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# Quantum Anharmonic Oscillator with Velocity- and Position-Dependent Anharmonicities: an Exactly Solvable Model under Rotating Wave Approximation

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**Abstract:** The electromagnetic field coupled to a nonlinear medium of having nonvanishing polarizations and magnetizations could be modeled as a classical anharmonic oscillator with velocity- and position-dependent anharmonicities. The Hamiltonian corresponding to the quantum anharmonic oscillator with velocity- and position-dependent anharmonicities is obtained from the knowledge of its classical counterpart. Under rotating wave approximation, the solution of the oscillator with  $q$ -dependent and  $p$ -dependent anharmonicities exhibit the shifts of the resonance peak frequency. Interestingly, the shifts of the resonance peak of the oscillator due to the  $q$ -dependent anharmonicity is opposite to those of the corresponding shifts due to the  $p$ -dependent anharmonicity. Therefore, the shifts of the resonance peak frequency asserts the presence of particular anharmonicity as well (i.e.  $p$ - or  $q$ -type)

**Keywords:** Quantum anharmonic oscillator ; Normal ordered form ; Rotating wave approximation.

## 1 Introduction

The model of a simple harmonic oscillator (SHO) arises when a particle moves under the action of a restoring force. The SHO model is an ideal one and is extremely useful for the explanation of basic physics. However, for real physical systems, the inclusion of damping and or anharmonicities are inevitable. In the present investigation, we neglect the damping altogether. By anharmonic oscillator, we normally mean the presence of  $q$ -dependent ( $q$  is the position coordinate of the oscillator) anharmonicity. Because of the wide range of applications and of the fundamental nature of the problem, the problems of anharmonic oscillator have attracted people from various branches of physics [1-8]. In addition to the  $q$ -dependent anharmonicity, we often encounter the  $p$ -dependent ( $p$  is the velocity of the oscillator with rest mass unity) anharmonic contribution due to the relativistic correction of the kinetic energy term [9-11]. Now, the Hamiltonian of a classical oscillator with unit mass and unit frequency with  $q$ -dependent and  $p$ -dependent anharmonicities is given by

$$H = \frac{p^2}{2} + \frac{q^2}{2} - k_1 p^{2l} + \lambda_1 q^{2m} \quad (1)$$

where  $k_1$  and  $\lambda_1$  are small positive constants. Of course, the Hamiltonian (1) is extremely simple in structure since we neglect the coupling between  $k_1$  and  $\lambda_1$  if any. Note that  $l \geq 2$  and  $m \geq 2$  are integers. For  $\lambda_1 = 0$  ( $k_1 = 0$ ), the equation (1) corresponds the Hamiltonian of an  $l$  ( $m$ )-th anharmonic oscillator with  $p$  ( $q$ )-dependent anharmonicity. Now, the quantum mechanical counterpart of the Hamiltonian (1) is obtained by the replacement of the classically conjugate position  $q(t)$  and momentum  $p(t)$  by their corresponding operators. During the passage from classical anharmonic oscillator governed by the Hamiltonian (1) to the corresponding quantum mechanical oscillator, the fundamental equal time commutation relation between the position and momentum operators should be respected. Depending upon the problems of interests, we solve the quantum anharmonic oscillator in two different formalism. In Schrödinger formalism (SF), the time development of the eigenfunction and hence the energy eigenvalues are obtained. On the other hand, the Heisenberg formalism (HF) gives rise to the time development of the operators. Most of the problems involving quantum anharmonic oscillators are solved under SF. However, the quantum anharmonic oscillator under HF still unexplored to its full

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In spite of the complicated nature of the analytical expressions (17) and (18), it is possible to adopt an approximate method to obtain the analytical solution to the Hamiltonian (17). However, it is our purpose to explore the analytical solution of the oscillator by neglecting the non-conserving energy terms. In order to obtain an exact analytical solution to the above Hamiltonian (17), we use the *rotating wave approximation* (RWA). The idea behind the RWA is to remove the fast rotating terms from the Hamiltonian (17). Removal of the fast rotating terms also ensure the conservation of the total energy. Under the RWA, the Hamiltonian (17) reduces to

$$\begin{aligned} \hat{H} = & \hat{a}^\dagger \hat{a} - \frac{k}{2l} \hat{a}^{\dagger l} \hat{a}^l + \frac{\lambda}{m} \hat{a}^{\dagger m} \hat{a}^m \\ & - \frac{k_1}{2l} \sum_{r=1}^l (2r-1)!!^{2l} C_{2r}^{2l} C_{l-r} \times \hat{a}^{\dagger l-r} \hat{a}^{l-r} \\ & + \frac{\lambda_1}{2m} \sum_{r=1}^m (2r-1)!!^{2m} C_{2r}^{2m} \times {}^{2m}C_{m-r} \hat{a}^{\dagger m-r} \hat{a}^{m-r} \end{aligned} \quad (22)$$

where  $k = \frac{k_1 \times \{1 \cdot 3 \cdot 5 \cdot 7 \cdot 9 \dots (2l-1)\}}{(l-1)!}$  and  $\lambda = \frac{\lambda_1 \times \{1 \cdot 3 \cdot 5 \cdot 7 \cdot 9 \dots (2m-1)\}}{(m-1)!}$  are proportional to  $k_1$  and  $\lambda_1$  and are called the anharmonic constants for  $p$ -dependent and  $q$ -dependent anharmonic oscillators respectively. The last two terms under summation signs appear due to the ordering of the field operators in normal form. These terms are proportional to  $k_1$  and  $\lambda_1$  respectively. Upon dropping the terms under summation signs, the Hamiltonian (22) reduces to the following form

$$\hat{H}_c = \hat{a}^\dagger \hat{a} - \frac{k}{l} \hat{a}^{\dagger l} \hat{a}^l + \frac{\lambda}{m} \hat{a}^{\dagger m} \hat{a}^m \quad (23)$$

For  $l = 0$ , the equation (23) corresponds the Hamiltonian for a  $m$ -photon anharmonic oscillator [17-19]. Interestingly, this Hamiltonian is widely used to investigate the squeezing, phase properties and other nonclassical properties of the coherent light coupled to the  $m$ -photon anharmonic oscillator [17-19]. By analogy, for  $\lambda = 0$ , the equation (23) corresponds the Hamiltonian for a  $l$ -photon anharmonic oscillator. Of course, the nature of anharmonicities in these two cases are completely different. Admittedly, under Schroedinger formalism, Maduemezia [9-10] obtained the solution of an oscillator with  $p$ -dependent anharmonicity. However, under Heisenberg formalism, the solution of an oscillator with  $p$ -dependent anharmonicity is yet to be explored. In this way, the present investigation is a first one which takes care both these  $p$ -dependent and  $q$ -dependent anharmonicities. Now, the equation of motion for the annihilation operator  $\hat{a}$  corresponding to the Hamiltonian (22) is given by

$$\dot{\hat{a}} = -i\hat{O}\hat{a} \quad (24)$$

where the operator

$$\begin{aligned} \hat{O}(t) = & 1 - k\hat{a}^{\dagger l-1} \hat{a}^{l-1} + \lambda\hat{a}^{\dagger m-1} \hat{a}^{m-1} \\ & - \frac{k_1}{2l} \sum_{r=1}^l (l-r)(2r-1)!!^{2l} C_{2r}^{2l} \times {}^{2l}C_{l-r} \hat{a}^{\dagger l-r-1} \hat{a}^{l-r-1} \\ & + \frac{\lambda_1}{2m} \sum_{r=1}^m (m-r)(2r-1)!!^{2m} C_{2r}^{2m} \\ & \times {}^{2m}C_{m-r} \hat{a}^{\dagger m-r-1} \hat{a}^{m-r-1} \end{aligned} \quad (25)$$

