy gap reveals the chemical stability of nanoalloy clusters. It exhibits that cluster with large HOMO–LUMO gap offers high stability to species. The HOMO–LUMO energy gap of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) nanoalloy clusters is presented in Fig. 4. The result shows that HOMO–LUMO energy gaps of neutral, cationic and anionic $[Au_nV]$ nanoalloy clusters are in the range of 1.41 eV to 2.25 eV, 1.04 eV to 2.37 eV and 1.25 eV to 2.24 eV, respectively. The result reveals that $[Au_3V]$, $[Au_5V]^+$ and $[Au_3V]^-$ clusters have the maximum energy gap of 2.504 eV, 2.374 eV and 2.248 eV, respectively. Similarly, clusters $[Au_6V]$, $[Au_4V]^+$ and $[Au_6V]^-$ have been observed with the least value of energy gap in this range. In recent years, it is reported that energy gap of bimetallic clusters ranging between 1.2 eV and 3.3 eV is suitable for applications in nonlinear optical devices, optoelectronic and photovoltaic especially for solar cells [45–53]. Therefore, $[Au_nV]$ clusters may also be suitable candidate for these applications. We have found an interesting odd–even oscillation behaviour in neutral, cationic and anionic clusters with respect to the function of cluster size, n. Clusters with odd number of n are more stable as compared to their neighbour cluster with even number of n. It means that clusters at $n=1$, 3, 5, 7 and 9 are having more HOMO–LUMO energy gap as compared to their corresponding neighbour clusters at $n=2$, 4, 6 and 8.

Molecular hardness is an important parameter to define stability, binding and dynamics of nanoalloy clusters [54]. Pearson reported that "every molecule tries to arrange themselves as hard as possible according to the rule of nature" [55]. When a molecular system changes from an unstable state to stable equilibrium state, its hardness value increases, whereas when it moves from a stable state to unstable state, its hardness value decreases [40]. The molecular hardness (in eV) of neutral, cationic and anionic V-doped Au nanoalloy clusters is presented in Fig. 5. The result exhibits that nanoalloy clusters $[Au_3V]$, $[Au_5V]^+$ and $[Au_3V]^-$ have the maximum hardness values of 1.252 eV, 1.187 eV and 1.124 eV, respectively, whereas clusters $[Au_6V]$, $[Au_4V]^+$ and $[Au_6V]^-$ have the least hardness values of 0.707 eV, 0.523 eV and 0.627 eV, respectively. The molecular hardness values also reflect odd–even oscillation behaviour, indicating that hardness at $n=1$, 3, 5, 7 and 9 is more as compared to their corresponding neighbour clusters at $n=2$, 4, 6 and 8. The computed results show a linear correlation between molecular hardness and energy difference between the frontier orbitals, i.e. HOMO–LUMO energy gap.

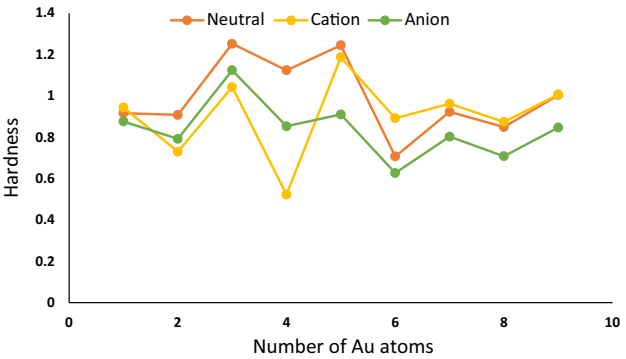


Fig. 5 Molecular hardness of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) as a function of cluster size, n

The hardness and softness is a fundamental concept to understand the depiction of chemical events [54, 55]. The computed softness (in eV) for neutral, cationic and anionic Au_nV nanoalloy clusters is shown in Fig. 6. The results reveal that molecular hardness and softness have an inverse relationship. It indicates that clusters at $n=2$, 4, 6 and 8 have a large value of softness as compared to their neighbour clusters at $n=1$, 3, 5, 7 and 9. The data show that clusters $[Au_6V]$, $[Au_4V]^+$ and $[Au_6V]^-$ have the maximum softness values whereas clusters $[Au_3V]$, $[Au_5V]^+$ and $[Au_3V]^-$ have the minimum softness values.

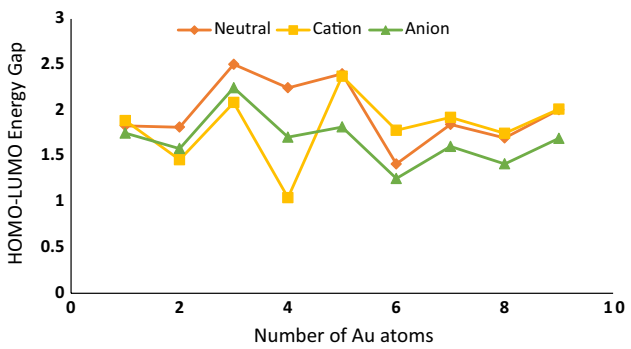


Fig. 4 HOMO–LUMO energy gap of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) as a function of cluster size, n

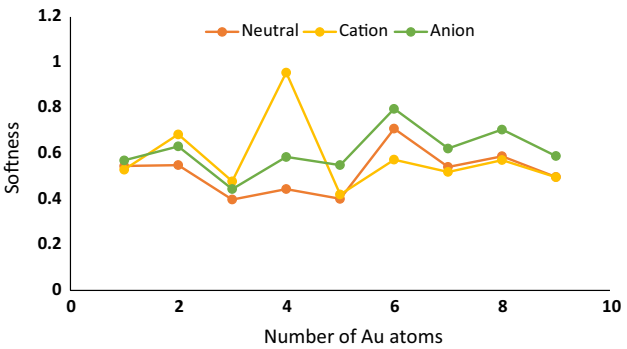


Fig. 6 Molecular softness of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) as a function of cluster size, n

Table 1 Electronegativity of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) nanoalloy clusters

Number of au atoms (n)	Neutral	Cationic	Anionic
1	3.678	11.332	1.032
2	3.788	9.681	0.136
3	5.223	9.945	1.138
4	5.592	9.772	0.226
5	4.446	9.642	0.626
6	5.086	9.089	0.816
7	5.062	9.122	0.759
8	5.463	9.019	0.688
9	5.008	9.093	0.533

Table 2 Electrophilicity index of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) nanoalloy clusters

Number of au atoms (n)	Neutral	Cationic	Anionic
1	7.388	68.004	0.608
2	7.898	64.217	0.012
3	10.894	47.410	0.576
4	13.915	91.269	0.030
5	7.938	39.163	0.216
6	18.290	47.699	0.531
7	13.879	43.256	0.359
8	17.571	46.518	0.334
9	12.494	41.062	0.168

The electronegativity equalization principle is an important factor to understand the charge transfer between donor and acceptor in chemical species [55–61]. It stipulates that when two complexes come in close contact, electrons start moving from lower electronegativity to higher electronegativity species till the electronegativity of all the systems—donor, acceptor and adduct will become stable at some transitional level [40]. The electronegativity (in eV) of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) nanoalloy clusters is calculated and presented in Table 1. The result shows that cationic clusters have high electronegativity values whereas, neutral and anionic clusters have moderate and low values, respectively. The maximum electronegativity values are observed for clusters $[Au_4V]$, $[AuV]^+$ and $[Au_3V]^-$.

The electrophilicity index is a parameter to calculate the reduction of energy in donor–acceptor molecular system due to excessive flow of charge carriers between donor and acceptor and it is influenced by IE and EA [62]. The electrophilicity index (in eV) of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) nanoalloy clusters is presented in Table 2. The result reveals that cationic clusters have a high electrophilicity index, whereas anionic and neutral clusters have a low and moderate value, respectively. The maximum value of electrophilicity index is observed for clusters $[Au_6V]$, $[Au_4V]^+$ and $[AuV]^-$.

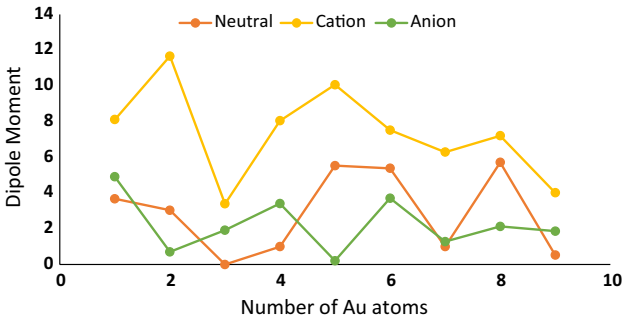


Fig. 7 Dipole moment of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) as a function of cluster size, n

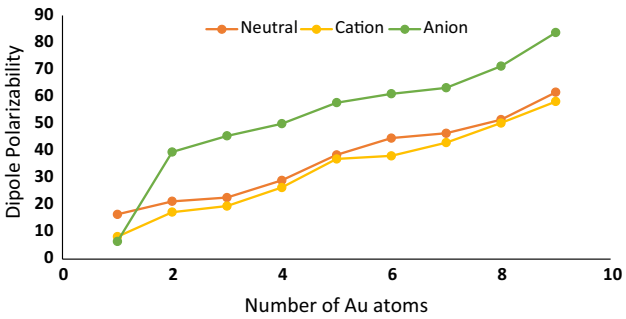


Fig. 8 Dipole polarizability of $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) as a function of cluster size, n

The dipole moment (in Debye) for $[Au_nV]^{\lambda}$ ($n=1$–9; $\lambda=0,\pm1$) nanoalloy clusters is presented in Fig. 7. The computed result shows that dipole moment of cationic clusters is more as compared to neutral and anionic clusters. In the case of neutral clusters, Au_9V has dipole moment less than one Debye, clusters Au_4V and Au_7V have dipole moment one Debye whereas, other clusters have large dipole moment. In cationic state, all clusters have large dipole moment, more than one Debye. The maximum dipole moment is observed for $[Au_2V]^+$ nanoalloy cluster. In anionic state, clusters $[Au_2V]^-$ and $[Au_5V]^-$ have low dipole moment, less than one Debye, whereas other clusters, $n=1$, 3, 4, 6, 7, 8, 9 have large dipole moment, more than one Debye. The maximum dipole moment of anionic state is found for cluster $[AuV]^-$ nanoalloy cluster.

The dipole polarizability (in Coulomb-meter^3) of neutral, cationic and anionic state is presented in Fig. 8. The result shows that dipole polarizability of neutral, cationic and anionic V-doped Au nanoalloy clusters increases with the cluster size. The dipole polarizability of anionic clusters

Table 3 Computed and experimental parameters of $[Au_2]^{\lambda}$ and $[AuV]^{\lambda}$ ($\lambda = 0, \pm 1$)

Species	Exp. bond length (Å)	Computed bond length (Å)	Exp. vibrational frequency (cm^{-1})	Computed vibrational frequency (cm^{-1})	Exp. dissociation energy (eV)	Computed dissociation energy (eV)
Au_2	2.47 [63,64]	2.49	191[64]	169	2.29 ± 0.02[64]	2.26
Au_2^+	2.63[65]	2.69		130	2.0 ± 0.3[65]	1.30
Au_2^-	2.58 ± 0.007[66]	2.73	149 ± 10[67]	114	1.93[66]	1.86
AuV		2.514		219	2.51 ± 0.09[64]	2.48
$[AuV]^+$		2.396		273		1.52
$[AuV]^-$		2.700		157		1.99

Table 4 Comparison of Au–Au bond distances

Species	Previously reported data (Å)	Species	Computed data (Å)
Au_3	2.72[68]	Au_2V	2.78
Au_4	2.69[69]	Au_3V	2.83
Au_6	2.72[70,71]	Au_5V	2.76

is more as compared to neutral and cationic clusters, except for $[AuV]^-$.

Bond length, dissociation energy and vibrational frequency for species $[Au_2]^{\lambda}$ and $[AuV]^{\lambda}$ ($\lambda = 0, \pm 1$) are computed and compared with experimental data in Table 3 [63–67]. A good agreement is observed between computed and experimental result from Table 3. Bond distance of Au–Au for species Au_3, Au_4 and Au_6 is compared with the corresponding mixed clusters in Table 4. Guo et al. [67] reported the bond distance between Au–Au for species Au_3 is 2.72 Å. For ground state configuration of Au_4, bond distance between Au–Au is reported as 2.69 Å by Balasubramanian et al. [68]. Electronic structure of Au_6 is reported by Liao et al. [69]. Udayabhaskararao et al. [70] studied the 13-atom silver-gold cluster, Ag_7Au_6. They found the Au–Au bond distance for Au_6 compound as 2.72 Å. Our results show the Au–Au bond distance for corresponding mixed clusters Au_2V, Au_3V and Au_5V as 2.78 Å, 2.83 Å and 2.76 Å, respectively. It indicates that Au–Au bond distance in vanadium-doped gold cluster is large as compared to the pure gold cluster.

4 Conclusion

In this report, we have investigated the structure and electronic properties of $[Au_nV]^{\lambda}$ ($n = 1$–9; $\lambda = 0, \pm 1$) nanoalloy clusters by using density functional theory technique. The lowest energy structure of neutral and cationic clusters favour planar structure. Cationic clusters, from $n = 1$ to 6, prefer planar geometry and structural transition occurs at $n = 7$. The result shows that the HOMO–LUMO energy gap of neutral, cationic and anionic nanoalloy clusters is in the range of 1.41 eV to 2.25 eV, 1.04 eV to 2.37 eV and 1.25 eV to 2.24 eV, respectively. This energy range ensures the applications of $[Au_nV]$ clusters as optoelectronic, photovoltaic and nonlinear optical devices. The nanoalloy clusters $[Au_3V]$, $[Au_5V]^+$ and $[Au_3V]^-$ are found as the most stable clusters with energy gap of 2.504 eV, 2.374 eV and 2.248 eV, respectively. A strong correlation is established between HOMO–LUMO energy gap and computed DFT-based descriptors. The HOMO–LUMO energy gap and molecular hardness reveal an odd–even alteration behaviour as a function of cluster size, indicating that clusters at $n = 1$, 3, 5, 7 and 9 are more stable as compared to their neighbouring clusters at $n = 2$, 4, 6 and 8. The electronegativity, electrophilicity index and dipole moment of cationic clusters are high as compared to neutral and anionic clusters. The dipole polarizability of neutral, cationic and anionic Au_nV nanoalloy clusters increases with the cluster size. Computed bond length, dissociation energy and vibrational frequency for species $[Au_2]^{\lambda}$ and $[AuV]^{\lambda}$ ($\lambda = 0, \pm 1$) are in agreement with the experimental data.

Acknowledgements Dr. Tanmoy Chakraborty would like to acknowledge the funding support from Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India, (under Grant No. [CRG/2020/002951]) and Sharda University for providing computational research facility.

Declarations

Conflict of interest All the authors declare that there is no conflict of interest.

References

1. Haruta M, Kobayashi T, Sano H, Yamada N (1987) Chem Lett 405:1989

2. Haruta M, Yamada N, Kobayashi T, Iijima S (1989) J Catal 115:301
3. Olson RM, Gordon MS (2007) J Chem Phys 126:214310
4. Hakkinen H (2008) Chem Soc Rev 37:1847
5. Assadollahzadeh B, Schwerdtfeger P (2009) J Chem Phys 131:064306
6. Schwerdtfeger P, Lein M (2009) Current trends and future directions. In: Mohr F (ed) Gold chemistry. Wiley, New York
7. Schwerdtfeger P (2003) Angew Chem Int Ed 42:1892
8. Schwerdtfeger P (2002) Heteroat Chem 13:578
9. Wang T, Hu XG, Dong SJ (2006) J Phys Chem B 110:16930
10. Die D, Zheng BX, Zhao LQ, Zhu QW, Zhao ZQ (2016) Sci Rep 6:31978
11. Jaiswal S, Kumar V (2016) Comput Theor Chem 1075:87
12. Wang HQ, Kuang XY, Li HF (2010) Phys Chem Chem Phys 2:5156
13. Zheng BX, Die D, Wang L, Yang JX (2014) J Phys Chem A 118:4005
14. Ranjan P, Chakraborty T (2018) Key Eng Mater 777:183
15. Janssens E, Tanaka H, Neukermans S, Silverans RE, Lievens P (2004) Phys Rev B 69:085402
16. Torres MB, Fernandez EM, Balbas LC (2008) J Phys Chem A 112:6678
17. Bhardwaj R, Singh JP, Chae KH, Goyal N, Gautam S (2018) Vaccum 158:257
18. CrevelingLuo LHL (1968) Phys Rev 176:614
19. Jaque P, Toro-Labbe A (2004) J Phys Chem B 108:2568
20. Poater A, Duran M, Jaque P, Toro-Labbe A, Sola M (2006) J Phys Chem B 110:6526
21. Seminario JM, Tour JM (1997) Int J Quantum Chem 65:749
22. Paz-Borbon LO, Barcaro G, Fortunelli A, Levchenko SV (2012) Phys Rev B 85:155409
23. Yan L, Seminario JM (2007) Int J Quantum Chem 107:440
24. Yang A, Fa W, Dong J (2010) J Phys Chem A 114:4031
25. Du Q, Wu X, Wang P, Wu D, Sai L, King RB, Park SJ, Zhao J (2020) J Phys Chem C 124:7449
26. Ben-Xia Z, Dong D, Ling W, J-Xian Y (2014) J Phys Chem A 118:4005
27. Torres MB, Fernandez EM, Balbas LC (2005) Phys. Rev. B 71:155412
28. Li X, Kiran B, Cui LF, Wan LS (2005) Phys Rev Lett 95:253401
29. Yuan DW, Wang Y, Zeng Z (2005) J Chem Phys 122:114310
30. Blades WH, Reber AC, Khanna SN, Sosa LL, Calaminici P, Koster AM (2017) J Phys Chem A 121:2990
31. Hua Y, Liu Y, Jiang G, Chen J (2013) Eur Phys J D 67:267
32. Medel VM, Reber AC, Chauhan V, Sen P, Koster AM, Calaminici P, Khanna SN (2014) J Am Chem Soc 136:8229
33. Nhat PV, Nguyen MT (2011) Phys Chem Chem Phys 13:16254
34. Hafner J, Wolverton C, Ceder G (2006) MRS Bull 31:659
35. Gaussian 16, Revision A.03, Frisch MJ, Trucks GW, Schlegel HB, Scuseria GE, Robb MA, Cheeseman JR, Scalmani G, Barone V, Petersson GA, Nakatsuji H, Li X, Caricato M, Marenich AV, Bloino J, Janesko BG, Gomperts R, Mennucci B, Hratchian HP, Ortiz JV, Izmaylov AF, Sonnenberg JL, Williams-Young D, Ding F, Lipparini F, Egidi F, Goings J, Peng B, Petrone A, Henderson T, Ranasinghe D, Zakrzewski VG, Gao J, Rega N, Zheng G, Liang W, Hada M, Ehara M, Toyota K, Fukuda R, Hasegawa J, Ishida M, Nakajima T, Honda Y, Kitao O, Nakai H, Vreven T, Throssell K, Montgomery JA, Peralta JE, Ogliaro F, Bearpark MJ, Heyd JJ, Brothers EN, Kudin KN, Staroverov VN, Keith TA, Kobayashi R, Normand J, Raghavachari K, Rendell AP, Burant JC, Iyengar SS, Tomasi J, Cossi M, Millam JM, Klene M, Adamo C, Cammi R, Ochterski JW, Martin RL, Morokuma K, Farkas O, Foresman JB, Fox DJ (2016) Gaussian, Inc., Wallingford CT
36. Lee HM, Ge M, Sahu BR, Tarakeshwar P, Kim KS (2003) J Phys Chem 107:9994
37. Ding XL, Wang D, Li RJ, Liao HL, Zhang Y, Zhang HY (2016) Phys Chem Chem Phys 18:9497
38. Parr RG, Yang W (1989) Density functional theory of atoms and molecules, Oxford, New York
39. Zhang M, He LM, Zhao LX, Feng XJ, Luo YH (2009) J Phys Chem C 113:6491
40. Ghosh DC, Bhattacharyya S (2004) Int J Mol Sci 5:239
41. Fujimoto H, Kato S, Yamabe S, Fukui K (1974) J Chem Phys 60:572
42. Fujimoto H, Kato S, Yamabe S, Fukui K (1974) J Am Chem Soc 96:2024
43. Ghosh DC (1984) Indian J Pure Appl Phys 22:346
44. Ghosh DC (1989) Indian J Pure Appl Phys 27:160
45. Ranjan P, Dhail S, Venigalla S, Kumar A, Ledwani L, Chakraborty T (2015) Mat Sci Pol 33:719
46. Ranjan P, Chakraborty T, Kumar A (2017) Phys Sci Rev 2:20160112
47. Ranjan P, Chakraborty T (2019) Acta Chim Slov 66:173
48. Ranjan P, Kumar P, Chakraborty T, Sharma M, Sharma S (2020) Mater Chem Phys 241:122346
49. Ranjan P, Chakraborty T (2020) Mat Today Comm 22:100832
50. Ranjan P, Chakraborty T (2020) J Nanopart Res 22:35
51. Chen L, Xia YD, Liang XF, Yin KB, Yin J, Liu ZG, Chen Y (2007) Appl Phys Lett 91:073511
52. Lin MC, Lee MW (2011) Electrochem Commun 13:1376
53. Sanchez OJJ, Peralta NP, Urbina RH, Sanchez M, Amarillas AP (2013) Chem Phys Lett 570:132
54. Chattaraj PK, Sengupta S (1999) J Phys Chem 103:6122
55. Pearson RG (1987) J Chem Ed 64:562
56. Sanderson RT (1951) Science 114:670
57. Sanderson RT (1952) Science 116:41
58. Sanderson RT (1955) Science 121:207
59. Sanderson RT (1952) J Chem Ed 29:539
60. Sanderson RT (1954) Science 31:238
61. Sanderson RT (1960) Chemical periodicity. Reinhold Publishing Corporation, New York
62. Parr RG, Szentpaly LV, Liu S (1999) J Am Chem Soc 121:1922
63. Morse MD (1986) Chem Rev 86:1079
64. Wasendrup R, Hunt T, Schwerdfeger P (2000) J Chem Phys 112:9356
65. Ho J, Erwin KM, Lineberge WC (1990) J Chem Phys 93:6987
66. Leon I, Yang Z, Wang LS (2013) J Chem Phys 138:184304
67. Guo R, Balasubramanian K, Wang X, Andrews L (2002) J Chem Phys 117:1614
68. Balasubramanian K, Feng PY, Liao MZ (1989) J Chem Phys 91:3561
69. Liao D, Balasubramanian K (1992) J Chem Phys 97:2548
70. Udayabhaskararao T, Sun Y, Goswami N, Pal SK, Balasubramanian K, Pradeep T (2012) Angew Chem Int Ed 51:2155

Indian Journal of Chemical Technology
Vol. 28, July 2021, pp. 467-472

QSAR study in terms of conceptual density functional theory based descriptors in predicting toxicity of nitrobenzenes towards *Tetrahymena pyriformis*

Sandip Kumar Rajak

Department of Chemistry, Dumkal College, Basantapur, Murshidabad, 742 406, West Bengal, India
E-mail: sandip1ku@gmail.com

Received 18 January 2021; accepted 12 May 2021

Quantitative Structure -Activity Relationship (QSAR) models are enormously significant to understand the correlation of chemical structure with the biological activity and toxicity of chemicals. In the ongoing study reveals the prediction power of toxicity of 45 nitrobenzenes (NBs) entailing some conceptual density functional theory based reactivity descriptors namely electrophilicity index (ω), lowest unoccupied molecular orbital (ε_{lumo}) and molecular compressibility (β) along with the hydrophobicity index (logP). Multilinear Regression (MLR) method is adopted to develop the QSAR model. Stability of the present QSAR model is confirmed through the cross validation method and is potentially describe the 85% of the variance of the experimental toxicity.

Keywords: CDFT, Nitobenzenes, QSAR, Regression, Toxicity

The quantitative structure-activity relationship (QSAR) analysis is accompanied to derive empirical models that relate the activity of chemical compounds to their structure[1]. The basic assumption is that the chemical structure of a compound implicit determines its actions towards biological systems. The most essential scientific principle of developing a QSAR model includes: understanding the mechanism of interaction between compounds and biological system. The attainment of information about a dose range for the biological effect of a chemical compound can be useful in the experimental drug design and toxicity research, and also calculation of the activity of new chemical compounds. Further, QSAR modes is popular for saving both time and experimental resources for synthesizing and biological experiment of a great number of compounds and offer possibility of reduction of living thing use in research and toxicity testing. Various statistical methods namely regression analysis, partial least squares, classification trees, and neural networks[2] are used widely in developing QSAR.

Toxicity prediction is crucial subject of concern and a lot of studies have been done to elucidate its effects with the help of various quantum chemical atomic and molecular descriptors[3]. Toxicity arises as a consequence of stereochemical electronic interaction amongst the reactive site and toxicant. Toxicity being a basic observable fact requires understanding of its origin so as to be concerned of its effects. In vivo and in vitro methods are followed simultaneously or separately for the prediction of toxicity. In vitro methodology is mostly preferred over the other due to its less time consuming and its economical property. QSAR (quantitative structure-activity relationship) and QSPR (quantitative structure-property relationship) are two major methodologies for correlating biological activity with physicochemical properties through descriptors characteristic of molecular structure and /or properties[4-8]. QSAR/QSPR domain is being dominated by Density Functional Theory (DFT) in the recent years. Several Conceptual Density Functional Theory (CDFT)- based descriptors have been invoked widely to study the reactive site, to model biological properties, and in addition to predict experimental behaviours[9-14].

Acute toxicity in the domain of QSAR study have been reported in a large number in the literature[15]. Many authors[16-20] have introduced quantitative relationship between toxicity and hydrophobicity, wherein the hydrophobicities are measured by octanol-water partition coefficient ($\log P_{oct}$ values) or octanol-water distribution coefficient ($\log D_{oct}$ values) as descriptors.

Response-surface approach has been widely invoked for the development of mechanistically comprehensible QSAR modes for toxicity. The central idea of this approach is that the toxic action depends on the biouptake and bioavailability as well as on the electrophilic reactivity of the toxicant at an active site. $\log P_{oct}$ or $\log D_{oct}$ have been introduced as

a descriptor for encoding biouptake and bioavailability and energy of lowest unoccupied molecular orbital (E_{LUMO}) as descriptor for encoding the electrophilc reactivity. This scientific knowledge has been applied to different species, including the bacterium Vibrio fischei[21], the protozoan Tetrahymena pyriformis[22-23], the yeast *Saccharomyces cerevisiae*[24], the mould *Aspergillus nidulans*[25], the algae *Scenedesmus obliquus*[26] and *Chlorella vulgais*[25], the plant *Cucumis sativus*[27-28], and mice[25].

To improve the statistical fit of the model, additional indicator variables and other parameters have been added with the response surface approach[29,30].

It is well established that toxicity is a outcome of electronic interaction among the atom/ molecules of the reactive site and the toxicant. In present study, CDFT based descriptor, that is Compressibility is used in addition to the other descriptors as compressibility plays a vital role in understanding various interactions including toxic interactions[31] as like as molecular polarizability which is a promising descriptor to study chemicl -biological interactions[32].

The expression of chemical toxicity is a combination of penetration into, or through, biological membranes and the interaction of the toxicant with the site of action. This principle is modeled mathematically as the following standard QSAR[33].

log (toxicity)$^{-1}$=A (log of penetration) +B (log of interaction)

Penetration to the site of action is generally represented by hydrophobicity, most often quantified by the 1-octanol/water partition coefficient (log P)[33]. Interaction of the chemical with the active site is more complicated and describes electronic and /or steric properties.

The purpose of the present work is to study the predictive potential of compressibility for modeling the toxicity of NBs on *Tetrahymena pyriformis* along withthe other well-known CDFT-based reactivity descriptors like electrophilicity index (ω), energy of lowest unoccupied molecular orbital (ε_{LUMO}) to examine the structure activity relationship for 45 NBs.

Theoretical Background

There is a paradigm shift in the realm of conceptual chemistry due to the density functional underpinning of Parr et al[34-37]. The useful qualitative entities like hardness, electronegativity and electrophilicity index which were abstract semiotic representations are now considered as theoretical quantities of cognitive representations. According to DFT, given the electron density function ρ(r) of a chemical system and the ground state energy and everything can be determined. The chemical potential, μ of that system in equilibrium has been defined as the derivative of the energy functional E (ρ) with respect to the electron density at fixed molecular geometry.

The chemical potential, μ, is given by[38]

$$\mu = -\chi = [\delta E(\rho) / \delta \rho]_v \quad \ldots(1)$$

where v is the external potential acting on an electron due to the presence of nucleus.

The differential definition more appropriate to atomic system is on the basis that for a system of N electrons with ground state energy E [N,v],

$$\mu = -\chi = [\partial E / \partial N]_v \quad \ldots(2)$$

The absolute hardness is defined[39] as

$$\eta = \tfrac{1}{2} [\partial \mu / \partial N]_v = \tfrac{1}{2} [(\partial^2 E / \partial N^2)]_v \quad \ldots(3)$$

The ansatz for hardness is mathematically difficult because the numerical method is required to be invoked to solve it[40]. However, Parr and Pearson[39], invoking finite difference approximation, suggested an approximate formula for the evaluation of hardness and electronegativity as

$$\eta = \tfrac{1}{2} (I - A) \quad \ldots(4)$$

$$\chi = \tfrac{1}{2} (I + A) \quad \ldots(5)$$

where, I is the ionization energy and A is the electron affinity of the chemical species.

Pearson[41] proceeded further to evaluate 'I' and 'A' in terms of orbital energies of the highest occupied molecular orbital, HOMO and the lowest unoccupied molecular orbital, LUMO by connecting it with Hartree - Fock SCF theory and invoking Koopmans' theorem the hardness and electronegativity are reformulated as

$$\eta = \tfrac{1}{2} (-\varepsilon_{HOMO} + \varepsilon_{LUMO}) \quad \ldots(6)$$

and $\chi = -\mu = -\tfrac{1}{2} (\varepsilon_{LUMO} + \varepsilon_{HOMO}) \quad \ldots(7)$

where $I = -\varepsilon_{HOMO}$, and $A = -\varepsilon_{LUMO}$.

Parr et al[42] defined another global parameter, the electrophilicity index (ω), as a measure of the decrease in energy due to the maximal transfer of electrons from a donor to an acceptor system and is given as

$$\omega = (\mu)^2 / (2\eta) \quad \ldots(8)$$

Atomic compressibility[31] is defined (β) as a property of electronic distribution. Thus, the study has been carried out with the concept that very selected compound display toxicity due to modification in its volume or size (compressibility) due to electrophilic (nucleophilic) attack. Higher compressibility signifies increased attractive interactions between atoms and molecules consequently pulling the atoms and molecules together. In, general, an increase in compressibility increases closeness of electrons in an atom/ molecule, perhaps contributing in exhibiting atomic/ molecular character more significantly, for instance, toxic behavior.

On extending this concept to molecular systems, Scientist defined group compressibility (Gβ) as a summation of compressibility of each atom present in a molecule[43]. Atomic compressibility (β) is represented mathematically[31] as

$$\beta=(12\pi^2\varepsilon_0/e^2)r^2/\omega \quad \ldots(9)$$

where e is the unit charge of an electron, r is the absolute radius of an atom, ω is the electropilicity index of the atom and ε_0 is the vacuum permittivity and group compressibility (Gβ) as represented as

$$G\beta = \sum\beta_i \quad \ldots(10)$$

where β_i signify the atomic compressibility of the i^{th} atom in a molecule with N atoms.

Method of computation

A total of 45 Nitro-benzenes with other substituents have studied in the present work. The outline of the structure is shown in Fig. 1.

The experimental toxicity data log ($1/IGC_{50}$) of the 45 NBs is listed in the table[44]

Computational study is performed within DFT (Density Functional Theory) framework and descriptors have been calculated using conceptual density functional theory. All the modeling and structural optimization of compounds have been performed using Gaussian 09 software package[45]. For optimization purpose, B3LYP with basis set 6-31G(d) has been adopted.

Atomic compressibility value for each atom taken from reference[31], to compute the molecular compressibility with the help of equation (10).

The value for the hydrophobicity term i.e logP (logarithum of octanol/water partition coefficient) is taken from reference[46].

Structural -toxicity models are developed using the multilinear regression using the statistical software

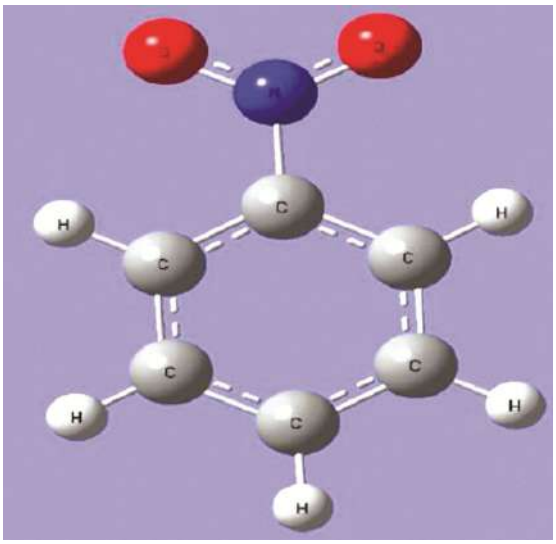


Figure 1 — Outline of the structure of nitrobenzenes (NBs)

Minitab[47]. log(I/IGC_{50}) values are used as the dependent variable and logP, ε_{lumo}, ω and β, as the independent variables. Goodness-of-fit for the proposed model is accomplished by assessing the coefficient of determination (R^2), R^2-adjusted, the standard error (S) and the number of sample size is also noted. The robustness of the model illustrates the stability of its parameters by performing validation of the model using leave-1/3-of set-out validation.

Results and Discussion

Several linear QSAR models involving one, two, three and four descriptors are established and strongest multi-linear correlations are identified by regression analysis of the Minitab program[45].

Four -parameter QSAR models:

$$\log(IGC^{-1}{}_{50}) = - 3.11 + 0.318 \log P + 0.0661 \beta + 3.31 \omega - 23.4 \varepsilon_{lumo} \quad \ldots(11)$$

N= 45 S = 0.268781 R-Sq = 85.1% R-Sq(adj) = 83.6%

The calculated quantum chemical descriptors, namely electrophilicity index (ω), ε_{LUMO}, compressibility (β) and the estimated partition co-efficient logP are given in Table 1

A significant improvement of the quality of QSAR model is obtained with a combination of the four parameters, namely partition coefficient logP, electrophilicity index(ω), LUMO energy (ε_{lumo}) and compressibility (β). Figure 2 shows the linear correlation between the observed and predicted toxicity values obtained using the four parameter QSAR model.

Table 1 — Descriptor values and predicted toxicity of nitrobenzene derivatives by Eq.11

S. No	Compound	ε_{LUMO}(au)	ω (au)	β(au)	log P	Observed toxicity log(IGC^{-1}_{50})	Predicted toxicity	Residual
1	2,6-Dimethylnitrobenzene	-0.08672	0.173449	2.995	2.87	0.3	0.603992949	0.303993
2	2,3-Dimethylnitrobenzene	-0.07445	0.150546	2.995	2.87	0.56	0.241068108	-0.31893
3	2-Methyl-3-chloronitrobenzene	-0.08719	0.174427	2.571	3.1	0.68	0.663342446	-0.01666
4	2-Methylnitrobenzene	-0.07747	0.156527	2.235	2.41	0.05	0.135016984	0.085017
5	2-Chloronitrobenzene	-0.08694	0.173913	2.081	2.34	0.68	0.38172225	-0.29828
6	2-Methyl-5-chloronitrobenzene	-0.08827	0.17654	2.571	3.1	0.82	0.695609106	-0.12439
7	2,4,5-Trichloronitrobenzene	-0.10982	0.224193	2.081	3.49	1.53	1.449239404	-0.08076
8	2,5-Dichloronitrobenzene	-0.10356	0.209766	2.147	2.95	1.13	1.08764776	-0.04235
9	6-Chloro-1,3-dinitrobenzene	-0.11718	0.242234	1.816	2.06	1.98	1.208925518	-0.77107
10	Nitrobenzene	-0.08179	0.16491	2.015	1.95	0.14	0.103029698	-0.03697
11	3-Methylnitrobenzene	-0.08651	0.173102	2.235	2.41	0.05	0.401413805	0.351414
12	1,3-Dinitrobenzene	-0.11382	0.229118	1.75	1.62	0.89	0.942604161	0.052604
13	3,4-Dichloronitrobenzene	-0.10659	0.215379	2.147	3.16	1.16	1.243908203	0.083908
14	4-Methylnitrobenzene	-0.08381	0.168142	2.235	2.41	0.17	0.321817331	0.151817
15	1,4-Dinitrobenzene	-0.12698	0.26173	1.75	1.37	1.3	1.278991766	-0.02101
16	4-Chloronitrobenzene	-0.09816	0.196654	2.081	2.6	0.43	0.8022227	0.372223
17	2,3,5,6-Tetrachloronitrobenzene	-0.11334	0.236069	2.454	3.73	1.82	1.671893361	-0.14811
18	6-Methyl-1,3-dinitrobenzene	-0.10724	0.215088	2.24	2.08	0.87	0.920862213	0.050862
19	3-Chloronitrobenzene	-0.0998	0.200436	2.081	2.64	0.73	0.86583791	0.135838
20	1,2-Dinitrobenzene	-0.10647	0.373047	1.75	1.84	1.25	1.316979587	0.06698
21	2-Bromonitrobenzene	-0.09387	0.190466	1.065	2.52	0.75	0.588756769	-0.16124
22	3-Bromonitrobenzene	-0.09913	0.199511	1.065	2.52	1.03	0.741781541	-0.28822
23	4-Bromonitrobenzene	-0.09789	0.196454	1.065	2.55	0.38	0.712183948	0.332184
24	2,4,6-Trimethylnitrobenzene	-0.08191	0.163948	2.605	3.33	0.86	0.580491684	-0.27951
25	5-Methyl-1,2-dinitrobenzene	-0.10223	0.348662	2.24	2.3	1.52	1.31571646	-0.20428
26	2,4-Dichloronitrobenzene	-0.10169	0.205448	2.147	3	0.99	1.045496163	0.055496
27	3,5-Dichloronitrobenzene	-0.10949	0.222328	2.147	3.34	1.13	1.392008534	0.262009
28	2,3,4,5-Tetrachloronitrobenzene	-0.11568	0.239098	2.279	3.94	1.78	1.791887824	0.011888
29	2,3-Dichloronitrobenzene	-0.10202	0.206657	2.147	2.9	1.07	1.025420726	-0.04458
30	2,5-Dibromonitrobenzene	-0.10324	0.212776	3.475	3.12	1.37	1.231961958	-0.13804
31	1,2-Dichloro-4,5 -dinitrobenzene	-0.12284	0.477847	1.882	3.2	2.21	2.488128523	0.278129
32	3-Methyl-4-bromonitrobenzene	-0.09478	0.189942	1.555	3.01	1.16	0.796525166	-0.36347
33	2,3,4-Trichloronitrobenzene	-0.10822	0.220949	2.081	3.44	1.51	1.385163842	-0.12484
34	2,4,6-Trichloro-1,3-dinitrobenzene	-0.12309	0.269736	1.948	3.41	1.43	1.876273533	0.446274
35	4,6-Dichloro-1,2-dinitrobenzene	-0.12206	0.4749	1.882	3.08	2.42	2.421962518	0.001963
36	3,5-Dinitrobenzylalcohol	-0.11037	0.222851	2.203	0.43	0.53	0.492654222	-0.03735
37	3,4-Dinitrobenzylalcohol	-0.1032	0.354222	2.203	0.65	1.09	0.829672482	-0.26033
38	2,3,5,6-Tetrachloro-1,4-dinitrobenzene	-0.14066	0.322619	2.454	2.92	2.74	2.340082588	-0.39992
39	4-Fluoronitrobenzene	-0.08513	0.171119	1.697	1.8	0.25	0.133018411	-0.11698
40	4-Fluoro-2-nitrotoluene	-0.086	0.172036	1.897	2.26	0.25	0.315909965	0.06591
41	1-Fluoro-2-nitrobenzene	-0.08431	0.169296	1.737	1.69	0.23	0.075459884	-0.15454
42	1-Fluoro-3-nitrobenzene	-0.09023	0.180471	1.737	1.9	0.2	0.317758254	0.117758
43	4-Nitrobenzaldehyde	-0.10872	0.220357	2.248	1.56	0.2	0.808101368	0.608101
44	3-Nitrobenzaldehyde	-0.0966	0.193354	2.248	1.75	0.14	0.495534978	0.355535
45	3-Nitroacetophenon	-0.09211	0.184343	2.468	1.49	0.32	0.292505258	-0.02749

Cross-validation

In order to check the reliability and stability of the QSAR model (Eq. 11), the leave -1/3-of -set -out validation is applied in the following way: the parent data points were divided three subsets namely A, B and C. In each of three combinations, two of the subset were combined into one and the correlation equation was determined with the same descriptors.