is constant of motion ( $i.e. [\hat{H}, \hat{O}] = 0$ ). The time independent nature of the operator  $\hat{O}(t) = \hat{O}(0)$  helps us to find the exact solution to the differential equation involving the annihilation operator  $\hat{a}$  (24). The corresponding solution is given by

$$\hat{a}(t) = \exp[-it\hat{O}(0)]\hat{a}(0) \quad (26)$$

Obviously, the solution for the creation operator  $\hat{a}^\dagger$  follows immediately by taking the Hermitian conjugate of the equation (26)

$$\hat{a}^\dagger(t) = \hat{a}^\dagger(0) \exp[it\hat{O}(0)] \quad (27)$$

The equations (26) and (27) could be used to establish that the relation (16) is valid indeed. By using the equations (14), the position and momentum operators are easily calculated to obtain the solution of the quantum oscillator governed by the Hamiltonian (23). Clearly, the solutions (26), (27) along with the operators  $\hat{q}(t)$  and  $\hat{p}(t)$  could be used to investigate the quantum statistical properties of the radiation field coupled to a nonlinear medium of having  $q$ - and  $p$ -dependent anharmonicities. Of course, these studies are altogether different issues and we do not have any intention to discuss here. Now, we rearrange the term  $\hat{a}^{\dagger m} \hat{a}^m$  in the following convenient form

$$\hat{a}^{\dagger m} \hat{a}^m = \hat{a}^\dagger \hat{a} (\hat{a}^\dagger \hat{a} - 1) (\hat{a}^\dagger \hat{a} - 2) \dots (\hat{a}^\dagger \hat{a} - \overline{m-1}) \quad (28)$$

where  $m \geq 1$  is an integer. In terms of the number state basis, we calculate the expectation values of the operator  $\hat{a}^{\dagger m} \hat{a}^m$

$$\begin{aligned} \langle n | \hat{a}^{\dagger m} \hat{a}^m | n \rangle = & n(n-1)(n-2) \dots (n-\overline{m-1}) \\ = & n! / (n-m)! \end{aligned} \quad (29)$$

where  $n$  is the eigenvalue of the number operator  $\hat{a}^\dagger \hat{a}$  corresponding to the eigenstate (number state)  $|n\rangle$ . By using the equations (14) and (26), the time evolution of the position and momentum operators of the oscillator under investigation may also be found. It is possible to calculate the dipole moment matrix elements from the knowledge of the position operator. The shifts of the frequency of the oscillator may also be evaluated from the knowledge of the dipole moment matrix elements. As a matter of fact, the shift of the frequency of the oscillator may also be obtained from the knowledge of the matrix elements  $\langle n | \hat{a}(t) | n+1 \rangle$ . Hence, we have

$$\langle n | \hat{a}(t) | n+1 \rangle = \sqrt{n+1} \exp(-itf) \quad (30)$$



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# Nonlinear effects on the dynamics of quantum harmonic modes coupled through angular momentum

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## Abstract

We investigate nonlinear effects on the dynamics of entanglement and other quantum observables in a system of two harmonic modes coupled through angular momentum. The nonlinearity arises from a Kerr-type anharmonic term in each mode. The emergence and evolution of entanglement, non-Gaussianity, photon number, photon antibunching and squeezing are examined for different initial coherent product states and couplings, through exact diagonalization in a truncated basis. It is shown that the anharmonic terms, even if weak, can lead to very significant effects for such initial states, considerably enhancing and stabilizing entanglement and leading to a non negligible non-Gaussianity of the evolved states. They also affect other observables, stabilizing the dynamics after an initial transient regime, for not too small initial average populations of each mode. Analytic short-time approximate expressions are also provided.

Keywords: quantum dynamics, coupled harmonic modes, nonlinear effects, quantum entanglement

(Some figures may appear in colour only in the online journal)

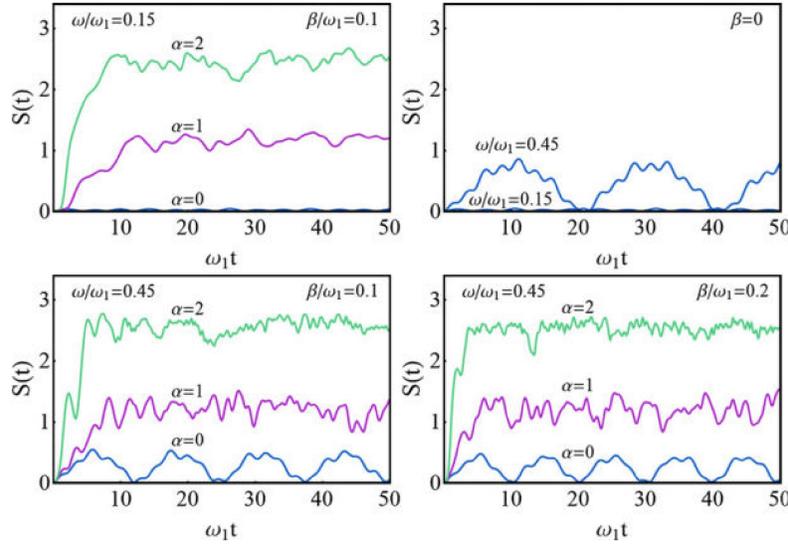
## 1. Introduction

Nonlinear effects can lead to the development of non trivial phenomena in many distinct scenarios. In the field of quantum optics nonlinear processes give rise, for instance, to spontaneous parametric down conversion [1], a fundamental tool for generating entangled photons and hence of most importance in the field of quantum optics [2] and quantum information [3, 4]. Another well known process associated with nonlinearity is the Kerr effect [1, 2, 5], which plays a fundamental role in the emergence of a wide variety of nonclassical phenomena. Kerr nonlinearities were employed for generating squeezing in optical fields [5–8] and for obtaining macroscopic coherent states superpositions (‘Schrödinger cat states’) [9–12],

entangled coherent states [13, 14] and Bell-type states [15]. They have also been used for implementing quantum gates for quantum computation [3, 16–20], quantum teleportation [21] and other quantum information protocols [22, 23], through optical platforms. The effects of Kerr terms have been recently investigated in connection with the enhancement of entanglement and other non classical properties in short chains of non linear oscillators [24, 25] as well as in the context of Bose Einstein condensates [26–29] and parity-time ( $\mathcal{PT}$ ) symmetric systems [30]. Kerr-like nonlinearities can now be also realized through Rydberg excitations in ultra-cold atomic ensembles (Rydberg nonlinear quantum optics) [31–33] and through Josephson junctions in microwave photonics [34, 35].

Motivated by these developments our aim is to investigate, in a system of two harmonic modes interacting through a

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**Figure 1.** Evolution of the entanglement entropy  $S(t)$  for coherent product initial states  $|\alpha, \alpha\rangle$ , equation (12), and different values of the quartic anharmonic coupling  $\beta = \beta_1 = \beta_2$  in  $H$  for  $\omega_2 = \omega_1/2$  and two values of the quadratic coupling  $\omega$  in (7). For  $\beta = 0$  (top right panel), entanglement is independent of  $\alpha$  and significant just for sufficiently large  $\omega$ . In contrast, for  $\beta \neq 0$  (top left and bottom panels) entanglement depends strongly on the initial state, stabilizing around an average value which depends only weakly on  $\beta$  and  $\omega$  (bottom panels).

in [56]. Equation (14) constitutes a proper Bogoliubov transformation (such that  $[a_i(t), a_j^\dagger(t)] = \delta_{ij}$ ,  $[a_i(t), a_j(t)] = [a_i^\dagger(t), a_j^\dagger(t)] = 0 \quad \forall t$ ). Averages at time  $t$  of any observable  $O$  can then be determined by replacing the operators  $a_i, a_i^\dagger$  by  $a_i(t)$  and  $a_i^\dagger(t)$  respectively and evaluating the ensuing expression in the initial state (12). We have also checked that the numerical procedure employed for the complete Hamiltonian leads in the quadratic case to the same results obtained from the analytic expressions within the working tolerance.