Table 2 — Cross-validation of the best QSAR model

Training Set	N	R^2	R^2_{adj}	Test Set	N	R^2(Pred)	R^2_{adj}(Pred)
A+B	31	0.88	0.86	C	14	0.76	0.73
A+C	30	0.81	0.78	B	15	0.89	0.88
B+C	29	0.88	0.85	A	16	0.84	0.82
Average		0.86	0.83			0.83	0.81

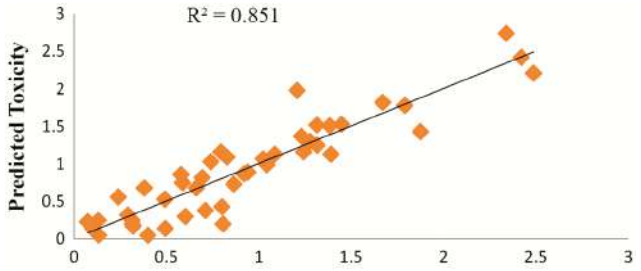


Figure 2 — Predicted vs observed toxicity using Eq.11

The obtained equation was used to predict data for the remaining subset. It turns out that the predicted R^2 values using subsets (A+B), (B+C) and (C+A) are close to that corresponding to the full training set (A+B+C) and the average values of R^2 and R^2(predicted) given in the Table 2, are also close. So the data given in the Table 2 speaks in favour of the efficacy of the present model for estimating the toxicity of the nitrobenzenes for which experimental data are unavailable.

Conclusion

A comprehensive QSAR analysis has been carried out for the 45 NBs using conceptual density functional theory based reactivity descriptors namely electrophilicity index (ω), lowest unoccupied molecular orbital (ε_{lumo}) and molecular compressibility (β) along with the hydrophobicity index (logP) to assess their toxic behaviour towards *T.pyriformis*. The high value of Coefficient of determination and robustness of the model establish the importance of these descriptors in the prediction of toxicity.

References

1 Martin Y C, *Quantitative Drug Design, Marcel Dekker*, New York, NY, USA, (1978).
2 Lessigiarska I, *Development of structure-activity relationship for pharmacotoxicological endpoints relevant to European Union legislation*, Ph.D. thesis, Liverpool John Moores University, Liverpool, UK, (2006).
3 Mekenyan O G & Veith G D, *SAR QSAR Environ Res*, 1 (1993) 335.
4 Comporti M, *Chem Biol Interact*, 72 (1989) 1.
5 Mikolajczyk A, Gajewicz A, Rasulev B, Schaeblin N, Maurer-Gardner E, Hussain S, Leszezynski J & Puzyn T, *Chem Mater*, 27(2015) 2400.
6 Mikolajczyk A, Sizochenko N, Mulkiewicz E, Malankowska A & Nischk M, *Beilstein J Nanotechnol*, 8 (2017) 2171.
7 Mikolajczyk A, Gajewicz A, Mulkiewicz E, Rasulev B, Marchelek M, Diak M, Hirano S, Zaleska-Medynska A & Puzyn T*, Environ Sci Nano*, 5 (2018) 1150.
8 Mikolajczyk A, Sizochenko N, Mulkiewicz E, Malankowska A, Rasulev B & Puzyn T, *Nanoscale*, 11 (2019) 1808.
9 Shalini A, Tandon H & Chakraborty T, *J Bioeqiv Availab*, 9 (2017) 518.
10 Singh P P, Srivastava H K & Pasha F A, *Biorg Med Chem*, 12 (2004)171.
11 Pasha F A, Srivastava H K & Singh P P, *Biorg Med Chem*, 13 (2005) 6823.
12 Srivastava H K, Pasha F A & Singh P P, *Int J Quantum Chem*, 103 (2005) 237.
13 Chakraborty T & Ghosh D C , *Correlation of drug activities of some anti-tubercular chalcone derivatives in terms of the quantum mechanical reactivity descriptors, In : A.K. Haghi (ed), Methodologies and applications for chemoinformatics and chemical engineering* , IGI Global, Hershey, PA, 155 (2013).
14 Vijayaraj R, Subramanian V & Chattaraj P K, *J Chem Theory Comput*, 5 (2009) 2745.
15 Lessigiarska I, Worth A P & Netxeva T I, *EUR Report 21559EN*, Joint Research Centre, Ispra, Italy, (2005).
16 Kapur S, Shusterman A , Verma R P, Hansch C & Selassie C D, *Chemosphere*, 41 (2000) 1643.
17 Bundy J G , Jorriss A W, Durham D G, Campbell C D & Paton G I, *Chemosphere*, 42 (2001) 885 .
18 Ren S & Frymier P D, *Water Res*, 36 (2002) 4406 .
19 Sverdrup L E, Nielsen T & Krogh P H, *Environ Sci Technol*, 36 (2002) 2429.
20 Worgan A D P , Dearden J C , Edwards R, Netzeva T I & Cronin M T D, *QSAR Comb Sci*, 22 (2003) 204.
21 Croni M T, Bowers G S, Sinks G D & Schultz T W, *SAR QSAR Environ Res*, 11 (2000) 301.
22 Cronin M T D & Schultz T W, *Chem Res Toxicol*, 14 (2001) 1284.
23 Cronin M T D, Manga N, Seward J R , Sinks G D & Schultz T W , *Chem Res Toxicol*, 14 (2001) 1498.
24 Wang X, Yin C & Wang L, *Chemosphere*, 46 (2002) 1045.
25 Cronin M T, Dearden J C & Duffy J C*, SAR QSAR Environ Res*, 13 (2002) 167.
26 Lu G H, Yuan X & Zhao Y H, *Chemosphere*, 44 (2002) 153.
27 Wang X, Sun C, Wang Y & Wang L, *Chemosphere*, 46 (2002) 153.
28 Wang X, Yu J, Wang Y & Wang L, *Chemosphere*, 46 (2002) 241.
29 Cronin M T D, Netzeva T I , Dearden J C, Edwards R & Worgan A D P, *Chem Research Toxicol*, 17 (2004) 545.
30 Schultz T W, Netzeva T I, Roberts D W & Cronin M T D, *Chem Res Toxicol*, 18 (2005) 330.
31 Tandon H, Chakraborty T & Suhag V, *J Mol Model*, 303 (2019) 1.

32 Tandon H, Ranjan P, Chakraborty T & Suhag V, *Mol Divers*, 25 (2021) 249.
33 Schultz T W, *Chem Res Toxicol*, 12 (1999) 1262.
34 Parr R G & Yang W, *J Am Chem Soc*, 106 (1984) 4049
35 Parr R G & Yang W, *Density Functional Theory of Atoms and Molecules,*Oxford, University Press, New York, (1989).
36 Yang W, Parr R G & Pucci R, *J Chem Phys*, 81 (1984) 2862.
37 Parr R G, Donnelly R A, Levy M & Palke W E, *J Chem Phys*, 68 (1978) 3801.
38 Gyftopoulos E P & Hatsopoulos G N, *Proc Natl Acad Sci*, 60 (1968) 786.
39 Parr R G & Pearson R G, *J Am Chem Soc*, 105 (1983) 7512.
40 Sen K D & Vinayagam S C, *Chem Phys Lett,* 144 (1988) 178.
41 Pearson R G, *Proc Natl Acad Sci*, 83 (1986) 8440.
42 Parr R G, Szentpaly L V & Liu S, *J Am Chem Soc*, 121 (1999) 1922.
43 Noorizadeh S & Parhizgar M, *J Mol Struct Thochem*, 725 (2005) 23.
44 Cronin M T D , Manga N , Seward J R, Sinks G D & Schultz T W, *Chem Res Toxicol*, 14 (2001)1498
45 Frisch M J, Toucks G W, Schlegel H B, Scuseria G E, Robb M A, Cheeseman J R, Scalmani G, Baron V, Mennucci B & Peterson G A, Gaussian 09 revision D.01; Gaussian, Inc., Wallingfort, CT, (2009).
46 Bellifa K & Melellece S M, *Arabian J Chem*, 9 (2016) S1683.
47 Minitab17 Statistical Software [Computer software] State College, PA: Minitab, Inc.(www.minitab.com), (2010).

South East Asian J. of Mathematics and Mathematical Sciences
Vol. 17, No. 3 (2021), pp. 109-118

ISSN (Online): 2582-0850

ISSN (Print): 0972-7752

ON CAUCHY'S BOUND FOR ZEROS OF TRANSCENDENTAL ENTIRE FUNCTIONS

Sanjib Kumar Datta and Tanchar Molla*

Department of Mathematics,
University of Kalyani, Kalyani,
Nadia - 741235, West Bengal, INDIA

E-mail : sanjibdatta05@gmail.com

*Department of Mathematics,
Dumkal College, Basantapur,
Murshidabad - 742406, West Bengal, INDIA

E-mail : tanumath786@gmail.com

(**Received:** *Apr. 28, 2021* **Accepted:** *Oct. 10, 2021* **Published:** *Dec. 30, 2021)*

Abstract: The prime concern of this paper is to derive bound for the moduli of the zeros of a transcendental entire function. A few examples are given here to validate the results obtained.

Keywords and Phrases: Transcendental entire function, Cauchy's bound, zero.

2020 Mathematics Subject Classification: 30D20, 30C10, 30C15, 30D10.

1. Introduction, Definitions and Notations

Fundamental theorem of algebra only gives information about the number of zeros of a polynomial but not location of the zeros. All zeros of a quadratic polynomial can be derived algebraically for all possible values of its coefficients. But, difficulty arises when degree of polynomial increases. So, it is desirable to know a region where the zeros of a polynomial lie.

Problem of finding a region containing all the zeros of a polynomial has a rich old history {cf.[7]}. In 1829, Cauchy {cf.[7]} develop the following classical result:

South East Asian Journal of Mathematics and Mathematical Sciences
PRINT ISSN : 0972-7752 | ONLINE ISSN : 2582-0850

LIST OF ALL ARTICLES

S.No	Title of The Article	Authors	Published In	Pages	
1	**CRYPTANALYSIS OF RSA-LIKE CRYPTOSYSTEM WITH MODULUS $N=pq$ AND $ed \equiv 1 (\bmod ~(p^2+p+1)(q^2+q+1))$**	L. Jyotsna L. Praveen Kumar	Volume 17 Issue 3	1-16	Read more
2	**CRYPTOGRAPHIC ALGORITHMS USING FINITE STATE MACHINE, BERNOULLI AND LUCAS NUMBERS**	Rachna Navalakhe Harsha Atre	Volume 17 Issue 3	17-28	Read more
3	**SPACE OF INVARIANT BILINEAR FORMS UNDER A REPRESENTATION OF $SL_2(3)$**	Dilchand Mahto Jagmohan Tanti	Volume 17 Issue 3	29-44	Read more
4	**SIMPLE EFFICIENT BOUNDS FOR ARCSINE AND ARCTANGENT FUNCTIONS**	Ramkrishna M. Dhaigude Yogesh J. Bagul	Volume 17 Issue 3	45-62	Read more
5	**HANKEL DETERMINANT OF GENERALISED CLASSES OF STARLIKE FUNCTIONS WITH RESPECT TO m-FOLD SYMMETRIC POINTS**	R. Reena Roy Thomas Rosy	Volume 17 Issue 3	63-72	Read more
6	**NEW GENERALIZED SUBCLASSES OF BI-UNIVALENT FUNCTIONS ASSOCIATED WITH FRACTIONAL DIFFERENTIAL OPERATOR**	Uday H. Naik Raisa M. Shaikh	Volume 17 Issue 3	73-82	Read more
7	**MAPPING PROPERTIES OF HYPERGEOMETRIC TRANSFORMS ON CERTAIN CLASS OF ANALYTIC FUNCTIONS**	Virendra Upadhayay K. K. Dixit Ankit Dixit Saurabh Porwal	Volume 17 Issue 3	83-100	Read more
8	**ON RADIUS PROBLEMS FOR SOME SUBCLASSES OF ANALYTIC UNIVALENT FUNCTIONS**	U. Vadivelan S. Sunil Varma Thomas Rosy	Volume 17 Issue 3	101-108	Read more
9	**ON CAUCHY'S BOUND FOR ZEROS OF TRANSCENDENTAL ENTIRE FUNCTIONS**	Sanjib Kumar Datta	Volume 17 Issue 3	109-118	Read more

		Tanchar Molla			
10	**CERTAIN PROPERTIES OF JACOBI'S THETA FUNCTIONS**	Satya Prakash Singh Ravindra Kumar Yadav Vijay Yadav	Volume 17 Issue 3	119-130	Read more
11	**RELATIONS ON CONTINUITIES AND BOUNDEDNESS IN INTUITIONISTIC FUZZY PSEUDO NORMED LINEAR SPACES**	Bivas Dinda Santanu Kumar Ghosh T. K. Samanta	Volume 17 Issue 3	131-146	Read more
12	**STRONG COUPLED FIXED POINTS OF α-ADMISSIBLE REICH TYPE COUPLED MAPPINGS IN S-METRIC SPACES**	G. V. R. Babu P. Durga Sailaja G. Srichandana	Volume 17 Issue 3	147-172	Read more
13	**SOME NEW RESULTS ON F-CONTRACTIONS IN RECTANGULAR b-METRIC SPACES WITH AN APPLICATION**	Mittal K. Patel Jaita Sharma Gunamani M. Deheri	Volume 17 Issue 3	173-188	Read more
14	**COUPLED FIXED POINT THEOREMS OF WEAKLY C-CONTRACTION WITH MIXED MONOTONE PROPERTY IN ORDERED MODULAR METRIC SPACES**	Shishir Jain Yogita Sharma	Volume 17 Issue 3	189-208	Read more
15	**A COMMON FIXED POINT THEOREM FOR COMPATIBLE MAPS IN COMPLEX VALUED METRIC SPACES**	Sanjay Kumar Tiwari Himanshu Kumar Pandey	Volume 17 Issue 3	209-214	Read more
16	**FIXED POINT THEOREM IN M COMPLETE NON-ARCHIMEDEAN FUZZY-METRIC-LIKE SPACES**	Sarika Saxena Abha Tenguria	Volume 17 Issue 3	215-224	Read more
17	**NEW OPERATOR VIA STRONG FORM OF NANO OPEN SETS**	V. Sutha Devi M. Lellis Thivagar S. Vaitheeswari	Volume 17 Issue 3	225-240	Read more
18	**EXISTENCE AND UNIQUENESS OF NEW FIXED POINTS OF (ψ,ϕ) CONTRACTIONS IN RECTANGULAR METRIC SPACES**	Jayesh Tiwari Dileep Kumar Sharma	Volume 17 Issue 3	241-252	Read more
19	**SOME MORE PROPERTIES OF (1,2)S_{β}-OPEN SETS IN BITOPOLOGICAL SPACES**	V. Subprabha N. Durga Devi	Volume 17 Issue 3	253-260	Read more
20	**λ^{α}_{g}-CLOSED AND λ^{α}_{g}-OPEN MAPS IN TOPOLOGICAL SPACES**	S. Subhalakshmi N. Balamani	Volume 17 Issue 3	261-276	Read more
21	**APPLICATIONS OF $\hat{g}^{\ast\ast}$s-CLOSED SETS IN TOPOLOGICAL SPACES**	Anto M Andrin Shahila S	Volume 17 Issue 3	277-284	Read more
22	**ADRIATIC INDICES OF SOME DERIVED GRAPHS OF TRIGLYCERIDE**	V. Lokesha M. Manjunath T. Deepika	Volume 17 Issue 3	285-298	Read more

		A. S. Cevik I. N. Cangul			
23	**ss-EXCELLENCE IN GRAPHS**	V. Praba V. Swaminathan	Volume 17 Issue 3	299-312	Read more
24	**ON THE M-POLYNOMIAL AND SOME TOPOLOGICAL INDICES OF THE PARA-LINE GRAPHS OF THE NANOSTRUCTURE $TUC_4C_8(R)$**	Narahari N. Swamy Chandan K. G. B. Sooryanarayana	Volume 17 Issue 3	313-330	Read more
25	**ON CORRELATION OF PHYSICOCHEMICAL PROPERTIES AND THE HYPER ZAGREB INDEX FOR SOME MOLECULAR STRUCTURES**	Keerthi G. Mirajkar Bhagyashri R. Doddamani Huchesh H. B.	Volume 17 Issue 3	331-346	Read more
26	**EDGE-ODD GRACEFUL LABELING OF JAHANGIR GRAPH**	J. Jeba Jesintha C. Yogalakshmi	Volume 17 Issue 3	347-354	Read more
27	**VERTEX - EDGE DOMINATING COLORING OF GRAPHS**	R. Madhiyalagan A. Wilson Baskar	Volume 17 Issue 3	355-362	Read more
28	**SIGMA COLORING AND GRAPH OPERATIONS**	J. Suresh Kumar Preethi K. Pillai	Volume 17 Issue 3	363-372	Read more
29	**CORDIAL LABELING FOR NEW CLASS OF GRAPHS**	J Jeba Jesintha K Subashini P Cathrine Silvya Jabarani	Volume 17 Issue 3	373-380	Read more
30	**FUZZY MATROIDS FROM FUZZY VECTOR SPACES**	Shabna O. K. Sameena K.	Volume 17 Issue 3	381-390	Read more
31	**AN INVESTIGATION ON VERTICAL POROUS PLATE IN A CONDUCTING FLUID WITH MULTIPLE BOUNDARY LAYER FLOW OF CASSON FLUID**	L. Rama Mohan Reddy P. V. Sanjeeva Kumar K. Suguna Rao K. S. N. Siddartha Goutham	Volume 17 Issue 3	391-402	Read more
32	**G-ATTRACTOR AND G-EXPANSIVITY OF THE G-UNIFORM LIMIT OF A SEQUENCE OF DYNAMICAL SYSTEMS**	Phinao Ramwungzan Khundrakpam Binod Mangang	Volume 17 Issue 3	403-414	Read more
33	**HALL CURRENT EFFECT ON DOUBLE DIFFUSIVE CONVECTION OF COUPLE-STRESS FERROMAGNETIC FLUID IN THE PRESENCE OF VARYING GRAVITATIONAL FIELD AND HORIZONTAL MAGNETIC FIELD THROUGH A POROUS MEDIA**	Sudhir Kumar Pundir Pulkit Kumar Nadian Rimple Pundir	Volume 17 Issue 3	415-438	Read more
34	**A METHOD FOR SOLVING ASSIGNMENT PROBLEM USING RANKING OF CENTROID OF CENTROIDS IN TRAPEZOIDAL INTUITIONISTIC FUZZY NUMBER**	K. Dhilipkumar C. Praveenkumar	Volume 17 Issue 3	439-446	Read more

35	**QUASI-SYMMETRIC DESIGNS WITH K NUMBERS OF INTERSECTION AS UNREDUCED DESIGNS**	Smita Jain Shakti Banerjee	Volume 17 Issue 3	447-456	Read more
36	**A MATHEMATICAL MODEL FOR ESTIMATING THE RELATIONSHIP BETWEEN PROLACTIN AND GROWTH HORMONES IN THE BLOOD OF THE MILKING GOAT TO MAXIMUM LIKELIHOOD**	M. Gayathri M. Chandra Malar	Volume 17 Issue 3	457-468	Read more
37	**BULK ARRIVAL QUEUEING SYSTEM WITH STAND BY SERVER AND MULTIPLE VACATION QUEUEING SYSTEM**	Shejal Gupta Pradeep K. Joshi K. N. Rajeshwari	Volume 17 Issue 3	469-478	Read more

News & Events

Brochure of National Conference on “Mathematics and its Application for the Advancement of Computer Science and Technology

Published issue of the South East Asian Journal of Mathematics and Mathematical Sciences, Vol. 19, No.2, August 2023

Submission method of article through new website of journal

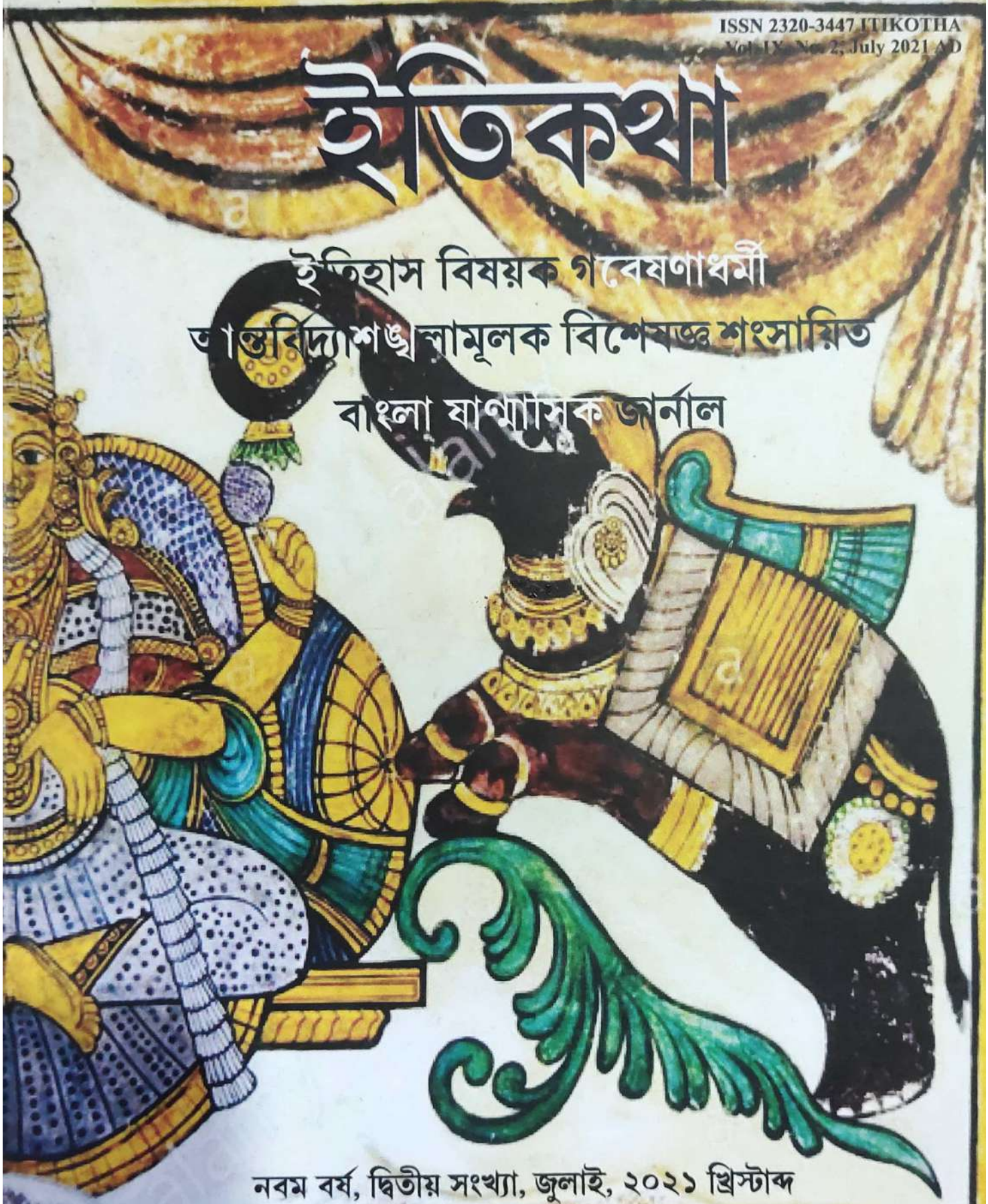
National Council for Science & Technology Communication (RASHTRIYA VIGYAN EVAM PRODYOGIKI SANCHAR PARISHAD) Department of Science and Technology sponsored workshop during November 15-19, 2023

Total View : Visitor Counter

ISSN 2320-3447 ITIKOTHA
Vol. IX, No. 2, July 2021 AD

ইতিকথা

ইতিহাস বিষয়ক গবেষণাধর্মী
আন্তর্বিদ্যাশৃঙ্খলামূলক বিশেষজ্ঞ শংসায়িত
বাংলা ষাণ্মাসিক জার্নাল



নবম বর্ষ, দ্বিতীয় সংখ্যা, জুলাই, ২০২১ খ্রিস্টাব্দ

বঙ্গীয় ইতিহাস সমিতি কলকাতা

ITIKOTHA

An interdisciplinary Half Yearly Research Oriented Referred Journal of History in Bengali

ISSN 2320-3447 Itikotha (Print)
Vol. IX, No. 2, July 2021 AD

Website
www.bangiyaitihas.in

E-mail
bangiyaitihas@gmail.com

Price : 200/-

The publication of this journal has been financially supported by the Indian Council of Historical Research.
The responsibility for the facts stated or opinions expressed is entirely of the author and not of the ICHR.

ইতিকথা

ইতিহাস বিষয়ক গবেষণাধর্মী আন্তর্বিদ্যাশৃঙ্খলামূলক বিশেষজ্ঞ শংসায়িত বাংলা যাণ্মাসিক জার্নাল
নবম বর্ষ, দ্বিতীয় সংখ্যা, জুলাই ২০২১ খ্রিস্টাব্দ

প্রকাশক
বঙ্গীয় ইতিহাস সমিতি কলকাতা-র পক্ষে কানাইলাল চট্টোপাধ্যায় কর্তৃক
কলকাতা ৭০০ ০০৭ থেকে প্রকাশিত

বর্ণ-সংস্থাপন
জয়ন্ত ভট্টাচার্য
নৈহাটি, উত্তর ২৪ পরগনা

মুদ্রণ
নিম্বার্ক অফসেট
৪এ, পটলডাঙা স্ট্রিট, কলকাতা ৭০০ ০০৯

মূল্য : ২০০ টাকা

ইতিকথা
ইতিহাস বিষয়ক গবেষণাধর্মী আন্তর্বিদ্যাশৃঙ্খলামূলক বিশেষজ্ঞ শংসায়িত বাংলা ষাণ্মাসিক জার্নাল
ISSN 2320-3447 *Itikotha* (Print)
Vol. IX, No. 2, July 2021 AD

ইতিকথা, বর্ষ ৯, সংখ্যা ২, জুলাই ২০২১ খ্রি. (ISSN 2320-3447 *Itikotha*) পৃ. ১৬৫-১৮৯
www.bangiyaitihas.in

প্রবন্ধ

সমাজ, রাজনীতি, ব্যক্তি ও সামাজিক আন্দোলন: হরিহরপাড়া, ১৯৯২

অর্ণব দেবনাথ*

(প্রাপ্ত: ৩১ জুলাই ২০২০ খ্রি., গৃহীত: ২২ ফেব্রুয়ারি ২০২১ খ্রি.)

পশ্চিমবঙ্গের মুর্শিদাবাদ জেলার হরিহরপাড়া ব্লকে ১৯৯২ খ্রিস্টাব্দের ২ নভেম্বর একটি গণতান্ত্রিক 'আইন অমান্য কর্মসূচি'কে (Civil Disobedience Programme) কেন্দ্র করে পুলিশের গুলিতে সাতজন স্থানীয় হিন্দু-মুসলিম মানুষের মৃত্যু ঘটে। এই কর্মসূচিটি ছিল বিগত প্রায় আট বছর (১৯৮৪-১৯৯২) ধরে চলা সমাজবিরোধী কার্যকলাপ আর প্রশাসনিক অবহেলার বিরুদ্ধে স্থানীয় নাগরিকদের গড়ে তোলা 'সামাজিক আন্দোলন' (Social Movement)-এর শেষ পর্যায় যার নিদারুণ পরিসমাপ্তি ঘটে রাষ্ট্রীয় হিংসার মধ্যে দিয়ে। এই সামাজিক আন্দোলন একদিকে ছিল নিতান্তই 'স্থানীয়'; অন্যদিকে এর মধ্যে মিশে গিয়েছিল হরিহরপাড়ার নিজস্ব সামাজিক প্রেক্ষিত, রাজনীতির অন্ধিসন্ধি। সর্বোপরি, আত্মসংরক্ষণ আর সামাজিক সুস্থিতির আশায় সাধারণ ব্যক্তি-নাগরিকের আবেগ (Emotion) আর মরিয়া প্রতিরোধের চেষ্টা। এই প্রবন্ধটিতে হরিহরপাড়ার রাজনৈতিক ইতিহাসের অ্যাখ্যানের মধ্যে জড়িয়ে থাকা সমাজ, রাষ্ট্র আর ব্যক্তিকে, তাদের মধ্যে সম্পর্কের তানাবানাকে অনুধাবনের প্রয়াস করা হয়েছে যার নিউক্লিয়াস ছিল হরিহরপাড়ার ব্লকের এই 'সামাজিক আন্দোলন'টি। সেইসঙ্গে এই নিরিখে 'ব্যক্তির সাবজেক্টিভিটি (Human Subjectivity), স্থানীয় রাজনীতি আর সামাজিক আন্দোলনের বিভিন্ন মাত্রাগুলি কী ছিল?' এবং 'কীভাবে ইতিহাসের ওই বিশেষ পর্বের মধ্যে (১৯৮৪-১৯৯২) সেগুলি ক্রিয়াশীল হয়ে উঠেছিল?' সেই প্রশ্নের উত্তর খুঁজে দেখার চেষ্টা করা হয়েছে এখানে।

* অ্যাসিস্ট্যান্ট প্রফেসর, রাষ্ট্রবিজ্ঞান বিভাগ, ডোমকল কলেজ, মুর্শিদাবাদ।
e-mail: arnav121206@gmail.com

ISSN 2249-3751

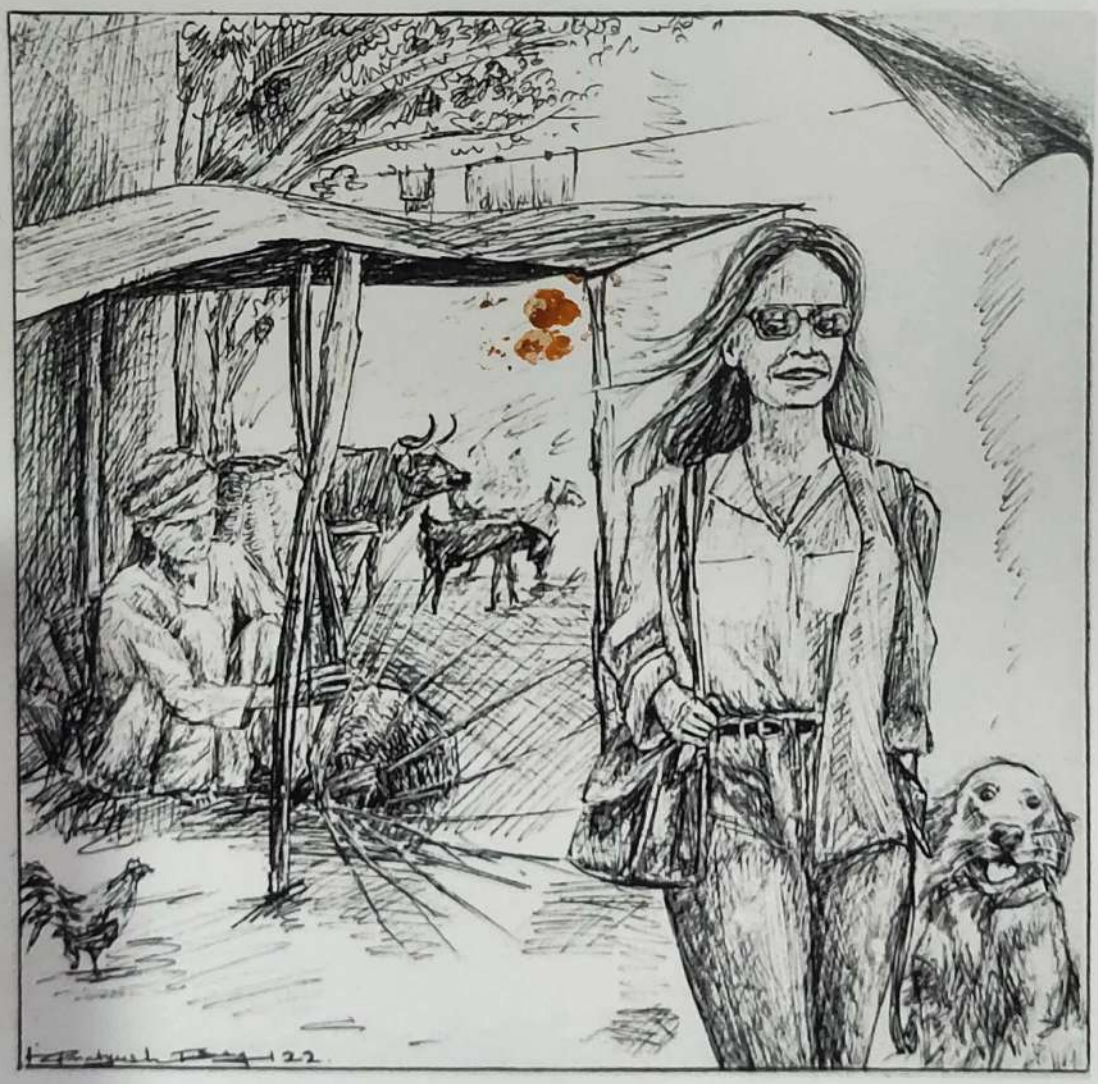
অন্তর্মুখ

সাহিত্য, সমাজ ও সংস্কৃতি বিষয়ক দ্বিভাষিক গবেষণা পত্রিকা

ANTARMUKH

Bilingual Research Journal Subjective to Literature, Society and Culture

Vol. : 11 Issue : 1 Quarterly Journal



সাহিত্য ও সমাজপ্রেক্ষিতে গ্রাম-শহর (২য় পর্ব)

Village and City in view of literature and society (Part-2)

অন্তর্মুখ

সাহিত্য, সমাজ ও সংস্কৃতি বিষয়ক দ্বিভাষিক গবেষণা পত্রিকা

ANTARMUKH

Bilingual Research Journal Subjective to Literature, Society and Culture

(A Peer Reviewed Journal)

Vol-11 Issue-1 Quarterly July-September 2021

["Published with financial assistance from the Central Institute of Indian Language (Dept. of Higher Education, Ministry of Human Resource Development, Government of India) Manasagangotri, Mysore 570 006 vide sanction letter F. No. 53-2(7)/2014-15/BEN/LM/ GRNT dated 5th Decenber 2016 under the Little Magazine scheme of Grant-in-aid".]

সাহিত্য ও সমাজ প্রেক্ষিতে গ্রাম ও শহর (২য় পর্ব)

Villege and City in view of literature and society (2nd Part)

Editor

Sampa Samanta Bag

'সাম্পান'

বাদশাহী রোড, ভাঙ্গাকুঠি, বর্ধমান

সূচিপত্র

Rural Development, Forest Management, and Violence : The Case of Jitpur Forest in the District of Murshidabad, West Bengal

Arnav Debnath

Abstract : A forest can be a useful means of rural development. It requires administrative planning and state support to work hand in hand with management of the resources of forest in bringing on well-being to the local rural people and their participation in the programme. But absence of such conditions may end up in misuse of the same : it is detrimental both to the forest and people living nearby villages to it because it is then no longer able to provide collective benefits, or even worse, may usher in violence intermixed with local political interest. The Jitpur forest in the Domkal block of the Murshidabad district (West Bengal) epitomizes the case. This article, therefore, tries to find out the reasons operating behind such scenario within the context of democratic society with reference to the forest concerned.

Key words : Rural development, Forest Management, Jitpur forest, Violence, Political Society.

1. Introduction

A forest is not a mere collection of trees, shrubs and bushes rather a forest is an 'ecological space' where the flora and fauna inhabit, grow, and procreate in their natural courses. The forest, again, is an organic entity, an end-in-itself which has been an inseparable part of the human existence, civilization, and culture. It also hexes a kind of resistance against the booming industrialization and the so-called urbanization, against the grey sheds of mundane life. A forest which is situated in the rural area may be a source, a means: of natural resources and socio-political tussle as well that sometimes leads to violence. It seems, however, paradoxical. An observer notes on the one hand "Life in a forest village is wondering",[1] and on the other hand, "beautiful forests were being robbed daily to meet the demand...by an unholy nexus among a section of forest officials,

Aug 04, 2021
ISSN: 2278-9758
Volume II, No. 19 – JULY 2021

CONTENT

Editor's Note...

Glad to inform that the current edition of Inclusive Volume II, No. 19 – JULY 2021 has now been published on time. It's not out of place to mention that this time the schedule of publication has been perfectly followed. It's a fruit of well-coordinated work of many distinguished members of the academia who have extended their constructive hands by investing invaluable time and energy for review and editing work. I am sincerely grateful to everybody and keep remembering their unequivocal support to make it a success.

Special Paper

Inclusive

Inclusive is a biannual online journal of the Kolkata Centre for Contemporary Studies (KCCS) which aims to publish serious, academic articles on the social sciences. It also publishes commentaries & critical analyses, insights and book reviews.

INFORMATION

About Inclusive
Editor's page
Author's Corner
Archive
FAQ
Notifications
Publication Ethics
Contact us

NEWSLETTER

Subscribe to receive inspiration, ideas & News in your inbox.

Email address

SUBSCRIBE

Journal of Molecular Structure 1257 (2022) 132644

Contents lists available at ScienceDirect

Journal of Molecular Structure

journal homepage: www.elsevier.com/locate/molstr

Inhibitory effect of compounds extracted from *Monochoria hastata* (L.) Solms on SARS-CoV-2 main protease: An insight from molecular docking and MD-simulation studies

Nabajyoti Baildya[a,*], Narendra Nath Ghosh[b], Asoke P. Chattopadhyay[a], Vivekananda Mandal[c], Sourav Majumdar[d], Delwar Ansary[e], Md Muttakin Sarkar[e]

[a] Department of Chemistry, University of Kalyani, Kalyani 741235, India
[b] Department of Chemistry, University of Gour Banga, Mokdumpur, Malda 732103, India
[c] Plant and Microbial Physiology and Biochemistry Laboratory, Department of Botany, University of Gour Banga, Mokdumpur, Malda 732103, India
[d] Department of Chemistry, Kandi Raj College, Kandi, Murshidabad, 742137, India
[e] Department of Chemistry, Dumkal College, Murshidabad, Domkal 742406, India

ARTICLE INFO

Article history:
Received 23 July 2021
Revised 6 February 2022
Accepted 15 February 2022
Available online 15 February 2022

Keyword:
COVID-19
Monochoria hastata (L.) Solms
Molecular docking
MD-simulation
Main protease of SARS-CoV-2

ABSTRACT

Using molecular docking and other studies, 20 compounds extracted from *Monochoria hastata* (L.) Solms were screened, and their inhibitory efficiency examined against main protease (3CLpro) of SARS CoV-2. All the compounds were found to binding with 3CLpro through van der Waals and electrostatic forces of attractions. Among them, Azelaic dihydrazide (ADZ) was found to have the highest docking score. 3CLpro-ADZ complex was studied by MD simulation. ADZ was found to disrupt the structure of 3CLpro after 2 ns. RMSD and RMSF analysis along with sequence and binding energy analysis suggest that ADZ can be a potential drug against SARS CoV-2.

1. Introduction

The devastating effect of novel coronavirus disease, COVID-19, progressively affects global health and economy. Such an emergency throws a challenge to the entire scientific community to work together and come up with an effective antidote against this deadly virus (SARS-CoV-2). Numerous attempts have been made to find useful drugs or vaccines to combat this virus [1–4]. But till date, no specific drug has been found. Drugs like chloroquine, hydroxychloroquine, favipiravir, remdesivir, azithromycine etc [5–9]., extracts from different plants [10–12], normally used in other diseases, are under clinical trial against this virus, but they are being used with caution.