### 3.1. Entanglement and non-Gaussianity

We will first analyze the emergence and evolution of entanglement between the two modes. It can be quantified through the entanglement entropy, which is the entropy of the reduced state of a single mode:

$$E_{12}(t) = S(\rho_1(t)) = S(\rho_2(t)), \quad (15)$$

where  $S(\rho_i(t)) = -\text{Tr} \rho_i(t) \log_2 \rho_i(t)$  is the von Neumann entropy and  $\rho_{1(2)}(t) = \text{Tr}_{2(1)} |\Psi(t)\rangle\langle\Psi(t)|$  are the isospectral reduced density matrices of each mode.

In the quadratic case  $\beta_1 = \beta_2 = 0$ , the global state  $|\Psi(t)\rangle$  will remain Gaussian at all times, implying Gaussian single mode reduced densities. The entanglement between the two modes will then be determined solely by the single mode covariance matrix, implying that it will be independent from the values of  $\alpha_1, \alpha_2$  determining the initial coherent state, coinciding with that generated from the initial vacuum. Explicitly, in the quadratic case equation (15) becomes

$$S(\rho_i(t)) = S_g(f_i(t)) \quad (\beta_1 = \beta_2 = 0) \quad (16)$$

$$S_g(f_i(t)) = -f_i(t) \log_2 f_i(t) + (1 + f_i(t)) \log_2 (1 + f_i(t)), \quad (17)$$

where  $f_i(t) = \sqrt{(\langle a_i^\dagger(t) a_i(t) \rangle - |\langle a_i(t) \rangle|^2 + \frac{1}{2})^2 - |\langle a_i^2(t) \rangle - \langle a_i(t) \rangle^2|^2} - \frac{1}{2}$ , is the symplectic eigenvalue of the single mode covariance matrix, with  $f_1(t) = f_2(t)$  in the quadratic case.

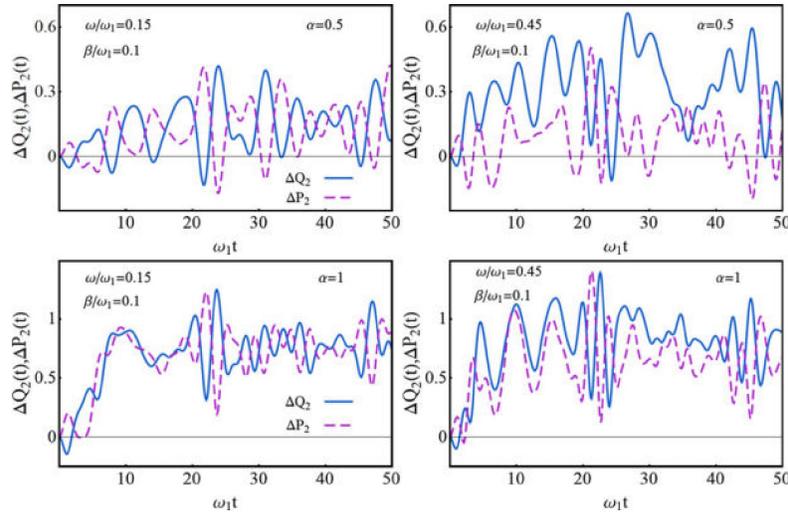
We remark, nevertheless, that in the presence of Kerr terms ( $\beta_1 > 0, \beta_2 > 0$ ) equation (16) no longer holds and the generated entanglement is to be computed through equation (15). It will strongly depend on the initial values of  $\alpha_1, \alpha_2$ . Moreover, the difference between (17) and (15),

$$\Delta S_i(t) = S_g(f_i(t)) - S(\rho_i(t)), \quad (18)$$

is an indicator of non-Gaussianity of the evolved state.

Results for the evolution of the entanglement entropy are shown in figure 1, for different initial coherent states. We have set  $\omega_2 = \omega_1/2$  and used two values of the coupling  $\omega$  in (2):  $\omega = 0.15\omega_1$  (weak quadratic coupling) and  $\omega = 0.45\omega_1$  (strong quadratic coupling regime, where  $\omega$  is close to  $\omega_2$  i.e. to the instability border of the quadratic case  $\beta_i = 0$ ). We have also used two different values of the quartic anharmonic coupling, setting  $\beta_1 = \beta_2 = \beta$ .

It is seen that the presence of quartic terms in  $H$  has a very significant effect on the evolved entanglement, even for small  $\beta$ . In the first place the generated entanglement depends strongly on the initial value of  $\alpha$ , i.e., on the initial average boson number, as seen in the left top and bottom panels, increasing substantially with  $\alpha$ . This is in sharp contrast with the quadratic case  $\beta_i = 0$  (top right panel) where it is independent of  $\alpha$ , i.e., the same as that obtained when the initial state is the vacuum (an analytical result verified in the numerical calculations). In the pure quadratic case entanglement from the initial vacuum is generated by the pair creation terms in (2) ( $\lambda_2$  coupling), rather than the  $\lambda_1$  coupling, remaining then small in the weak coupling regime. However, for  $\beta \neq 0$  the



**Figure 5.** Evolution of the shifted squeezing ratios  $\Delta Q_2(t)$  and  $\Delta P_2(t)$  for  $\beta = 0.1$  and  $\omega/\omega_1 = 0.15$  (left panels) and  $0.45$  (right panels) for an initial coherent state with  $\alpha = 0.5$  (top panels) and  $\alpha = 1$  (bottom panels).

The exact equations of motion for the Heisenberg field operators  $a_i(t) = e^{iHt/\hbar} a_i(0) e^{-iHt/\hbar}$  are

$$\begin{aligned} \dot{a}_1 &= \frac{i}{\hbar} [H, a_1(t)] = -\omega_1 a_1 + \lambda_1 a_2 + \lambda_2 a_2^\dagger - 2i\beta_1 a_1^\dagger a_1^2 \\ \dot{a}_2 &= \frac{i}{\hbar} [H, a_2(t)] = -\omega_2 a_2 - \lambda_1 a_1 + \lambda_2 a_1^\dagger - 2i\beta_2 a_2^\dagger a_2^2 \end{aligned} \quad (25)$$

where  $a_i \equiv a_i(t)$ . These equations are obviously nonlinear in the field operators for  $\beta_i > 0$ . From (25) we can obtain the second derivatives as  $\ddot{a}_i = (\frac{i}{\hbar})^2 [H, [H, a_i]]$ :

$$\begin{aligned} \ddot{a}_1 &= -(\omega_1^2 + \lambda_1^2 - \lambda_2^2) a_1 - i\lambda_1(\omega_1 + \omega_2) a_2 - i\lambda_2(\omega_1 - \omega_2) a_2^\dagger \\ &\quad - 4\beta_1 \omega_1 a_1^\dagger a_1^2 - 2i\beta_2 a_2^\dagger (\lambda_1 a_2 - \lambda_2 a_2^\dagger) a_2 - 4i\beta_1 a_1^\dagger a_1 \\ &\quad \times (\lambda_1 a_2 + \lambda_2 a_2^\dagger) - 2i\beta_1 a_1^2 (\lambda_1 a_2^\dagger + \lambda_2 a_2) - 4\beta_1^2 a_1^\dagger a_1 a_1^2 a_1^2 \\ \ddot{a}_2 &= -(\omega_2^2 + \lambda_1^2 - \lambda_2^2) a_2 + i\lambda_1(\omega_1 + \omega_2) a_1 + i\lambda_2(\omega_1 - \omega_2) a_1^\dagger \\ &\quad - 4\beta_2 \omega_2 a_2^\dagger a_2^2 + 2i\beta_1 a_1^\dagger (\lambda_1 a_1 + \lambda_2 a_1^\dagger) a_1 + 4i\beta_2 a_2^\dagger a_2 \\ &\quad \times (\lambda_1 a_1 - \lambda_2 a_1^\dagger) + 2i\beta_2 a_2^2 (\lambda_1 a_1^\dagger - \lambda_2 a_1) - 4\beta_2^2 a_2^\dagger a_2 a_2^\dagger a_2^2 \end{aligned} \quad (26)$$

The first terms of the Taylor series of  $a_i(t)$  around  $a_i(0)$  are then given by

$$a_i(t) = a_i(0) + \dot{a}_i(0)t + \frac{t^2}{2} \ddot{a}_i(0) + O(t^3). \quad (27)$$

and the second order short time approximation is obtained neglecting terms  $O(t^3)$ . Setting now  $a_i(0) = a_i$  we obtain

$$\begin{aligned} a_1(t) &= [1 - i\omega_1 t - (\omega_1^2 + \lambda_1^2 - \lambda_2^2) \frac{t^2}{2} + \dots] a_1 + [\lambda_1 t \\ &\quad - i\lambda_1(\omega_1 + \omega_2) \frac{t^2}{2} + \dots] a_2 + [\lambda_2 t - i\lambda_2(\omega_1 - \omega_2) \\ &\quad \frac{t^2}{2} + \dots] a_2^\dagger - [2i\beta_1 t + 4\beta_1(\beta_1 + \omega_1) \frac{t^2}{2}] a_1^\dagger a_1^2 \end{aligned}$$

$$\begin{aligned} &+ [2i\beta_2 a_2^\dagger (-\lambda_1 a_2 + \lambda_2 a_2^\dagger) a_2 - 4i\beta_1 a_1^\dagger a_1 (\lambda_1 a_2 + \lambda_2 a_2^\dagger) \\ &\quad - 2i\beta_1 a_1^2 (\lambda_1 a_2^\dagger + \lambda_2 a_2) - 4\beta_1^2 a_1^\dagger a_1^3] \frac{t^2}{2!} + \dots \\ a_2(t) &= [1 - i\omega_2 t - (\omega_2^2 + \lambda_1^2 - \lambda_2^2) \frac{t^2}{2} + \dots] a_2 \\ &\quad + [-\lambda_1 t + i\lambda_1(\omega_1 + \omega_2) \frac{t^2}{2!} + \dots] a_1 \\ &\quad + [\lambda_2 t + i\lambda_2(\omega_1 - \omega_2) \frac{t^2}{2!} + \dots] a_1^\dagger \\ &\quad - [2i\beta_2 t + 4\beta_2(\beta_2 + \omega_2) \frac{t^2}{2!}] a_2^\dagger a_2^2 \\ &\quad + [2i\beta_1 (\lambda_1 a_1^\dagger a_1 + \lambda_2 a_1^\dagger) a_1 + 4i\beta_2 a_2^\dagger a_2 (\lambda_1 a_1 - \lambda_2 a_1^\dagger) \\ &\quad + 2i\beta_2 a_2^2 (\lambda_1 a_1^\dagger - \lambda_2 a_1) - 4\beta_2^2 a_2^\dagger a_2^3] \frac{t^2}{2!} + \dots \end{aligned} \quad (28)$$

By taking the Hermitian conjugate of (28) we obtain the creation operators for the two field modes. The commutation relations  $[a_i(t), a_j^\dagger(t)] = \delta_{ij}$  are verified up to second order. These expressions can be used to determine the initial trend of the evolution of any observable. For instance, the population of the first mode  $N_1(t) = a_1^\dagger(t) a_1(t)$  is given by

$$\begin{aligned} N_1(t) &= a_1^\dagger a_1 + [\lambda_1 (a_1^\dagger a_2 + a_2^\dagger a_1) + \lambda_2 (a_1 a_2 + a_1^\dagger a_2^\dagger)] t \\ &\quad + [-2(\lambda_1^2 - \lambda_2^2) a_1^\dagger a_1 + i\lambda_1(\omega_1 - \omega_2) \\ &\quad \times (a_1^\dagger a_2 - a_2^\dagger a_1) + i\lambda_2(\omega_1 + \omega_2)(a_1^\dagger a_2^\dagger - a_1 a_2) \\ &\quad + 2\lambda_1 \lambda_2 (a_2^{\dagger 2} + a_2^2) - 2i \{ \beta_1 a_1^\dagger [\lambda_1 (a_1^\dagger a_2^\dagger - a_1^\dagger a_1 a_2) \\ &\quad + \lambda_2 (a_1^\dagger a_2 - a_1^\dagger a_1 a_2^\dagger)] + \beta_2 a_2^\dagger [\lambda_1 (a_1 a_2^\dagger a_2 - a_1^\dagger a_2^\dagger) \\ &\quad + \lambda_2 (a_1^\dagger a_2^\dagger a_2 - a_1 a_2^\dagger) \}] \} \frac{t^2}{2} + \dots \end{aligned} \quad (29)$$

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## Private Tuition versus Regularity in Classes as Tools of Achieving Higher Score in Examination: Evidences from Purulia District in West Bengal

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### Abstract

*This study assesses the impact of private tuition, which is a common and dominant phenomenon in education system in India, on the scores of the students along with the regular attendance in the schools in Purulia district, a western most district in West Bengal. This empirical study is based on a set of primary data collected from 309 students of class X from 20 public schools of ten blocks in Purulia district in 2020. This study reveals that regular attendance is more important than spending on private tuition to achieve better score in examination. The average score is 5 percentage-points higher for the students with regular attendance over the year than other students. Other things remaining unchanged, if the household spend 100 rupees more per month for private tuition the average percentage of score increases only by 0.5 percentage points. Thus regularity in classes is far better instrument than private tuition for improving the scores in examination. We find that both the SC and ST students fall behind the students belonging to General castes and OBCs in respect of the percentage of score in last final examination. However, the interaction effect of private tuition expenditure with SC category increases the average score in last exam, while this interaction effect for ST students does not appear significant. Therefore, private tuition may help the students belong to lower social castes.*

**Keywords:** Private Tuition, Purulia district, Regularity in School, Scoring function of Education

### Introduction

The main purpose of education is all round development of a student. It is the human development purpose of education system. In this sense school education is crucial for building and maintaining the social structures and values of a nation. Partially, the education system helps students to learn a particular syllabus and assesses and classifies the students on the basis of educational achievement. Regularly higher achieving students are selected for higher education and for attractive occupation. This is referred to as 'scoring' function of education (Muralidharan, 2019). Traditionally Indian education system is driven by scoring rather than human development. With this end in view; Muralidharan, (2019) has argued that current Indian education system is best understood as a filtration system. There is nothing wrong with the scoring function of the education system. Every country in the world takes the help of academic scores at different stage of education to identify its most talented citizens and pick them for serving the society as a whole in an efficient manner. Further, employers use the scores of the student as signal of their capability. So parent considers expenditure on education as a good investment. Achievement in examination is considered as the return of investment. However, an important point is that, in scoring based education system there is no formal facility of teaching to the students with low scores in achievement. That is why; private tuition is needed for pushing the students with low scores and capacity as well as for

**Father's Education:** It is a time variable indicating the years of schooling of the father of the student. It is the control variable in our regression model.