Coronavirus was first found in 1960 [13]. It returned in new avatars in 2002 and 2012 to haunt us [14–17]. However, the novel coronavirus viz. SARS-CoV-2 or COVID-19 has created a pandemic because of its higher transmission rate (R_0) compared to previous cases. The SARS-CoV-2 belongs to the β-coronavirus group, and its genome is quite similar to that of previous SARS-CoV. Although exact origin of this virus is not clear [18], it is transmitted rapidly among human beings by community transmission [19]. The outer surface of this virus contains spike glycoprotein, an enveloped membrane and nucleocapsid protein containing a positive sense single strand of RNA. It mainly binds with human angiotensin-converting enzyme-2 (ACE-2) receptors using its spike glycoprotein. Along with spike proteins it contains the cellular serine protease TMPRSS2, cysteine protease, main protease (3CLpro), papain-like protease (PLpro) and different non-structural proteins (nsp) which are basically used for its replication. Therefore, drugs that effectively block one or more of these proteins or the ACE-2 enzyme involved in binding to host cell or those active in replication process are much focused [20–22].

From ancient times, herbs have been used as effective medicinal resource. There are approximately 25,000 plants in India which are used in traditional and folk medicine [23]. An aquatic medicinal plant of India, *Monochoria hastata* (L.) Solms, belonging to the family Pontederiaceae, is being used as remedy in Indian villages for various disorders. The extracts obtained from its leaf show antibacterial and anti-viral effects. It contains different types of alkaloids, phenols, terpenoids, flavonoids, glycosides, monoacyl glycerol etc. [24]. 20 different compounds were selected from extracts of

* Corresponding author.
E-mail addresses: nabajyotibaildya@gmail.com (N. Baildya), asoke@klyuniv.ac.in (A.P. Chattopadhyay).

https://doi.org/10.1016/j.molstruc.2022.132644
0022-2860/

this plant for in-silico screening against 3CLpro of SARS-CoV-2 by docking and molecular dynamics simulation.

2. Methodology

2.1. Virtual screening of Monochoria hastata (L.) Solms extracts with 3CLpro

The crystal structure of 3CLpro of SARS-COV-2 (PDB ID: 6LU7) was obtained from the Protein Data Bank. The sdf files of the drugs were downloaded from PubChem (National Library of Medicine) and were converted to pdb format to check ligand-protein binding interactions. UCSF Chimera [25] package was used to clean the structure of 3CLpro. Autodock Vina [26] was used to investigate docking between 3CLpro and the drug molecules and necessary files were prepared by using Autodock Tools.

2.2. Molecular dynamics simulation studies of ADZ docked 3CLpro complex

Azelaic dihydrazide (ADZ) was found to have the highest docking score with 3CLpro. The minimum energy docked configuration of 3CLpro-ADZ complex was selected for molecular dynamics (MD) simulation studies. GROMACS (version 5.1) [27] was used to perform the MD simulation using CHARMM36-mar2019 force-field [28] with TIP3P solvation model [29]. Ligand parameters and topology files were generated with the help of CHARMM General Force Field server. Periodic boundary conditions were applied to maintain a cubical box in which the 3CLpro-ADZ complex was at least 1 nm from the edges for successive imaging of the complex. To maintain electroneutrality, four Na^+ ions were added to the system. Energy minimization was carried out by the steepest descent algorithm followed by conjugate gradient protocol, until the system reached a minimum force of 10 $kJmol^{-1}nm^{-1}$. For equilibration of the system, isochoric-isothermal (NVT) ensemble was used at 300 K for 100 ps. The time step was set to 2 fs. This was followed by equilibration in an isothermal-isobaric (NPT) ensemble for 100 ps at 300 K. Modified Berendsen thermostat was used for the NPT ensemble. Here also the time step was set to 2 fs. For both the NVT and NPT equilibration, 1 nm cut-off was kept for van der Waals and electrostatic interactions. For the calculation of long range interactions, smooth particle mesh Ewald (PME) [30] method was used. Finally, MD simulation was performed for 10 ns using the equilibrated ensembles with the same cut off as used before. A modified Berendsen thermostat and a Parinello-Rahman barostat at 300 K temperature and 1 bar pressure were used. Snapshots of the trajectory were taken after each nanosecond of simulation.

2.3. Analysis of MD simulations

The trjconv tool was used for analysis of structural trajectories of the 3CLpro-ADZ complex during simulation. Drug, water, counter ions and 3CLpro were re-centered within the cubical box using the same tool. Variation of root mean square deviation (RMSD), root mean square fluctuations (RMSF), radius of gyration (Rg) and solvent accessible surface area (SASA) were plotted using xmgrace plotting tool. g_mmpbsa tool [31,32] was used to calculate average binding free energy, polar free energy (ΔG_{polar}), non-polar free energy ($\Delta G_{non\text{-}polar}$), average MM-energy ($\Delta E_{MM}$), van der Waals energy, SASA energy and electrostatic energy. The change of binding energy with time was plotted using Origin 8.0.

3. Results and discussions

20 compounds, extracted from *Monochoria hastata* (L.) Solms, were screened against SARS-CoV-2 main protease (3CLpro). Binding affinity of these compounds was found to be in the range of −3.6 to −5.8 Kcal/mol as shown in Fig. 1. The highest binding affinity of −5.8 Kcal/mol was observed for Azelaic dihydrazide (ADZ) against 3CLpro. Previous studies showed that Azelaic Acid and its

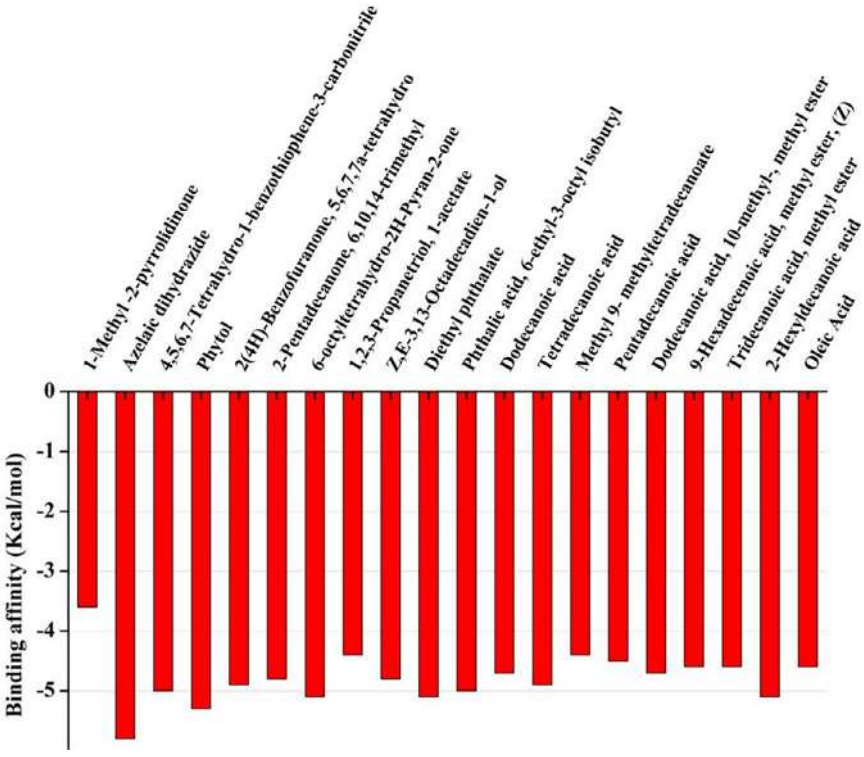


Fig. 1. Binding affinity (Kcal/mol) of *Monochoria hastata* (L.) Solms extracts.

Table 1
Toxicity parameters for 20 *Monochoria hastata* (L.) Solms compounds studied.

Compound	AMES toxicity	Max. tolerated dose (human)	hERG I inhibitor	hERG II inhibitor	Oral Rat Acute Toxicity (LD50) (mol/kg)	Oral Rat Chronic Toxicity (LOAEL) (log mg/kg_bw/day)	Hepato-toxicity	Skin Sensiti-sation	T.Pyriformis toxicity (log ug/L)	Minnow toxicity (log mM)
1-Methyl −2-pyrrolidinone	No	1.077	No	No	2.153	1.255	No	Yes	−0.887	2.861
Azelaic dihydrazide	No	0.907	No	No	1.762	2.87	No	Yes	0.143	2.839
4,5,6,7-Tetrahydro-1-benzothiophene-3-carbonitrile	No	0.438	No	No	2.049	1.882	No	Yes	1.431	1.005
Phytol	No	0.05	No	Yes	1.607	1.043	No	Yes	1.884	−1.504
2(4H)-Benzofuranone, 5,6,7,7a-tetrahydro	No	0.783	No	No	1.94	2.412	No	No	0.037	2.224
2-Pentadecanone, 6,10,14-trimethyl	No	0.244	No	No	1.532	1.094	No	Yes	2.14	−1.478
2H-Pyran-2-one, tetrahydro-6-octyl-	No	0.276	No	No	1.826	2.429	No	Yes	1.491	0.216
1,2,3-Propanetriol, 1-acetate	Yes	1.506	No	No	1.708	2.789	No	No	−0.616	3.366
Z,E-3,13-Octadecadien-1-ol	No	−0.207	No	Yes	1.578	1.106	No	Yes	1.703	−1.156
Diethyl phthalate	No	1.37	No	No	2.09	2.648	No	No	0.656	1.441
Phthalic acid, 6-ethyl-3-octyl isobutyl	No	1.324	No	No	1.712	2.42	No	No	1.468	−1.526
Dodecanoic acid	No	−0.34	No	No	1.511	2.89	No	Yes	0.954	−0.084
Tetradecanoic acid	No	−0.559	No	No	1.477	3.034	No	Yes	0.978	−0.601
Methyl 9- methyltetradecanoate	No	0.337	No	No	1.653	2.832	No	Yes	2.268	−1.044
Pentadecanoic acid	No	−0.642	No	No	1.458	3.107	No	Yes	0.922	−0.842
Dodecanoic acid, 10-methyl-, methyl ester	No	0.421	No	No	1.697	2.679	No	Yes	2.166	−0.558
9-Hexadecenoic acid, methyl ester, (Z)	No	0.125	No	No	1.608	2.926	No	Yes	2.005	−1.245
Tridecanoic acid, methyl ester	No	0.301	No	No	1.645	2.779	No	Yes	2.191	−0.638
2-Hexyldecanoic acid	No	−0.574	No	No	1.564	3.068	No	Yes	0.457	−0.923
Oleic Acid	No	−0.81	No	No	1.417	3.259	No	Yes	0.676	1.438

hydrazide derivation have high binding affinity with DNA Polymeraze I (2KFN) due to enhance H-bonding showing its potential inhibitory activity against 2KFN [33]. This observation is in accordance with our simulated results. It has been also reported that Azalaic Acid showed potential anti-viral inhibitory activity [34]. To analyze the stereochemistry of the drug-protein complex we have plotted contour diagram of drug with neighbouring residue of the 3CLpro as shown in Table S2. van der Waal donor-acceptor isosurfaces of drug-protein complex clearly indicates electrostatic interaction is exists between them while the 2D contour plot demonstrates van der Waal and the number of H-bonding interaction between drug and protein.

To predict toxicity of these compounds, ADME toxicity analysis was performed using pkCSM online server [35]. All the estimated pharmacokinetic properties are listed in Table 1.

3.1. ADME toxicity prediction

Pharmacokinetic analysis reveals that the compounds have low blood-brain barrier (BBB) permeability, with values ranging between −0.016 and 0.816. The drugs were found to have no effect on CYP2C9, CYP2D6 and CYP3A4 inhibitors. Skin permeability values were found between −1.384 and −4.376 for the drugs. These drugs also do not inhibit renal OCT2 substrate as shown Table S3 (in Supporting Information).

3.2. Toxicity prediction

Table 1 represents the toxicity level of the studied compounds. None of the compounds have AMES toxicity and they do not have hERGI inhibitory activity. Estimated oral rat toxicity values were found to lie between 1.417 and 2.153 mol/kg. Estimates of chronic oral rat toxicity (LOAEL) values are in between 1.094 and 3.259 (log mg/kg_bw/day). None of the compounds show hepatotoxicity, though most of the compounds show skin sensitization.

From the above analysis it is clear that all 20 compounds under consideration could serve as drugs for SARS CoV-2. The bound structures of some of the drugs with 3CLpro are shown in Fig. 2.

From the docking results it is clear that Azelaic dihydrazide (ADZ) showed the highest binding affinity to the main protease (3CLpro) of SAR-CoV-2. The docked structure along with a 2D contour plot of ADZ with 3CLpro are shown in Fig. 3 considering the electrostatic and van der Waals interactions.

From the above figure it is clear that ADZ binds strongly with 3CLpro via formation of five strong H-bonds ranging from 2.15 to 2.97 Å along with donor-acceptor interactions ranging from 2.37 to 2.62 Å which are very short with respect to other systems.

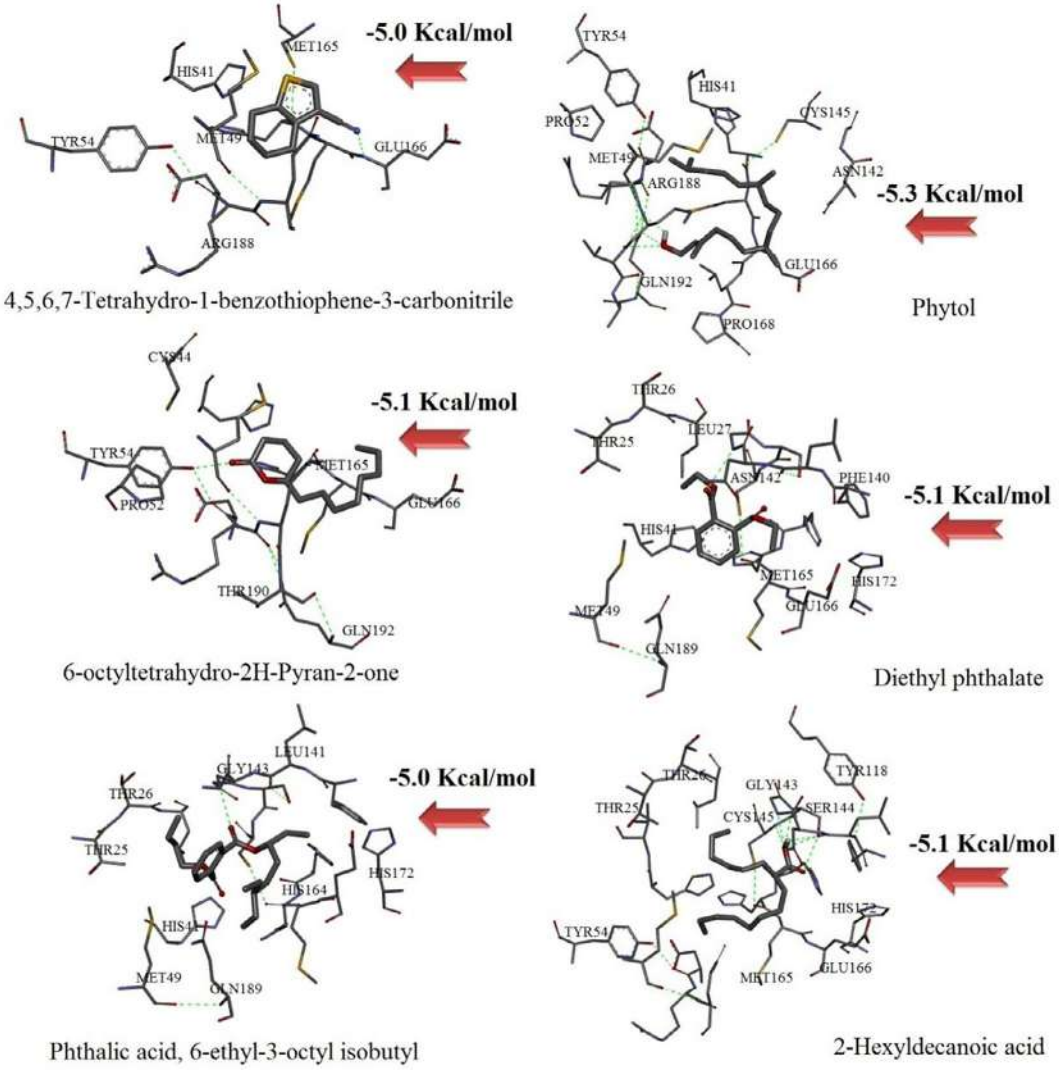


Fig. 2. Docked structures of some of the drugs considered with 3CLpro.

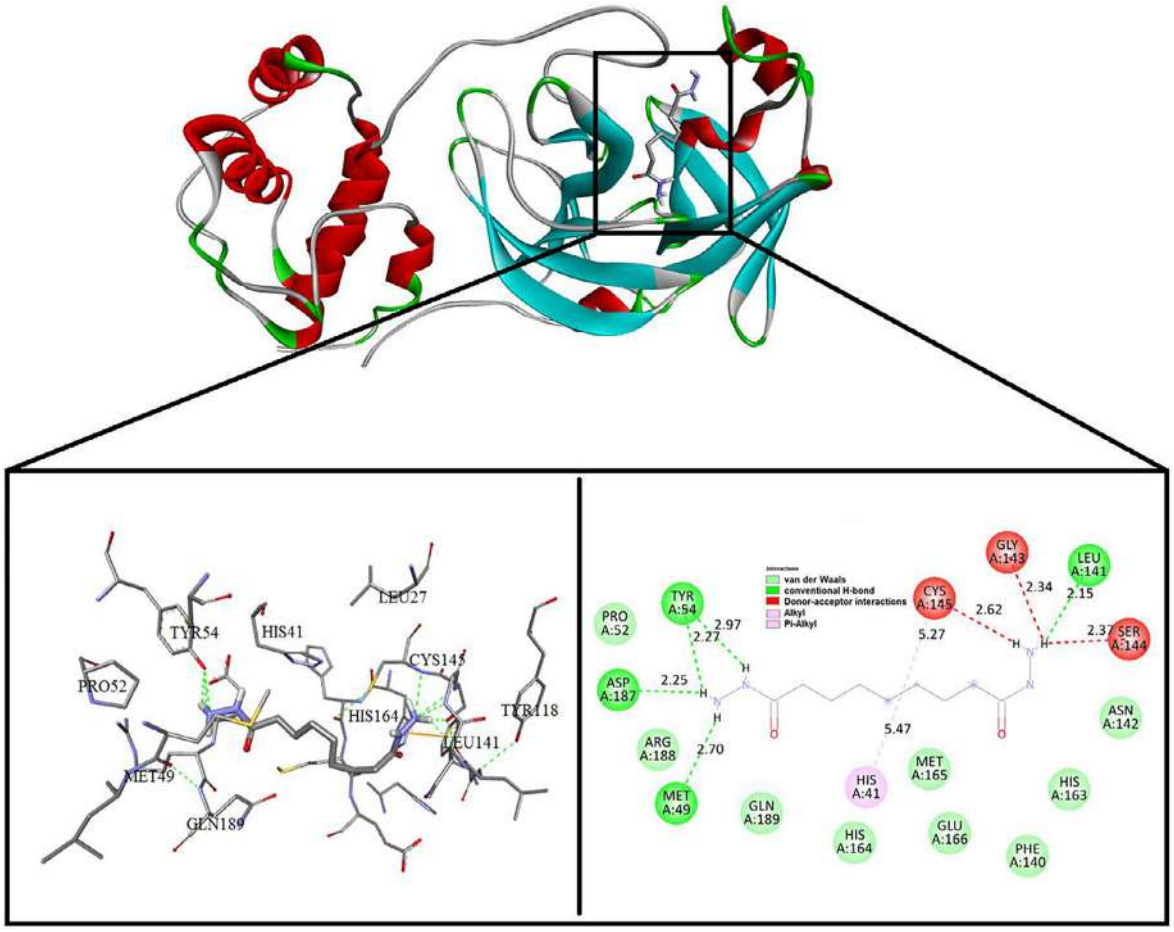


Fig. 3. Docked structure (left) and 2D contour plot of 3CLpro-ADZ complex.

The lower value of inhibition constant (Ki) between ADZ and 3CLpro indicates stronger binding affinity between them. The neighboring residues are shown in both the views of the docked structure. It was decided to carry out molecular dynamics (MD) simulation on the 3CLpro-ADZ complex to investigate the effect of the drug on 3CLpro in greater detail. Fig. 4a represents the RMSD plot of undocked 3CLpro and ADZ, and of 3CLpro-ADZ complex. Fig. 4b represents the RMS fluctuation plot of docked and undocked 3CLpro. The RMSD plot for the 3CLpro showed much lesser fluctuation as compared to 3CLpro-ADZ complex after 2 ns which suggests decreased stability of the docked structure vis-a-vis the undocked one. It is clear from the above analysis that ADZ creates a huge structural disruption in 3CLpro. This is further supported by the RMSF plot which reveals that ADZ docked 3CLpro showed less fluctuations in the residues compare to the undocked 3CLpro. Moreover, RMSF plots Fig. 4c accounts less fluctuation of the neighboring catalytic residues (HIS41, TYR54, GLY143, SER144, CYS145, ASP187) to the drug molecule in the binding pocket of 3CLpro. The structural changes of ADZ docked 3CLpro is also corroborated by the sequence analysis of the docked and undocked 3CLpro as shown in Fig. 5.

Sequence analysis revealed that the residues after 202 had completely changed their positions indicating huge conformational change within the 3CLpro. The binding free energy of polar and non-polar groups of the docked structure with respect to time are shown in Fig. 6c and 6d, respectively. With the passage of time, polar binding free energy (H-bonding and electrostatic) decreased indicating much stronger binding of the drug ADZ in the 3CLpro cavity. It is to be noted that the stronger binding of ADZ with 3CLpro explains the huge structural change and protein chain sequence changes in 3CLpro. Magnitudes of some major interactions in the 3CLpro-ADZ complex are listed in Table 2.

The compactness of a system is measured by the radius of gyration (Rg) analysis. Variation of Rg with time is shown in Fig. 7a for undocked and docked 3CLpro with ADZ. Form Fig. 7a it is clear that the docked structure is more compact as compared to the undocked one. The solvent accessible surface area (SASA) of docked and undocked 3CLpro are plotted against time in Fig. 7b. The figure clearly shows that the docked structure has lesser surface area compared to the undocked structure, which reveals destabilization of the former.

Fig. 8 represents structural changes during MD simulation. From the above analysis it is clear that ADZ creates a large impact to destabilize the structure of 3CLpro. This is also clearly reflected in Fig. 8. Snapshots are given in the figure after every 2 ns starting from the beginning. The RMSD plot and Fig. 8 are in agreement with each other. At 2 ns, a substential conformational change is indicated in Fig. 4a and in Fig. 8. The structure continues to change as reflected in Fig. 4a and b, and also in Fig. 8. The docked structure does not seem to attain equilibrium up to 10 ns, i.e. till the end of simulation, whereas the undocked structure of the protease reaches equilibrium after 3 ns, as revealed from the RMSD plot (Fig. 4a). It is clear, therefore, that the molecule ADZ from *M. hastata* destabilized the structure of 3CLpro on binding with it. This is expected to affect the activity of SARS-CoV-2 to noticeable extent. 3CLpro plays an essential role in processing the ploy proteins

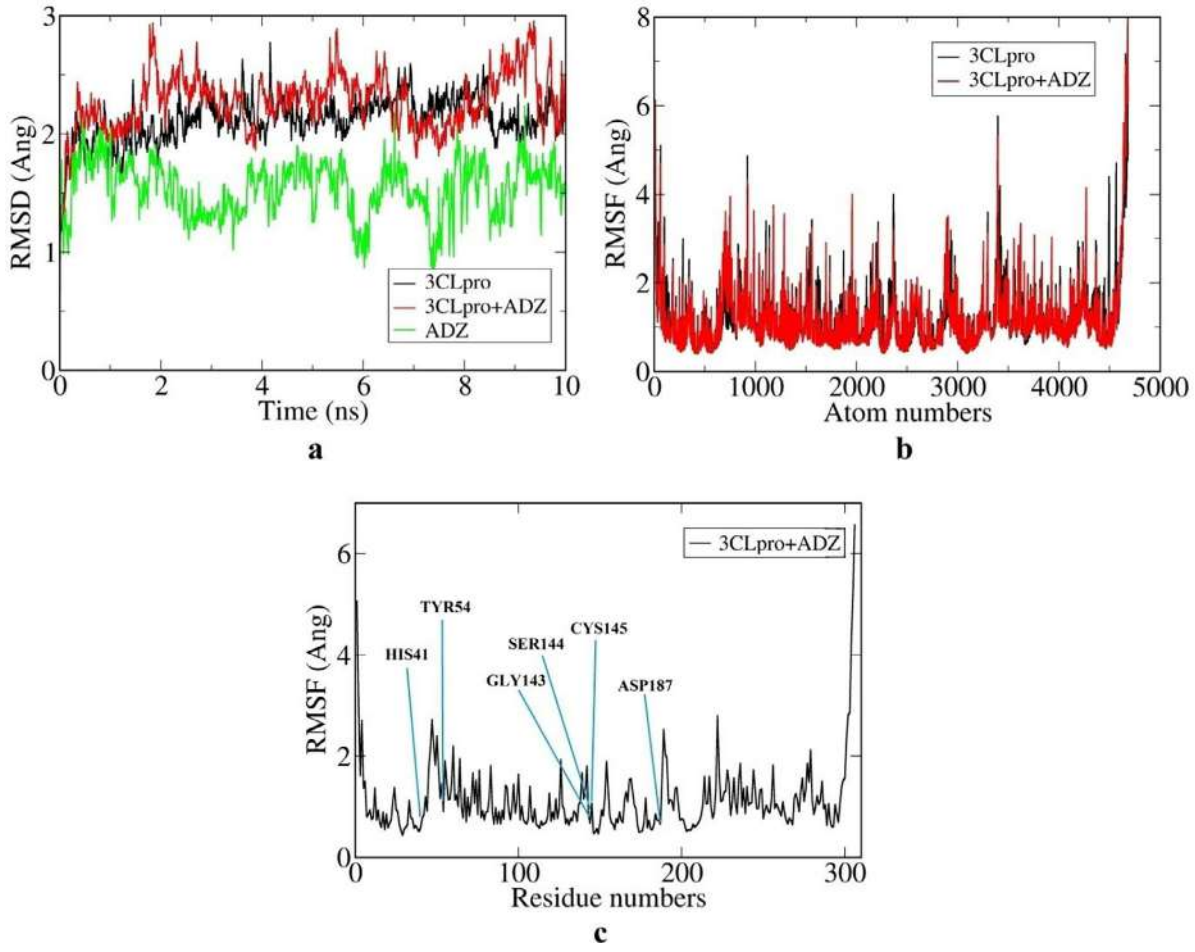


Fig. 4. RMSD (a) and RMSF (b) plots of docked and undocked 3CLpro, the color codes have been mentioned in the figure.

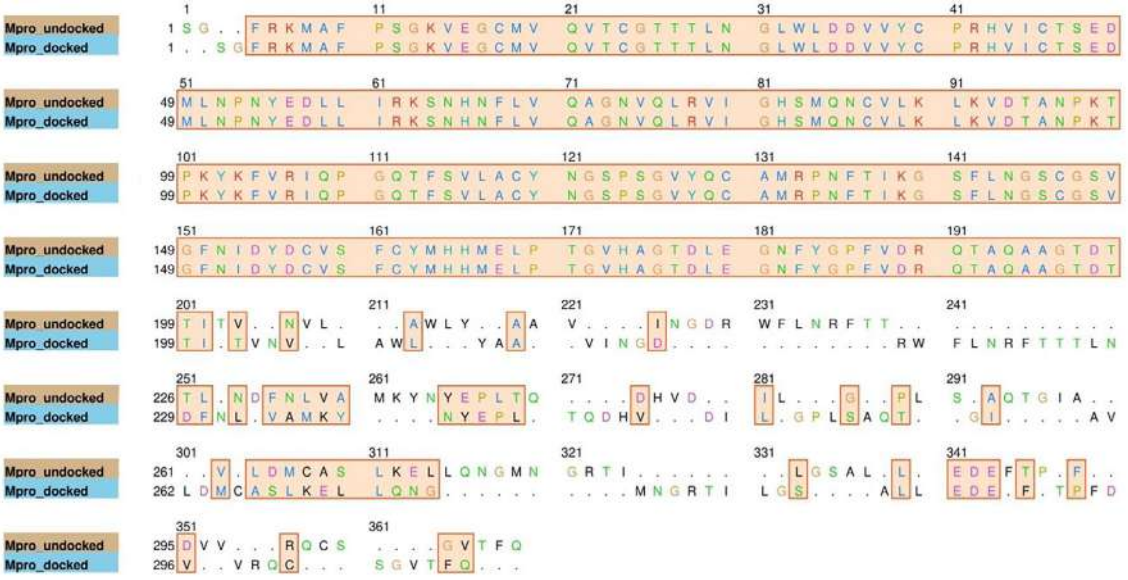


Fig. 5. Sequence analysis of 3CLpro after MD in undocked and docked structure.

Table 2
Average values of various binding free energy components of 3CLpro-ADZ complex.

System	Binding free energy (kJ/mol)	van der Waal energy, ΔE_{vdW}(kJ/mol)	Electrostatic energy, ΔE_{elec} (kJ/mol)	Polar solvation energy, ΔG_{polar} (kJ/mol)	SASA energy (kJ/mol)
3CLpro+ADZ	**- 49.1 ± 18.8**	**- 82.7 ± 17.4**	**- 91.3 ± 20.0**	**137.3 ± 26.8**	**- 12.3 ± 1.5**

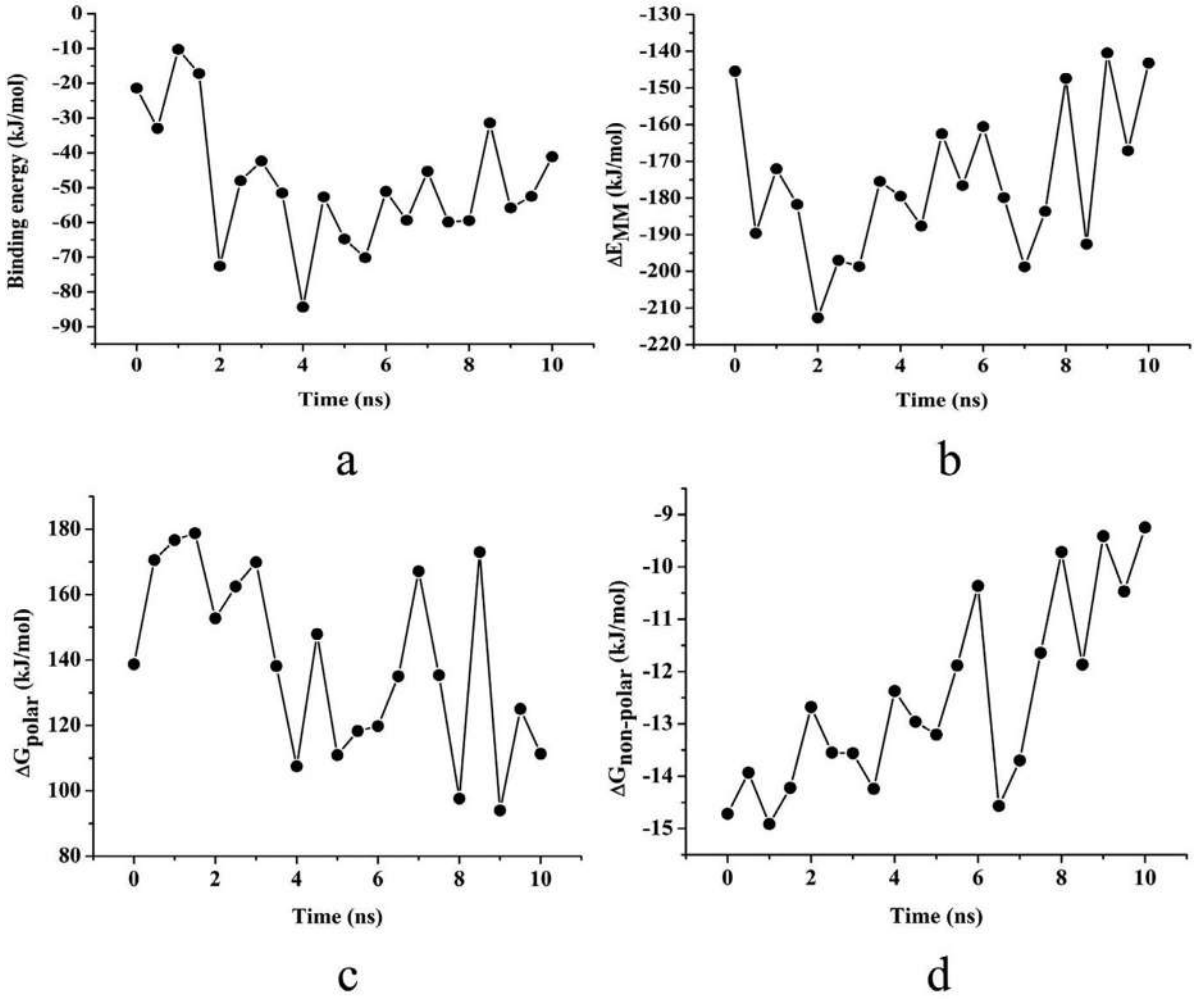


Fig. 6. Variation of different binding energy components: (a) Binding energy, (b)ΔE_{MM}, (c) ΔG_{polar} and (d) $\Delta G_{non\text{-}polar}$ with time.

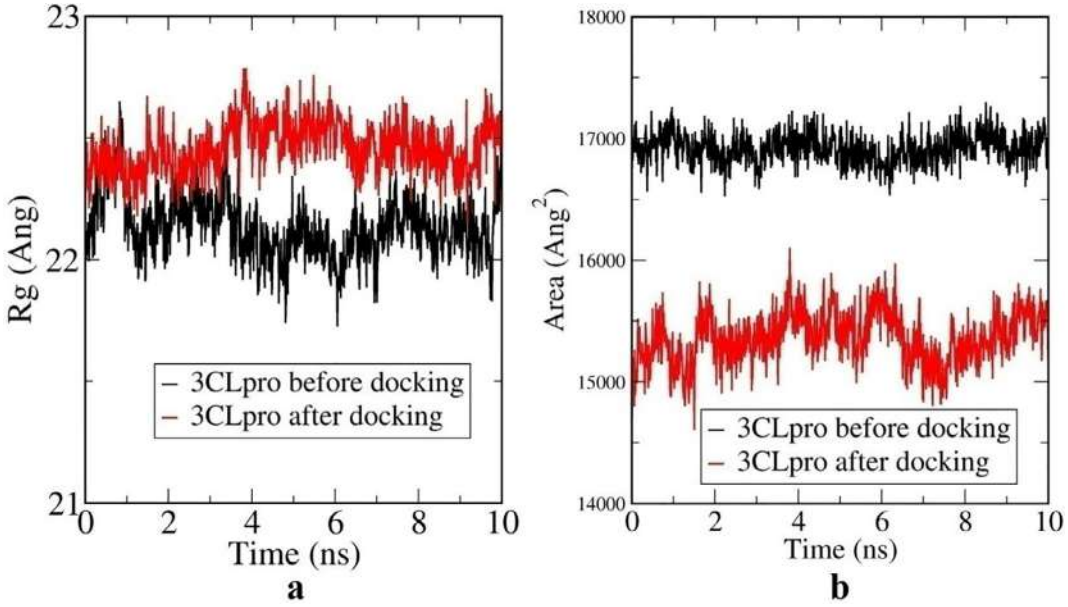


Fig. 7. Radius of gyration (a) and SASA (b) plot of docked and undocked 3CLpro.

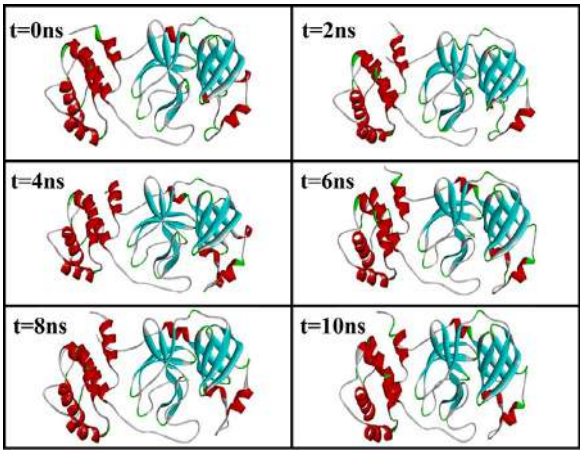


Fig. 8. Conformational changes in 3CLpro upon binding with ADZ during MD-simulation.

translated from viral RNA and thus aids in replication of the coronavirus. Inactivation of 3CLpro is therefore expected to lead to inhibiting viral replication of SARS-CoV-2.

4. Conclusions

20 compounds from the extract of the ethnomedical aquatic herb *M. hastata* (L) Solms were screened against the main protease (3CLpro) of the novel coronavirus SARS-CoV-2. All the compounds were found to have good docking affinity with 3CLpro, as also desirable properties of pharmacokinetics, as obtained from ADME and related analysis. Among all the compounds, Azelaic dihydrazide (ADZ) was found to have the best docking score with 3CLpro. This docked structure of 3CLpro-ADZ was then subject to molecular dynamics (MD) simulation for 10 ns. Analysis of the simulation data viz. RMSD, RMSF, Rg and SASA plots, as well as from the structures of the 3CLpro-ADZ complex during simulation, the following conclusion can be drawn: ADZ creates a large conformational change on 3CLpro after binding or docking with it. This may cause noticeable change of activity of 3CLpro, and thereby inhibiting the replication process SARS-CoV-2. This calls for further investigations on effect of same and other compounds of *M. Hastate* (L.) Solms on SARS-CoV-2 and ACE2 of host cell.

Data availability

Data is available upon request to the corresponding author.

Declaration of Competing Interest

The authors declare no conflicting interest in the present work.

CRediT authorship contribution statement

Nabajyoti Baildya: Conceptualization, Writing – original draft, Methodology, Supervision. **Narendra Nath Ghosh:** Conceptualization, Writing – original draft, Methodology. **Asoke P. Chattopadhyay:** Conceptualization, Writing – original draft, Supervision. **Vivekananda Mandal:** Conceptualization, Writing – original draft, Methodology. **Sourav Majumdar:** Writing – original draft, Methodology. **Delwar Ansary:** Writing – original draft, Methodology, Data curation. **Md Muttakin Sarkar:** Writing – original draft, Methodology, Data curation.

Acknowledgements

The authors wish to acknowledge infrastructural support from Department of Chemistry, University of Kalyani, Kalyani, Nadia, India. The authors also like to acknowledge Dr. Debabrata Misra, University of Gour Banga, Malda, India and KIIT University, Bhubaneswar, Odisha, India for help with finding and phytochemical profiling of aquatic plant *Monochoria Hastata* (L) Solms.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.molstruc.2022.132644.