**Mother's Education:** It is a time variable indicating the years of schooling of the mother of the student. It is also a control variable in our regression model.

**Caste:** We collect our data from four conventional castes i.e., GEN, OBC SC, and ST But in regression model we have included two dummies; one for caste SC (SC=1 and 0 otherwise) and another caste ST (ST=1 and 0 otherwise). We have included these caste dummies to understand the variation of academic result across the social strata. Finally, to access the importance of private tuition for the students from lower social castes, we have incorporated two interaction variables for the caste dummies with the monthly private tuition expenditure of the households.

The regression model has been estimated applying ordinary least squares addressing the problem of multicollinearity, heteroscedasticity and autocorrelation if any.

### Empirical Findings and Discussion

This section discusses the findings of our primary survey and estimated results. The study has surveyed 20 government aided secondary schools from Purulia district which is backward in respect of education and other infrastructure. Most of the people in this district live in village. From the selected schools this study collected information from 309 students who have been selected using lottery method. Table-1 deals with the frequency distribution of the categorical variables of the households of our sample students. Our sample comprises 60 per cent female students. This is because of the selection of some exclusive girls schools. We have interviewed students from four strata of social castes. Almost one fourth of our sample students belong to general castes. Among the sample students 28.5 (15.5) per cent are belonging to scheduled castes (scheduled tribe). Most of the sample students are Hindu. With this composition of caste and religion our sample is matching with the caste religion distribution of the population in Purulia district. More than two third of the sample students comes from nuclear households. In our sample 30 per cent students belongs to landless households. Among the sample students 46 per cent has reported that their households don't have ownership of agricultural land. Therefore, incidence of landlessness and poverty are not negligible in the district of Purulia. Mothers of only 13 per cent of the students are in labour force whereas fathers of 98 percent students are participating in labour force. It shows that there is a huge gender gap in labour force participation in the society which is an important feature of patriarchal society. It is not surprising that among our sample students 30 per cent students don't have access to safe drinking water in their home. Still now in Purulia, 4.2 per cent of the sample students at night do their home task in the light of kerosene and one fourth of the student don't have access to improved sanitation facility in their residential premises.

**Table 1 Socio-Economic Background of the Sample Students. (N=309)**

Category	Frequency	Percent
Gender of the Students (1=Female)	183	59.2
Caste of the Students (1=General Caste)	74	23.9
Caste of the Students (1= Scheduled Caste)	88	28.5
Caste of the Students (1= Scheduled Tribe)	48	15.5
Caste of the Students (1= Other Backward Classes)	99	32
Religion of the Students (1=Hindu)	282	91.3
Student belong to Nuclear Family	224	72.5
Student belong to Agricultural Landless Household	93	30.1
Economic Status of the Students(1=BPL card holder)	144	46.6

lower social castes or for the students who obtain lower marks in midterm examinations or in class tests. For this purpose government may take the help of school teachers and local educated persons with some honorarium.

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# A study of non-positive operators between real normed linear spaces

ARUP CHATTOPADHYAY, DEBMALYA SAIN and TANUSRI SENAPATI

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**Abstract.** We introduce the concept of non-positive operators with respect to a fixed operator defined between two real normed linear spaces. Significantly, we observe that, in certain cases, it is possible to study such type of operators from a geometric point of view. As an immediate application of our study, we explicitly characterize certain classes of non-positive operators between particular pairs of real normed linear spaces. Furthermore, we present a complete characterization of smooth and strictly convex Radon planes in connection with non-positive operators.

## 1. Introduction

Although the study of dissipative operators was first initiated in Hilbert spaces, later on it was extended by Lumer and Philips [10] to the setting of normed linear spaces by using the concept of semi-inner-product [4, 9, 15]. We also refer the readers to [11] for some nice applications of dissipative operators. In case of real Hilbert spaces, the concept of dissipative operators coincides with that of non-positive operators. Likewise non-positive operators on real Hilbert spaces, through the method introduced by Lumer and Philips [10], we can study non-positive operators on real normed linear spaces. The purpose of the present article is to study a generalization of such operators. Observe that the study of non-positive operators on real Hilbert spaces as well as on real normed linear spaces is strictly restricted to the case when the domain space and the codomain space of the operator are identical. In our present work, we remove this restriction. Here we introduce and study the notion

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of non-positive operators with respect to a fixed operator. The usefulness of our consideration lies in the fact that the notion of non-positive operators obtained from [10] is actually a special case of the newly introduced non-positive operators proposed by us. Now onwards we call our presently introduced non-positive operators as generalized non-positive operators. From [10], it is clear that for a bounded linear operator on a real normed space, the property of being non-positive is invariant under any semi-inner-product consistent with the norm of the respective space. We prove that a similar type result holds true for the generalized non-positive operators, introduced in the present article. Before proceeding further, let us first mention some useful notations and terminologies relevant to this article.

Since the concept of semi-inner-product in a normed linear space is very crucial to the study of non-positive operators between real normed linear spaces, let us first recall the definition of semi-inner-product [9]. Note that throughout this present article, the letters  $\mathbb{X}$ ,  $\mathbb{Y}$  stand for real normed linear spaces and  $\mathbb{H}$  stands for a real Hilbert space. We use the symbol  $\theta$  to denote the zero vector of any normed linear space other than the scalar field  $\mathbb{R}$ .

**Definition 1.1.** Let  $\mathbb{X}$  be a normed linear space. A function  $[\cdot, \cdot]: \mathbb{X} \times \mathbb{X} \rightarrow \mathbb{R}$  is said to be a *semi-inner-product* on  $\mathbb{X}$ , if for all  $x, y, z \in \mathbb{X}$  and for all  $\alpha, \beta \in \mathbb{R}$  the following conditions are satisfied:

- (1)  $[x, x] > 0$  for every non-zero  $x$ ,
- (2)  $[\alpha x + \beta y, z] = \alpha[x, z] + \beta[y, z]$ ,
- (3)  $[x, y]^2 \leq [x, x][y, y]$ ,
- (4)  $[x, \alpha y] = \alpha[x, y]$ .

It was proved in [4] that, corresponding to any normed linear space  $\mathbb{X}$ , there exists at least one semi-inner-product  $[\cdot, \cdot]$  consistent with the norm of  $\mathbb{X}$  in the sense that  $[x, x] = \|x\|^2$  for all  $x \in \mathbb{X}$ . In this article, whenever we talk about semi-inner-product on a normed linear space  $\mathbb{X}$ , we always mean that the semi-inner-product is consistent with the norm of  $\mathbb{X}$ . Moreover, there exists a nice connection between semi-inner-product and supporting functionals. Let  $\mathbb{X}^*$  denote the dual space of  $\mathbb{X}$ . A functional  $f_x \in \mathbb{X}^*$  is said to be a supporting functional at  $x \in \mathbb{X}$  if  $f_x(x) = \|x\|^2$  and  $\|f_x\| = \|x\|$ . A non-zero point  $x \in \mathbb{X}$  is said to be a smooth point if there exists a unique supporting functional at  $x$ . It follows from the arguments given in [4, 10], in the construction of semi-inner-products that corresponding to each supporting functional  $f_x \in \mathbb{X}^*$ , there exists a semi-inner-product  $[\cdot, \cdot]$  on  $\mathbb{X}$  such that  $[y, x] = f_x(y)$ . Conversely, corresponding to each semi-inner-product  $[\cdot, \cdot]$  on  $\mathbb{X}$ , and any non-zero  $x \in \mathbb{X}$ , there exists a unique  $f_x \in \mathbb{X}^*$  such that  $[y, x] = f_x(y)$  for all  $y \in \mathbb{X}$ , where  $f_x$  is a supporting functional at  $x$ . Consequently, if each  $x \in \mathbb{X}$

Let us now choose a point  $x = (x_1, 0, \dots, 0, x_j, 0, \dots, 0) \in \mathbb{X}$  with  $x_1 = \pm 1$ ,  $x_j \neq 0$  for some  $n + 1 \leq j \leq m$ . Without loss of generality, let  $x_1 = 1$ . Then, as  $T$  is  $A$ -non-positive, this implies that  $a_{11} + a_{1j}x_j \leq 0$  for all  $x_j \in \mathbb{R}$ . This is possible only when  $a_{1j} = 0$  for each  $j = n + 1, n + 2, \dots, m$ . In a similar manner, we obtain  $a_{ij} = 0$  for all  $n + 1 \leq j \leq m$ , and for all  $i = 1, 2, \dots, n$ .

Next, we consider an extreme point  $x = (x_1, x_2, \dots, x_m) \in S_{\mathbb{X}}$ . It is well known that  $x = (x_1, x_2, \dots, x_m)$  is an extreme point of  $S_{\mathbb{X}}$  if and only if  $x_i = \pm 1$  for all  $i = 1, 2, \dots, m$ . Clearly,  $Ax = (x_1, \dots, x_n)$  will also be an extreme point of  $S_{\mathbb{Y}}$ . As  $T$  is  $A$ -non-positive, if  $x_1 = 1$  then Theorem 2.5 implies that  $a_{11} \pm a_{12} \pm \dots \pm a_{1n} \leq 0$  which implies  $\pm a_{12} \pm \dots \pm a_{1n} \leq -a_{11}$ . Again, if  $x_1 = -1$  we have  $-a_{11} \pm a_{12} \pm \dots \pm a_{1n} \geq 0$  which implies that  $a_{11} \leq \mp a_{12} \mp \dots \mp a_{1n}$ . Therefore, we obtain  $\pm a_{12} \pm \dots \pm a_{1n} \leq |a_{11}|$ . In a similar spirit, one can check that  $\sum_{j=1, j \neq i}^n \pm a_{ij} \leq |a_{ii}|$  for all  $i = 2, \dots, n$ . This completes the proof of the necessary part of the theorem.

Let us now prove the sufficient part. Let  $T \in L(\mathbb{X}, \mathbb{Y})$  be such that

$$T(x_1, x_2, \dots, x_m) = (a_{11}x_1 + \dots + a_{1m}x_m, \dots, a_{n1}x_1 + \dots + a_{nm}x_m),$$

where  $\sum_{j=1, j \neq i}^n \pm a_{ij} \leq |a_{ii}|$ ,  $a_{ii} \leq 0$  for all  $i = 1, 2, \dots, n$ , and  $a_{ij} = 0$  for all  $j = n + 1, \dots, m$ . To prove that  $T$  is  $A$ -non-positive, it suffices to show that, for all  $z \in S_{\mathbb{X}}$ ,  $[Tz, Az] \leq 0$  for some semi-inner-product  $[ \cdot, \cdot ]$  on  $\mathbb{Y}$ . If, for some  $z \in S_{\mathbb{X}}$ ,  $Az = \theta$  then there is nothing to show. Let us choose  $z \in S_{\mathbb{X}}$  such that  $Az$  is an extreme point of  $S_{\mathbb{Y}}$ . Then, from the above hypothesis, one can verify that  $f_{Az}(Tz) \leq 0$  for every supporting functional  $f_{Az}$  corresponding to each facet meeting at  $Az$ . This implies that for all supporting functionals  $f_{Az}$  at  $Az$ ,  $f_{Az}(Tz) \leq 0$ . Next we consider  $z \in S_{\mathbb{X}}$  such that  $Az$  is either a non-zero, non-smooth, non-extreme point of  $S_{\mathbb{Y}}$  or a smooth point of  $\mathbb{Y}$ . For each  $i = 1, \dots, n$ ,  $\sum_{j=1, j \neq i}^n \pm a_{ij} \leq |a_{ii}|$  implies that  $\sum_{j=1, j \neq i}^n \pm k_j a_{ij} \leq |a_{ii}|$  for all  $|k_j| \leq 1$ . Using this one can check that at every non-extreme point  $Az$ ,  $f_{Az}(Tz) \leq 0$  for all supporting functionals  $f_{Az}$  at  $Az$ . As we know that corresponding to every supporting functional at a non-zero point of a normed linear space it is possible to construct a semi-inner-product  $[ \cdot, \cdot ]$  on  $\mathbb{Y}$ , applying Theorem 2.5, we conclude that  $[Tz, Az] \leq 0$  for all semi-inner-products on  $\mathbb{Y}$ . This implies that  $T$  is an  $A$ -non-positive operator. This completes the proof of the sufficient part of the theorem and establishes it completely. ■

**Remark 3.2.** If  $m = n$  in the above theorem, then  $A$  will be the identity operator. Therefore,  $T \in L(\mathbb{X})$  with  $T(x_1, x_2, \dots, x_n) = (a_{11}x_1 + \dots + a_{1n}x_n, \dots, a_{n1}x_1 + \dots + a_{nn}x_n)$  is non-positive if and only if  $a_{ii} \leq 0$  and  $\sum_{j=1, j \neq i}^n \pm a_{ij} \leq |a_{ii}|$  for all  $i = 1, 2, \dots, n$ .

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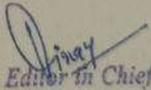
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## EDUCATION FOR WOMEN EMPOWERMENT : VIVEKANANDA IN PRESENT SCENARIO

□ Sourish Dey\*

### ABSTRACT

Swami Vivekananda a great thinker and reformer Of India represented the country on the global platform as a unique culture with its diversity. He has always dreamt of an education which would serve the function of man-making. Swamiji feels that the sole obstacle behind the nation development is its negligence towards women- in India women are always treated as the 'other' and are subjected to suppression, repression and oppression. Swamiji realizes that if the womankind wants to come out of this situation to exert their 'Self' they need the light of the education. Now a day we clearly feel the usefulness of women education. Various women colleges, universities were opening today for this purpose. In this paper the author tries to show the ideas of Vivekananda's Philosophy on women education and his perspective with the current scenario.

**Keywords :** Women Education, Empowerment, Equality, Curriculum

#### Research Methodology :

The methodology followed in this paper is analytical. The paper has analyzed Vivekananda's philosophical thought and mission on women education. Also the paper has discussed the relevance of his ideals in present scenario.

#### Introduction :

Swami Vivekananda a monk, a teacher, a great leader and above all a great philosopher who had incessantly worked for India and represented the country on the global platform as a unique culture with its diversity. According to him, "education is the manifestation of perfection already in men." To him, education was not only collection of information, but something more meaningful. He has always dreamt of an education which would serve the triple function of man-making, life giving and character building.

Swamiji feels that the sole obstacle behind the nation development is its negligence towards women- in India women are always treated as the 'other' and are subjected to suppression, repression and oppression. Swamiji realizes that if the womankind wants to come out of this situation to exert their 'Self' they need the light of

the education. He also opined that a women needs education because on her rests the fate of the nation. She is the one who moulds the minds of the generation that comes after next. He gave highest priority to the upliftment of women through education.

Vivekananda predicted that if India wants to get back its lost honor and pride, it has to try to better the condition of women. He considered men and women as two wings of a bird, and it is not possible for a bird to fly on only one wing. So the progress and welfare of the world depends on the improvement of the condition of women. So the need for women education is two-fold – it is essential for the development of the nation and also for the upliftment of the womenfolk. So, on this point he utmost emphasis on women education. In their way of journey only education can bring the light.

#### Swamiji's Vision of Education :

Swamiji defines education as, "the manifestation of the perfection already in men". This implies that something already exists and is waiting to be expressed. In his view, it is a fact that knowledge is not coming from any out sources but it's coming from internal sources.