References

[1] P. Colson, J.M. Rolain, J.C. Lagier, P. Brouqui, D. Raoult, Chloroquine and hydroxychloroquine as available weapons to fight COVID-19, Int. J. Antimicrob. Agents (2020) 105932 10.1016.
[2] P. Colson, J.M. Rolain, D. Raoult, Chloroquine for the 2019 Novel Coronavirus SARS-CoV-2, Elsevier, 2020.
[3] J. Gao, Z. Tian, X. Yang, Breakthrough: chloroquine phosphate has shown apparent efficacy in treatment of COVID-19 associated pneumonia in clinical studies, Biosci. Trends (2020).
[4] A.A. Khan, T. Dutta, M. Palas Mondal, S.K.C. Mandal, M. Ahmed, N. Baildya, S. Mazumdar, N.N. Ghosh, Novel coronavirus disease (COVID-19): an extensive study on evolution, global health, drug targets and vaccines, (2021).
[5] N. Baildya, N.N. Ghosh, A.P. Chattopadhyay, Inhibitory activity of hydroxychloroquine on COVID-19 main protease: an insight from MD-simulation studies, J. Mol. Struct. 1219 (2020) 128595.
[6] N. Baildya, N.N. Ghosh, A.P. Chattopadhyay, Inhibitory capacity of chloroquine against SARS-COV-2 by effective binding with angiotensin converting enzyme-2 receptor: an insight from molecular docking and MD-simulation studies, J. Mol. Struct. 1230 (2021) 129891.
[7] A.A. Elfiky, Ribavirin, Remdesivir, Sofosbuvir, Galidesivir, and Tenofovir against SARS-CoV-2 RNA dependent RNA polymerase (RdRp): a molecular docking study, Life Sci. 253 (2020) 117592.
[8] A.A. Khan, N. Baildya, T. Dutta, N.N. Ghosh, Inhibitory efficiency of potential drugs against SARS-CoV-2 by blocking human angiotensin converting enzyme-2: virtual screening and molecular dynamics study, Microb. Pathog. (2021) 104762.
[9] M. Mandal, S.K. Chowdhury, A.A. Khan, N. Baildya, T. Dutta, D. Misra, N.N. Ghosh, Inhibitory efficacy of RNA virus drugs against SARS-CoV-2 proteins: an extensive study, J. Mol. Struct. (2021) 130152.
[10] N. Baildya, A.A. Khan, N.N. Ghosh, T. Dutta, A.P. Chattopadhyay, Screening of potential drug from Azadirachta Indica (Neem) extracts for SARS-CoV-2: an insight from molecular docking and MD-simulation studies, J. Mol. Struct. 1227 (2021) 129390.
[11] T. Dutta, S. Ghorai, A.A. Khan, N. Baildya, N.N. Ghosh, Screening of potential anti-HIV compounds from Achyranthes aspera extracts for SARS-CoV-2: an insight from molecular docking study, J. Phys. Conf. Ser. (2021) 012042 IOP Publishing.
[12] T. Dutta, N. Baildya, A.A. Khan, N.N. Ghosh, Inhibitory effect of anti-HIV compounds extracted from Indian medicinal plants to retard the replication and transcription process of SARS-CoV-2: an insight from molecular docking and MD-simulation studies, Netw. Model. Anal. Health Inform. Bioinform. 10 (1) (2021) 1–11.
[13] D. Tyrrell, M. Bynoe, Cultivation of viruses from a high proportion of patients with colds, Lancet (1966) 76–77.
[14] C. Drosten, S. Günther, W. Preiser, S. Van Der Werf, H.R. Brodt, S. Becker, H. Rabenau, M. Panning, L. Kolesnikova, R.A. Fouchier, Identification of a novel coronavirus in patients with severe acute respiratory syndrome, N. Engl. J. Med. 348 (20) (2003) 1967–1976.
[15] J.S. Kahn, K. McIntosh, History and recent advances in coronavirus discovery, Pediatr. Infect. Dis. J. 24 (11) (2005) S223–S227.
[16] T.G. Ksiazek, D. Erdman, C.S. Goldsmith, S.R. Zaki, T. Peret, S. Emery, S. Tong, C. Urbani, J.A. Comer, W. Lim, A novel coronavirus associated with severe acute respiratory syndrome, N. Engl. J. Med. 348 (20) (2003) 1953–1966.
[17] J. Peiris, S. Lai, L. Poon, Y. Guan, L. Yam, W. Lim, J. Nicholls, W. Yee, W. Yan, M. Cheung, Coronavirus as a possible cause of severe acute respiratory syndrome, Lancet North Am. Ed. 361 (9366) (2003) 1319–1325.
[18] J. Zheng, SARS-CoV-2: an emerging coronavirus that causes a global threat, Int. J. Biol. Sci. 16 (10) (2020) 1678.
[19] C.S.G. of the International, The species Severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2, Nat. Microbiol. 5 (4) (2020) 536.
[20] S. Belouzard, J.K. Millet, B.N. Licitra, G.R. Whittaker, Mechanisms of coronavirus cell entry mediated by the viral spike protein, Viruses 4 (6) (2012) 1011–1033.
[21] A. Sharif-Yakan, S.S. Kanj, Emergence of MERS-CoV in the Middle East: origins, transmission, treatment, and perspectives, PLoS Pathog. 10 (12) (2014) e1004457.

[22] Y.M. Báez-Santos, S.E.S. John, A.D. Mesecar, The SARS-coronavirus papain-like protease: structure, function and inhibition by designed antiviral compounds, Antiviral Res. 115 (2015) 21–38.
[23] M. Pandey, S. Rastogi, A. Rawat, Indian traditional ayurvedic system of medicine and nutritional supplementation, Evid. Based Complement. Alternative Med. 2013 (2013).
[24] D. Misra, M. Mandal, N. Ghosh, V. Mandal, *In-vitro* antioxidant and antibacterial activity and phytochemical profile of methanol extract of Monochoria hastata (L.) Solms leaf, Int. Res. J. Man. Sci. Tech. 8 (2017) 225–240.
[25] E.F. Pettersen, T.D. Goddard, C.C. Huang, G.S. Couch, D.M. Greenblatt, E.C. Meng, T.E. Ferrin, UCSF chimera – a visualization system for exploratory research and analysis, J. Comput. Chem. 25 (13) (2004) 1605–1612.
[26] O. Trott, A.J. Olson, AutoDock Vina: improving the speed and accuracy of docking with a new scoring function, efficient optimization, and multithreading, J. Comput. Chem. 31 (2) (2010) 455–461.
[27] H.J. Berendsen, D. van der Spoel, R. van Drunen, GROMACS: a message-passing parallel molecular dynamics implementation, Comput. Phys. Commun. 91 (1–3) (1995) 43–56.
[28] S. Lee, A. Tran, M. Allsopp, J.B. Lim, J. Hénin, J.B. Klauda, CHARMM36 united atom chain model for lipids and surfactants, J. Phys. Chem. B 118 (2) (2014) 547–556.
[29] S. Boonstra, P.R. Onck, E. van der Giessen, CHARMM TIP3P water model suppresses peptide folding by solvating the unfolded state, J. Phys. Chem. B 120 (15) (2016) 3692–3698.
[30] M.J. Abraham, J.E. Gready, Optimization of parameters for molecular dynamics simulation using smooth particle-mesh Ewald in GROMACS 4.5, J. Comput. Chem. 32 (9) (2011) 2031–2040.
[31] N.A. Baker, D. Sept, S. Joseph, M.J. Holst, J.A. McCammon, Electrostatics of nanosystems: application to microtubules and the ribosome, Proc. Natl. Acad. Sci. 98 (18) (2001) 10037–10041.
[32] R. Kumari, R. Kumar, O.S.D.D. Consortium, A. Lynn, g_mmpbsa a GROMACS tool for high-throughput MM-PBSA calculations, J. Chem. Inf. Model. 54 (7) (2014) 1951–1962.
[33] J. Shawon, A.M. Khan, A. Rahman, M.M. Hoque, M.A.K. Khan, M.G. Sarwar, M.A. Halim, Molecular recognition of azelaic acid and related molecules with DNA polymerase I investigated by molecular modeling calculations, Interdiscip. Sci. Comput. Life Sci. 10 (3) (2018) 525–537.
[34] Q.H. Nguyen, T.P. Bui, Azelaic acid: pharmacokinetic and pharmacodynamic properties and its therapeutic role in hyperpigmentary disorders and acne, Int. J. Dermatol. 34 (2) (1995) 75–84.
[35] D.E. Pires, T.L. Blundell, D.B. Ascher, pkCSM: predicting small-molecule pharmacokinetic and toxicity properties using graph-based signatures, J. Med. Chem. 58 (9) (2015) 4066–4072.

UGC-CARE List-Social Sciences ISSN 0974-0074

राधा कमल मुकर्जी : चिन्तन परम्परा

National Peer Reviewed Journal of Social Sciences

वर्ष 24 अंक 1
जनवरी–जून, 2022

समाज विज्ञान विकास संस्थान
बरेली (उ.प्र.)

इस अंक में

राधाकमल मुकर्जी : चिन्तन परम्परा
वर्ष 24 अंक 1, जनवरी-जून 2022
Regd. No. UPHIN/1999/00955 ISSN 0974-0074
UGC-CARE List-Social Sciences

भारत में राष्ट्रवादी आंदोलन का ऐतिहासिक विश्लेषणः स्वदेशी आंदोलन (1905-11) के सन्दर्भ में

❑ मानस कुमार दास

सूचक शब्दः विभाजन विरोधी आंदोलन, स्वदेशी आंदोलन, विभाजन और शासन नीति, स्वायत्तता, स्वराज, निष्क्रिय प्रतिरोध, क्रांतिकारी आतंकवाद

1905 में लार्ड कर्जन की बंगाली राष्ट्रवाद की उपेक्षा और विभाजन की योजना के विरोध में पूरे बंगाल में शुरू हुए विभाजन विरोधी आन्दोलन या स्वदेशी आन्दोलन ने देश की राजनीति को प्रभावित किया। अब तक के भारत के राष्ट्रवादी आंन्दोलन का नेतृत्व मुख्य रूप से उदारवादी नेताओं ने किया था। 1885 से 1905 तक, आन्दोलन का मुख्य लक्ष्य अनुनय- विनय से ब्रिटिश शासन से स्वायत्तता प्राप्त करना था, लेकिन भारत मे ब्रिटिश विरोधी आन्दोलन स्वदेशी आन्दोलन के साथ अलग दिशा में बहने लगा। यह पहली बार हुआ कि बंगाली राष्ट्र ने अपने लक्ष्य को प्राप्त करने के लिए 'स्वदेशी' और 'बहिष्कार' की नीति का प्रयोग ब्रिटिश विरोध के उपकरण के रूप मे किया। इसके साथ ही क्रांतिकारी आतंकवादी गतिविधियों द्वारा सक्रिय ब्रिटिश विरोध को देखा जा सकता है। इस आंन्दोलन की प्रतिक्रिया को बंगाल के अलावा भारत के विभिन्न हिस्सों में देखा जा सकता है। कुछ ही दिनों में इस आंन्दोलन ने अखिल भारतीय रूप ले लिया।[1] स्वदेशी आंन्दोलन के जवाब में राष्ट्रीय कांग्रेस के भीतर 'चरमपन्थी' विचारधारा का उदय हुआ। इसके परिणामस्वरूप भारत में राष्ट्रीय आंन्दोलन की प्रकृति पूरी तरह से बदल गई। प्रस्तुत शोध-पत्र का मुख्य उद्देश्य इस बात पर प्रकाश डालना है कि किस प्रकार इस स्वदेशी आंन्दोलन की घटनाओं के कारण भारत में ब्रिटिश विरोधी राष्ट्रवादी आंन्दोलन मे एक नई राष्ट्रीय चेतना का विकास हुआ।

1905 का स्वदेशी आंदोलन बंगाल और भारत में राष्ट्रीय आंदोलन के इतिहास में एक युगांतकारी घटना है। 1905 में लॉर्ड कर्जन की योजना और बंगाल विभाजन की नीति के खिलाफ पूरे बंगाल में जो ब्रिटिश विरोधी आंदोलन हुआ, उसे विभाजन विरोधी आंदोलन या स्वदेशी आंदोलन के रूप में जाना जाता है। विभाजन की योजना के मुख्य रुपकार लॉर्ड कर्जन, उनके सहयोगी गृह सचिव हर्बर्ट रिजले और बंगाल के लेफ्टिनेंट गवर्नर सर एंड्रयू फ्रेजर थे। बंगाल के विभाजन की योजना की आधिकारिक रूप से 19 जुलाई 1905 को घोषणा हुई थी और 16 अक्टूबर को लॉर्ड कर्जन के आदेश से पूरे बंगाल प्रेसीडेंसी को दो भागों में विभाजित किया गया था।[2] एक हिस्से की राजधानी ढाका को बनाया गया। दूसरे हिस्से पश्चिम बंगाल, बिहार और उड़ीसा को लेकर 'बंगाल प्रांत' का गठन किया गया था जिसकी राजधानी कलकत्ता थी। बंगाल के इस विभाजन के लागू होने के विरोध में पूरे बंगाल और भारत में एक मजबूत जन आंदोलन शुरु किया गया था। यह आंदोलन बंगाली राष्ट्र का पहला पूर्ण राष्ट्रवादी आंदोलन था जिसका उद्देश्य आत्म-जागरूकता, स्वतंत्रता स्थापित करने के लिए दृढ़ संकल्पित होना था।[3]

सरकारी रिपोर्ट के अनुसार बंगाल के विभाजन का कारण मुख्यतः प्रशासनिक था। यह तर्क दिया गया था कि बंगाल-बिहार-उड़ीसा से मिलकर बने इस विशाल 'बांग्ला प्रेसीडेंसी' पर शासन ठीक से एक केन्द्र से करना संभव नहीं। अतः प्रशासनिक सुविधा के लिए राज्य के आकार को कम करने की जरूरत है। लेकिन सुमित सरकार और अमलेश त्रिपाठी जैसे इतिहासकारों ने बंगाल के विभाजन के पीछे साम्राज्यवादी उद्देश्य को स्पष्ट रूप से दिखाया है। **भारत** सरकार के गृह सचिव रिज़ले ने 6 दिसंबर 1904 को कहा, "Bengal united, is Power, Bengal divided, will pull several different ways"[4] यानि 'संयुक्त बंगाल एक ताकत है, लेकिन अगर इसे तोड़ा गया तो वह बल अलग-अलग क्षेत्रों में बहेगा और कमजोर हो जाएगा'। इस प्रकार लॉर्ड कर्जन ने बंगाल के विभाजन की योजना प्रशासनिक सुविधा के लिए नहीं, बल्कि भारतीय राष्ट्रवादी आंदोलन के केन्द्र बंगाल को विभाजित करके राष्ट्रीय आंदोलन को कमजोर करने के लिए और दो बंगालों में बंगाली हिंदुओं के महत्व को कम करने और नवगठित राज्य में धार्मिक विभाजन हिंदू-मुस्लिम में मतभेद बनाने के लिए बनाई। इस अवधि में अंग्रेजों द्वारा अपनाई गई 'फूट डालो और राज करो की नीति' (Divide and rule

❑ सहायक प्रोफेसर इतिहास विभाग, डोमकल कॉलेज, मुर्शिदाबाद (पश्चिम बंगाल)

policy) का एक उदाहरण 1902 में देखा गया जब बरार के मराठी मुख्य क्षेत्र को मध्य प्रदेश में मिला दिया गया था, न कि मराठी बसे हुए महाराष्ट्र में।[8] यदि विभाजन की योजना बनानी ही थी तो बिहार और उड़ीसा को बंगाल से अलग किया जा सकता था। कांग्रेस के अध्यक्ष सर हेनरी कॉटन ने भी इसी तरह का प्रस्ताव रखा था। लेकिन न तो सर एंड्रयू फ्रेजर, रिजले और न ही लॉर्ड कर्जन ने अधिक ध्यान दिया। यह स्पष्ट है कि बंगाली राष्ट्रवाद को कमजोर करने के लिए, बंगाल में एक के बाद एक जिले के विभाजन की प्रक्रिया चल रही थी। बंगाल के विभाजन की योजना को आधिकारिक तौर पर 16 अक्टूबर, 1905 को अपनाया गया था।[6]

'चरमपंथी' (गरमदल) विचारधारा का उदयः बंगाल के विभाजन की घोषणा के विरोध में पूरे बंगाल में एक मजबूत आंदोलन शुरू किया गया था। यह आंदोलन 1905 के अंत से 12 दिसंबर 1911 को दिल्ली की अदालत में जॉर्ज पंचम द्वारा बंगाल के विभाजन के उन्मूलन की आधिकारिक घोषणा तक, चलता रहा था। प्रारंभिक दौर में इस आंदोलन का एकमात्र उद्देश्य बंगाल के विभाजन का विरोध करना और विभाजन को समाप्त करना था। उस समय इस आंदोलन को भारत के स्वतंत्रता संग्राम के एक प्रकरण के रूप में स्वीकार करने का कोई तर्कसंगत कारण नहीं था। लेकिन जल्द ही इस आंदोलन में एक विशिष्टता आ गई जिसे पूरे भारत ने स्वीकार कर लिया। ऐसा इसलिए है क्योंकि 1885 से 1905 तक भारतीय उदारवादी नेताओं द्वारा चलाए गए ब्रिटिश विरोधी आंदोलन का मुख्य उद्देश्य याचिका के माध्यम से ब्रिटिश शासन से स्वायत्तता का अधिकार प्राप्त करना था। स्वदेशी आंदोलन के दौर में राष्ट्रीय कांग्रेस के भीतर एक 'चरमपंथी' विचारधारा का उदय हुआ। बाल गंगाधर तिलक, लाला लाजपत राय, बिपिन चंद्र पाल, ब्रह्मबंधब उपाध्याय, अरविंद घोष और अन्य लोग इस चरमपंथी विचारधारा से जुड़े थे। चरमपंथियों ने स्पष्ट रूप से घोषणा की थी- ब्रिटिश शासन से जुड़कर भारत के लिए उचित कल्याण प्राप्त करना असंभव था। इसलिए उन्होंने भारत के लिए पूर्ण स्वतंत्रता की मांग की।[7] धीरे-धीरे नरमपंथी दलों के नेताओं को हटा दिया गया और भारतीय राजनीति में चरमपंथियों का प्रभाव बढ़ गया। इसके साथ ही भारतीय राजनीति में एक नए युग का प्रारंभ हुआ। हरिदास मुखर्जी ने कहा है कि लाला लाजपत राय ने 1905 में वाराणसी कांग्रेस में कहा था, "Congratulated Bengal on heralding a new political era for the country- If other provinces followed the example of Bengal the day was not far distant when they would win"[9]

'स्वदेशी' और 'बहिष्कार' का उपयोग : स्वदेशी आंदोलन के दौरान, भारतीय नेताओं ने अनुभव किया कि निहत्थे भारत के लिए स्वतंत्रता संग्राम अधिक दिन तक कार्यकारी नहीं हो सकता। हथियार आत्मनिर्भरता के साथ-साथ 'निष्क्रिय प्रतिरोध' आंदोलन के ठोस अनुप्रयोग के माध्यम से राष्ट्रीय मुक्ति का प्रयास आंदोलन को एक नई दिशा में प्रवाहित करेगा। हालांकि, बिपिन चंद्र पाल का मानना था कि स्वदेशी युग में 'निष्क्रिय प्रतिरोध' के बजाय 'निहत्थे प्रतिरोध' शब्द का प्रयोग अधिक स्वीकार्य है। उनके अनुसार, कई लेखक आज 'Passive Resistance' शब्द का प्रयोग 'निष्क्रिय प्रतिरोध' के बंगाली पर्याय के रूप में करते हैं। लेकिन यह प्रयोग भ्रमित करने वाला है। 'Passive Resistance' का अर्थ है 'Not non active but non-aggressive' यानि 'गैर-सक्रिय नहीं बल्कि गैर-आक्रामक'- जिसका अर्थ यह है कि इसकी मूल प्रकृति गैर-आक्रामक है, लेकिन निष्क्रिय नहीं है। इसलिए 'निहत्थे प्रतिरोध' शब्द का प्रयोग करना उचित प्रतीत होता है। बीसवीं शताब्दी के प्रारंभ में, प्रतिरोध का यह निष्क्रिय रूप बंगाल में साम्राज्यवाद-विरोधी आंदोलन में एक नए उपकरण के रूप में उभरा। यह निष्क्रिय प्रतिरोध मुख्यतः 1905 और 1906 ई. के बीच 'बहिष्कार' और 'स्वदेशी आंदोलन' के माध्यम से विकसित हुआ था। रमेश चंद्र मजूमदार के अनुसार, बहिष्कार का विचार पहले आया है, स्वदेशी भी इसके पूरक के रूप में लोकप्रिय हुए हैं और समय के साथ वे एक दूसरे के परिपूरक के रूप में सामने आए हैं। बंगाल के विभाजन की कर्जन की योजना के विरोध में 'बहिष्कार' और 'स्वदेशी' ब्रिटिश सरकार के खिलाफ एक आर्थिक और राजनीतिक धर्मयुद्ध था। 'बहिष्कार' का अर्थ था अंग्रेजों या उनके द्वारा बनाए गए कानून या संस्था के साथ असहयोग और विदेशी सामान, विदेशी शिक्षा, कार्यालय-अदालत, उपाधि आदि का बहिष्कार। 13 जुलाई 1905 को कृष्णकुमार मित्रा ने अपनी 'संजीवनी पत्रिका' में पहले ब्रिटिश सामान के बहिष्कार का आह्वान किया।[10] सभी वर्गों के लोग बहिष्कार आंदोलन में सम्मिलित हुए। सरकारी कार्यालयों-अदालतों, सभी शिक्षण संस्थानों का बहिष्कार

किया गया। इस समय भी निष्क्रिय प्रतिरोध की विचारधारा से प्रेरित कई कारखानों में हड़तालें देखी गईं। छात्रों को आंदोलन से दूर रखने के लिए सरकार द्वारा 'कार्लाइल सर्कुलर' जारी किया और आंदोलनकारी छात्रों के निष्कासन और दंड की घोषणा के बाद, छात्र समाज ने सचिंद्र प्रसाद बसु के नेतृत्व में एक 'एंटी सर्कुलर सोसाइटी' का गठन किया। दूसरी ओर, 'स्वदेशी' शब्द का अर्थ है स्वयं के स्वदेशी उत्पादों का उत्पादन और उपयोग। इसके साथ ही स्वदेशी सभ्यता, स्वदेशी संस्कृति, स्वदेशी साहित्य और स्वदेशी संगीत, स्वदेशी वस्तुएं आदि सभी स्वदेशी लोगों के अंग थे। सुमित सरकार ने अपनी पुस्तक 'The Swadeshi Movement in Bengal' में इस अवधि को 'रचनात्मक स्वदेशी' या 'आत्म- सशक्तीकरण' के रूप में संदर्भित किया है। उन्होंने कहा कि- व्यर्थ और अपमानजनक भीख मांगने की राजनीति को रद्द करके तथा स्वदेशी उद्योगों की स्थापना करके आत्मनिर्भरता प्राप्त की गई। राष्ट्रीय शिक्षा, ग्राम विकास भी इसके उद्देश्य में सम्मिलित थे।[11] इसी को रवींद्रनाथ टैगोर ने अपने निबंध 'स्वदेशी समाज' में 'आत्मशक्ति' कहा है। प्रफुल्ल चंद्र राय, नीलरतन सरकार और अन्य व्यावसायिक उपक्रम, रवींद्रनाथ टैगोर द्वारा स्थापित 'स्वदेशी भंडार', सरला देवी का 'लक्ष्मी भंडार', डॉन सोसाइटी का 'स्वदेशी बिपनी' आदि की स्थापना की गयी थी। वैज्ञानिक प्रफुल्ल चंद्र रॉय ने स्वदेशी पहल पर उद्योग स्थापित करने के उद्देश्य से 'बंगाल केमिकल एंड फार्मास्युटिकल वर्क्स' की स्थापना की थी। सतीश चंद्र मुखर्जी ने गुरुदास बंद्योपाध्याय, सत्येंद्रनाथ टैगोर, हीरेंद्रनाथ दत्त के सक्रिय सहयोग से अंग्रेजी प्रभाव से मुक्त राष्ट्रीय शिक्षा की स्थापना के लिए 'डॉन सोसाइटी' की स्थापना की। दत्ता और अन्य विचारकों, 92 सदस्यों के साथ 11 मार्च 1906 को कलकत्ता में 'राष्ट्रीय शिक्षा परिषद' (National Council of Education) का गठन किया गया था।[12] 'बंगाल तकनीकी संस्थान' (Bengal Technical institute) का गठन किया गया था जो बाद में 'जादवपुर इंजीनियरिंग कॉलेज' बन गया; और अनेक राष्ट्रीय विद्यालयों का गठन किया गया। इस प्रकार, स्वदेशी आंदोलन के प्रारंभ से, पहले बंगाली राष्ट्र ने अपने लक्ष्यों को प्राप्त करने के लिए 'स्वदेशी' और 'बहिष्कार' की दोधारी तलवार का इस्तेमाल एक उपकरण के रूप में किया, जो कि भारतीय स्वतंत्रता आंदोलन के इतिहास में दुर्लभ है। **यह बहिष्कार** आंदोलन और इसके परिणामस्वरूप ब्रिटिश सामानों का बहिष्कार और स्वदेशी वस्तुओं का उपयोग शुरू में बंगाल तक सीमित था; लेकिन जल्द ही शिक्षा, दीक्षा और संस्कृति के इन विभिन्न क्षेत्रों में विदेशियों के आकर्षण को त्यागकर भारत की अपनी सभ्यता को पुनर्जीवित करने का प्रयास स्वदेशी आंदोलन का मुख्य उद्देश्य बन गया। यह धीरे-धीरे भारतीय राष्ट्रीय आंदोलन का मुख्य लक्ष्य बन गया। इस प्रकार जिस राजनीतिक व्यवस्था और उद्देश्य के साथ बंगाल में स्वदेशी आंदोलन शुरू किया गया था, वह पूरी तरह से बदल गया और एक राष्ट्रीय आंदोलन में विस्तारित हो गया। इस संदर्भ में रमेश चंद्र मजूमदार लिखते हैं, "हम 1905 में भारतीय स्वतंत्रता संग्राम और राष्ट्रीय जागरण की पहली महत्वपूर्ण प्रवृत्ति देखते हैं जो 1947 में पूरी गति से प्रवाहित हो रही थी। इसलिए मेरा दृढ़ विश्वास है कि यह भारत के इतिहास में हमेशा के लिए स्वतंत्रता संग्राम और नए युग के अग्रदूत के रूप में पहचाना जाएगा।"[13]

क्रांतिकारी आंदोलन का सूत्रपातः 1905 के बंगाल विभाजन से, बंगाल के नेताओं ने अनुभव किया कि उनकी मांगों को ब्रिटिश सरकार द्वारा याचिकाओं के माध्यम से पूरा नहीं किया जा सकता था, जिसके लिए एक सशस्त्र तख्तापलट की आवश्यकता थी। इसी कारण इस काल में बंगाल में निष्क्रिय प्रतिरोध आन्दोलन के साथ-साथ क्रांतिकारी गतिविधियाँ चलती रहीं। स्वदेशी आंदोलन के इस चरण को 'क्रांतिकारी आतंकवाद' (Terrorism) कहा जाता है। रमेश चंद्र मजूमदार इसे 'Militant Nationalism' या सैन्यवादी राष्ट्रवाद' कहने के पक्षधर थे। बंगाल के विभाजन की प्रतिक्रिया में, बंगाल के विभिन्न हिस्सों में गुप्त क्रांतिकारी संगठनों की गतिविधियों में वृद्धि जारी रही। सतीश चंद्र बोस, चित्तरंजन दास, अरविंद घोष, ज्योतिंद्रनाथ मुखर्जी और अन्य ने 1906-07 तक बंगाल में क्रांतिकारी गतिविधियों के संचालन में महत्वपूर्ण भूमिका निभाई। क्रांतिकारी हेमचंद्र कानूनगो ने कोलकाता के मानिकतला में बम बनाने का कारखाना बनाया। 'ढाका अनुशीलन समिति' की स्थापना पूर्वी बंगाल में सितंबर 1908 में पुलिन बिहारी दास के नेतृत्व में की गई थी। 'जुगांतर समिति' की स्थापना 1906 में बरिंद्रनाथ घोष और भूपेंद्रनाथ दत्त के नेतृत्व में हुई थी। जुगांतरदल के दो युवा क्रांतिकारियों खुदीराम बसु और प्रफुल्ल चाकी ने 30 अप्रैल 1906 को कलकत्ता प्रेसीडेंसी के एक मजिस्ट्रेट, तानाशाह किंग्सफोर्ड की हत्या की योजना रची। इस प्रकार, 1911 में बंगाल के विभाजन की वापसी

तक आतंकवाद की प्रवृत्ति छिटपुट रूप से जारी रही।[15] यहां तक कि बंगाली राष्ट्र का एक बड़ा वर्ग जो इतने लंबे समय से राजनीति से बाहर था, वो भी आंदोलन में सक्रिय रूप से सम्मिलित हो गया। परिणामस्वरूप, स्वदेशी आंदोलन में विभिन्न प्रकार की विचारधाराएं एक साथ आयीं और यह साम्राज्यवाद विरोधी आंदोलन का एक महत्वपूर्ण प्रकरण बन गयीं और ब्रिटिश विरोधी आंदोलन की तीव्रता कई गुना बढ़ गई।

अखिल भारतीय राजनीति का प्रारंभः 1905 में बंगाल की धरती पर भारतीय क्रांति की शुरुआत बंगाल के विभाजन के कारण हुई उथल-पुथल भारत के एक छोर से दूसरे छोर तक फैल गई।[16] मद्रास प्रेसीडेंसी आदि में स्वदेशी और बहिष्कार आंदोलन की प्रतिक्रिया संयुक्त राज्य के 23 जिलों, मध्य प्रदेश के 15 जिलों, बॉम्बे प्रेसीडेंसी के 24 जिलों, पंजाब के 20 जिलों और मद्रास प्रेसीडेंसी के 13 जिलों में देखी जा सकती है।[17] सतीश चंद्र बोस, चित्तरन्जन दास, अरविंद घोष, ज्योतिन्द्रनाथ मुखर्जी आदि ने महत्वपूर्ण भूमिका निभाई। हालाँकि, बिपिन चंद्र पाल बंगाली विद्वानों में सबसे उल्लेखनीय थे। बंगाल के बाहर, लाला लाजपत राय और बाल गंगाधर तिलक के नेतृत्व में पंजाब और बॉम्बे प्रेसीडेंसी में आंदोलन सबसे व्यापक था।[18] इसके अलावा, यह आंदोलन किसी विशेष वर्ग या समुदाय तक ही सीमित नहीं था। राष्ट्रवाद की इतनी स्पष्ट अभिव्यक्ति भारतीय इतिहास में पहले कभी नहीं देखी गई। इल्बर्ट बिल आन्दोलन या सुरेंद्रनाथ बंद्योपाध्याय की कैद के विरोध में 1883 ईस्वी में पूरे देश में जो एकजुट आंदोलन देखा गया था, उससे भी यह आन्दोलन कहीं अधिक तीव्र और व्यापक था।

बंगाल में महिला समाज की सक्रिय भागीदारीः बंगाल का विभाजन और स्वदेशी आंदोलन भारतीय स्वतंत्रता के इतिहास में पहला स्वतंत्र ब्रिटिश विरोधी आंदोलन था। ब्रिटिश विरोधी भावना का स्वर इतना व्यापक पहले कभी नहीं था। स्वदेशी आंदोलन में ही बंगाल की पहली महिला समाज कठिन सामाजिक बाधाओं को पार करके स्वदेशी आंदोलन में सक्रिय रूप से सम्मिलित हुईं। बेशक, 1921-22 के असहयोग आंदोलन, 1930-34 के सविनय अवज्ञा आंदोलन या 1942 के भारत छोड़ो आंदोलन में बड़ी संख्या में महिलाएं सम्मिलित हुईं थीं। लेकिन जातीय आंदोलन में गांधीजी के अवतरण के बाद के आंदोलनों के साथ इसकी तुलना करना अनुचित है। वास्तव में 19 जुलाई 1905 को विभाजन योजना की आधिकारिक घोषणा और 16 अक्टूबर को बंगाल के विभाजन के फैसले के विरोध में बंगाल की महिलाएं भी पुरुषों के सहयोगी के रूप में आंदोलन में सम्मिलित हुईं। स्वदेशी आंदोलन में महिलाओं की भागीदारी के बारे में भारती रॉय ने अपने निबंध 'स्वदेशी आंदोलन और बंगनारी जागरण' में दिखाया है, "स्वदेशी युग में, भारतीय लड़कियों में पहली राजनीतिक चेतना जागृत हुई थी। बाद के दौर में राजनीतिक आंदोलन में उन्होंने जो सक्रिय भूमिका निभाई, उसके पीछे स्वदेशी आंदोलन का काफी योगदान था।"

16 अक्टूबर, 1905 को बंगाल विभाजन की पूर्व संध्या पर, लड़कियों ने हिंदू-मुस्लिम भाईचारे के बंधन के रूप में रवींद्रनाथ टैगोर द्वारा आयोजित 'राखी बंधन' उत्सव में उत्साहपूर्वक भाग लिया। रामेंद्रसुंदरा त्रिवेदी के आह्वान पर, बंगाली महिला समाज के एक बड़े वर्ग ने 'अरंधन उपवास दिवस' मनाया। बंगाल की माताओं और बहनों ने उस शाम रामेंद्रसुंदर त्रिवेदी द्वारा लिखित बंगलक्ष्मी का व्रत लिया। इसके अलावा, लड़कियों ने दो बंगालों की एकता के प्रतीक के रूप में बंगाल विभाजन की दोपहर को कोलकाता में अपर सर्कुलर रोड पर 'मिलन मंदिर' की आधारशिला रखने में भी भाग लिया।

विभाजन विरोधी आंदोलन में भाग लेने वाली महिलाओं में उल्लेखनीय थीं सरला देवी चौधुरानी, कुमुदिनी बसु, सुबाला आचार्य, हेमांगिनी दास, निर्मला सरकार, लीलावती मित्रा और प्रमुख। इसके अलावा, मुर्शिदाबाद की गिरिजा सुंदरी, बीरभूम की दूकरीबाला देवी, बरिसाल की सरोजिनी देवी और मनोरमा बसु, खुलना की लावण्या प्रभा दत्ता, ढाका की ब्रह्ममयी सेन, फरीदपुर की सौदामिनी देवी और अन्य ने विभाजन विरोधी आंदोलन में सक्रिय रूप से भाग लिया। क्रांतिकारियों को आश्रय देने और उनकी देखभाल करने, समाचार और हथियारों की आपूर्ति आदि के माध्यम से, बंगाल की महिलाओं ने स्वदेशी आंदोलन में बड़ी गतिविधियों से स्वयं को जोड़ा। महिलाएं स्वतः ही बहिष्कार आंदोलन में सम्मिलित हो गईं, जो स्वदेशी आंदोलन का एक हिस्सा था। महिलाओं ने विदेशी कपड़ों का बहिष्कार और जलाना, चूड़ियों सहित रसोई में ब्रिटिश नमक, मसाले और विदेशी दवाओं के उपयोग पर प्रतिबंध लगाने, विदेशी स्कूलों को छोड़ने और शराब की दुकानों पर धरना देने जैसे कार्यक्रमों में भी भाग लिया। कोलकाता में एक महिला सभा में नटोर की रानी ने विदेशी वस्तुओं के बहिष्कार का आह्वान

किया। जलपाईगुड़ी में अंबुजा सुंदरी दासगुप्ता, मयमनसिंह में पुष्पलता गुप्ता, काशी में सुशीला बसु और कोलकाता में हेमांगिनी दास ने विदेशी उत्पादों का बहिष्कार करने का आह्वान किया।

विदेशी वस्तुओं के बहिष्कार के साथ ही महिलाओं से घरेलू उत्पाद बनाने और उपयोग करने का आग्रह किया गया। स्वदेशी उत्पादों के उपयोग को बढ़ाने के लिए, स्वर्णकुमारी देवी ने 'सखी समिति' की स्थापना की और रवींद्रनाथ की भतीजी सरलादेवी चौधुरानी ने 'लक्ष्मी भंडार' की स्थापना की। विभाजन विरोधी स्वदेशी आंदोलन के दौरान चरण कवि मुकुंद दास ने बंगाल की महिला समाज के लिए गाया, 'रेशम की चूड़ियाँ छोड़ो, बंगनारी, कभी और मत पहनो'। महिलाएं स्वदेशी उत्पादों का व्यापक उपयोग करने के साथ-साथ स्वदेशी धन के लिए धन और यहां तक कि सोने के गहने भी दान करती हैं। अबला बसु की उद्दयोग से बनी 'मैरी कारपेंटरहॉल' में लगभग एक हजार महिलाओं ने बंगाल विभाजन के विरूद्ध निष्ठा की शपथ ली।

बंगाल की महिला समाज ने भी विभिन्न पत्रों और पत्रिकाओं के प्रकाशन के माध्यम से बंगाल के विभाजन के खिलाफ प्रचार में महत्वपूर्ण भूमिका निभाई। उदाहरण के लिए, सरलादेवी चौधुरानी द्वारा संपादित 'भारती' पत्रिका, स्वदेशी आंदोलन के पुजारियों में से एक कृष्ण कुमार मित्रा की बेटी कुमुदिनी मित्रा द्वारा संपादित 'सुप्रभात' पत्रिका, मीरा दासगुप्ता द्वारा संपादित 'रेणु' पत्रिका और सरजूबाला द्वारा संपादित 'भारत महिला' पत्रिका बंगालियों के बीच देशभक्ति के प्रचार-प्रसार में महत्वपूर्ण भूमिका निभाई। स्वदेशी आंदोलन के दौरान मुस्लिम महिला खैरुननेसा ने 1905 में अखबार 'नबनूर' में 'स्वदेशानुराग' नामक एक कविता लिखी, जिससे बंगाली महिलाओं में राष्ट्रवाद की भावना पैदा हुई।

संस्कृति की विभिन्न शैलियों का विकासः बंगाल का विभाजन और स्वदेशी आंदोलन राजनीति की संकीर्ण सीमाओं तक ही सीमित नहीं थे। बंगाल ने संस्कृति की विभिन्न शैलियों के विकास में भी महत्वपूर्ण भूमिका निभाई। वास्तव में, स्वदेशी आंदोलन ने बंगाली संगीत, साहित्य, विज्ञान और चित्रकला के सभी पहलुओं को प्रभावित किया। सुमित सरकार ने सही लक्षित किया है कि हमारे राष्ट्रीय आंदोलन के किसी भी दौर में सांस्कृतिक क्षेत्र में इतनी उपलब्धियां नहीं रही जितनी स्वदेशी आंदोलन के दौर की रहीं। इस दौरान असंख्य कविताओं और गीतों के माध्यम से देश प्रेम का संदेश फैलाया गया। रवींद्रनाथ के अलावा, अतुल प्रसाद सेन, रजनीकांत सेन, द्विजेंद्रलाल रॉय और कवि मुकुंद दास के लेखन भी उल्लेखनीय हैं। कवि इस्माइल हुसैन के काव्य प्रवाह में हिंदू और मुस्लिम दोनों राष्ट्रों को भारतमाता की संतान माना जाता है। स्वदेशी या इसकी विचारधारा ग्रामीण बंगाल के लोक गीतों और बाउल गीतों में भी परिलक्षित होती थी। रवींद्रनाथ के 'घरेबाईरे' और इस घटना के संदर्भ में 'गोरा' लिखा गया था। इस दौरान कई लेख प्रकाशित हुए। इसमें रवींद्रनाथ ने अहम भूमिका निभाई। उनमें 'आत्मशक्ति', 'भारतवर्ष', 'स्वदेशी समाज', 'शिक्षा, विशेष रूप से महत्वपूर्ण हैं। प्रमथ चौधरी ने 'भारत' पत्रिका में बहिष्कार और राष्ट्रवाद पर कई लेख लिखे। इसके अलावा, द्विजेंद्रनाथ टैगोर, सखाराम गणेश देउस्कर, देवी प्रसन्ना रॉय चौधरी और अन्य के लेखन में बंगाल विभाजन आंदोलन की स्पष्ट छाप थी। बंगाली साहित्य और संस्कृति के अध्ययन के लिए एक केंद्र के रूप में 1894 में गठित बंगीय साहित्य परिषद, बंगाल के विभाजन के दौरान तत्कालीन संपादक रामेंद्र सुंदर त्रिवेदी के नेतृत्व में साहित्य के अध्ययन का मुख्य केंद्र बन गया। 1907 में रवींद्रनाथ की अध्यक्षता में बंगाल साहित्य सम्मेलन के पहले वार्षिक कार्यक्रम ने बंगालियों को प्रेरित किया।

देशभक्ति की विचारधारा ने बंगालियों को विज्ञान की खोज पर ध्यान केंद्रित करने के लिए मजबूर कियाथा। उस समय दो प्रमुख वैज्ञानिकों - आचार्य जगदीश चंद्र बोस और प्रफुल्ल चंद्र रॉय ने बंगालियों को गौरवान्वित किया। जगदीश चंद्र अपने 'प्लांट रिस्पांस थ्योरी' के लिए ऊंचे स्थान पर बैठे थे। यह 1906 ई. की देशभक्ति की सबसे बड़ी उपलब्धि थी। विज्ञान के अभ्यास की उनकी विचारधारा राष्ट्रवाद के अनुरूप हो गई। प्रफुल्ल चंद्र का लेखन उनकी देशभक्ति और शोध का सबसे अच्छा उदाहरण रहा है। इन दो वैज्ञानिकों के बाद प्रेसीडेंसी कॉलेज के केंद्र में कई और युवा वैज्ञानिक आए - उनमें से उल्लेखनीय हैं लाल दत्त, नीलरतन धर, ज्ञानेंद्र चंद्र घोष, मेघनाद साहा और सत्येंद्रनाथ बोस।

बंगाल विभाजन के अवसर पर बंगाल में प्रकाशित सभी समाचार पत्रों और समकालीन पत्रों ने बंगाली पत्रकारिता के इतिहास में एक नया अध्याय शुरू किया। इस समय, जैसा कि बंगाली अखबारों की भाषा में देखा जाता है, एक तरफ मातृभूमि के विचार में राजनीतिक विश्लेषण और दूसरी तरफ आजादी की धुन, मांगों को पूरा करने के लिए एक मजबूत कदम। इसी प्रकार स्वदेश व्रत के महान