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Actually knowledge is an intrinsic quality of human mind. The stimulus of education causes the friction that ignites the fire of knowledge. It refers to a human being's potential, which is the range of the abilities and talents, known and unknown that is born with.

The concepts of education refer by Swamiji known to us as man-making education. Our practical need and value of education pointed out by this concept. In the case of proving practical value of education his experiences were very helpful. At the time of travelling in European cities he observed that poor persons were educated and also living with comfort. This picture is very rare in India. So education is the most valuable thing throughout the world which easily differentiates the living condition of two countries. So education was perceived to be an agent who elevated the level of individual human existence as well as the social existence level. In Indian society education was granted as the primary need. Only education can develop the position of backward classes in our society.

In Swamiji's view, spirituality can attain through education. Through this way own salvation can be possible. The way to achieve spiritual development and diversity within oneself only can be possible by those ideas which are the gift of education for a person. In the fields of humanities, social sciences and technology he expressed the practical need for the prevailing secular education. For improving the material conditions of man's life this kind of education was considered as necessary. So, in his view education must be considered a continuous and lifelong process.

#### **Swamiji's Views on Women Education :**

Since last decades world is busy enough including India to discuss about women empowerment and development. In this context gender discrimination is also an alarming issue which should abolish. Women are struggling for equal rights parallel with men and it is a global problem towards upliftment of women power.

Raja Rammohan, Vidyasagar were also engaged for the service of women before Swami Vivekananda. They eradicated the burning of a chaste wife on the funeral pile of her husband, child marriage and polygamy and so on. But Swamiji was the man different pole. The

main goal of his mission of women education was to make them strong, fearless and conscious of their charity and dignity. If women take a strong position, then they can solve their problems in their own way.

Through Swamiji's view the progress of a society somehow depends on female literacy. He also said, that it is totally unfair to discriminate between sex and gender system. Because there is no sex distinction in 'Atman (soul)'. The soul has neither sex nor caste. It was his suggestion that only human beings are exists. Men and women- the differentiation created by society is not important. Swamiji said that the eastern ideals of women hood are mother, where the western ideals are wife. He explains the matter by looking back into the past where there were many glorious women like Sita, Savtree, Maitrayee who uplifted social status. But when we look on mediaeval age to colonial era where women suppressed by society.

In past there were many examples where monks decided that women are obstacle in the way to attain moksha, where Swamiji's view were extremely opposite. He viewed that, unless the situation of women are improved, there is no possibility of any welfare of the world. He also said that, It is not possible for a bird to fly on one wing. Soul has no gender bias. Every soul is potentially divine.

It was his realization that, proper education needed for women's in our country for their right upliftment. To achieve a position and to solve their problems it is important to educate women in a proper way. Training like nursing, sewing, culinary art etc. can enhance their inner quality. Then he suggests for vocational skills and training which can change with time and technology and also enhance way of living.

Vivekananda was against the marginalization of women and try to improving the situation of women. In 1895 when he was in England, he met Margaret Elizabeth Noble who was an Irish lady and was in the midst of learning about the Buddha. She was influenced by Swamiji and known to us as Bhagini Nivedita. She had a vital role in promoting the rights of women in rural India. She started a school for the basic education for girls which was motivated by Swamiji, established in

November 1989. Today the school known as 'Ramkrishna Sarada Mission Sister Nivedita Girl's School', situated in Bagbazar in North Kolkata.

#### **Swamiji's Curriculum for the Women Education :**

In Swamiji's view, the best medium of women education is mother tongue. After thinking on some social status of women he suggested a different curriculum which includes- moral value, literature and Sanskrit, grammar, craft and cooking, home science along with yapa, worship, meditation. In the present era the necessity of those curriculum suggested by Swamiji is proving its value for women. He also suggests that women should learn the lesson of self-defense with those curriculums.

The main goal of education are man making and character building. Men and women will parallel participate in every custom of society. It was his wish to build schools in rural areas, where some devoted nuns will teach. He suggested religion centric education for women and all the other trainings will be secondary rather than religion. Religious training, the formation of character and observance of the vows of celibacy these should be attend to Brahmacharinis of education and character should take up the task of teaching. The Brahmacharinis should strive for the female education and for this purpose they should open centers in villages and towns. Through such religious preaches of character, there will secular education. It was Swamiji's opinion that women should not imitate men when they acquired proper education. Instead of that through this education they would be modern Sita, Savtree, Maitrayee, and Gargy. 'Sarada Math' was established by Swamiji for the purpose of education for women in a proper way. He wished that, women should follow Ma Sarada as their idol of life. 'Example is more important than advice'- is thought of Ma Sarada, which was experienced by her in her entire life.

#### **Vivekananda's Thought in Today's Relevance :**

After 1947 when India got independence women education became an important issue in India which was Vivekananda's mission towards women empowerment. To fulfill the purpose of education for all women government took various steps. As a result, literacy rate in India have risen sharply from 16.7% in 1951 to 74.07% in

2011 in which enrolment of women in education have also risen from 7.3% to 65.46%.

The ongoing situation is very crucial for us. Today we can realize why Swamiji utmost emphasis for the women education as well as overall development and advancement occur on flow. Now we realize the value of women education. In every field of life now a day's women are working parallel with men. Swamiji also says- "500 males can win India in 50 years which can be done with a few weeks by 500 women". According to educational psychology mother is the first teacher of her children and they always learn from their mother and other family member also. It is a fact that education and ideal culture both together may control children future. Swamiji's mission for women education and related issues with women education can be fulfills through inaugurating women colleges and institutions for their higher studies.

In 1999 when the 81 report of the committee on value based education focused on the need to inculcate the principles of truth, rightness conduct, peace, love and non-violence which are the religious values lightened by Swamiji.

The development issue of the twenty first century for the purpose of education as the main objective of women empowerment follows those valuable issues said by Swamiji in 19<sup>th</sup> century. The millennium development goals envisage that education of women increases their productivity, raising output and reducing poverty. In 19<sup>th</sup> century Vivekananda wished that, women can be a decision maker in every field of their life, and in present era this lesson promote gender equality.

#### **Conclusion :**

To conclude, education serves as the main pillar in the women empowerment which would ultimately lead to the regeneration of the nation both socially and culturally and to a great extent economically. So Swamiji sees women education and women empowerment as the manifesto to the growth and progress of the nation. That is why he calls everybody as, "arise, awake and stop not till the goal is reached". For this purpose his objective is to take out the womenfolk from the cocoon and revive their lost confidence so that they may lead a dignified life of

their own. This can be done only through proper education. But one is to bear in mind this is not so easy a task and cannot be done overnight.

Swamiji ardently felt that unless women achieve a respectable place in the society it would be difficult for the nation to march forward. So the government should take care and put emphasis on the proper education on every girl child. Only then the nation would become successful in every sphere. It is the fact that at present time the educated women played a very significant role in overall development and progress of the country. The rise of outstanding women administrators, scientists, writers is gradually proving the truth of these prophetic words. No wonder Vivekananda's words and propagations are relevant even today's context. In fact he has a great contribution in the improvement of the state of women education.

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word is in the centre of all deliberations in contrast to the western tradition of grammar where 'Artha' or meaning acquires the centre point.

But, as described by Burnell, Aindra grammar prescribes four fold division of words (padas) namely: nām (noun), ākhyāta (verb), upsarga (preposition) and nipāta (particles).

In Pāṇini, the parts of speech are treated in a more complicated way. Although it uses the terms upsarga and nipata but not with that significance as found in the Aindra Grammar.