संकल्प में पत्रिकाओं ने भी संयुक्त रूप से ब्रिटिश साम्राज्यवाद के विरुद्ध लेख लिखे। कृष्ण कुमार मित्रा ने अपनी 'संजीवनी' पत्रिका में पहला बहिष्कार आंदोलन प्रस्तावित किया था। उन्होंने बंगाल के विभाजन के विरोध में लिखा कि जब तक बंगाल एकजुट नहीं होगा, बंगाली ब्रिटिश सामान नहीं खरीदेंगे और सभी ब्रिटिश सामानों का बहिष्कार करेंगे। कृष्णकुमार अंग्रेजों को चोट पहुँचाना चाहते थे ताकि यदि उनका व्यापार तनावपूर्ण हो, तो अंग्रेज अपने अस्तित्व के आग्रह पर बंगाल की समस्याओं को देखें। इसके अलावा, रामानंद चट्टोपाध्याय की 'प्रबासी', ब्रह्मबंधब उपाध्याय की 'संध्या', भूपेंद्रनाथ दत्त की 'जुगंतर', अरविंद घोष की 'बंदेमातरम', कृष्णकमल भट्टाचार्य की 'हिताब्दी' बंद्योपाध्याय की 'बंगाली' पत्रिका आदि ने स्वदेशी आंदोलन के प्रसार में महत्वपूर्ण भूमिका निभाई।

मूल्यांकनः इस प्रकार स्वदेशी आंदोलन के परिणामस्वरूप भारत में राष्ट्रवादी आंदोलन के चरित्र में भारी बदलाव आया। इस आंदोलन के परिणामस्वरूप, राष्ट्रीय कांग्रेस के भीतर चरमपंथी विचारधारा का उदय हुआ और ब्रिटिश विरोधी आंदोलन पूरी तरह से अलग दिशा में बहने लगा। यह पहली बार है कि बंगाली राष्ट्र ने अपने लक्ष्यों को प्राप्त करने के लिए 'स्वदेशी' और 'बहिष्कार' की दोधारी तलवार का इस्तेमाल एक उपकरण के रूप में किया है। इस आंदोलन के प्रारंभ से ही बंगाल और भारत के विभिन्न हिस्सों में गुप्त संगठन अधिक सक्रिय हो गए। अंततः इस आंदोलन का असर सिर्फ बंगाल में ही नहीं बल्कि पूरे भारत में अनुभव किया गया। इस आंदोलन की प्रतिक्रिया में भी, 12 दिसंबर 1911 को, जॉर्ज पंचम को दिल्ली के दरबार में औपचारिक रूप से बंगाल के विभाजन की घोषणा करने के लिए मजबूर होना पड़ा, जिसने भारत में ब्रिटिश विरोधी आंदोलन को एक नई गति दी और स्वदेशी आंदोलन पहले बंगाल की भूमि में पैदा हुआ और धीरे-धीरे एक अखिल भारतीय रूप ले लिया। 1908 में महात्मा गांधी ने स्वदेशी आंदोलन के बारे में ठीक ही कहा था, 'The real awakening (of India) took place after the partition of Bengal---That day may be considered to be the day of the partition of British Empire'[19]- विल डुरंट ने भी स्वीकार किया कि "It was in 1905, then, that the Indian Revolution began"[20] इस स्वदेशी आंदोलन के माध्यम से नवजात भारतीय राष्ट्रवाद का एक क्रांतिकारी रूप प्रकट हुआ और भारतीय राजनीति में एक नए युग का प्रारंभ हुआ।

सन्दर्भ

1. मुखर्जी हरिदास, उमा मुखर्जी, 'स्वदेशी आंदोलन और बंगलार नब युग', सरस्वती पुस्तकालय, कलकत्ता, 1961, पृ.1.
2. Sarkar Sumit, 'The Swadeshi Movement in Bengal (1903-1908), People's Publishing House, New Delhi, 1973, p. 12
3. देसाई ए. आर, 'भारतीय जातीयतावाद एवं सामाजिक पृष्ठभूमि', केपी बागची एंड कंपनी, कलकत्ता, 1987, पृ. 263-265।
4. Chandra Bipan, Mridula Mukherjee, Aditya Mukherjee, Sucheta Mahajan, K. N. Panikkar, 'India's Struggle For Independence 1857-1947', Penguin Books, New Delhi, 1989, p. 125.
5. सुमित सरकार, पूर्वोक्त, पृ. 15.
6. Banerjee Surendranath, 'A Nation in Making', London, Oxford University Press, 1925, p. 184.
7. बंद्योपाध्याय शेखर, 'पलाशी थेके पार्टिशन : आधुनिक भारतेर इतिहास', कृष्णेंदु रॉय द्वारा अनुवादित, ओरिएंट लॉन्गमैन, दिल्ली, 2004, पृ. 297.
8. चंद्र बिपन, 'आधुनिक भारतेर इतिहास', अनुवादित, ओरिएंट ब्लैकसोवन, नई दिल्ली, 2013, पृ. 353।
9. मुखर्जी हरिदास और उमा मुखर्जी, पूर्वोक्त, पृ. 7
10. सरकार सुमित, आधुनिक भारत (1885-1947), के.पी. बागची एंड कंपनी, कलकत्ता, 2004, पृ. 94।
11. Sarkar Sumit, op.cit., 1973, p. 31.
12. Mukherjee Haridas and Uma Mukherjee, 'Origins of the National Education Movement (1905-1910)', Jadavpur University, Calcutta, 1957, pp. 37-44.
13. मुखोपाध्याय हरिदास और उमा मुखोपाध्याय, पूर्वोक्त, पृ.6
14. Majumdar R. C., 'History of the Freedom Movement in India', Vol. I, Firma K. L. Mukhopadhyay, Kolkata, 1971, p. 390.
15. चंद्र बिपन, पूर्वोक्त, पृ. 267
16. Sitaramayya Pattabhi B., 'The History of the Indian National Congress' Vol. 1 (1885-1935), Working Committee of the Congress, 1935, p. 70.
17. मुखर्जी हरिदास और उमा मुखर्जी, पूर्वोक्त, पृ. 34
18. बंद्योपाध्याय शेखर, पूर्वोक्त, पृ. 297
19. हरिदास मुखर्जी और उमा मुखर्जी, पूर्वोक्त, पृ. 7
20. Durant Will, 'The Case for India', Simon and Schuster, New York, 1930, p. 123.

July 2021 E-ISSN – 2348-7143

INTERNATIONAL RESEARCH FELLOWS ASSOCIATION'S

RESEARCH JOURNEY

International E-Research Journal

PEER REFEREED & INDEXED JOURNAL

Special Issue 269(D)

Multidisciplinary Issue

For Details Visit To : www.researchjourney.net

SWATIDHAN PUBLICATIONS

INTERNATIONAL RESEARCH FELLOWS ASSOCIATION

INDEX

Our Editors have reviewed papers with experts' committee, and they have checked the papers on their level best to stop furtive literature. Except it, the respective authors of the papers are responsible for originality of the papers and intensive thoughts in the papers. Nobody can republish these papers without pre-permission of the publisher.

- Chief & Executive Editor

'RESEARCH JOURNEY' International E- Research Journal
Special Issue – 266(D) : Multidisciplinary Issue
Peer Reviewed Journal
E-ISSN : 2348-7143
July - 2021

The Role of Education in Women's Empowerment in India

Manas Kumar Das
Assistant Professor, Department of History, Dumkal College,
Dist. - Murshidabad (W.B.)
Email:manasdas725@gmail.com

Abstract:

The women have significant place in society and play a vital role in the development of any country. Hence women progress in every field is very important for developing country and it could be possible only by empowering the women. The education plays an important role in human progress and women empowerment. Because Education not only educates a woman but enables her to take decisions and accept responsibilities at her home and outer world. Education helps a woman to understand her rights to equal treatment like a man in the society of this nation. Education of women is the most powerful tool to change the position in society. Occupational achievement, self-awareness and satisfaction are among the many things that will be ensured by effective use of education. This article describes the need of women's education in rural area and also focuses on the role of education in women's empowerment in India.

Keyword: Education, women, milestone, Women's empowerment, women's participation.

Introduction:

"Countries and Nations which do not respect women have never become great nor will ever be in future" - Swami Vivekananda

The term 'Empowerment' is defined as "the process of changing the distribution of power in institutions and interpersonal relationships across society." The empowerment strengthens the innate ability by way of acquiring knowledge, power and experience. Empowerment is the process of enabling or authorizing individual to think, take action and control work in an autonomous way. Women Empowerment is the process by which women control their own lives by establishing those rights, from their homes to the international stage, by knowing what their rights are. Nowadays women Empowerment is a global issue and discussion on women political right are at the fore front of many formal and informal campaigns worldwide. The concept of women empowerment was introduced at the international women conference at Nairobi in 1985.

Women have a very in-distinctive position in our economy and are an indispensable part of the society. But women are discriminated and marginalized at every level of the society whether it is social participation, political participation, economic participation, access to education, and also reproductive healthcare. Women are found to be economically very poor all over the India. A few women are engaged in services and other activities. So, they need economic power to stand on their own legs on per with men. It has also noticed that some of women are too weak to work. They consume less food but work more. Therefore, from the health point of view, women folk who are to be weaker are to be made stronger. Another problem is that workplace harassment of women. There are so many cases of rape, kidnapping of girl, dowry harassment, and so on. For these reasons, they require empowerment of all kinds in order to protect themselves and to secure their purity and dignity. Hence women empowerment is necessary and important for development of country. The only way a society or nation can move forward, and aspire to economic growth and development is not just through education-

but especially education among the women citizens. Once she is on the move, the family moves, the village moves, the nation moves.

Objectives of the study:

- The main objective of our study to find out how the education played an important role in the empowerment of Indian women
- Assess the present scenario of women empowerment in India.

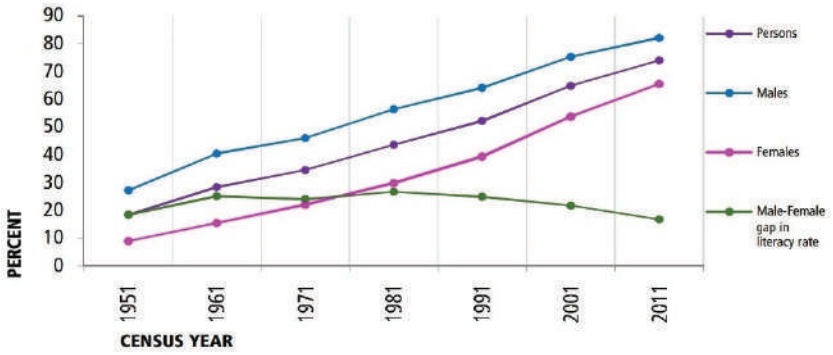
Methodology:

The present paper is based on secondary data. The required data was collected from Government records, Indian census record from 2001 to 2011, various articles, Newspaper, books, internet sources and journals etc.

Need of Women Empowerment:

In present Scenario, Women empowerment and gender equality in India is India is an alarming Same problem such as dowry, domestic violence, sex selective abortion, female infanticide are still prevalent. As per the 2011 Census, women are subject to disadvantages as compared to men in terms of literacy rates, labor participation rates and earnings. The Census, 2011 reveals that total literate population is 74.04% comprising 65.46% female and 82.14% males. The gap between women and men is severe. While 82.14% of adult men are educated, only 65.46% of adult women are known to be literate in India. The gender bias is higher education, specialized professional trainings which hit women very hard in employment and attaining top leadership in any field. Literacy Educational levels are the increasing for Indian women still there is gap between Male and female literacy rate which can be seen in the following Table.

Census Year	Persons	Males	Females	Male-Female gap in literacy rate
1	2	3	4	5
1951	18.33	27.16	8.86	18.30
1961	28.3	40.4	15.35	25.05
1971	34.45	45.96	21.97	23.98
1981	43.57	56.38	29.76	26.62
1991	52.21	64.13	39.29	24.84
2001	64.83	75.26	53.67	21.59
2011	74.04	82.14	65.46	16.68



The above table, we come to know that at no point could the literacy rate of women match that of men. As a result, 72 years of independence, Women occupy a secondary position in our social hierarchy. Inspire of being aware of her position, women can't transform the situation due to lack of education. Therefore, women's empowerment can't be effected unless we persuade the importance of women's education.

Role of Education in Women's Empowerment:

According to Nehru, "If you educate a man you educate an individual, however, if you educate a woman you educate a whole family. Women empowered means mother India empowered". Hence to educate women is more important than men. Education in India plays the most crucial role in women empowerment because it enables them to responds to the challenges, to confront their traditional role and change their life. So we can't neglect the importance of education in reference to women empowerment. Education increases women's self-confidence and also enables them to find better job and she can help family economically. It develops the women's capabilities to fight against injustice, domestic violence, corruption and many other bad elements in the society. Education empowers women to make choices that can improve their welfare, including marrying beyond childhood and having fewer children. Education helps a woman to understand her rights to equal treatment like a man in the society of this nation and realize that she is not inferior to man. It enables her to take decisions at her home and it enables her to accept responsibilities at her home and outer world. Education will help women to empower through the knowledge of science and technology to face the challenges of today's technological age and it helps her to build career path. Finally education not only educates a woman but also helps her realize that she is a vital part to the society.

The impact of women empowerment in Rural Areas:

Women's empowerment in rural India is far less visible than in urban areas. Rural women, as against women in urban settings, face inequality at much higher rates and in all spheres of life. In rural areas of India generally education problems are faced by girls due to family responsibilities such as caring for younger siblings, domestic work etc. Also there are some barriers for women's education in rural areas like Priority to Son's Education Compared to Daughter's Education, Lack of Adequate Number of Female Teachers and Gender Bias in Curriculum Still Exists etc. From the start, girl children are seen as burdens rather than blessings, bearers of exorbitant dowries, who will eventually move into the homes of their husbands. The result is low literacy rate among women. The female children are not receiving the same medical, emotional and educational attention as their male counterparts due to some overwhelming cultural and economic reasons. It was observing that women were always depicted as weak and helpless, often as the victims of abuse and beatings. We can say that these depictions are strong barriers for improving women's position in society.

The illiterate women have high levels of fertility and mortality and with more children she cannot pay proper attention on them and hence a woman's lack of education has a negative impact on the health and well-being of her children. The illiterate women have poor nutritional status, low earning potential, and little autonomy within the household. In order to fight against all these socially constructed gender biases, girls and women have to swim against the system and for this they require more strength. Obviously such strength comes only from the education.

Conclusion:

Women empowerment is there but still we have miles to go on this path of empowerment. We hope that in coming year's ahead women empowerment will prove its worth. Women are an integral part of a society. They play an important role in determining the destiny of a nation. The education of women is the most powerful tool to change the position of society. Education also brings a reduction in inequalities and functions as a means of improving their status within the family. We can say that the progression of women in society is not possible without education. Without educated women the world cannot become a better place for peoples. That's why women's education is needed to turn this world into better place. We can conclude for development and evolution of any country there is need for women's education. In the 21st century we see that women are working in each field of corporate world, empowering them is truly essential and necessary. We cannot ignore the importance of women education in reference to women empowerment. The goals or dreams of our citizens will not be achieved without effective education of women.

References:

1) *Shindu J, Women's Empowerment through Education, Abhinav Journal: Vol. 1 Issue-11.*
2) *Suguna M, Education and Women's Empowerment in India, International Journal of Multidisciplinary Research: Vol.1. Issue-8.*
3) *Gupta N. L., Women's Education through Ages, Concept Publications Co, New Delhi, 2003.*
4) *Islam Rezaul& Mia Ahmadullah (2007): The role of education for rural population transformation in Bangladesh, Dhaka, April.*
5) *Rao R. K. Women and Education, Kalpaz Publications, Delhi, 2001.*
6) *D. Janaki (2006): Empowering women through distance learning in India, New Delhi.*
7) *Mahajan VD. Modern Indian History, Delhi, S. Chand, 2010.*
8) *Nagaraja, B. (2013). Empowerment of Women in India: A Critical Analysis. Journal of Humanities and Social Science (IOSRJHSS), 9(2).*
9) *Anonuevo Medel Carolyn (Ed) (1995): Women Education and Empowerment: Pathways towards autonomy; Hamburg.*
10) *Kadam, R. N. (2012). Empowerment of Women in India- An Attempt to Fill the Gender Gap. International Journal of Scientific and Research Publications, 2(6).*
11) *Kishor, S. and Gupta, K. Gender Equality and Womens Empowerment in India, National Family Health Survey (Nfhs-3) India, 2009,*
12) *http://censusindia.gov.in*

International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 5, July-August 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Enhancing School Education: Challenges, Innovations, and Future Directions

Dr. Bhabesh Pramanik

Principal, Dumkal College, Murshidabad, West Bengal, India

ABSTRACT

School education plays a pivotal role in shaping the future of individuals and societies by providing foundational knowledge, skills, and values essential for personal development and societal progress. However, the landscape of school education is fraught with challenges that necessitate innovative solutions and strategic directions to ensure quality, equity, and relevance in educational outcomes. School education serves as the foundation for individual development and societal progress. This research article examines the multifaceted landscape of school education, exploring its current challenges, innovative practices, and future directions. By synthesizing existing literature and empirical studies, this article aims to provide a comprehensive overview of key issues in school education, highlight innovative approaches being adopted globally, and propose strategies for advancing quality and equity in education systems. The findings underscore the critical role of school education in shaping lifelong learning outcomes and contributing to inclusive socioeconomic development.

KEYWORDS: *School Education, Innovative Practices, Lifelong Learning, Intellectual Growth, Studying Challenges*

How to cite this paper: Dr. Bhabesh Pramanik "Enhancing School Education: Challenges, Innovations, and Future Directions" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-5, August 2021, pp.2502-2506, URL: www.ijtsrd.com/papers/ijtsrd44992.pdf

IJTSRD44992

INTRODUCTION

School education is fundamental to fostering intellectual growth, social development, and economic empowerment among individuals. It forms the bedrock of human capital formation and plays a pivotal role in shaping future generations' capabilities and opportunities. Amidst global efforts to achieve education for all, the landscape of school education is evolving, driven by technological advancements, demographic shifts, and evolving societal needs. This research article delves into the complexities of school education, addressing current challenges, innovative practices, and emerging trends that shape the educational landscape.

Concurrently, changes in teaching methods are redefining how education is conducted. The shift towards student-centered learning approaches, project-based learning, and experiential learning indicates a departure from conventional didactic methods (Clark & Mayer, 2018). There is a growing recognition among educators of the significance of cultivating critical thinking, collaboration, and problem-solving abilities. This section examines the efficacy of these instructional changes in improving student involvement and equipping learners for the demands of a swiftly changing global environment.

In the ever-changing field of education, it is now more important than ever to effectively plan for the future. This article undertakes a thorough examination of the current trends and advancements that are influencing modern education (Jones & Brown, 2018). As various social, technological, and global factors continue to impact the field of education, educators policymakers, and stakeholders are confronted with the task of adjusting to this changing environment.

Justification of the study:

Studying challenges, innovations, and future directions in enhancing school education is imperative for advancing educational quality, equity, and relevance in a rapidly evolving global context. By addressing current challenges, embracing educational innovations, and envisioning future directions, stakeholders can collaboratively shape a transformative agenda that empowers learners, strengthens educational systems, and contributes to sustainable societal development. This study aims to

International Journal of Trend in Scientific Research and Development

Online Open Access Journal ISSN: 2456-6470

Certificate of Publication

This Certificate is Proudly Presented for Honorable Achievement to

Dr. Bhabesh Pramanik

Principal, Dumkal College,
Murshidabad, West Bengal, India

For Paper title ***"Enhancing School Education: Challenges, Innovations, and Future Directions"***

Published in International Journal of Trend in Scientific Research and Development (IJTSRD), Vol - 5 | Issue - 5 (Jul-Aug 2021). With Impact Factor 6.410, issued in the year of 2021 by I2OR

IJTSRD44992
Unique Paper ID

www.ijtsrd.com
Available Online

M M Patel

Dr. M. M. Patel
Chief Editor

European Journal of Innovation in Nonformal Education (EJINE)
Volume 1 | Issue 02 | Dec - 2021 ISSN: 2795-8612

Evaluation: Methods, Applications, and Challenges in Research and Practice

Dr. Bhabesh Pramanik
Principal, Dumkal College, Murshidabad, West Bengal, India

ABSTRACT
Evaluation is a systematic process of collecting, analyzing, and interpreting data to assess the design, implementation, effectiveness, and impact of programs, policies, interventions, or initiatives. Evaluation plays a crucial role in assessing the effectiveness, impact, and quality of programs, interventions, policies, and initiatives across diverse fields. The overarching goal of evaluation is to generate credible evidence that informs stakeholders about the strengths, weaknesses, and outcomes of the entity being evaluated, with the aim of improving its performance and achieving desired outcomes. This research article explores the multifaceted nature of evaluation, examining its methods, applications, and challenges in both research and practical contexts. By synthesizing current literature and empirical studies, this article aims to provide a comprehensive understanding of evaluation processes, highlight innovative approaches, and discuss key challenges faced by evaluators. Ultimately, this research contributes to enhancing the rigor and relevance of evaluation practices in informing decision-making and improving outcomes.

ARTICLE INFO
Article history:
Received 26 October 2021
Received in revised form
28 November 2021
Accepted 30 December 2021

Keywords: The Design, Implementation, Effectiveness, Interventions, Policies, And Initiatives.

Introduction:

The process of teaching and learning includes evaluation. Teaching and learning are both enhanced by it. Rather than being a one-time event, evaluation is an ongoing procedure. Students' values of judgement, educational standing, and accomplishment can be shaped by this. As with any area of educational endeavour, evaluation, in some shape or another, is intrinsic to the teaching and learning process. Therefore, it's ideal for educators to learn all they can about assessment and how to use it in the classroom. (Cabrera,2006)

Incorporating value judgement into assessment is what evaluation is all about. Its focus is on putting its results into practice, which in turn requires making a value judgement on a product, process, or advancement in light of predetermined goals and principles. It is common practice to give suggestions for positive actions in evaluations. (Trochim, & Kane,2005) A qualitative assessment of the current state of affairs is, thus, evaluation. It demands proof that the programme is good, appropriate, or effective. Valuation is the process of determining the value of an item, process, or programme so that important decisions can be made regarding it. (Dougherty, & Conway,2008)

Significance of the Study:

the study of evaluation - encompassing its methods, applications, and challenges - holds significant implications for research, policy, and practice. By advancing our understanding of how to effectively evaluate programs and interventions, this study contributes to improving decision-making, enhancing accountability, fostering innovation, and addressing pressing societal challenges. Ultimately, evaluation serves as a cornerstone for evidence-based practice, driving continuous improvement and promoting

5.302

SJIF

CERTIFICATE

OF PUBLICATION

THIS CERTIFICATE IS PROUDLY PRESENTED TO

Dr. Bhabesh Pramanik

in recognition of the paper publication on open access peer-reviewed Journal of
European Journal of Innovation in Nonformal Education (EJINE) with the title:

Evaluation: Methods, Applications, and Challenges in Research and Practice

Vol. 01 Issue 02 (2021): *EJINE* eISSN: 2795-8612

Dec - 2021

Joe Lewis
editor-in-Chief

International Journal of Formal Education

Volume: 01 Issue: 02 | 2022
ISSN: 2720-6874
www.academiczone.net

TEACHER PROFESSIONAL DEVELOPMENT: MODELS AND OUTCOMES

Dr. Bhabesh Pramanik

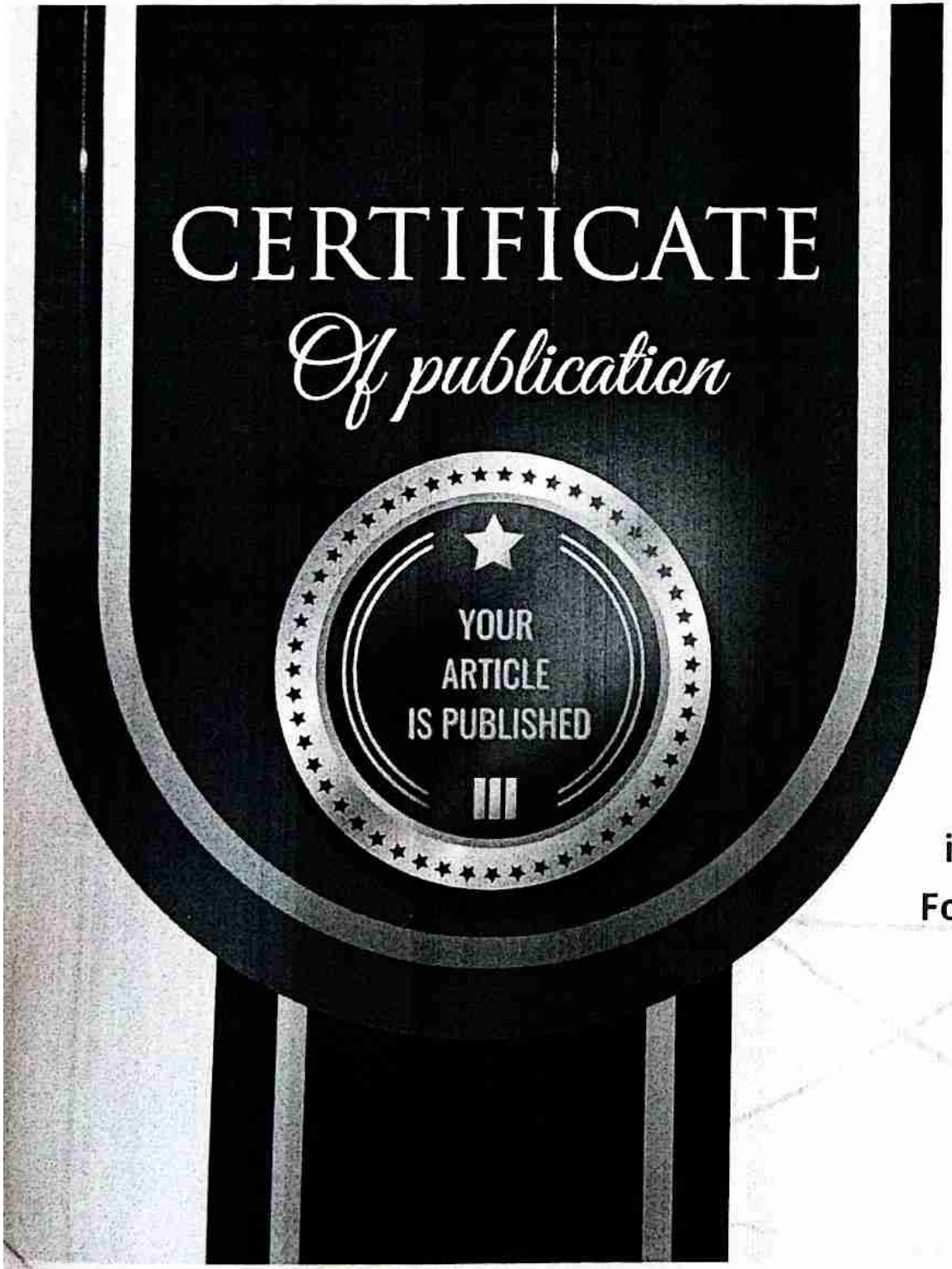
Principal, Dumkal College, Murshidabad

Abstract

Teacher professional development (PD) plays a crucial role in enhancing teaching effectiveness and student outcomes. This research article explores various models of teacher PD, examines their effectiveness, and analyzes the outcomes for educators and students alike. The study synthesizes current literature, discusses challenges and best practices, and provides recommendations for implementing effective PD programs in educational settings. Beginning with their initial preparation and continuing all the way until retirement, professional development of teachers is an ongoing process. Teachers are the key players in bringing about change in the classroom, which is why investing in their professional development is so crucial. The study emphasised the positive impact of effective methods and approaches on the growth and development of teachers in an era marked by rapid technological advancements and changing educational paradigms. It highlighted strategies for teacher professional development for 21st century education.

Key words: Professional Development, Teaching, Effectiveness, Student Achievement.

Introduction: Teacher professional development (PD) is recognized globally as essential for improving instructional practices and fostering student achievement. The landscape of PD has evolved significantly over the years, moving from traditional one-off workshops to more comprehensive, ongoing models aimed at sustained improvement. This article aims to explore different PD models, their effectiveness, and the outcomes they produce in terms of teacher growth and student learning. (Bayar, 2014)



ACADEMIC ZONE

THIS CERTIFICATE IS PROUDLY PRESENTED TO

Dr. Bhabesh Pramanik

For publication of paper entitled:
"TEACHER PROFESSIONAL DEVELOPMENT: MODELS AND OUTCOMES"

in Vol. 1 No. 2 (2022): International Journal of Formal Education eISSN: 2720-6874 with Impac Score of 4.758 by SJIF for the year of 2022

Feb - 2022
DATE

Dr. ALMA BANGAYAN- MANERA
EDITOR-IN-CHIEF

Jordan Journal of Mathematics and Statistics (JJMS), 16(1), 2023, pp 153 - 163
DOI: https://doi.org/10.47013/16.1.10

A NOTE ON THE BOUNDS OF ZEROS OF POLYNOMIALS AND CERTAIN CLASS OF TRANSCENDENTAL ENTIRE FUNCTIONS

TANCHAR MOLLA[1] AND SANJIB KUMAR DATTA[2]

Abstract. In the paper we wish to find bounds of zeros of a polynomial. Our result in some special case sharpen some very well known results obtained for this purpose. Also, we obtain lower bound for a certain class of transcendental entire functions by restricting the coefficients of its Taylor's series expansions to some conditions.

1. Introduction

Fundamental theorem of algebra asserts that every non constant polynomial of degree n with complex coefficients has exactly n zeros but gives no information about location of zeros of a polynomial. All zeros of a polynomial of degree less than or equal to 4 can be derived algebraically for all possible values of its coefficients. But, difficulty arises when degree of polynomial is greater than or equal to 5. So, it is desirable to know bounds of zeros of a polynomial. Problem of finding bounds for zeros of a polynomial is classical one which is essential in various disciplines such as controling engineering problems, eigenvalue problems in mathematical physics and digital audio signal processing problems {cf. [18]}. Gauss and Cauchy were first contributors in this area [16]. To find bounds for the moduli of the zeros of a polynomial, Cauchy {cf. [16]} introduced the following classical result:

***Theorem* A** [16]. *If $P(z) = \sum_{j=0}^{n} a_j z^j$ is a polynomial of degree n, then all the zeros of $P(z)$ lie in $|z| \leq 1 + max_{0\leq j\leq (n-1)}|\frac{a_j}{a_n}|$.*

Theorem A was improved in several ways by many researchers {cf. [6], [13], [15] &

2020 *Mathematics Subject Classification.* 30D20, 30C10, 30C15, 30D10.

Key words and phrases. Polynomial, transcendental entire function, coefficients, zeros, bounds.

Received: Feb. 18, 2022 Accepted: Jun. 13, 2022 .

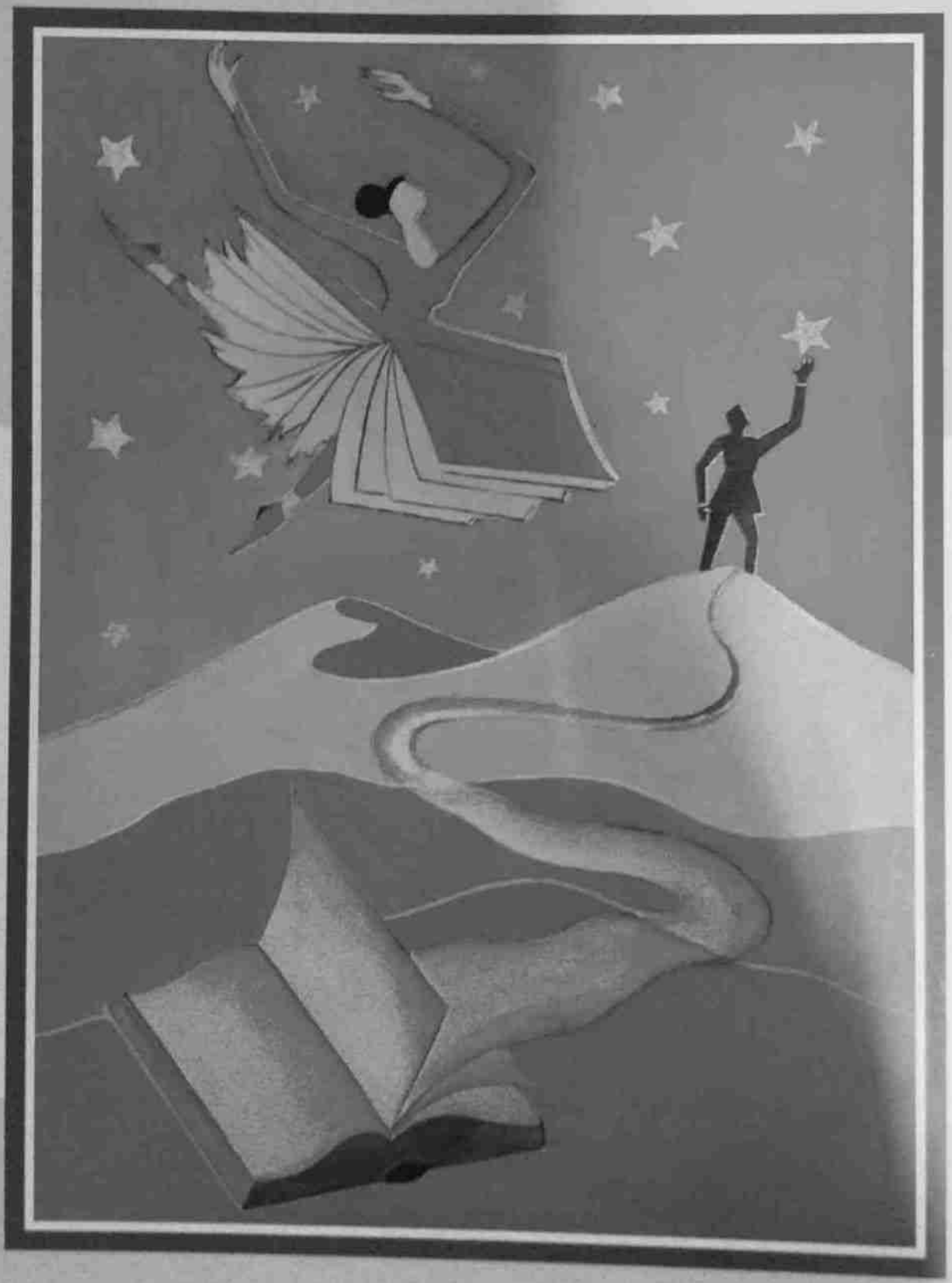
Jordan Journal of Mathematics and Statistics
An International Refereed Research Journal

Latest Issue

Volume 16, No. 1, March 2023

ISSN - 2454-2512

সহবতি



সপ্তম বর্ষ, বইমেলা সংখ্যা - ২০২৩

সহবতি

ষান্মাসিক গবেষণা পত্রিকা

সপ্তম বর্ষ, বইমেলা সংখ্যা :২০২৩

ISSN : 2454-2512

প্রধান সম্পাদক

ড. নন্দিনী বন্দ্যোপাধ্যায়

অধ্যাপক, বাংলা বিভাগ, কল্যাণী বিশ্ববিদ্যালয়, কল্যাণী, নদিয়া

সহযোগিতা

দিবাকর বর্মন, নয়ন ভল্লা, বুদ্ধদেব সাহা, কৃষ্ণময় দাস, হেমন্ত মণ্ডল, জয়ন্ত ঘোষ, টোটন বায়েন, সিদ্ধার্থ ঘোষ, সুস্মিতা ঘোষ, সুরূপা কর, সমৃদ্ধি শেখর মণ্ডল

দপ্তর

সহবতি পরিষদ, কনকাঞ্জলি অ্যাপার্টমেন্ট, বি-৭/১৪৫, কল্যাণী, নদিয়া।

প্রচ্ছদ

সুদীপ চক্রবর্তী

বর্ণ সংস্থাপন

প্রিন্টম্যাক্স

ইছাপুর

মুদ্রক

অজন্তা প্রিন্টার্স

কলকাতা : ৭০০০০৯

মূল্য : তিনশো পঁচাত্তর টাকা

প্রসঙ্গ : নাটক

প্রসঙ্গ : কাব্য-কবিতা

লোকনাট্যের স্বরূপ বিচার

অচিন্ত্যকুমার গঙ্গোপাধ্যায়

ইংরেজিতে 'ফোক' শব্দটি আভিধানিক অর্থ হল 'লোক' বা সাধারণ মানুষ।[১] তবে লোকসাহিত্যে এই 'লোক' শব্দটির বিশেষ তাৎপর্য রয়েছে। জাতিগত দিক থেকে নির্দিষ্ট শ্রেণীর মানুষকে বোঝানো হয়। যেমন নাগরিক বলতে একটি রাষ্ট্রের অনুমোদিত সদস্যকেই বোঝায়, তেমনি নৃতাত্ত্বিক দিক থেকে আর্থিক দিক থেকে পশ্চাৎপদ শ্রেণির মানুষকেই এই 'লোক'-এর অন্তর্ভুক্ত করা হয়। আপাতদৃষ্টিতে 'লোক বলতে কোন নির্দিষ্ট ব্যক্তিকে বোঝায় না। লোকসংস্কৃতির দৃষ্টিকোণ থেকে বলা চলে একই ভৌগোলিক পরিবেশে কম-বেশি একই রূপ জীবনদর্শনের অধিকারী, পরম্পরা অনুসরণকারী, সংহত সমাজের সদস্যকেই বলা হয় 'লোক'। এক্ষেত্রে লোক কোন ব্যক্তিবিশেষ নয়, বরং সমষ্টিবদ্ধ মানুষের একজন হিসেবেই স্বীকৃত।'[২]

পশ্চিমী বিশিষ্ট সমালোচক অ্যালেন ডান্ডেস অবশ্য যে কোন একটি বিষয়ে যদি দু'জন মানুষের ঐক্য বা সাযুজ্য থাকে তাহলে ঐ মানবদ্বয়ের সাযুজ্য বা ঐক্যকেই লোক বা 'ফোক' বলে চিহ্নিত করার পক্ষপাতী। তবে বিশেষভাবে স্মরণীয় যে, সংখ্যার দিক থেকে না হলেও এতে সমাজ নিয়ন্ত্রিত ঐতিহ্য যদি অটুট থাকে, তবেই তাকে 'লোক' হিসাবে স্বীকৃতি দেওয়া যায়।[৩]

পাশাপাশি উল্লেখ করতে হবে যে, লোক বৈশিষ্ট্যগুলি এক একটি জনগোষ্ঠীকে ছাপিয়ে তা একটি শিক্ষিত শহরে জীবনযাত্রার মধ্যেও সহজে প্রবেশ করে। তখন তাতে শহুরে জনগোষ্ঠীর বৈশিষ্ট্য প্রতিফলিত হতে দেখি। প্রকৃতপক্ষে বিভিন্ন পরিস্থিতিতে লোকনৃত্য, লোকক্রীড়া লোক উৎসবের আনন্দময় ঘটনা ও ধর্মাচরণ পদ্ধতি ইত্যাদি জীবনঘনিষ্ঠ বিষয়গুলি এই ধরণের লোকনাট্যে উপস্থাপিত হয়। উন্নত দেশগুলিতে নগরকেন্দ্রিক লোকসংস্কৃতিকে (Urban folk) ঘিরে তৈরি হয় বিষন্নসঙ্গীত, কর্মসংগীত, পেশাগত কথামালা (Jargon), শিশু-ক্রীড়া, ধর্মীয় আচার যার সঙ্গে আফ্রো-আমেরিকানদের ঐতিহ্য প্রকৃতির তুলনা চলে আসে।[৪]

ফলত লোকসংস্কৃতি চর্চার প্রধান উপাদান 'লোক' বলতে যে বিভিন্ন গোষ্ঠীকে চিহ্নিত করা হয়, তাদের প্রাত্যাহিক জীবনযাপনের অভিজ্ঞতা অনুভূতি বা উপলব্ধি সমস্ত কিছুই সংমিশ্রিত হয়ে থাকে তাদের জীবনচর্চায়। আদতে লোকসংস্কৃতি এখানেই প্রাণবন্ত হতে চায় তাদের লোকাচারগুলিকে নিয়ে।

লোকসংস্কৃতি বাস্তবিক পক্ষে একটি সুবৃহৎ আয়তনিক ক্ষেত্র। লোকসাহিত্য সেই বৃহৎ ক্ষেত্র বা আঙিনার একটি অতি সংক্ষিপ্ত পরিসর। যেখানে প্রায় সমস্ত উপাদানই মৌখিক বা ঐতিহ্য নির্ভর। আর অন্যদিকে সংস্কৃতি বলতে বুঝি জীবনচর্য্যার বিকাশশীল সভ্যতাজনিত উৎকর্ষকে। যে ঐতিহ্য একদিকে সংস্কার ভাবনায় মেশানো, আবার অন্যদিকে

ক্রমবিবর্তনশীল। তেমনি সভ্যতার আদিম স্তরে মানুষের নিজস্ব বুদ্ধি ও যুক্তির প্রয়োগভূমি ছিল না তবুও আধুনিকতার নামে আজও মানুষ জীবনচর্চার ধারায় পূর্বতন মানুষের বিশ্বাস ও প্রথাবদ্ধ ধ্যানধারণাকে লালন করে থাকে অতীতের সেই ঐতিহ্যের অনুবর্তনে, যে কোন লোকসংস্কৃতিতেই তার সুপষ্ট প্রভাব চোখে পড়ে।

লোকসাহিত্যের একটি বিশিষ্ট ধারা হল লোকনাট্য। 'নাট্য' শব্দটির সহযোগে একধরনের অভিনীত শিল্পরীতির প্রতি গ্রামীণ জনসাধারণকে আকৃষ্ট করে তোলার চেষ্টা হয়। লোকায়ত জীবন প্রেক্ষিত থেকে এই নাটকের বিষয়ভাবনা গড়ে ওঠে। সাধারণ মানুষের জীবনসংশ্লিষ্ট চিন্তা-চেতনা ও ধ্যানধারণা জীবন্ত রূপ পায় এই ধরনের নাটকের মধ্যে। আবার কোথাও কোথাও পুরোদস্তুর জনমনোরঞ্জনের জন্য এটি রচিত হয়। তবে আবার অন্যত্র এই সমালোচক উল্লেখ করেন

"কোনো পৌরাণিক কিংবা ধর্মীয় কাহিনি এর ভিতরে প্রবেশ করতে পারেনা, তার পূর্ববর্তী কোনো ধারা বা ঐতিহ্যও এতে প্রধান হয়ে উঠে না।"[৮]

প্রথম সংজ্ঞায় পরিবেশ ও পরিস্থিতির দ্বারা যে লোকনাট্য অভিনীত হয়ে থাকে সাধারণ মানুষের সমবেত চেষ্টার ফলে তার ছবি ধরা দেয়নি। কেবল দৃশ্যগতভাবে মৌখিক এই শিল্পকর্মটি প্রধান্য পেয়েছে সমালোচকের চোখে। তবে দ্বিতীয় সংজ্ঞায় আশুতোষবাবু কিছুটা আধুনিক মনের পরিচয় দিয়েছেন, নিতান্ত ধর্মীয় বা পৌরাণিক বৃত্তে আবদ্ধ রাখেননি লোকনাট্যের পরিধিকে। বিশেষত মনে রাখতে হবে নাটক জীবনের সঙ্গে ঘনিষ্ঠ একটি শিল্প মাধ্যম। সমকালীন জীবনের উত্তাপ এতে স্থায়ী প্রভাব রাখে। প্রতিটি যুগের বিশেষ লক্ষণ এতে ধরা পড়ে তার কাহিনিবৃত্ত ও চরিত্রের নির্মার্ণের মধ্যে দিয়ে। বাংলা লোকনাট্যগুলি বহুদিন ধরে সংস্কৃতি ও তার প্রবহমান ঐতিহ্যকে লালন করেছে। তার সাক্ষ্য ছড়িয়ে আছে মধ্যযুগের বাংলা নাট্যরীতি পাঁচালি, নাট্যগীতি প্রভৃতি মৌখিকরীতির মাধ্যমে। কিন্তু সেই এক ধারাতেই নাটকের পরিচিতি বা নন্দনরীতিগুলি সীমাবদ্ধ থাকেনি মঙ্গলনাট, রামযাত্রা, কৃষ্ণযাত্রা, বিদ্যাসুন্দরপালা, লিখিত আকারে অভিনীত হয়েছে প্রায় গ্রাম বাংলার সর্বত্র।[৯] এইভাবেই প্রাচীন ও মধ্যযুগের লোকনাট্যের গঠন কাঠামো রূপান্তরিত হয়েছে আধুনিক কালের উপযুক্ত মাপে। এখানে শিল্পী সত্তার আশ্রয়ে নিজস্ব পরিবেশন রীতি গড়ে উঠেছে। সুতরাং লোকসমাজে প্রচলিত ও পরিবেশিত উপাদানই লোকনাটকের সবথেকে বড় অবলম্বন। বিভিন্ন সময়ের চাপ ও সমস্যা অনিবার্য্য ভাবে এই অখ্যাত লোকনাট্যগুলিতে স্থান পাবে সে বিষয়ে কোন সন্দেহ নেই। আশুতোষ ভট্টাচার্য্য তাঁর সংজ্ঞায় একটি সাধারণ সত্যকে প্রকাশ করতে গিয়ে যে সংকোচ বোধ করেন বোধ হয় তা ঔপনিবেশিক শিক্ষা ধারায় তার চেতনা স্নাত হওয়ার কারণে। প্রকৃতপক্ষে ইউরোপের শিষ্ট নাট্যসাহিত্যেও মধ্যযুগীয় শিল্প রীতির ডেল আর্ট এর ব্যবহার এসেছে, যা লোকজ শিল্প থেকে জন্মানো বলে মেনে নিতে অসুবিধা নেই। লোকসাহিত্য যে কোন সমৃদ্ধশালী সাহিত্যরূপকে পুষ্টিরস যুগিয়েছে যুগে যুগে। বিশ্বনাটকের ইতিহাসের পর্যালোচনা করলে সে সত্য প্রকাশ পায়। কালগত ব্যবধান ও ভৌগোলিক পরিবেশের

ভিন্নতা সত্ত্বেও নাট্যধারার উদ্ভব ঘটেছে প্রাচ্য ও পাশ্চাত্যের মাটিতে একইভাবে একই উৎস থেকে। তাই দেখি আর্থসামাজিক প্রেক্ষাপটের ভিন্নতার মধ্যেও প্রাচীন মিশর গ্রীস ও ভারতে এর উদ্ভব ঘটেছে। উল্লেখ্য যে, কৃষিভিত্তিক সমাজে উর্বরতা নাট্যসাহিত্যকে বিশেষ রূপ দেখায়। প্রাচীন গ্রীসে শস্য ও সুরার দেবতা দাউনিসের উপর আস্থা রেখে নাটকের উদ্ভব ঘটেছিল খ্রীষ্টপূর্ব পঞ্চম শতাব্দীতে। আবার ভারতে মহেঞ্জোদারো সভ্যতায় শিব শস্য ও পশুপালনের দেবতা হিসেবে পুজিত হন, সেখানে নৃত্যরত শিবের মূর্তি আবিষ্কৃত হয়। স্মরণীয় যে ভারতের নাট্যশাস্ত্রে সংস্কৃত নাটক প্রসঙ্গে শিবলীলার উল্লেখ আছে। প্রকৃত অর্থে সমাজ পরিবর্তনের অন্তর্বর্তীকালীন বন্ধ্যাত্ব বারেবারে নাট্যসাহিত্যকেও আক্রান্ত করেছে।[১০] ফলে গতিশীল সমাজ স্রোতে হারিয়ে গেছে লোকসংস্কৃতির নিজস্ব ভূখণ্ড। যার কারণে বাঙালি সমাজের লোকবিশ্বাস, ধর্মীয় আচারনীতি, লৌকিক সংস্কারগুলি ইউরোপের সভ্যতার স্পর্শে হারিয়ে যাচ্ছে ক্রমশ। ইংরেজি শিক্ষিত শ্রেণির বাইরে প্রত্যন্ত এলাকার মানুষই এই সব লোকনাট্যকে টিকিয়ে রাখতে সচেষ্ট হয়েছেন।

একথা ঐতিহাসিকভাবে সত্য যে, আমাদের মধ্যযুগের রচিত যাবতীয় শিল্পকর্মের একটি সাধারণ বৈশিষ্ট্য ছিল লোকঐতিহ্য। সুদীর্ঘকাল ধরে একই বিষয়ে কবি ও শিল্পীরা চেষ্টা করে গেছেন তাদের প্রতিভাকে নিয়োজিত করে প্রচলিত স্রোতের মধ্যেও নবনির্মাণকে গড়ে তুলতে। মঙ্গলকাব্যের ঐতিহ্যকেও নানারূপে ব্যবহার করেছেন তাঁরা। সেক্ষেত্রে বিষয়বস্তুর অভ্যন্তরে বৈচিত্র্যের সন্ধান ছিল অকল্পনীয়। যেমন দেখি মনসামঙ্গলের বাইশকবি লেখা বাইশা, আবার চৈতন্যভাগবত থেকে উঠে এসে মহাপ্রভুর জীবনকথা বিভিন্ন ভাবে প্রকাশ পেয়েছে।[১১] একই সঙ্গে আমরা দেখতে পাই প্রাচীন ও মধ্যযুগের পৌরাণিক চরিত্র তার প্রাসঙ্গিক অথবা উপযোগিতাকে নতুন কালের দাবি মেনে ব্যবহার করতে পারেন না। তাই মূল চরিত্রটি এক পরিবর্তিত রূপ নিয়ে একালের নাট্যধারায় ব্যবহৃত হচ্ছে। যেমন মনসামঙ্গলের বেহুলা চরিত্রটিকে নিছক দেবী মাহাত্ম্য প্রচারের জন্য ব্যবহার করা হচ্ছে না। তার পরিবর্তে বেহুলা চরিত্র শুধু তার ব্যক্তিসত্তাকে একালের সমাজ ও পরিবারের মধ্যে খুঁজে পেতে চাইছে। এক অর্থে নারী যে বৃহত্তর সংসারের অর্ধেক আকাশ সেই সত্য উন্মোচিত হচ্ছে এযুগের লোকনাট্যগুলির মধ্যে। আবার স্বীকার করতে হয় যেকোন প্রগতিশীল সমাজচৈতন্যের মধ্যে আচার সর্বস্বভাবে খোলস থেকে বেরিয়ে নিছক গ্রামীণ জীবনধারার চিৎপ্রকর্ষের পরিচয়বাহী হয়ে ওঠে এই ধরণের লোকনাট্যগুলি। এক্ষেত্রে সুভাষ বন্দ্যোপাধ্যায়ের মতামতটি বিশেষভাবে প্রণিধেয়- "লোকনাট্যের মধ্যে পৌরাণিক বিষয়বস্তুর প্রাধান্য থাকলেও তার মধ্যে একটি ভক্তিরস কিংবা ধর্মচেতনা মুখ্য হয়ে ওঠে না।"[১২]

আবার দুর্গাশঙ্কর মুখোপাধ্যায় তাঁর যুক্তিনির্ভর মন্তব্যে জানান, লোকনাট্যের বিষয় ভাবনায় পৌরাণিক কাহিনি বর্জিত হওয়াই সঙ্গত। কারণ পৌরাণিক চরিত্র ও তাদের নিয়ে রচিত কাহিনি সংক্রান্ত এক অবিচলিত সংস্কার মানুষের মনে থাকে; যে বৃত্তের বাইরে গিয়ে সাধারণভাবে দর্শকমনে তা আঘাত আনে না।[১৩] তাই বলতে হয়, সমাজনির্ভর

চাপান উতোর পারিবারিক টানাপোড়েন লোক্যনাট্যকে এক বাস্তব জীবনের মুখোমুখি দাঁড় করায়। পাশাপাশি উল্লেখ্য যে, নির্মলেন্দু ভৌমিক তাঁর প্রদত্ত সংজ্ঞায় বলেন-

"কোন লোকগোষ্ঠীর সংহতি জ্ঞাপক Myth, ritual জীবনযাত্রার সকল দিক যখন তাদের অভিনয়ে ও সংলাপে প্রতিফলিত হয় তখন তাকে লোক্যনাট্য বলে।"[১৪]

উল্লেখিত লোকনাট্যের সংজ্ঞায় যে শর্তটি ঘোষিত হয়েছে তা সব লোকনাট্য মাত্রই বিশেষ ঐ দুটি উপাদানের গড়া বলে মনে হয় না। বরং সরল বা জটিল লোকনাট্যের বিষয় যাই হোক না কেন, এক বাস্তব জীবনমুখিনতা এই লোকনাট্যের সর্বাঙ্গে লেগে থাকে। তবে মনে রাখতে হবে, যে কোন শিল্প-আঙ্গিক জীবনেরই অঙ্গ। সমগ্র জীবনের সমস্যা নিয়েই তৈরি হয় যে কোন ধরনের শিল্প প্রকরণ। সেই সঙ্গে লোকনাট্য জীবনের সমস্যাকে নিয়ে আবর্তিত হয়। যদিও বিবেকবুদ্ধি সম্পন্ন কোন দর্শকই একটি লোকনাট্য থেকে তেমন কিছু গভীরতা ও বিস্তৃতি লাভ করতে পারে না। আর একারণেই সমালোচক ধ্রুব দাস গুরুত্ব আরোপ করেন লোকনাট্যের বৈশিষ্ট্যের উপর, যাতে অভিনয়ক্রিয়া ও তার মুখ্য কুশীলবেরা কেন্দ্রভূমিতে চলে আসে। তাঁর মতে, লোকনাট্য হল লোকধর্মী আচরণের বা সংস্কারের এমন এক নাট্যরূপ যা তার আপন ক্ষেত্রের জনমানসকে আনন্দিত উল্লসিত এবং অনুপ্রাণিত করে তোলে।[১৪]

নৃত্যগীত, গ্রামীণ মানুষের আনন্দদায়ক বিষয়গুলি স্বল্প সংলাপের উপস্থিতির মাধ্যমে কোন প্রসঙ্গের কথা এতে বলা হয়ে ওঠে না সামগ্রিকভাবে। আর এই পর্বে প্রত্যেক সংজ্ঞাতেই এই অসম্পূর্ণতা দেখা যাচ্ছে। তাই মানিক সরকার লোক্যনাট্যের বৈশিষ্ট্যের উপর গুরুত্ব আরোপ করতে গিয়ে অন্যান্য বিষয়গুলি এতে যুক্ত করতে চান-

"লোকাশ্রিত কাহিনি, কাহিনি আশ্রিত চরিত্র, চরিত্র অনুযায়ী উক্তি-প্রত্যুক্তি সহজ সরল এবং বলিষ্ঠতার সঙ্গে গীতিনৃত্য, স্বল্প সংলাপ এবং লৌকিক বাদ্যযন্ত্রের মাধ্যমে ঋজু দৃঢ় ভাবভঙ্গির দ্বারা লোকাকীর্ণ উন্মুক্ত আসরে যা প্রকাশ পায় তা সাধারণ অর্থে লোকনাট্য (ফোকড্রামা)।"[১৫]

লোকসমাজ বা স্রষ্টার ভূমিকায় থাকা সাধারণ গ্রামীণ মানুষের মনে এই আশা-আকাঙ্খা ও প্রাণাবেগ তেমন কোন দাগ কাটতে পারেনি এই সংজ্ঞাটিতে। সমালোচকের ভাষায় স্পষ্টতই বাহ্যিক বৈশিষ্ট্য ধরা পড়ে বেশি। সমালোচক মানিক সরকার তাঁর পূর্বোক্ত সংজ্ঞায় লোকনাট্যের অন্তকাঠামোর মধ্যে যে প্রাণের স্পন্দন থাকে তাকে দেখতে পাননি। তাই তাঁর সংজ্ঞা সীমাবদ্ধ পরিসরে আবদ্ধ হয়ে পড়ে। পক্ষান্তরে বিশ্বকোষ প্রদত্ত সংজ্ঞাটির দিকেও আমরা চোখ ফেরাব, যেখানে বাইরের উপকরণের প্রচুর ব্যবহার দেখা যায়। নীচে সেই সংজ্ঞা দেওয়া হল যেখানে লৌকনাট্যের মৌল বৈশিষ্ট্যগুলিকে পাওয়া গেলেও সমগ্র চালচিত্র ধরা পড়েনি।

"Belonging only remotely to ora literature is folk drama, dances containing speeches or songs are to be found in many parts of the preliterate world. Though the action and dramatic imitation is always

the most prominent part of such performances, this may be part of natural and involve speaking or chanting of sacred texts learned and passed on by word of mouth."[১৬]

লোকনাট্যের অন্তর্গত বৈশিষ্ট্য যা বিশ্বকোষ প্রদত্ত সংজ্ঞাটিতে উপেক্ষিত থেকেছে তাকে চুলচেরা বিশ্লেষণে পর্যালোচনা করবার প্রয়াস আমরা এই নাটকের অনুপস্থিত উপাদানগুলি সমেত দেখতে চেষ্টা করবো তালিকাবদ্ধ রূপে। প্রাচীন ভারতে এই জাতীয় লোকনাট্যের প্রচলন ছিল, যার কারণে নাট্যাচার্য ভরত তাঁর নাট্যদর্শনে লোকনাট্যের বিশ্লেষণ করে দেখিয়েছেন যদিও পশ্চিমী নাট্যবেত্তারা একে সেভাবে গুরুত্বপূর্ণ বলে মনে করেননি। তবুও আমরা দেখি পশ্চিমের চসারের লেখায় কিংবা ষোল শতকের শেক্সপীয়রের বহু নাটকে এই লোকসংস্কৃতির উপাদান ছড়িয়ে আছে। সেদিক থেকে মহাকবি কালিদাসের লেখা নাটক ও কাব্য বহুবিধ লোকায়ত ঐতিহ্যকে স্পর্শ করা সম্ভব। যা হোক এখন আমরা সূত্রাকারে বিশ্বকোষ ও আমাদের প্রচলিত লোকনাট্যের বৈশিষ্ট্যগুলিকে দেখাতে চেষ্টা করবো।

১. ভারতীয় প্রাচীন নাট্যদর্শনে ভরতমুনি উল্লেখ করেন যে, নাটকের চরিত্রের নিজস্ব ভাব (Mood) ও উদ্যোগ (Enterprise) জাগতিক কার্যকলাপ সংঘটিত হওয়ার মধ্য দিয়ে যে রসকে জন্ম দেয়, তা নাট্যবৈচিত্র্য সৃষ্টির পক্ষে সহায়ক।[১৭] কিন্তু বিশ্বকোষ প্রদত্ত সংজ্ঞায় তার উল্লেখ নেই।

২. কোন লোকনাট্যের কাহিনি সুনির্দিষ্ট অবয়বে সূচনা, ফলপ্রাপ্তি, চরমবিন্দু, অবনমন, বিপর্যয়ের যে সুস্পষ্ট কাহিনির সূত্রে বিধৃত থাকে না তার পূর্ণাঙ্গ স্বরূপ এতে পাওয়া যায় না। কেবল বাইরের দিকে এপিসোডিক ঘটনাক্রমের অবতারণা প্রত্যক্ষগোচর হয়, এনসাইক্লোপিডিয়া গ্রন্থে লোকনাট্যের এই সংজ্ঞায় এগুলিকে পাওয়া যায় না।

৩. পরিশীলিত নাটকে ঘটনা ও চরিত্রের পরিপূর্ণতা আসে স্বয়ংসম্পূর্ণ প্লট বা সাব প্লটের ভিত্তিতে। আদি মধ্য অন্তের কোন বিকাশ বা বিস্তার পাওয়া যায় না তেমনভাবে। সর্বাধিক ৪৫ মি. থেকে এক ঘন্টা সময়কালের মধ্যে বিস্তৃত হয়ে থাকে এধরণের লোকনাট্যগুলি। তাই বিশ্বকোষের সংজ্ঞাতে এর সময়সীমার স্পষ্ট উল্লেখ আমাদের চোখে পড়ে না।

৪. এই জাতের নাটকে উপকাহিনিকে আশ্রয় করে লোকজীবনের সংকট বা সমস্যা প্রাধান্য পায় না। ফলে পূর্ণদৈর্ঘ্য বা শিষ্ট নাট্য নির্মাণের সঙ্গে তার যে ব্যবধান তাকে নির্মূল ভাবে চিহ্নিত করা হয়নি সংজ্ঞাতে।

৫. অঙ্ক বা দৃশ্যের বিভাজন প্রচলিত ধারার নাট্যে যেমনভাবে মেলে, তেমনটি ঠিক পাওয়া যায় না লোক প্রচলিত লোকনাট্যের মধ্যে। তার কোন ছাপ উল্লেখিত হয়নি এই সংজ্ঞাটিতে।

৬. অ্যারিষ্টটল কথিত তৃতীয় ব্যক্তির আবির্ভাব (Increasing the number three) নাট্যদৃশ্যে বিশেষত লোকনাট্যের কাহিনিবৃত্তে কোন ধরনের জটিলতা আনে না[১৯] তার

পরিচয় এই বিশ্বকোষের সংজ্ঞাতে দেখা যায় না। তবু এর কোনরূপ উল্লেখ এনসাইক্লোপিডিয়ার সংজ্ঞাতে উল্লেখ করা হয় নি।

৭. লোকনাট্যের প্রাণবস্তু যে হাস্যরস বিশ্বকোষের বর্ণনায় তাকে পাওয়া যায় না। ফলে লোকনাট্যে বহিরঙ্গের বৈশিষ্ট্য যত গুরুত্ব লাভ করেছে তার অন্তরঙ্গ বৈশিষ্ট্য সেভাবে ধরা পড়ে না। তাই সমস্ত দিক দিয়ে লোকনাট্যের এই ভূমিকার পরিচয় সঠিকভাবে ব্যক্ত হয়নি। বরং আংশিক সত্যকে বহন করেছে এই সংজ্ঞা।

লোকনাট্যের মধ্যে নৃত্যগীত ও বাদ্যের সমন্বয় সাধনের চেষ্টা দেখা যায়। নৃত্যকে কাজে লাগিয়ে লোকনাট্যের নানান ফর্ম গড়ে তোলা হয়, যেমন ছৌ, টুসু, ভাদু, পুতুলনাচের মত বিষয়ের মধ্যে এই নাচ দর্শক মনের একঘেয়েমি ভাবকে দূর করে। নাট্য সংহতির আকর্ষণও বাড়িয়ে দেয়। গ্রামের সাধারণ মানুষ যখন কোন উদ্দেশ্যকে সামনে রেখে দেহচাঞ্চল্যের উচ্ছলতায় কর্মকাণ্ডে নিজেকে মানসিক স্বতঃস্ফূর্ত ভাবে প্রকাশ ঘটায় তখন তার থেকেই তৈরি হয় লোকনৃত্য।

নতুন শিল্পের ক্রমবিবর্তনের ইতিহাসে আমরা প্রধানত তিনটি শ্রেণিবিভাগ দেখতে পায়- ১. আদিবাসী নৃত্য, ২. লোকনৃত্য, ৩. শাস্ত্রীয় নৃত্য। দ্বিতীয় ধারানুসারে লোকনৃত্য গ্রামীণ সংস্কৃতিকে কেন্দ্র করে নৃত্যের নিবেদন। এই নৃত্যের বৈশিষ্ট্য হলো সংঘবদ্ধ অংশগ্রহণ যাতে দর্শক ও শিল্পীর মধ্যে কোন বিভাজন থাকে না। বৃত্তাকার বা অর্ধবৃত্তাকার রূপে পরস্পরের হাতের শৃঙ্খল বা কোমর বন্ধনের মধ্যে নৃত্যের উপস্থাপন সংঘটিত হয়। নৃত্যের কিছু নির্বাচিত বিষয় রয়েছে। যেমন, আচার, উৎসব, কুসংস্কার যা নিত্যদিনের কাজের সঙ্গে সংযুক্ত হয়ে গ্রামীণ মানুষের জীবনকে নন্দিত করে তোলে। মানুষের লোকয়ত সংস্কৃতি এবং সভ্য সমাজের সংস্কৃতি- দুই সংস্কৃতির সেতুবন্ধনের সমাধান ঘটায় গ্রাম সংস্কৃতির কেন্দ্রীভূত লোকসংস্কৃতি। এর মধ্যে গুরুত্বপূর্ণ এক উপাদান হল লোকনৃত্য। বহু কাল ধরে শারীরিক বিভঙ্গের দ্বারা মানুষ তাকে প্রকাশ করে আসছে শিল্পসম্মতভাবে।[২০]

বৃহত্তর বঙ্গভূমির বাইরে লৌকিক নাট্যকলাতে রাম কাহিনী স্থান পেয়েছে। ক্রমান্বয়ে বাংলাতে ছৌ ও কুষাণের মাধ্যমে এসেছে এই রামায়ণী কথা। এ সময়ে, পাশাপাশি এটিও স্বীকার্য্য যে, যাত্রার মধ্যে রাম ও কৃষ্ণ বিশেষভাবে জনপ্রিয় হতে শুরু করেছিল। গিরিশচন্দ্র তাঁর অনেক পরে উচ্চারণ করেন 'কানু বীনা গীত নেই' এর কথা। প্রারম্ভিক পর্বে তাই এসেছে গ্রামের নাট্যমোদী সাধারণ মানুষের জন্য উনিশ শতকে ঐক্যতানবাদন ও জুরির গান। প্রাচীন সংস্কৃত নাটকে অনিবার্য্য ছিল সূত্রধর। এই সূত্রধরেরা থাকতেন শিষ্ট নাটকে কিন্তু লোকনাট্য তাদের ভূমিকা নাচ ও গানের মধ্যে সীমাবদ্ধ রাখার চেষ্টা করা হত। লোকশিক্ষা ও মনোরঞ্জন উভয় ধারার সংমিশ্রণ ঘটেছে এই চরিত্রের সেই সময় থেকে।

লোকসংগীত এর মূলবিকাশ পর্বটি যেভাবেই গড়ে উঠুক না কেন, তাতে প্রত্যক্ষত যুক্ত আছে সমষ্টিবদ্ধ মানুষের আনন্দ ও সুখের বিশেষ অনুভব। অঞ্চলবিশেষের গান

সেখানে ভৌগলিক পরিবেশ, সামাজিক পটভূমি, ক্ষেত্রবিশেষে বেশ কিছু শ্রম-প্রক্রিয়া, ধর্মবিশ্বাসভাবনা ও সংস্কার নিয়ে ব্যক্ত হয়েছে। গান হল শিল্পীর মানসিক জীবন ভাবনার ফসল। মামুলি সংলাপের মাধ্যমে যখন কোন ভাবনাকে বোঝানো যায় না, তখন অনির্বচনীয়তাকে বাঁধার জন্যে আসে গান। একজন শিল্পী যখন একটি গানকে গড়ে তোলেন গোষ্ঠীসমাজের জন্য তখন তার প্রয়োগিক অভিব্যক্তিগুলি এক পরম্পরাগত ঐতিহ্যের অনুবর্তন করেই প্রকাশ পায়।

ব্যক্তির সৃষ্ট গানটি গাইতে গোষ্ঠীর কেউই অসুবিধা অনুভব করে না। যে বিশেষ উপলক্ষে গানটির উদ্ভব যেটা সবাই মিলে সুরতালে নিমজ্জমান থেকে এগিয়ে চলেন, আর ঐতিহ্যের শরিক করে তোলে সেই সৃষ্টিকে। তাই বলা চলে, ব্যক্তিগত সুখ-দুঃখ ও তখন ঐ লৌকিক ঐতিহ্যের শিল্পকলায় তৈরি হয় এক ধরনের সর্বজনীন আবেগ।[২১] আর সেখানেই লোকায়ত এই সংগীত ভাবনা লোকনাট্যের মধ্যে প্রকাশ পায় নির্দ্বিধায়। সামগ্রিকভাবে তাই সংগীতের সাথে লোকনাট্যের সংযোগ ক্ষেত্রটি অত্যন্ত নিবিড়ভাবে যুক্ত। বাংলার লোকনাট্য শৈলীর নামকরণের মধ্যে (যেমন- পালটিয়া গান, আলকাপ গান) এই ধারণাকেই প্রকাশিত হতে দেখি। বস্তুতপক্ষে লোকনাট্য, লোক প্রচলিত বা অবহিত কোন শব্দ নয়। প্রায় সমস্ত ধরণের লোকনাট্যের একটি প্রাথমিক পর্যায় বা ধাপ হল এই গান। যার মাধ্যমেই আমরা পরিচিত হই এককালের বিভিন্ন লোকনাট্যের মূল ফর্মের সঙ্গে। তাই গানের যোগসূত্রটি সর্বত্র লোকনাট্যের সঙ্গে দৃঢ়ভাবে যুক্ত। আর সেই সঙ্গে এটি স্বীকার্য্য যে, এই গানের মাধ্যমেই এই লোকনাট্যগুলির মূল পরিচয়। একালের বাংলায় বিভিন্ন লোকনাট্যের মূল ফর্মের সঙ্গে গান যুক্ত থাকে। লোকনাট্যের বিকাশপর্বে একটি সংযোগসূত্র রূপে কাজ করে।[২১]

ছৌ, গম্ভীরা, চোরচুন্নী, বোলান কিংবা গাজনের নাচে মুখোশের ব্যবহার দেখা যায়। এই 'মুখোশ' শব্দটি মুখোশ থেকে উদ্ভূত। 'মুখোশ' শব্দের অর্থ হল মুখাবরক বা মুখচ্ছদ। 'মুখোশ' যুক্ত নৃত্য দেশে ও বিদেশে বহুস্থানেই প্রচলিত আছে। যেমন, এদেশে কর্নাটকের যক্ষ ও কেরালার 'কথাকলি' সবেতেই প্রচলিত রয়েছে এই মুখোশের ব্যবহার। লোকশিল্পের নিদর্শন হিসেবে মুখোশের যথেষ্ট আকর্ষণ ও চাহিদা আছে এই লোকনাট্যের দর্শকদের কাছে। লোকশিল্পীদের চোখে এই মুখোশ একইসঙ্গে ধর্মাশ্রয়ী, অন্যদিকে ধর্মবিযুক্ত এই দুই শ্রেণীতে বিভক্ত। আফ্রিকায়, এশিয়ার মধ্যে ভারত ছাড়া চীন, জাপান, ইন্দোনেশিয়া ও সিংহল পৃথিবীর প্রায় সর্বত্র এই মুখোশের ব্যবহার আছে। বিশেষত নৃত্যকলায় মুখোশের ব্যবহার হয়ে আসছে। নৃত্যকলায় কৃত্রিম মুখাবয়ব বা জীবজন্তুর মুখকে প্রদর্শন করার একটি তাগিদ তার শিল্পভাবনার অন্তর্কাঠামো থেকেই জন্ম নেয়। মূলত এই শিল্পের অংশগ্রহণকারী ব্যক্তি নিজেকে দৃশ্যমান না রেখে অন্য চরিত্র ফুটিয়ে তুলতে গেলে অনেক ক্ষেত্রেই এই মুখোশের সাহায্য তাকে নিতে হয়।[২২] মুখোশ রূপে জাগতিক কোন বস্তুকে স্বীকার করা বা কিছু একটা গড়ে তোলার সঙ্গে আদিম সমাজ মানসের বহির্কাঠামোতে উদ্ভূত ধর্মের অনুভূতিও সংমিশ্রিত হয়। কালক্রমে সভ্যতার বিবর্তনের

সঙ্গে সঙ্গে মুখোশগুলি এক একটি প্রতীক রূপে গৃহীত হতে লাগল এই পরিবর্তমান সমাজে। পশুর বদলে মানুষের মুখ এবং উত্তরপর্বে তার বিবর্তিত পশু ও মানুষের সহাবস্থিতি প্রকাশ পেল মুখের মধ্যে দিয়ে। মুখোশের মাধ্যমে প্রতিফলিত হতে দেখা যায় বিভিন্ন আদিম সমাজের শিল্পীদের মনোভঙ্গীকে। যার ফলশ্রুতিতে এই সিদ্ধান্তে আসতে হয় এটি একটি যাদুবস্তু এবং তার উত্তর পর্বে তার বিবর্তিত পশু ও মানুষের সহাবস্থিতি প্রকাশ পেল মুখের মধ্যে দিয়ে। মুখোশের মাধ্যমে প্রতিফলিত হতে দেখা যায় বিভিন্ন আদিম সমাজের শিল্পীদের মনোভঙ্গীকে। যার ফলশ্রুতিতে এই সিদ্ধান্তে আসতে হয় এটি একটি যাদুবস্তু এবং তার মাধ্যমে বাস্তব ও অতিপ্রাকৃতের সংযোগের সাধন ঘটানো যায়।[২৩]

পরিবর্তনশীলতা লোকনাট্যের একটি প্রধান বৈশিষ্ট্য। কিছু ক্ষেত্রে এটি প্রতিবন্ধকতার কারণ হয়ে ওঠে, সুগঠিত ও শিল্পসম্মত নাটকের নিয়মকানুন সব বাঁধা থাকে। কিন্তু লোকনাট্য প্রাচ্য ও প্রাশ্চাত্য কোন সুনির্দিষ্ট নাট্যরীতিকেই গ্রহণ করতে সক্ষম নয়। বরং এর সঙ্গে পশ্চিমী ব্রেশটীয় নাট্যরীতির কিছু ক্ষেত্রে মিল দেখা যায়। তবু একই সঙ্গে একথাটিও মেনে নিতে হয় যে, এই শ্রেণির দর্শকরুচিতে আস্থা রেখে কোন শিল্প নিয়মের আওতায় আসতে চায় না। প্রয়োজনের খাতিরে এর আকার ও আয়তন নিত্য পরিবর্তনশীল। সময়ের চাহিদা অনুযায়ী স্থায়ীভাবে ছাপ রেখে দেওয়ার লক্ষ্যে এতে নতুন উপাদানের ক্রমাগত প্রবেশ ঘটে। সুতরাং দেখা যাচ্ছে যে, সাধারণ গ্রামীণ জনতার প্রত্যক্ষ অভিনয়ের ফলে এবং দর্শনগত অভিজ্ঞতার কারণে লোকনাট্যের বিষয় ও উপস্থাপন কৌশল পাল্টে যায়। সৈয়দ মুস্তাফা সিরাজ রচিত গ্রন্থ 'মুসলিম চিত্রকলা ও অন্যান্য'তে এর হদিশ পাওয়া যায়।[২৪] লোকশিল্পীদের দ্বারা অভিনীত ও পরিচালিত হয়ে থাকে বলে জীবনকেন্দ্রিক সমস্যা এতে জটিল হয় না। ক্ষেত্রবিশেষে স্থূল পরিচয় তাতে থাকলেও জীবন ঘনিষ্ঠ উপলব্ধিতে তা অত্যন্ত জীবন্ত অভিনয়কলার ভাষ্য হয়ে ওঠে।

বেশ কয়েকটি দিক থেকে লোকনাট্য পরিশীলিত নাটকের ধারা থেকে স্বতন্ত্র হয়ে ওঠে। পরিশীলিত নাটক একটি সংস্কৃতির উচ্চস্তর থেকে জন্ম নেয়। মার্কসীয় দর্শনে নাগরিক নাটক সমাজের উপরিসৌধ (Superstructure) থেকে জন্মস্থান বলে মনে করা হয়।[২৫] তাই নাটকে সামাজিক দ্বন্দ্বের ছবি থাকে। এখানে শিষ্ট সমাজ বা ঘরোয়া পরিমণ্ডলের মাধ্যমে ব্যক্তি বা পরিবার বৃহত্তর অর্থে জীবনেরই সমস্যাকে নির্দেশ করে থাকে পরিশীলিত নাটক। কিন্তু লোকনাট্যের মধ্যে সেই জটিলতার কোন স্থান নেই।

পরিশীলিত নাটকের মধ্যে স্থায়ী মঞ্চব্যবস্থা ও তার বিশেষ নাট্য পরিকল্পনা থাকে। এই গোত্রের নাটকের লিখিতরূপটি (Script) একটি বিশেষ বৈশিষ্ট্য। কিন্তু লোকনাট্যে কোন মঞ্চের ব্যবহার থাকে না। যদিও আধুনিককালে কোন কোন লোকনাট্য পরিচালক ও আয়োজক গোষ্ঠীর উৎসাহে মঞ্চে অভিনীত হচ্ছে এবং এমনকি প্রম্পটার সহযোগে তার লিখিতরূপ অভিনয়ের সময় অনেক কুশীলবের হাতেই দেখা যায়।

আবার পরিশীলিত নাটকে এক ধরনের স্বীকৃত কথ্যরূপের ব্যবহারকে সংলাপে

পাওয়া যায়। যদিও এর কিছু ব্যতিক্রম রয়েছে (যেমন- মাধবমালঞ্চ কইন্যা বা সোজনবাদিয়ার ঘাটে) বন্ধনীভুক্ত দুটি নাটকেই এক বিশেষ আঞ্চলিক ভাষার ব্যবহার দেখা যায়। কিন্তু লোকনাট্যে আঞ্চলিক ভাষার প্রাধান্য সংশয়াতীতভাবে প্রতিষ্ঠিত যদিও একালের বহু লোকনাট্য শিষ্ঠভাষার সংলাপ বা অভিনীত চরিত্রের মুখের ভাষা রূপে প্রকাশ করতে উদ্যত হচ্ছে, তা সার্থকও হচ্ছে। কারণ একটি শিষ্টভাষার মাধ্যমে বহু শিক্ষিত ও প্রায় অল্পশিক্ষিত দর্শকের কাছে তারা পৌঁছাতে পারেন। তবে চরিত্রগুলি ওই আঞ্চলিক ভাষায় যথেষ্ট জীবন্ত হয়ে ওঠে। সঙ্গত কারণে পুরোদস্তর একটি আঞ্চলিক ভাষার লেখা নাট্যসংলাপের দৃষ্টান্ত এতে দেওয়া হল-

ওগো কোটাল শোন না
শিকার যাব্যার হৈয়াছে বাসনা
অতি শীঘ্রই ফিরব..।
কোটাল বেশি দেরি কোরব না।
শিকার যাব্যার হৈয়্যাছে বাসনা।[২৬]

লোকনাট্যের পালাগুলি গ্রামীণ জীবনের দীর্ঘকালের লালিত শুভবোধকে ধারণ করে বিকশিত হয়ে উঠেছে। এদের মূলস্বর উঠে আসে অন্যায়, প্রতিবাদ, অবিরাম শোষণের বিরুদ্ধে। প্রতিবাদ ও পরিণামে যে জয়লাভ তা এই নাটকগুলির মূল চারিত্রিক বৈশিষ্ট্য হয়ে ওঠে। যেমন নগ্ন পচনশীল দীর্ঘদিনের সামন্তব্যবস্থার বিরুদ্ধে গ্রামীণ জীবনের এক সাধারণ গৃহবধুও যে প্রতিবাদ জ্ঞাপন করতে সক্ষম তার পরিচয়টি এখানে ধরা পড়ে। সাধারণ কৃষকেরা বিভিন্ন সময় অনাবৃষ্টি, অতিবৃষ্টিতে ফসল নষ্ট হলে কিংবা অজন্মা, মহামারী, আপদ-বিপদ, অসুখ বিসুখে মহাজনের কাছেই ছুটে যান। মহাজনেরা শুধু চড়া সুদই আদায় করে না, সেই সঙ্গে অসহায়তার সুযোগ নিয়ে গ্রামীণ নারীর সতীত্ব হরণে তৎপর হয়ে উঠতে চায়। লোকনাট্য আলকাপে তারই একটি প্রাণময় ছবি পাওয়া যায়—

পল্লীবধূ—শুনে ওহে মহাজন
বাঁচে না আর ছেলের জীবন
দুটি টাকা দিবেন আমারে।
মহাজন- আরে, বল বল ও সুন্দরী
কত লিবে ধার;
আমার তো হল এ কারবার।
যত লিবে লেও না;
আমি থাকতে অভাব কি তোমার
আমার তো এ হল কারবার।[২৭]

মহাজনের বক্তব্যের সহজ অর্থ বুঝতে বধূটির কোন অসুবিধা হয় না। দুষ্টব্যক্তির ইঙ্গিতে যে পাপাচারের সংকেত লুকিয়ে আছে তাকে বুঝেই প্রতিবাদিনী হয়ে ওঠে সে। লোকসমাজের মধ্যে দাম্পত্য সংকটের বা সম্পর্কের নানান উত্থান পতনের সাক্ষী রয়েছে

লোকসংস্কৃতির এই লোকনাট্যটি বিশেষভাবে। নিজের স্ত্রীর উপর বিরক্ত স্বামী বর্তমানে চাইছেন তাঁর পূর্বতন স্ত্রীকে ছেড়ে, কিছুটা বেলেল্লাপনার স্বাধীনতাকে পূর্ণমাত্রায় গ্রহণে উৎসাহী হবেই। এই কারণে আগের স্ত্রীর উদ্দেশ্যে স বলে ওঠে—

পাইনা (লাঠি) পিট্যা খা
বাপের বাড়ি যা
তোকে লিয়্যা হৈবে না গিরস্থালি।[২৮]

স্পষ্টতই রাগ, ক্রোধ, হতাশার নানান তাৎক্ষনিক অনুভব লোকজীবনের ভাষাভঙ্গিতে ও তাদের নাটকীয়তার দৌলতে অনায়াসে প্রকাশ পায়। পূর্বোক্ত এই আলকাপের অনুসরণে মহাজন ও এক মহিলার মধ্যে যে বিতণ্ডা দেখা দেয় তাতেও গ্রামীণ মানুষের সহজাত অনুভবগুলি চমৎকার রসগ্রাহী ব্যঞ্জনার সৃষ্টি করে। মহাজনের মানসিকতায় যে দুরভিসন্ধি আছে তা প্রায় অর্ধশিক্ষিত এক গ্রামীণ কুলবধূর মুখে বলিষ্ঠ স্বরে ঘোষিত হয়।

এবার মুখ সামলিয়ে কথা বল
নইকো অসতী হে।
ঝকমারী তোর টাকাকড়ি
ঘুরে ফিরে চললাম বাড়ি।

উপরন্তু এখানেই ক্ষান্ত হয় না। অন্তরের সমস্ত ঘৃণাকে একত্রিত করে বলে—

তোর টাকা লিবে কেটা
তোর মুখে মারি ঝাঁটা।[২৯]

এখানেই পল্লিবধূটির সতীত্বই যে সবচেয়ে বড় সম্পদ তাকে মেনে নিতে অসুবিধা হয় না। তাই নিজের চারিত্রিক জীবনচেতনার নির্মলতা রক্ষার স্বার্থে সে প্রতিবাদী হয়েছে, স্বয়ং মহাজনের কদর্য্য আচরণধারার উপর। প্রথমে সম্মান জ্ঞাপন করে তাকে 'আপনি' বলে সম্বোধন করতে চেয়েছে। কিন্তু মানসিকতার ঘৃণ্যবৃত্তিকে উপলব্ধি করে 'তুই' বলতেও দ্বিধা করে না সে। ভাষার এই সুক্ষ্ম পরিবর্তনে তার মানসিকতার এক গতিপ্রকৃতি সহজেই টের পাওয়া যায়।

সাধারণভাবে ধরা হয় লোকনাট্যগুলি অলিখিত। দীর্ঘকাল পর্যন্ত এই ধারণা ছিল যে, পরিবেশ ও পরিস্থিতি অনুযায়ী এর অভিনেতা বা কুশীলবেরা তাদের পরিচিত কোন কাহিনিকে সাধ্যমত রূপদান করেন। তবে পালটিয়া, মনসাগান কিংবা বোলানের বেশ কিছু পালাকে লিখিত আকারে পাওয়া যাচ্ছে এখন প্রত্যন্ত এলাকার গ্রামেগঞ্জে। উল্লেখ্য যে, রূপকথা, লোককথা, পুরাণ, মহাকাব্যের যে কোন ছোট বা বড় চরিত্র স্থান করে নেয় এই শ্রেণীর লোকনাট্যগুলিতে। রামায়ণ কিংবা মহাভারতের পৌরাণিক চরিত্র যেমন কর্ণ বা কুন্তী বা সীতা- এদের উপস্থিতি ধরা পরে একটু ভিন্ন আকারে। গ্রামীণ কবিরা অতিমানব, আবার কখন সাধারণ নরনারীর অবয়বেও হাজির করেন তাদের। অনেকটা পূর্ববঙ্গীয় গীতিকার মতো চরিত্রগুলি নিজস্ব আবেগে দীপ্ত। মূল কাহিনির সঙ্গে যদিও কোন উপকাহিনি যুক্ত থাকে না, একটি সরলরৈখিক সাধারণ ঘটনার ঘটনাবৃত্তে আবদ্ধ

থাকে সমগ্র কাহিনির প্রেক্ষিতটি। আর নাট্যক্রিয়া চলাকালীন নাট্যবৃত্তে আবদ্ধ হয়ে থাকে না, নাট্যবৃত্তের আবশ্যিক কোন শর্ত এখানে কঠোরভাবে পালন করাও হয় না। প্রসঙ্গত বরুণকুমার চক্রবর্তী যথার্থই মন্তব্য করেছেন- "এক তো লিখিত রূপের অভাব, তার উপর মূলত তাৎক্ষনিকভাবে রচিত। অবয়বে তার সর্বত্র শৈথিল্যের চিহ্ন, সংগীতের আধিক্য, স্বল্পদৈর্ঘ্য সমন্বিত, কোন মঞ্চব্যবহৃত হয় না, আলোক মঞ্চের প্রয়োজন বিমুক্ত, সহজলভ্য প্রসাধন সামগ্রীতে লোকনাট্যের কুশীলবেরা সজ্জিত, সাধারণ বেশবাস-নাটক সম্পর্কে প্রচলিত ধারণার প্রেক্ষিতে এতগুলি নেতিবাচকতার সঙ্গে যুক্ত তাকে কী নাট্য মর্য্যাদা দেওয়া সমীচীন?"[৩০]

কাহিনির গঠনশৈলির সঙ্গে ঘনিষ্ঠভাবে যুক্ত আছে আদি, মধ্য ও অন্ত্য সমন্বিত আনুপূর্বিক ঘটনার কোন স্মারকচিহ্ন যা লোকনাট্যের তেমনভাবে প্রকাশ করা সহজ নয়। একটি বিচ্ছিন্ন এপিসোডিক দৃশ্যায়ণ এই শ্রেণির লোকনাট্যে প্রত্যক্ষগোচর হয়। আদতে একটি পূর্ণাবয়ব লোকনাট্যের মধ্যে তার শিল্পরূপের বৈচিত্র্য আমাদের চোখে পড়ে। যদিও শহুরে প্রসেনিয়ামের সঙ্গে এর একটি নির্ভেজাল সংহতি স্থাপন নিসন্দেহে রীতিমতো কষ্টকর ব্যাপার। স্মরণীয় লোকনাট্যের পালাগুলি খুব একটা জটিল নয়। এই নাটকের মধ্যে ভালো ও খারাপ দু'জাতের চরিত্রের অবস্থান দেখি। সেখানে সাদা ও কালোয় দুটি বিচ্ছিন্ন রঙের সমবায়ে এক মিশ্রিত রঙকে সাধারণ মানুষ হিসাবে চিহ্নিত করতে হয়।

পাদটীকা ও সূত্রনির্দেশ

১. বরুণকুমার চক্রবর্তী (সম্পা), লোকসংস্কৃতি ও নৃবিদ্যার অভিধান। সুমহান বন্দ্যোপাধ্যায় কৃত টীকা ২০০৯। পৃ. ১৮২
২. তদেব, পৃ. ১৮২
৩. তদেব, পৃ. ১৮৩
৪. নির্মলেন্দু ভৌমিক, লোকসংস্কৃতি ও নৃবিদ্যার অভিধান।
৫. সঞ্জীব নাথ, বাংলার লোকনাট্য স্বরূপ ও বৈশিষ্ট্য। ২০০৩। পৃ.৬
৬. অজিতকুমার ঘোষ, নাটকের কথা। ১৯৮৬। পৃ.১৮১
৭. আশুতোষ ভট্টাচার্য্য, উত্তর বাংলার গ্রামীণ লোকনাট্য। লোকসংস্কৃতি গবেষণা পত্রিকা, ৮ম বর্ষ, ৪র্থ সংখ্যা, ১৮০২। পৃ. ২৬৬
৮. আশুতোষ ভট্টাচার্য, বাংলার লোকসংস্কৃতি। ১৯৮২। পৃ.১২৯
৯. লুৎফর রহমান, নাট্যবিষয়ক প্রবন্ধ। ২০০১। পৃ.৯
১০. তদেব, পৃ.১৮
১১. সুভাষ বন্দ্যোপাধ্যায়, পশ্চিমসীমান্ত বঙ্গের নাট্যচর্চা। ১৯৯৬। পৃ.২০
১২. নির্মলেন্দু ভৌমিক, গ্রামীণ লোকনাট্যের চতুষ্কোণ। ১৯৭৬। পৃ.১৩৪-১৩৫
১৩. ধ্রুব দাস, ভারতের লোকনাট্য। ১৩৯১। পৃ.১
১৪. মানিক সরকার, বাংলা লোকনাট্যের কয়েকটি দিক। ১৯৭৬। পৃ.৮
১৫. মানস মজুমদার, লোক ঐতিহ্যের দর্পণে। ১৯৯৩। পৃ. ১৩৪

১৬. Art & Entertainment, Folk Literature Encyclopedia, 15th edition, Vol-7, 1992, p.437
১৭. ভরতমুনি, নাট্যশাস্ত্র (সম্পা, ধ্যানেশনারায়ণ চক্রবর্তী), ১৯৯২। ২য় অধ্যায়, ২৪ তম শ্লোক।
১৮. By water,s translation of poeties-1964, p.42
১৯. বরুণকুমার চক্রবর্তী, লোকসংস্কৃতি ও নৃবিদ্যার অভিধান। ২০০৯। পৃ.২৮৭
২০. সঞ্জীব নাথ, বাংলার লোকনাট্য স্বরূপ ও বৈশিষ্ট্য। ২০০৩। পৃ.২৯
২১. তদেব, পৃ. ৩৫
২২. বরুণকুমার চক্রবর্তী, লোকসংস্কৃতি ও নৃবিদ্যার অভিধান। ২০০৯। পৃ.২৮৭
২৩. বরুণকুমার চক্রবর্তী, বঙ্গীয় লোকসংস্কৃতি কোষ। ২০০৪। পৃ.১৯২
২৪. সৈয়দ মুস্তফা সিরাজ, মুসলিম চিত্রকলার আদিপর্ব ও অন্যান্য। ১৯৯৩। পৃ. ৫৭
২৫. ওস্তাদ ফুলচাঁদের কাছ থেকে ২০০৮, ৯ ডিসেম্বর মাসে প্রাপ্ত।
২৬. দলীপ ঘোষ, বাংলার লোকনাট্য আলকাপ। ১৯৮৫। পৃ. ৪৫
২৭. মহবুব ইলিয়াস, নবাবগঞ্জের আলকাপগান। ১৯৯৫। পৃ.১২১
২৮. তদেব, পৃ. ১২৬
২৯. তদেব, পৃ. ১২৮
৩০. সঞ্জীব নাথ, বাংলার লোকনাট্য স্বরূপ ও বৈশিষ্ট্য। গ্রন্থের মুখবন্ধে অধ্যাপক বরুণকুমার চক্রবর্তীর উক্তি এটি, ২০০৩, পৃ.৩

অচিন্ত্যকুমার গঙ্গোপাধ্যায় : অ্যাসোসিয়েট প্রফেসর, বাংলা বিভাগ, ডোমকল কলেজ, মুর্শিদাবাদ

Vol. 96. No. 12 December 2022
ISSN: 0972-0766 (Print)

(Established in 1804)

JOURNAL OF THE ASIATIC SOCIETY OF MUMBAI

(A UGC - CARE Listed Journal)

Editors
Parineeta Deshpande
Ambarish Khare

Published by
The Asiatic Society of Mumbai
Town hall, Mumbai - 400 001
Maharashtra State (INDIA)
2022

Contents

Journal of the Asiatic Society of Mumbai
ISSN: 0972-0766 UGC Care Group Journal

INVESTIGATE THE RELATIONSHIP OF GOLD PRICE WITH OTHER MACRO ECONOMIC VARIABLES WITH RESPECT TO INDIA

Amritendu Roy
Assistant Professor, Department of Economics, Dumkal College, Murshidabad, India

ABSTRACT

Gold is a precious metal with limited existence. Gold is employed for storing value. India's gold price is linked with international price of gold. In case of global uncertainty people tends to hedge their funds through gold ETF, which increases the demand for gold as fund houses need to buy gold for the new investments, as gold ETF are backed by physical gold and so gold prices rise in international markets. Again if rate of interest decreases by Federal Reserve, demand for gold increases. There are many other reason for rise of gold prices, in international markets some of them are due to weakness of dollar, huge stimulus packages for revive of economies, US and Chinese tensions etc. From an economic and financial point of view, gold price fluctuations are important and interesting. In India price of gold is affected by depreciated rupee, inflation, crude price etc. Here the gold price is depended variable while CPI, Crude oil, Exchange rate are independent variable. Gold price is measured by rupee per Troy ounce, inflation is measured by CPI, Crude oil is measured by Indian rupee per Barrel and Exchange Rate is measured in rupee to that of US dollar (INR). 124 monthly observations from January 2011 to April 2021 were used for our study. Unit root test, correlation analysis, granger causality test were employed for analyzing data. The empirical results show positive, moderate relationship between gold price, CPI, INR whereas negative correlation between crude price and gold price though of less significance. However CPI and INR showed positive or direct correlation with high level of significance. Unidirectional relationship was found between CPI and INR.

KEYWORDS: Gold Price, Inflation, Consumer Price level, Exchange Rate

INTRODUCTION

India is the world largest consumer of gold and consumes around 446.4 MT of gold per year. Production of gold in India is only 1.4 to 1.5 MT per year. Thus India imports large amounts of gold of which around 15% to 17% is through illegal method. According to RBI only notified entity by DGFT (like MMTC, HHEC, STC, PEC, MSTC, GJEPC etc) could import gold directly in India. Gold is one among the oldest means of exchange known to us besides its role as a metal or as a commodity. In fact gold has a dual role, both as a commodity and currency. Till today it continues to be a psychological barometer of market sentiment. Governments all round the world holds gold as a foreign exchange reserve, highlights the importance of gold.

Indian people buy gold for consumption as jewellery, investment or as a hedging instrument. Usually the price of gold is affected by various economic factors such as inflation, exchange rate, interest rate, price of crude, lastly demand and supply of gold etc. Inflation is the rise of price of goods and services thus if the inflation goes up, the value of local currency goes down therefore people purchase more gold to safeguard their value of wealth because gold is seen as a store of value. Inflation might be for several reasons like increase in price of oil or due to decrease in rate of interest, as interest rate falls, money flow increases in the economy, income rises, demand for goods and services increases which further leads to inflation. Again if the imports are greater than export, demand for US dollar increases, which helps Indian rupee to depreciated as compared to US dollar. We need more Indian Rupees to buy one US dollar, thus import of gold is more costly than before.

JOURNAL of THE ASIATIC SOCIETY OF MUMBAI

CERTIFICATE OF PUBLICATION

This is to certify that the article entitled

INVESTIGATE THE RELATIONSHIP OF GOLD PRICE WITH OTHER MACRO ECONOMIC VARIABLES WITH RESPECT TO INDIA

Authored By

Amritendu Roy

Published in Vol. 96, No. 12 December 2022

JOURNAL OF THE ASIATIC SOCIETY OF MUMBAI with ISSN : 0972-0766

UGC-CARE List Group I

Impact Factor: 5.29

UGC

Editor in chief

ISSN: 2320-7698

Phalanx

A Quarterly Review for Continuing Debate

Vol-18, No-2 April – June -2023

Phalanx: A Quarterly Review for Continuing Debate

(Peer reviewed Refereed UGC Care Listed Journal)

CONTENTS

Phalanx: A Quarterly Review for Continuing Debate
Vol-18, No-2, April - June, 2023
(UGC Care Listed Journal) ISSN: 2320-7698

PROMOTING DE–DOLLARIZATION: A GLOBAL MONETARY RESET

[1]AMRITENDU ROY

Abstract

Dollar has been used as the world's commanding reserve currency since World War II. At present, dollar is the primary currency used in cross-border transactions, held by central banks in reserves, and traded in foreign exchange markets. It gives the US control in the international financial market. This dollar system has its own consequences in geopolitical risks, cyclical liquidity risks and inflationary crises which is directly associated with US. Moreover, the US's own over-indebtedness and stagflation also damaged the long-term credibility of the dollar. This has led some emerging economies to re-assess the role of the dollar. Many countries like Russia and China are making efforts towards ending the dominance of dollar i.e. De-dollarization.

Keywords: Dollar, Petrodollar, Sanctions, Inflation, Gold, Weaponization

De-Dollarization

De-Dollarization refers to decreasing the dollar's governance in global markets, substituting US dollar as the currency used in

1. Trading oil or other commodities
2. Bilateral trade agreements
3. Buying US dollars as forex reserve
4. Dollar-denominated assets

US enjoy a disproportionate amount of influence in global economy due to its dollar usages in international trade and commerce. US has used dollar as a weapon to impose sanctions to achieve foreign policy goals. Thus central banks of different countries interest to De-dollarization are driven by the desire to cover the geopolitical risk.

Causes of Dollar Prominence

In order to understand US dollar dominance in global economic system, it is important to study the importance of dollar. US helped Israel in 1973 at Yom Kippur War. Thus Arab countries impose an official ban on the oil which hiked the prices of petroleum products. Oil prices were hiked from 3 dollars to 17 dollars per barrel, which led to one of the biggest economic recession of the world. USA decided to separate its dollar from gold, and it led to rapid decline of dollars value.

After the collapse of Bretton Wood system, the status of dollar was enhanced by the secret agreement with oil rich Saudi Arabia related to oil exports. Saudi Arabia's energy trade with other countries must be in dollars according to the deal made with US, and in return US provided military assistance in form of selling weapons to Saudi Arabia.

Currently 60% of foreign exchange reserve of central banks and about 70% of global trade is done using US dollars.

[1] Assistant Professor, Department of Economics, Dumkal College, Murshidabad, West Bengal, India

CERTIFICATE OF PUBLICATION

This is to Certify that the article entitled

PROMOTING DE–DOLLARIZATION: A GLOBAL MONETARY RESET

Authored By

AMRITENDU ROY

Published in

Phalanx-A Quarterly Review for Continuing Debate

Vol-18, No.2 (April - June) 2023

ISSN: 2320-7698 Peer Reviewed Refereed UGC Care Listed Journal

Impact Factor: 5.6

ज्ञान-विज्ञान विमुक्तये

Phalanx

A Quarterly Review for Continuing Debate

ISSN: 2320-7698

Phalanx

A Quarterly Review for Continuing Debate

Vol-18, No-2 April – June -2023

Phalanx: A Quarterly Review for Continuing Debate

(Peer reviewed Refereed UGC Care Listed Journal)

CONTENTS

CERTIFICATE OF PUBLICATION

This is to Certify that the article entitled

PROMOTING DE–DOLLARIZATION: A GLOBAL MONETARY RESET

Authored By

AMRITENDU ROY

Published in

Phalanx-A Quarterly Review for Continuing Debate

Vol-18, No.2 (April - June) 2023

ISSN: 2320-7698 Peer Reviewed Refereed UGC Care Listed Journal

Impact Factor: 5.6

ज्ञान-विज्ञान विमुक्तये

Phalanx

A Quarterly Review for Continuing Debate

Phalanx: A Quarterly Review for Continuing Debate
Vol-18, No-2, April - June, 2023
(UGC Care Listed Journal) ISSN: 2320-7698

PROMOTING DE–DOLLARIZATION: A GLOBAL MONETARY RESET

[1]AMRITENDU ROY

Abstract

Dollar has been used as the world's commanding reserve currency since World War II. At present, dollar is the primary currency used in cross-border transactions, held by central banks in reserves, and traded in foreign exchange markets. It gives the US control in the international financial market. This dollar system has its own consequences in geopolitical risks, cyclical liquidity risks and inflationary crises which is directly associated with US. Moreover, the US's own over-indebtedness and stagflation also damaged the long-term credibility of the dollar. This has led some emerging economies to re-assess the role of the dollar. Many countries like Russia and China are making efforts towards ending the dominance of dollar i.e. De-dollarization.

Keywords: Dollar, Petrodollar, Sanctions, Inflation, Gold, Weaponization

De-Dollarization

De-Dollarization refers to decreasing the dollar's governance in global markets, substituting US dollar as the currency used in

1. Trading oil or other commodities
2. Bilateral trade agreements
3. Buying US dollars as forex reserve
4. Dollar-denominated assets

US enjoy a disproportionate amount of influence in global economy due to its dollar usages in international trade and commerce. US has used dollar as a weapon to impose sanctions to achieve foreign policy goals. Thus central banks of different countries interest to De-dollarization are driven by the desire to cover the geopolitical risk.

Causes of Dollar Prominence

In order to understand US dollar dominance in global economic system, it is important to study the importance of dollar. US helped Israel in 1973 at Yom Kippur War. Thus Arab countries impose an official ban on the oil which hiked the prices of petroleum products. Oil prices were hiked from 3 dollars to 17 dollars per barrel, which led to one of the biggest economic recession of the world. USA decided to separate its dollar from gold, and it led to rapid decline of dollars value.

After the collapse of Bretton Wood system, the status of dollar was enhanced by the secret agreement with oil rich Saudi Arabia related to oil exports. Saudi Arabia's energy trade with other countries must be in dollars according to the deal made with US, and in return US provided military assistance in form of selling weapons to Saudi Arabia.

Currently 60% of foreign exchange reserve of central banks and about 70% of global trade is done using US dollars.

[1] Assistant Professor, Department of Economics, Dumkal College, Murshidabad, West Bengal, India

INDIAN JOURNAL OF GEOGRAPHY & ENVIRONMENT 19 (2022)
Indian Journal of Geography 19 (2022) 55-64
Vidyasagar University, West Bengal, India
(http://vidyasagar.ac.in/journal) **ISSN:0972-7388**

VIDYASAGAR UNIVERSITY
Dept. of Geography

A Study on the Ruins of Buddhist Monasteries in West Bengal in the Context of Buddhist Tourism Development

Bhaskar Das[1], Prasenjit Kumar Mandal[2] , Saswati Das[3] and Premangshu Chakrabarty[4]

1. Cartographer, Department of Geography, Visva Bharati, Santiniketan, West Bengal
2. Assistant Professor of Geography, Dumkal College, Murshidabad, West Bengal
3. Assistant Professor of Geography, Krishnagar Womens' College, Nadia, West Bengal,
4. Professor of Geography, Visva Bharati, Santiniketan, West Bengal

Article History:
Received 31 July 2021
Received in revised form XXXX
Accepted 26 February 2022

Keywords:
Buddhism, heritage, river, historiography, toponymy

ABSTRACT

Buddhism and its heritage draw the attention of around 10 percent of total tourist traffic in India but unfortunately, West Bengal is not getting its justified share although the country was under Buddhist rule for about 400 year since the mid 8th century. None of the available studies have focused on its reasons. This paper is an attempt to evaluate the scope of Buddhist tourism in West Bengal while addressing this research gap found from interdisciplinary literature survey. Although there is abundance of descriptive historical and archaeological studies on abandoned Buddhist monasteries of West Bengal, spatial analysis dedicated to Buddhist tourism development is rare. Extensive literature survey has been followed by committed field workto obtain data which are historiographic, toponymic and archaeological in nature. IRSLISS III images have been analyzed to evaluate the changing course of rivers on the Buddhist ruins and the effects of flooding on them. An appraisal is made on policy measures to exploit the maximum potentials of Buddhist tourism which may bring opportunities of income and scope of employment, thereby contributing to backward area development.

Introduction:

The Buddhist sites distributed across the whole India are considered as precious resources for heritage tourism development. The states like Uttar Pradesh, Bihar, Odisha and Maharashtra are drawing large influx of Buddhist tourists, both domestic and international every year by virtue of Buddhist heritages but instead of the rule of a Buddhist dynasty from 8th to 11th century AD, the tangible Buddhist heritage in Bengal, particularly in West Bengal, a state of India being considered insufficient till the discovery of the Moghalmari Buddhist monastery of Paschim Medinipur district which is comparable with the Somapura monastery of Bangladesh, a UNESCO declared world heritage site. Before the discovery of Moghalmari, Nandadirghi monastery of Jagjivanpur, situated in the interfluve of Punarbhaba and Tangon River, was the only structure around which the issues of Buddhist tourism have been seriously dealt with. Three other seats of ancient Buddhist monasteries namely Karnasubarna (Murshidabad district), Subarnabehar (Nadiadistrict) and Bangarh (Dakshin Dinajpur district) are woefully neglected because of the lack of appreciation of their tourism value in government level.The goal of Buddhist pilgrimage is not merely the visiting of the sacred centres considered to be'axis mundi' (Eliade, 1959) but to pass through an itinerary of greater and lesser sites (Behrendt, 2009). The lesser category sites are characteristically not associated with the life of Buddha or any miraculous event associated with the divine power of the Lord. Buddhist tourism of India incorporates a number of such sites that are more cultural and historical rather than sacred. Monastery tourism is already emerged as an off shoot

Correspondence to Premangshy Chakrabarty
Professor of Geography, Visva Bharati, Santiniketan, West Bengal
E-mail address : drpremangshuindia@gmail.com

of Buddhist tourism, which could rather be classified as heritage tourism than a branch of religious tourism. With a focus on addressing the research question on why the ruins of Buddhist heritage in West Bengal have not been successfully utilized for tourism, the present study is undertaken to fulfill the following objectives:

a) To evaluate the status of the Buddhist ruins in West Bengal with special emphasis on the role of river on them.

b) To recommend policy measures for a comprehensive planning and management of monastery based Buddhist tourism in West Bengal

With a view to the growing tourist traffics in excavated Buddhist sites, it is essential to focus on their art, architecture and cultural history for better tourism marketing. This not only may generate income and employment but also sensitize the community living in the vicinity of such centres on the past glory of their civilization so that spontaneous public participation could be obtained for ensuring the preservation of the past heritages. There is no doubt that lack of community awareness on the value of excavated sites in the past led to their decay which could be prevented otherwise. This paper isan attempt to address the research gap on the past role of rivers in depletion of Buddhist monasteries when the popular hypothesis assumes only on the role of religious rivalries for their mysterious disappearance from cultural landscape.

Data and Methods:

Spatial distribution of the ruins of Buddhist monasteries of West Bengal is under study with special emphasis on Moghalmari. Detailed field work was made first at Moghalmari and it has been then compared with Jagjivanpur where experimentation to develop heritage tourism could not be materialized few decades ago and scope of developing such tourism in the soils of West Bengalis somewhat challenged. Extensive field works have been made to collect both primary and secondary data on the places of other threefamous Buddhist ruins of West Bengal namely Karnasubarna, Bangarh and Subarnabehar (Table.1). Satellite images (IRSLISS III) have been used to analyze their spatial organization focussing on shifting of river courses in relation to their survival from flood hazards. In this context, maps have been produced using Geographical Information System (GIS) in the domain of Arc GIS 10.1 version. With triangulation of qualitative aspects of the attraction factor, the Buddhist heritages have been assessed from tourism promotion perspectives. A number of policy recommendations have been derived by studying the demand of the visitors and perceptions on the value of Buddhist heritage by the host communities.

Study Area:

In the present study, focus is primarily made on Jagjivanpur buddhist sitein Habibpur Block of Malda district, and Moghalmari buddhist site of Dantan I Block in Paschim Medinipur district. From a mound named Tulabhita, a copper plate inscription of Mahendrapaladeva (9th Century AD) was discovered (Chakrabarti, 2001) from which patronage of Pala dynasty of Bengal to this monastery is prominent. The ground plan of the monastery resembles with the world famous Nalanda Mahavihar while the sculptural pattern is the manifestation of post-Gupta art of India (Sen Majumdar, 2013). The discovery of the Buddhist monastery at Moghalmari was made in the year 2003 from excavation of a large mound at Moghalmari named "Sakhisonar Dhipi".

The Bengali word *Dhipi* denotes the structural mound while Sakhisona according to folklore, was the daughter a local king named Raja Bikramkeswari. The love story of Princess Sakhisona and Ahimanik, the adopted son of one of the ministers of the then Amarabati state (presently in West Bengal and Odisha border) is a subject matter of popular folklores in the region. In Jhargram under Jambani block, in a picturesque village named Kuliapal, a local weekly market is named after the princess Sakhisona.

Table 1: Ruins of monastic complexes in West Bengal

Sl. No.	Place	District	Name of the Mahavihar
1	Datan	Paschim Medinipur	Sribandak
2	Jagjivanpur	Malda	Nandadirghi
3	Karnasubarna	Murshidabad	Raktamrittika
4	Bangarh	South Dinajpur	Devikot
5	Subarnabehar	Nadia	Subarnabehar

Source: Compiled by the authors, 2021

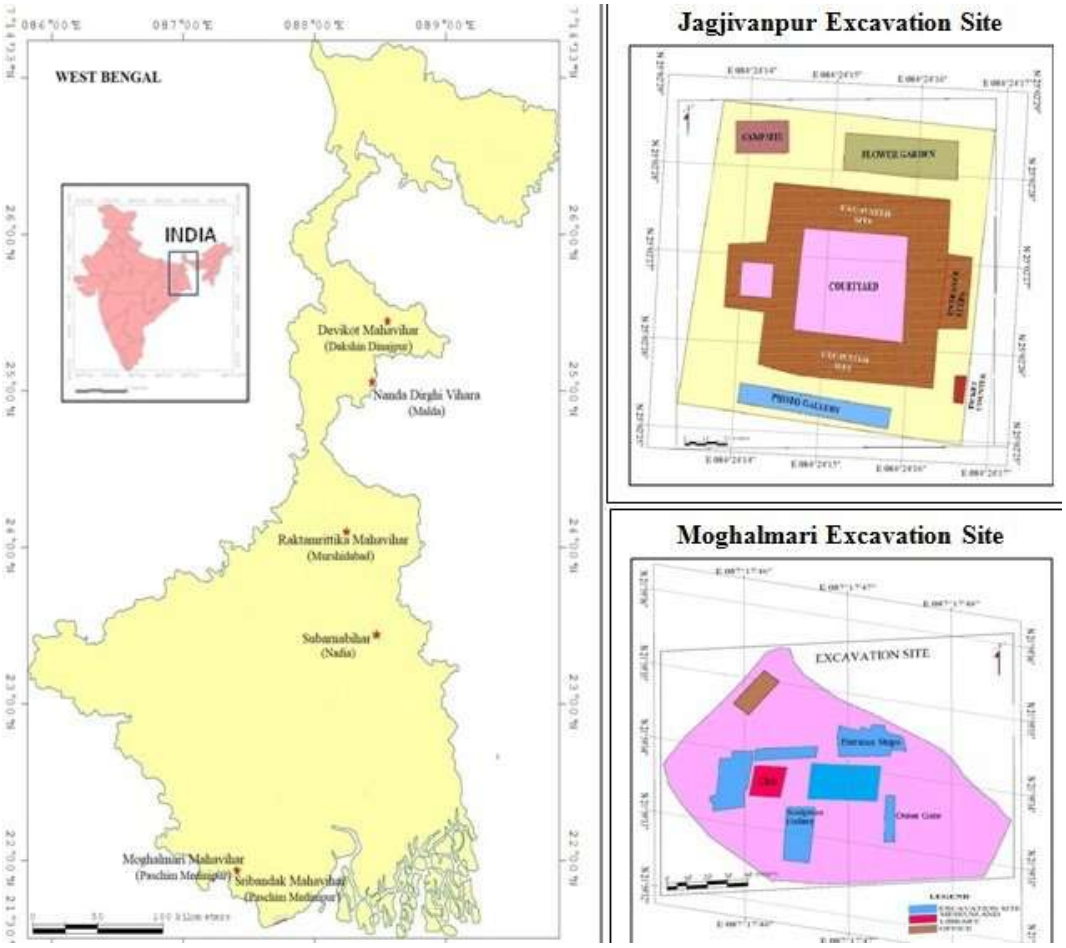


Fig. 1: Study Area
Map prepared by the authors

In Nayagram Police Station, a huge ground is also named after her. The mound in Moghalmari was popularly known as "Sakhisonar Pathsala", the primary school (called *Pathsala*in Bengali language) where Sakhisona met first Ahimanik. The epigraphic records from 6th to 10th century, establish the historic presence of Dandabhukti as a province of ancient Bengal, where the monastery was situated. Table.2 presents a comparison between these two Buddhist sites.

Among the other three Buddhistruins, the condition of Subarnabehar site is the worst. Only a few bricks of the ancient monastery is found scattered in Subarnabehar where maximum human encroachment took place and the site was never been under any protection. Both in case of Subarnabehar and Bangarh, role of river as a destructive agentis worth mentioning. The situation of Karnasubarna however is better but the neibouring community is reluctant on its preservation since the site never contributed to the local economy by generating sufficient revenue from tourism. The occasional domestic visitors interested in history come and become disappointedviewing its condition and also lack of facilities and tourist amenities. Such grim scenario is the inspiration to undertake this study with research question on the requirements that could make the state a Buddhist tourism paradise. Fig 1 represents the location of these monasteries with special emphasis on Moghalmari and Jagjivanpur.

Results and Discussion:

Moghalmari, the site of ancient Buddhist Sribandak Mahabihar is the most promising site forBuddhist

Table 2: General comparison between Jagjivanpur and Moghalmari archaeological sites

Items	Jagjivanpur	Moghalmari
Location	Lat- 25°02' N, Long- 88°22'E	Lat- 21°57' N, Long- 87°16'E
Nearest Town	Malda	Kharagpur
District Headquarter	Malda town in North Bengal	Midnapore town in South Bengal
Distance from District Head Quarter	41 km	63 km
Area (sq. mtr)	78.58m× 78.33 m	80m × 80m
Antiquity documented	9th century AD	6th century AD
Involvement of conservational agency	State Archaeology since 1990	State Archaeology since 2013
Community involvement	Not found	Yes
Museum on site	Not found	Yes
Nearest Railway station	Malda town (41 km)	Belda (15 km)

Source: Field Survey 2019-20

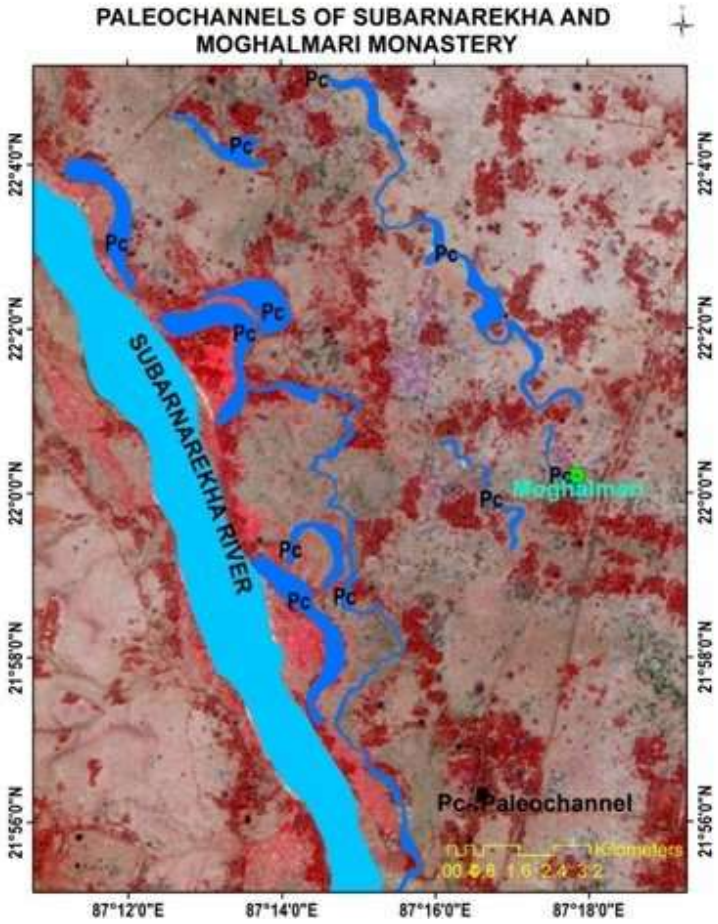


Fig. 2: Paleochannels of Subarnarekha River
(Map prepared by the authors)

tourism in West Bengal. From the stand point of archaeological design, it iscompared with the Somapura Mahabihar of Paharpur founded in 9th Century by the Pala kings, which is located in Rajshahi district of Bangladesh (i.e. eastern portion of undivided Bengal under British Rule before 15th August, 1947).Recognition of Somapura Mahabihar as UNESCO's World Heritage Site (in the year 1985)depicts the heritage value of Moghalmari monastery which is characteristically of similar type excavated in the year 2003. The Chinese pilgrim Huen-Tsang, who visited Tamralipta kingdom in 638 AD reported the presence of ten active monasteries. Moghalmari, a monastic complex that dates back to 5th/6thcentury ADmight be one of them (Datta, 2010). Once located on the bank of the Subarnarekha as evident from the presence of paleochannels and evidences of river shifting in the region (Fig 2), the monastery was then situated on the levee of the river near the junction point of inland trade route and the river route connecting Bengal and Odisha in ancient period. The linear inland trade route is referred to as *Danda* and the region in the reign of king Shashanka(600-637 AD), the first powerful king of Bengal was known as Dandabhukti (*bhukti* stands for the integral part of kingdom). Pataliputra, the nerve centre of the then North India's trade and commerce was connected with Tamralipta port for sea trade by this historical road, which was extended towards south probably upto Vishakhapatnam. Instead of imposing direct rule from his capital at Karnasubarna, Shashanka preferred to appoint local rulers. Somdatta was one of them, the ancestor of whom ruled present Dantan and its surrounding areas during 6th-7th century AD (Mukherjee and Mukherjee, 2014).

The word Dantan has association with another popular legend regarding the waterway transportation of Buddha's tooth that was distributed from his mortal remains after cremation in the 5thcentury B.C. The tooth was worshipped about 800 years at Dantapur, a place in Kalinga, a Buddhist kingdom (present Odhisha) and according to a few scholars, the shrine of Lord Jagannath at Puri was the original place of tooth worship (O'Malley, 1908). However, with the fall of the Buddhist empire in Kalinga, this tooth was said to be transported to Ceylon through the Tamralipta port, which is now worshipped at the temple of Kandy, the most revered Buddhist site in Sri Lanka. It is firmly believed that the tooth relic was sheltered at the monastrial complex of Moghalmari before it was sent to Ceylon in the first quarter of the 4th century from which the locality derived the name Dantan (*Danta* means tooth and *pur* stands for city) . The non-believers however relate the place name with the *Datun* (tooth stick) of Sri Chaitanya, a 15th century legendary Vaishnava leader who visited the place on his way to Puri.

Moghalmari is now a village situated at a distance of 5.2 kms north from the Dantan town. The place named Jahajghata (meaning harbour) in Dantan (near Dantan High School) issignificant toponymic data supporting the presence of a sheltered site for the ships. The place named Jahajdubi (*Jahaj* stands for ship and *dubi* means submergence) within paddy field at present near the Moghalmari village is indicative of the past incidence of sinking of ship/ships. The river Subarnarekha which was then navigableused to flow beside the Sribandak Mahabihar (now it has been shifted about 5 kms in western direction) and the lowland used for paddy cultivation today was once the river bed (Fig. 2). If the tooth legend is taken into consideration, Moghalmari Mahabihar was serving the devoteeseven in the beginning of the 4th century. In the Dathavamsa (literally means the history of the tooth relic), a chronicle of Ceylon, written in Pali language by Dhammakitti, a 13th century Buddhist scholar, it is mentioned that Princess Hemlata and Prince Dantakumar brought the tooth of Buddha from Kalinga to Sri Lanka using the Tamralipta port (Pradhan, 2005). The Mahagovinda Sutta, another famous Buddhist text mentions Dantapura of Kalinga was one of the six famous cities of contemporary India.The tooth of Buddha was kept there in a magnificent stupa built by king Brahadutta who received the tooth relic from Khema, a Buddhist monk in 5th Century B.C. (Ganguli. 1975).

The name Moghalmari (literally means the slaughter of the Mughals) is of medievalorigin. It may have historical association with a series of battles fought by the Mughals in the year 1575 against the Afghans in which they faced considerable casualties despite of final win. A few scholars however reservea different opinion that 'mari' is a word depicting road, which facilitated the movement of Mughal troop in the 16th centurythat persisted since the time of Shashanka in 7th century connecting Pataliputra with Visakhapatnam. The disappearance of the monastery beneath a mound at Moghalmari might be the outcome of the destruction made by Mohamedans during the battle fought at the time of Akbar, the Great Emperor (Vasu,1911).

Buddhism was established in Bengal by royal patronage of a number of dynasties among which the Mouryan of

the 3rd century BCwas the pioneer.King Ashoka (273-236 BC), the Great Emperorhimself was said to be present physically at Tamralipta port on occasion of sending his son and daughter to Ceylon with the branch of Bodhi tree.It was I-tsing, a Chinese traveler who noticed the presence of Ashoka's stupa during his travel at Tamralipta in the later half of the 7th centurywhich was probably one of the 84000 stupas said to be built up by Ashoka in different parts of Indian subcontinent. The archaeological evidences and epigraphic records represent that Buddhism was a dominant faith in Tamralipta kingdom during the Sunga (185-73 BC) and Kusana (30-300 AD) period when Tamralipta's maritime trade with outside world was at its high (Dasgupta, 1958). Buddhism had been more consolidated itself in the region in succeeding years as evident from the travel record of Fa-Hien (405-411 AD) who observed the presence of 24 monasteries in the region.(Ramachandran,1951) The monastery where tooth relic of Buddha was kept before its transportation to Ceylon might be one of them.

As the excavated monasterial complex of Moghalmari dates back to 6th century AD, it may be assumed that it had been developed on ruins of previous Buddhist establishments. By the Hindu Guptas, who ruled during 300-500 AD century, Buddhism was never treated as the religious rival of Hinduism. The Palas who rose from the middle of the 8th century and ruled for a period of about 400 years were devout Buddhistsand their reign is known as the Golden Age of Buddhism in Bengal (Chakma, 2011). The similarities between the Moghalmari monastery and the famous Somapura Mahabihar of Paharpur (that was founded not before the 8th century) depict that art and architecture of Paharpur was guided by the model of Moghalmari monastery, because Moghalmari which was established much earlier as evident from historiographic records. As the gigantic monastery and the magnificent temple at Somapura werenot built even in the early 7th century, it was unnoticed by Chinese pilgrim Hiuen-Tsang during his travel (Gill, 2007). Archaeological data further reveals thatthe Buddhist establishments of Moghalmari were inspired from the art and architectural stage of Nalanda, the principle seat of Buddhist learning in Northern India where Hiuen- Tsang stayed for years(Hazra, 1983). The great monastery of Nalanda came into prominence towards the close of 5th century AD (Roy Acharyya, 2005).The stucco work of Stupa No- 3 at Nalanda clearly depicts the relationship between Nalanda Mahabihar and Sribandak Mahabihar, which are contemporary and thereby considered to be the paradise for archaeological tourism. For architectural ornamentation, stucco work was made at the outer boundary wall of the Buddhist temple complex of Moghalmari following the Nalanda architectural style, which provided protective coating for the structures (Basu, 2008).The ground plan of Moghalmari Buddhist complex is different from Nalanda, whichresembles Paharpur. Moghalmariis thus endowed withheritage tourism potentials not only from the standpoint of antiquity but also for a finer craftsmanship manifested in its art and architecture (Sanyal, 2001). Table 03 represents the phases of excavations undertaken by the Department of Archaeology, University of Calcutta who discovered the monastery excavating a mound at Moghalmari in the year 2003.

Since November 2013, Archaeological Department of West Bengal Government took over the custody of the excavated monasterial complex and the conscious efforts on developing tourism based on this Buddhist site had beeninitiated from the Block level administration of West Bengal government. Organizing a Buddhist festival at the site in the year

Table 3: Major Excavations Outcomes at Moghalmari

Phase	Major discoveries that attract the attention of tourists
2003-04	Phase I in the mound MGM I (Sakhisonar Dhipi) gave indication on presence of a monastic complex
2006-07	Phase II concentrated on eastern and southern side of MGM I and discovered a wall of the monastic complex, the square/rectangle structures used as cells of the resident monks, structure of circular bricks forming the bases of stupas and other antiquities such as pottery strewn over the surface, stucco figures
2007-08	Phase III was devoted to the discovery of stucco decorated walls in the eastern side specially
2009-10	In the Phase IV, the entrance of the monastic complex was discovered in the northern side
2010-11	In the Phase V, the prayer hall of the monastery was excavated
2011-12	In Phase VI, stucco works, pottery, and votive tablets are further discovered

Source: Review of literatures and excavation reports by the authors, 2012

2016, the place was first successfully introducedin the Buddhist tourism map of the country. It is noteworthy to mention that on the day of the festival (i.e. 24th January, 2016) in which Buddhist monks from all over the country were gathered at Moghalmari for special prayers, about 40 artifacts dating back to 5th and 6th centuries had been unearthed by the effort of the Archaeology Department, Govt. of West Bengal (Khanra and Pandey, 2016).Undoubtedly such coincidence boosted the glory of the place as a potential Buddhist tourism destination.

Among the sites in the periphery of the ruins of the Moghalmari monastic complex, Satdeula (the name derived probably from presence of seven deuls) is another archaeo-tourism site. According to folklore, the Pala king Dharmapala (770-810 AD)visited this place and his presence could have been linked with rejuvenation or reconstruction of the Buddhist establishments in the region.Archaeological investigations revealedthat the rebuilding of the monasterial complex took place in the 9th century for the second time after its 6th century construction phase.Dharmapala and his son Devpala (810-847 AD) were very famous for their patronage to the Buddhist monasteries of eastern India and Sribandak Mahabihar, one of the oldest monastery in their kingdom could not be deprived from their aids and supervisions. Satdeula, only 7 km from Moghalmari is famous for its archaeological remains said to be built by Dharmapala,who married the granddaughter of Dhruba, the king of Biratgarh. Some historians however identified this Dharmapala as the regional ruler of Dandabhukti, who dug a pond (nearly 7 acres surface area at present) in the east side of the village for the benefit of people. It was named Dharmasagar after him. The nearby conspicuous Sharasanka Dighi was probably named after Sarasanka Deva of Ganga dynasty who ruled over present Odisha. It is the largest pond of the state covering 117 acres 35 decimals of area that could be used for diversified water centric recreational purposes. According to legend on its antiquity, the digging of this water body was initiated by King Ashoka (273-236 BC), while Shashanka in the 7th century had further dug it and thus by the effort of a number of kings in different epoch, such a huge waterbody came into existence. A few kilometers of its west, there is another pond named Bidyadhar (surface area 21 acres 30 decimals) named after Bidyadhar, who was a minister of 12th century Odisha king. The territory was under Odisha kingdom after the end of the Pala rule in eastern India.According to a tale, this waterbody was connected with Sharasanka Dighi by an underground tunnel (Ghosh and Mahapatra, 2016). All such water bodies offer immense potentialities to develop recreational tourism coatedwith historical flavor.

Hiuen-Tsang wrote a vivid description of Karnasubarna. Archaeological excavations in the early 1960s unearthed the Buddhist monastic complex but the excavated ruins still lie in total neglect from heritage tourism development point of view (instead it is located only 15 km far from the modern town Berhampore) situated in the left bank of the river Bhagirathi (Fig-3).It is noteworthy in this context that this monastery was also affected due to multiple flooding and shifting of the Bhagirathi River after the 8th century (Majumdar, 2019).It is because of the favourable location in the interfluve of Punarbhaba river and Tangan riverthe Jagjivanpur monastery was the least affected from such flooding. In North Bengal, vagaries of Punarbhaba are responsible for the decay of Devikot and Bangrah Archaeological complex.

As the Buddhistswere subject of slaughtering by the Muslim rulers, any renovation of Buddhist complex after 12th century in Bengal was absent. Either they turned into mounds with time or converted into shrines of other religions.For the ruins of Subarnabehar (the name of a mouza at present that supposed to acquire its name from a bihar i.e. monastery), clear evidences of the course change of Jalangi river could be traced from satellite images (Fig.4). An Archaeological monument preserved under the supervision of Archaeological Survey of India named Ballaldhipi (after the name of Ballal Sen, the most powerful king of Sena dynasty in Bengal) is about 5 km from the site of the lost Subarnabehar. According to the archaeologists, a Hindu temple-palace structure was imposed on the base of a 9th century structure. In the 9th century, the region was under the Buddhist Pala rule and the Hindu Sena dynasty has taken over the monarchy from them in the 11th century after which this structure was probably rebuilt.It previously might be a Buddhist monasterial complex as seems from its fortified boundary and internal structural arrangements (Roy, 1997). Ballal Dhipi is therefore a suitable site in the proposed Buddhist tourism circuit particularly when it is not possible to incorporate Subarnabehar.

There is a Hindu temple in Subarnabehar Mouza dedicated to Lord Nrisinha, an incarnation of Lord Vishnu. From the sculpture, it appears that it was probably a Buddhist Tantric deity of Subarnabehar and came under the fold of Hinduism with the fall of

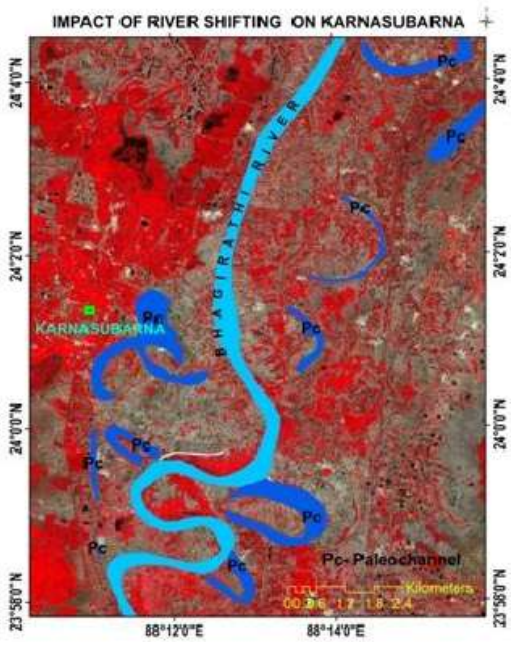


Fig. 3: Impact of river shifting on Karnasubarna (Map prepared by the authors)

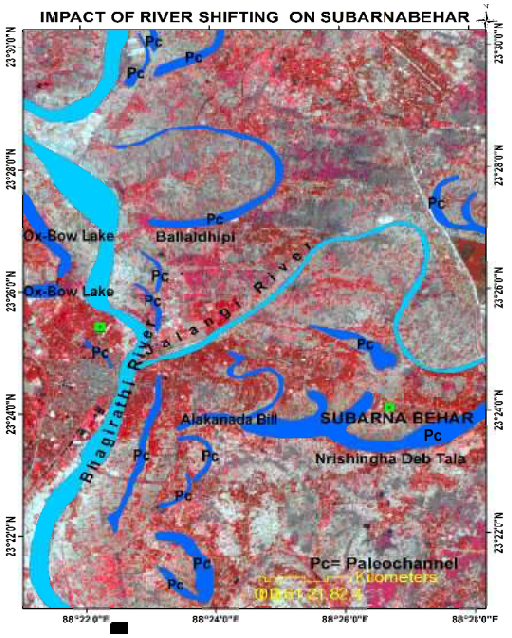


Fig. 4: Impact of river shifting on Subarnabehar (Map prepared by the authors)

Buddhism in Bengal. The large waterbody in the vicinity of the temple is the evidence of the past course of Jalangi that destroyed the monastery. A flow path of the paleo-channel is still prominent in the field. The Alakananda bill in the confluence of this past course of Jalangi with the Bhagirathi where Krishnachandra , the legendary king of Krishnagar built a retreat in the year 1776 named Gangabas (literarlly meaning an abode on the Ganga) might be the river coursethat destroyed Subarnabehar. The detailed microlevel geomorphological studies made by Basu (1976) and Sarkar (2002) vividly explain the river dynamics of the area which strengthens the observation on the past role of the river in the destruction of one of the stupendous monasterial complex of ancient Bengal. A devastating earthquake took place in the region in 1762 A.D.(Mukhopadhyay, 2009) and the lineament passing through the region (Chakrabarti& Nag, 2015) is the key in understanding the river dynamics and landscape change experienced by the region.The paleochannels have been widely accepted as historic evidence of changing drainage pattern in Ganga –Bhagirathi river system as revealed from the application of Remote sensing technology (Chakrabarti et. al., 2001)

Sensitivity is prerequisite in developing Buddhist tourism sites because of concern over commodification and negativity affecting the spiritual dimension of certain sites (Hall, 2006). Fortunately for the sites under discussions, it is not a problem because worship had been discontinued in remote past. They are rather classified as secondary sites concerning education and festivities ofthe Buddhist pilgrims who undertake travel as the expression of reverence to the history of their religion. Such travel is designated as pilgrimage tourism which is intermediate between religious tourism and pure pilgrimage, thereby demands a better understanding of the Buddhist heritage in terms of history, culture and aesthetics.

If the following measures would be adopted, it will gradually develop the excavated Buddhist monastic complexes suitable for promoting sustainable Buddhist tourism

I. Beautification around the excavation sites with provision of amenities and facilities for satisfying visitors (as demanded by 97 percent respondents not being satisfied with the present state of affairs).

II. Development of Archaeological museum near the site preferably preserving the sculptures and artifacts found during excavation (the present status is described unsatisfactory during interview by 75% visitors of Moghalmari who

simultaneously have praised the effort of local club for display of some excavated items in their premise. In Jagjivanpur no such museum is present as well as in other three places generating utter dissatisfaction of tourists.

III. Train the local youth to serve as guide narrating the folklores associated with the site as well as explaining the historical and Archaeological significance of the monastery in order to generate more interest among the heritage tourists.

IV. Launch the archaeo-religious sites through virtual tourism platform especially for the Buddhist dominated countries as it is a modern mode of tourism marketing whichis information technology based and constantly growing as well as acting as means to mitigate the adverse consequences of mass tourism (Voronokova, 2018). The advanced technical capacity of fifth generation (5G) network may provide the better opportunity to experience the feeling of visit without reaching the site and thereby virtual reality could be used for advertising the Buddhist heritage places to obtain the advantages of the growing digital economy.

V. Provision of adequate security with the installation of modern security measures in the sites by employing civic police from local youth, who could be designated as Tourist Police.

Destination image is vital for Buddhist tourism and it is essential to develop comprehensive planning and management system so that allegation on commodification of Buddhist culture could be avoided. The idea of pilgrimage to spiritual centres which is intrinsic in nature was introduced by Lord Buddha himself (Singh and Rana, 2011). The monastery tourism has to serve both the demand of the Buddhists and the demand of secular tourists attracted for Buddhist culture and heritage for which a careful handling and sensitive planning is necessary (Asraf, 2005). This study is a contribution in such planning process with its retrogressive, retrospective and prospective approaches.

Conclusion:

Pilgrimage for the Buddhists is described as physical movement symbolic of inner spiritual journeys and Buddhist tourism might be effective as a sustainable activity only when environmental damage and commercialization of the spiritual experiences could be avoided by implementation of inclusive planning measures.Excavated Buddhist sites are icons of identity and pride in the context of the past civilization of Bengal. Heritage is that part of the past given special emphasis in the present for contemporary purposes such as cultural, economic or social (Graham, et.al, 2000). Buddhist tourism could serve such purposes for whichsustainable planning is essential incorporating environmental, economic and socio-cultural issues.The Buddhist monasteries like Moghalmariin West Bengal may invariably attract large number of visitors generating both income and employment. If commodification and commercialization of heritage is required to boost the arrival for the interest of local and national economies, it must be done with maximum level of sensitivity and care (Aplin, 2002). For sustainable marketing of the Buddhist monastic complexes of West Bengal, it is essential to concentrate on introducing the scope for appreciation of intangible heritages of Buddhist culture on the platform of tangible structures. There is huge scope in experimenting with different forms of dance-dramacomprising diverse dimensions of Buddhist folk heritageonce persisted in Bengal. Inclusive technology driven space management and a wisersite sustainability surveillance may ensurethe bright futureof Buddhist tourism in and around the excavated Buddhist sites for which acommunity oriented integrated heritage tourism planning is the additional necessity.

Acknowledgement:

We do hereby acknowledge all the individuals (especially Sukumar Sarkar of Gangaramrampur, Uday Chatterjee of Dantan and RakhahariShee of NabadwipPuratattva Parishad) and organizations who extended their co-operations during field survey. The University Grants Commission is also acknowledged for funding of the study in some pockets which came under its sanctioned major research project entitled GEOGRAPHY OF TOURISM IN RARH REGION OF WEST BENGAL: A SUSTAINABLE APPROACH.

References:

Aplin, G. (2002). Heritage: Identification, conservation and Management, Oxford: Oxford University Press.

Asraf, S. H. (2005). Promotion and Development of Buddhist Tourism in India in Jacob, R. (ed.). New Facets of Tourism Management. Abhijeet. Delhi, 150-161.

Basu, D. (2008). Stucco Art in Datta, A. (ed.). Excavations at Moghalmari: First Interim Report (2003-04 to 2007-08). The Asiatic Society. Kolkata, 24-28.

Basu, S.R. (1976). Some Fundamental Problems of Meander Formation with special reference to the Bhagirathi River. *Geographical Review of India*, 38(1), 54-67.

Behrendt, K. (2009). Traces of Buddhist Pilgrimage in Ancient India in Malville, J. M. and Saraswati, B. (eds.). Pilgrimage: Sacred Landscapes and Self-organized Complexity. Indira Gandhi National Centre for the Arts, New Delhi.

Chakma, N. K. (2011). Buddhism in Bengal: A brief study. Bangladesh e-journal of Sociology, 8 (1), 87-94.

Chakrabarti, D.K (2001). Archaeological geography of the Ganga plain, Delhi; Parmanent Black, 15

Chakrabarti , P. & Nag, S. (2015). *Rivers in West Bengal: Changing Scenario*. Geoinformatics and Remote Sensing Cell, West Bengal. State Council of Science and Technology, Department of Science and Technology, Government of West Bengal. 106-107.

Chakrabarti , P. , Nag, S and Mitra, A.K.(2001). Changing drainage pattern of the Ganga-Bhagirathi system in historic times : a study based on remote sensing technology, Indian Journal of Geology, 73(1), 35-41.

Dasgupta, P. C. (1958). The Early Terracottas from Tamralipta. Indian Folklore, 1 (1), 17-34.

Datta, A. (2010). Excavation at Moghalmari: A Pre-Pala Buddhist Monastic Complex. Journal of Bengal Act, 15, 276-293.

Eliade, M. (1959). The Sacred and the Profane (translated from the French by Willrard, R. Trask: 1964). Harvest, New York and Evanston.

Ganguli, D. K. (1975). Historical Geography and Dynamic History of Orissa. Punthi Pustak. Kolkata, 26.

Ghosh, B. and Mahapatra, T. S. (2016). Moghalmari and the nearby villages: A search for Archaeological Heritage sites in Nandi, S. (ed.). Moghalmari Bodhbihar Bibidha Prasanga. Parul Prakashani. Kolkata, 167-188.

Gill, S. (2007). Spatial Organization of Paharpur Buddhist Establishment in Ray, H. P. (ed). Sacred Landscapes in Asia: Shared Traditions, Multiple Histories. Monohar. New Delhi, 169-197.

Graham, B., Ashworth, G. J. and Turnbridge, J. E. (2000). A Geography of Heritage, London: Arnold.

Hall, M. (2006). Buddhism, tourism and the middle way in Timothy, D. J. and Olsen, D. H. (eds.). Tourism, Religion and Spiritual Journeys. Routledge. London and New York, 172-185.

Hazra, K.L(1983). Buddhism in India as described by the Chinese Pilgrims: AD 399-689, Munshiram Manoharlal, New Delhi, 84.

Kharna, S. and Pandey, J. M. (2016). 40 Buddhist relics unearthed at Moghalmari. The times News Agency, January 25th, 2016; Retrieved from May 27th, 2021, timesofindia.com.

Majumdar, S. (2019). Locating the Monastery in Landscape Context: A preliminary study of Raktamrittika Mahavihara of Karnasubarna. Heritage Journal of Multidisciplinary Studies in Archaeology, 17, 622-641.

Mitra, D. (1971). Buddhist Monuments. Sahitya Samsad. Kolkata, p238.

Mukherjee, S. and Mukherjee, T. T. (2014). Discovery of a Buddhist Monastery at Moghalmari, Paschim Medinipur. Chitralekha International Magazine of Art and Design, 4 (1), 2-13.

Mukhopadhyaya, R.K.(2009). *The Changing Face of Bengal*. University of Calcutta, Calcutta. (Original work published in 1938). pp.6.

O'Malley, L. S. S. (1908). Bengal District Gazetteers Puri. The Bengal Secretariat Book Depot, Calcutta.

Pradhan, A. K. (2005). Maritime Heritage of Orissa. Orissa Review, April issue, 51-57.

Ramachandran, T.N.(1951). Tamralipti (Tamluk). Artibus, Asiae,14(3), 226-239.

Roy Acharyya, S.(2005). Mahasthangarh epigraph- an odyssey. Banerjee, M. &Goswami,B. (eds) Essays on Early Bengal epigraphy. Sanskrit Pustak Bhandar, Kolkata,127.

Roy, M.(1997). Itihaser Ruparekhai Nadia o Nadiar Purakirti. *Paschimbanga , Nadia Jilla Sankhya*, 31(17-21), 43-62.

Sanyal, R. (2008). Decorating and Non-decorative Bricks in Datta, A. (ed.). Excavation at Moghalmari: First Interim Report (2003-04 to 2007-08). The Asiatic Society. Kolkata, 53.

Sarkar, A. (2002). Dynamics and Environmental Impacts of Channel Platforms, A Study of Bhagirathi and Jalangi Rivers. *Indian Journal of Geography and Environment*, 7, 38-49.

Sen Majumdar, G. (2013). Buddhism in Ancient Bengal. Maha Bodhi Book Agency, 199.

Singh, R. P. B. and Rana, P. S. (2011). The Mythic Landscape of Buddhist Places of pilgrimages in India in Singh, R. P. B. (ed.). Sacred scape and Pilgrimage System. Shubhi Publication, New Delhi, 247-284.

Vasu, N. N. (1911). The Archaeological Survey of Mayurabhanja. The Mayurabhanja state. Orissa, 1, 120.

Voronkova, L.P. (2018).*Virtual Tourism: On the way to the digital Economy*. IOP Conf. series:Material science and engineering, IOP Publishing,463, 1-5.

European Journal of Innovation in Nonformal Education (EJINE)
Volume 2 | Issue 07 | Jul - 2022 ISSN: 2795-8612

Understanding Maladjustment: Causes, Consequences, and Interventions

Dr. Bhabesh Pramanik
Principal, Dumkal College, Murshidabad, West Bengal, India

ABSTRACT

Maladjustment refers to the inability of an individual to adapt or function effectively in their social, educational, or occupational environments. It is characterized by difficulties in coping with the demands and expectations of these contexts, often resulting in emotional distress, impaired social relationships, academic underachievement, and challenges in maintaining employment or fulfilling roles within society. This research article explores the multifaceted nature of maladjustment, examining its causes, consequences, and various intervention strategies. By synthesizing current literature and empirical studies, this article aims to provide a comprehensive understanding of maladjustment and offer insights into potential avenues for intervention and prevention. Understanding its characteristics, causes, and impacts is crucial for developing effective interventions and support strategies to promote resilience, enhance adaptive functioning, and improve overall quality of life for affected individuals. In conclusion, maladjustment represents a significant challenge affecting individuals across the lifespan, with implications for mental health, social functioning, and overall well-being.

ARTICLE INFO

Article history:
Received 05 May 2022
Received in revised form
03 Jun 2022
Accepted 27 Jul 2022

Keywords: Maladjustment, examining its causes, consequences, various interventions.

Introduction: Impaired functioning, distress, and/or poor health can arise from maladjustment, which is caused by inadequate responses to demands that can happen at any point in a person's life. Maladaptive processes are those that lead to bad results, such as particular behaviours, ways of thinking, or emotions, and maladjustment is the end result of these processes.

Many different situations, including social, psychological, and biological ones, make use of the words maladjustment and maladaptive. A person's difficulties in forming and maintaining relationships, particularly with their peers, are at the heart of social maladjustment. When people are still learning how to fit in with their peers and deal with interpersonal conflicts, they are more likely to exhibit maladaptive behaviours in this area. During this time, kids encounter shifting social and educational environments. Peer rejection can result from aggressive or rough play, among other maladaptive behaviours, exhibited by children who struggle to adapt to these new situations (Ladd & Price, 1987).

In the field of psychology, the words maladjustment and maladaptive can also mean a person's level of emotional regulation. Emotions usually have an adaptive role in how people engage with their surroundings. Therefore, a lack of capacity to react suitably to the ever-changing needs of a particular circumstance, or high levels of "emotional inertia" (Kuppens, Allen, & Sheeber, 2010), may characterize psychological maladjustment.

Significance of the Study:

The significance of studying maladjustment, focusing on its causes, consequences, and interventions, lies in its profound impact on individuals, families, and society as a whole. By addressing these aspects comprehensively, the study aims to enhance understanding, improve treatment outcomes, and promote

5.71

SIF

ORCID OPEN ACCESS OXFORD

WorldCat ROAD Crossref Academic Dimensions

CERTIFICATE

OF PUBLICATION

THIS CERTIFICATE IS PROUDLY PRESENTED TO

Dr. Bhabesh Pramanik

in recognition of the paper publication on open access peer-reviewed Journal of

European Journal of Innovation in Nonformal Education (EJINE) with the title:

Understanding Maladjustment: Causes, Consequences, and Interventions

Vol. 02 Issue 07 (2022): *EJINE* eISSN: 2795-8612

Jul - 2022

Joe Lewis

editor-in-Chief

International Journal of Formal Education

Volume: 01 Issue: 11 | Nov - 2022 ISSN: 2720-6874
http://journals.academiczone.net/index.php/ijfe

Pedagogical Approaches in the Light of National Education Policy 2020

Dr. Bhabesh Pramanik

Principal, Dumkal College, Murshidabad

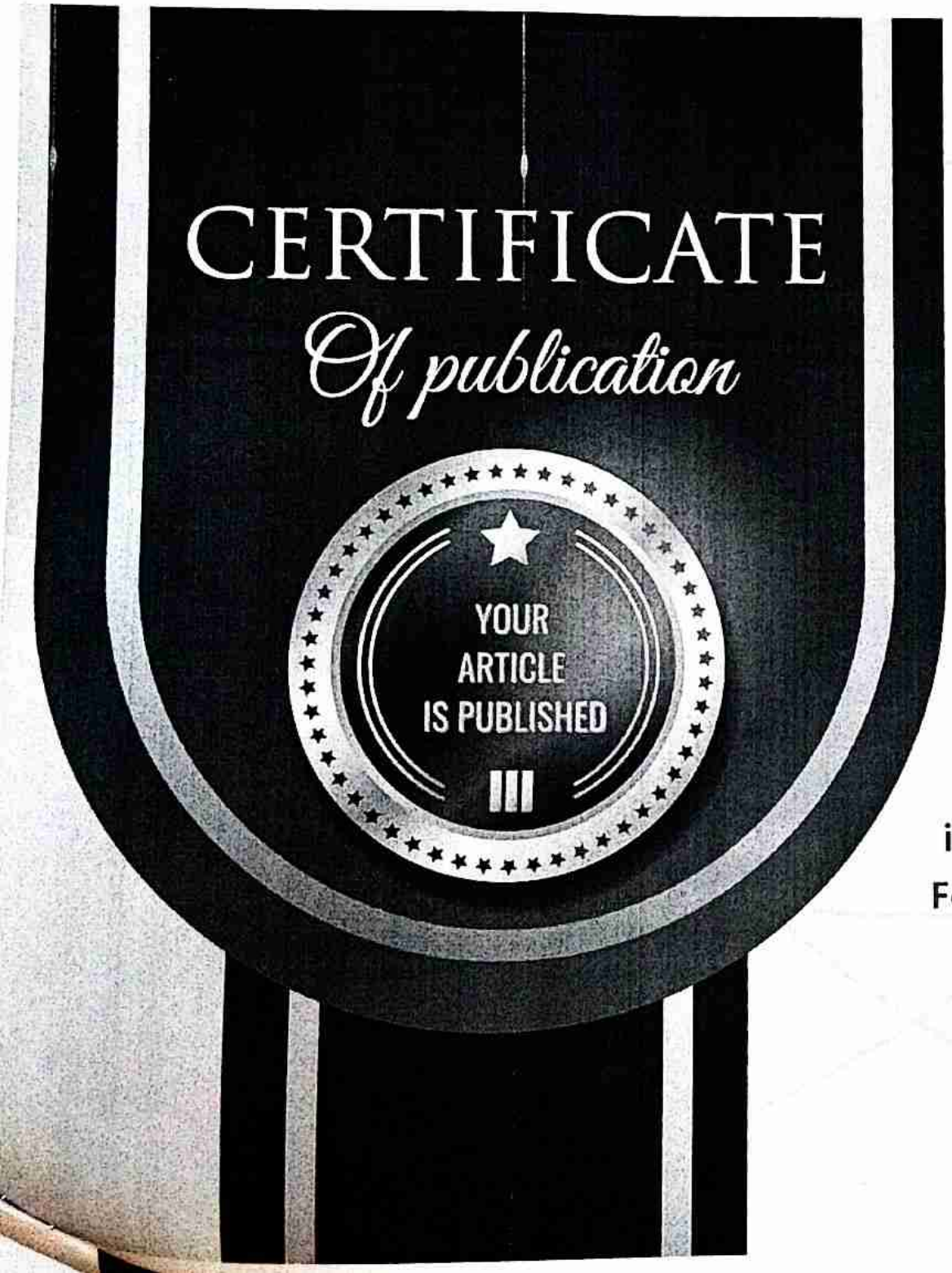
Abstract

The National Education Policy (NEP) 2020 represents a landmark reform initiative aimed at transforming the Indian education system. The National Education Policy (NEP) 2020 introduced by the Government of India marks a significant departure from traditional educational frameworks, aiming to transform the landscape of teaching and learning across schools and higher education institutions. This research article explores the pedagogical approaches advocated by NEP 2020, analyzing their implications for teaching and learning practices in schools and higher education institutions. By examining key policy recommendations and their potential impacts, this study aims to provide insights into how educators can adapt and innovate pedagogically to foster holistic development and prepare students for the challenges of the 21st century. The pedagogical approaches outlined in NEP 2020 represent a paradigm shift towards inclusive, flexible, and quality education. By reimagining teaching and learning practices, embracing technological advancements, and prioritizing holistic development, India can aspire to achieve educational excellence and equity for all learners.

Keywords: NEP 2020, creativity, multidisciplinary education, teaching and learning, pedagogy, creativity.

Introduction:

A new approach to education that is both comprehensive and interdisciplinary has been proposed by the Indian government in their National Education Policy (NEP) 2020. To foster students' critical thinking, creativity, and problem-solving abilities, it stresses the need of rethinking educational procedures. The pedagogical concepts and methodologies presented in NEP 2020 are the subject of



ACADEMIC ZONE

THIS CERTIFICATE IS PROUDLY PRESENTED TO

Dr. Bhabesh Pramanik

For publication of paper entitled:
"Pedagogical Approaches in the Light of National Education Policy 2020"

in Vol. 1 No. 11 (2022): International Journal of Formal Education eISSN: 2720-6874 with Impac Score of 4.758 by SJIF for the year of 2022

Nov - 2022
DATE

Dr. ALMA BANGAYAN- MANERA
EDITOR-IN-CHIEF

Journal of Education, Ethics and Value
Vol. 2, No. 3, 2023 ISSN: 2181-4392
Innova Science

An Exploration of the Tribal Educational Barriers with Reference to NEP 2020

Annotation: *The present article aims to throw light on the educational issues and concerns of the tribal community and discuss the government programmes and policies for the educational development of the tribal community. It also highlights the recommendations of the NEP 2020 for tribal education. The present study is a qualitative analysis of Tribal educational challenges and the recommendations of NEP 2020 based on secondary data and information in the form of reviews, books, journals, policy, drafts, internet, etc. The article is descriptive in nature and an amalgamation of related ideas is done to conclude. The study concludes that the tribal students should be encouraged to take education by using both tribal and state languages simultaneously during the pre- primary and primary levels and creating supplementary relevant tribal learning materials.*

Keywords: *Tribal Community, Primary Levels, Economic Growth, Educational Issues, Internal Problems, Learning.*

Information about the authors

Dr. Bhabesh Pramanik
Principal, Dumkal College, Murshidabad, West Bengal, India

Introduction: "In India the tribes form a significant section of the population mainly because of two factors:(a) they constitute 8.14% of the total population, numbering 8,45,11,216 persons (2001 census) and (b) they have distinct cultures, dialects and economic pursuits in different ecological settings. Since independence they have been incessantly drawing the attention of policy makers because of their geographical isolation, backwardness, shyness of contact, primitive traits etc. Since the 16th century, the tribes have been perceived as sub-humans who live under primitive conditions".(Xaxa, 2005) "Ancient Indian texts and historical documents describe them as dasyus, daityas, rakshasas and nishads. Moreover, in the sociological and anthropological literatures this community has been described by various nomenclatures such as aborigines/aboriginals (Risley 1903., Elwin 1944), submerged humanity (Das & Das 1955) and backward Hindus". (Ghurye 1963) But these people have been conceptualized as Scheduled Tribes under article 342 of Indian constitution.

Scheduled tribes are defined under Article 366(25) of the Indian Constitution as those groups that are designated as such in Article 342 of the Constitution. Any tribe, tribal community, or subset thereof that the President, by public notice, has designated as a Scheduled Tribe is considered to be a "Tribe" under Article 342 of the Constitution. All states except Haryana, Punjab, Chandigarh, and Delhi have Scheduled Tribe populations, as shown in the 2001 Census. A group of people reside in a certain area along the Himalayas, which stretches from the western states of Jammu & Kashmir, Himachal Pradesh, and Uttrakhand to the northeastern states of Assam, Meghalaya, Tripura, Arunachal Pradesh, Mizoram, Manipur, and Nagaland. Orissa, Madhya Pradesh, Chhattisgarh, and, to a lesser degree, Andhra Pradesh are hill states in central India where there is another concentration. Jharkhand and West Bengal are also home to indigenous peoples.

Certificate

OF PUBLICATION

Proudly Presented to

Dr. Bhabesh Pramanik

For Publication of Paper Entitled

"An Exploration of the Tribal Educational Barriers with Reference to NEP 2020"

in Vol. 2 No. 3 (2023): Open Access Peer-Reviewed
Journal of Education, Ethics and Value eISSN: 2181-4392
with Impact Score of 5.503 by SJIF for the year of 2023

Mar - 2023

DATE

ORCID Google Scholar

ISSN WorldCat Crossref

INNOVA SCIENCE

INNOVATIVE SCIENCE PUBLISHING

International Journal of Formal Education
Volume: 2 Issue: 6 | Jun - 2023 ISSN: 2720-6874
http://journals.academiczone.net/index.php/ijfe

A Comparative Study on the Educational Barriers of Tribal Girls Students at Secondary and Higher Secondary Level

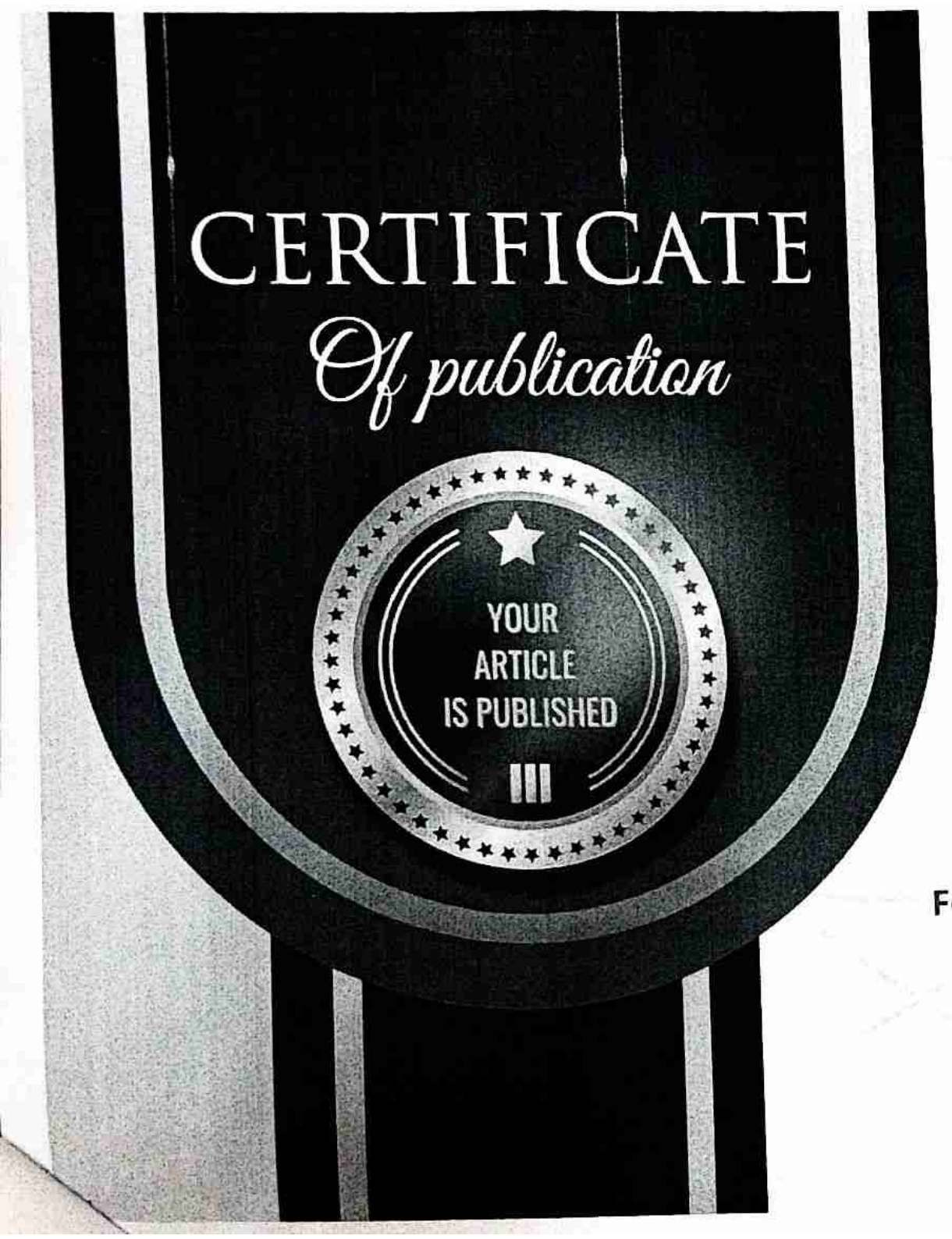
Dr. Bhabesh Pramanik
Principal, Dumkal College, Murshidabad

Abstract
The present study aims to find out the educational problems of tribal girls students at secondary and higher secondary level. In terms of school location, medium, and kind, it has also attempted to compare the educational issue at the secondary and higher secondary levels. The researcher has used a combination of primary and secondary sources to accomplish this. The primary data was gathered via the use of a validated structured questionnaire. Books, journals, and other secondary sources were used in order to compile this data. The study's findings indicate that indigenous girls' educational challenges at the secondary and upper secondary levels are similar. To sum up, tribal female students encounter a wide range of challenges that make it impossible for them to study or advance in their studies. In addition to seeing education as a liberating force, we must work to eliminate barriers that prevent women from gaining access to high-quality, universal education.

Keywords: Higher Secondary, Tribal Girls Students, Society, Primary Education, National Development.

Introduction:

Reforming and transforming society is best accomplished via education. Because it serves as a foundation for growth, education is a crucial component of national development. The country's educational system as a whole will always have a higher secondary education component. It connects elementary and secondary schools. (Majumdar,& Sikdar, 2017). While secondary school broadens one's horizons, primary education teaches one the fundamentals of life and paves the way to further study. For historically oppressed groups including religious and linguistic minorities, as well as those from tribal backgrounds, it is crucial in improving their socioeconomic status and raising their knowledge of the need of self-governance. For increased access and engagement, females seek out



ACADEMIC ZONE

THIS CERTIFICATE IS PROUDLY PRESENTED TO

Dr. Bhabesh Pramanik

For publication of paper entitled:

"A Comparative Study on the Educational Barriers of Tribal Girls Students at Secondary and Higher Secondary Level"

in Vol. 2 No. 6 (2023): International Journal of Formal Education eISSN: 2720-6874 with Impac Score of 5.587 by SJIF for the year of 2023

Jun - 2023
DATE

Dr. ALMA BANGAYAN- MANERA
EDITOR-IN-CHIEF