For, nāma (noun) Pāṇini used 'sup' and 'subanta' and for ākhyāta (verb), he uses 'in' which apparently are more artificial and technical and belong to a far more advanced state of analysis.<sup>1</sup>

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**The Idea of 'Puruṣa' in Śrīmad-Bhāgavatā and the Sāṃkhyakārikā: A Comparative Study**

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**Summary:**

The nature of 'puruṣa' has been discussed in both Iśvarakṛṣṇa's *Sāṃkhyakārikā* and the *Śrīmad Bhāgavatā Purāṇa*. Issues include its *āharaṇa*, its role in the process of creation etc. An analysis of the two shows that in place of differences there are instead broad similarities in their handling of the issues in majority of the cases. *Sāṃkhyakārikā*'s assertion that *puruṣa* is *nirguṇa*, *mūla*, *nirvyaḍa*, extraordinary and above all sense-imbed and eternal is repeated in the *Bhāgavatā*. The function of *pradhāni* in creation is the same across both texts and so is that of the *puruṣa* when it comes in contact with *pradhāni*. Context and author intentionality reflect itself in the theory of *puruṣa* as fundamentally distinct in both the texts. In the *Sāṃkhyakārikā* *puruṣa* is shown to be independent and acknowledged as the Supreme Being, while in the *Bhāgavatā* a superior force is seen to override its supremacy.

Key Words: *Sāṃkhyakārikā*, *Bhāgavatā*, *Iśvarakṛṣṇa*, *Puruṣa*, *Nirguṇa*

Scholars of Sāṃkhya accept Iśvarakṛṣṇa's *Sāṃkhyakārikā* as one of the texts which plays an explanatory role within the confines of Sāṃkhya philosophy. The theory and nature of the Puruṣa being one of the major terms thus dealt with. The *Bhāgavatā*, on the other hand, is a key source for the *Vaiṣṇavus*. The latter, while discussing the theory of *Bhāgavatā*, pulls in its ambit the terms and theories from Sāṃkhya including *puruṣa*. It would be pertinent here to keep in mind that the two texts are from two different chronological periods, one being philosophical and the other being devotional. *Sāṃkhyakārikā* was written in circa 4<sup>th</sup>-5<sup>th</sup> CE<sup>1</sup> while the *Bhāgavatā* was composed in circa 11<sup>th</sup> to 12<sup>th</sup> centuries CE.<sup>2</sup> According to Larson, these differences reflect in their approach and use of *puruṣa* as well.<sup>3</sup> This provides the possibility for a study of the different approaches to the term in the texts which will be the concern of the essay.

*Puruṣa* appears in various *śāradhas* of the *Bhāgavatā* where the author of this *Purāṇa* tries to explain soul's (*jīva*) salvation following the achievement of *viveka-jñāna*. Knowledge of *puruṣa* as well as an understanding of its role is essential for achieving *viveka-jñāna*. In the 16<sup>th</sup> *adhyaīya* of the 3<sup>rd</sup> *skandha* Kapila while speaking to his mother Devāhūtī discusses the character and nature of the 25 principles, one of which being *puruṣa*. He says -

*anādirāma puruṣo nirṅuṣaḥ prakṛteḥ parah |*

*pratyagdhāmā swayamjyotiṣwam yamasamanvitam ||<sup>4</sup>*

The *puruṣa*, according to Kapila, is *nitya*, *nirguṣa*, *aīndriya*, *swayamprakāśa* and is separate from *prakṛti* and the *puranāimā*. Again in the 7<sup>th</sup> *skandha* Pahlāda while explicating *puruṣa* to his companions follows Nārada to describe it as –

*ātmā nityo vyayāḥ suddhāḥ ekah kṣetrajñah āśrayāḥ |*

*avikrīyāḥ svadghetavyāpako śaṅjānānāvrītaḥ ||<sup>5</sup>*

The *ātmā* is permanent, indestructible, not corrodible, pure, unparallelled, omniscient, unadorned, root of all things, always by oneself.

As *puruṣa* has neither the origin nor the destruction hence it is eternal. Due to the absence of *satva*, *tanu*s and *rajas* from the character of the *puruṣa*, it is called as *nirguṣa*. In fact, these *guṇas* are attributed to the *prakṛti*. The *puruṣa* is not perceived by the senses as it is formless and indefinite. The sense-organs being born from *prakṛti* can only feel and understand those that are mothered by it. *Puruṣa*, as mentioned above, is beyond the features related to *prakṛti*. *Īsopaniṣad*'s assertion bolsters this argument –

*nainadādevā āpnuṣan pūrvamaṣṭat |<sup>6</sup>*

Even the Mīmāṃsakas are of the opinion that *puruṣa* cannot be known and understood as material objects.

*nīmāṃsakādhyavimata jñānavācaryasam vācayati - swayamjyotiḥ<sup>7</sup>*

That is, the *puruṣa* is the knower not the matter to be known. Although both *puruṣa* and *prakṛti* are eternal the non-existence in the former and existence in the latter of the three *guṇas* makes them distinct and different. *Puruṣa* is stable and the *guṇas* do not effect changes in it. Being immutable it is *avyaya*. The *Śrūti*s opine that *puruṣa* is,

*ṛico kṣare parama vyomamātī śruteḥ<sup>8</sup>*

The *puruṣa* being free from pleasure and misery is pure and pristine. The *puruṣa* is ubiquitous, endless and unembellished.

*sa ināḷbokān sṛjate 'ti śruteḥ<sup>9</sup>*

The *puruṣa* is all-knowing

*vijñātaramadhikena vijānyadātī śruteḥ<sup>10</sup>*

The *Sāṃbhvyakīrikā* explains the *puruṣa* opposite to the similarity that exists between *vyākā* and *avyākā*. *Īsvara*kṛṣṇa notes that the *puruṣa* is –

*irigūṇamavireki viśayāḥ sāmānyamacetanam prasavadharmi |*

*vyāktaṃ tatha pradhanaṃ. tabhīparīḥastaiḥ ca punān |<sup>11</sup>*

Thus the *puruṣa* is *nirguṣa*, i.e. beyond the three *guṇas*. Possessing knowledge it is discerning, exceptional, conscious and constant. But, it should always be kept in mind that the *puruṣa* though possessing of *avyākā* characters of not being born of anything and eternal, it also has *vyākā*'s plural character. *Īsvara*kṛṣṇa also notes the same. All created objects are the combination of two or more of the *tri-guṇas* hence *saṅgata*, while the *puruṣa* is not so and hence is discerning. The *puruṣa* cannot be known or used as material objects. There is nothing common or mundane about it. To the contrary all unconscious things are revealed in the light of the *puruṣa* who is conscious and possessed of the said light. Commenting on the unchangeable and non-productive nature of *puruṣa* Gaudapāda notes that:

*aprasavadharmi puruṣo nahi kīṭeci puruṣatprasavyate<sup>12</sup>*

As mentioned above, the *puruṣa* does not undergo any change in reality. The 2<sup>nd</sup> *kārikā* refers to *puruṣa* as 'jñā' the knowing and not to be known. Aniruddha in *Yuktidīpikā* while discussing the term *jñā* says

*cetanāśaktirūpavā (cetanāśaktirūpatvā) cetram śūpavyatnam jānātī jñāḥ<sup>13</sup>*

The above discussion shows that in broad terms there is no major difference regarding the character and nature of *puruṣa* as stated both in the *Bhāgavata* and the *Sāṃkhyakārikā*. However, as has been stressed earlier, it should be noted that the difference in nature of the texts and their period of composition has left their marks on their interpretations of the same terms. The divergences are visible not only in the texts but in their commentaries as well and hence are targets for discovery.

Śrīdharasvāmī, the famous commentator of the *Bhāgavata*, talks about two forms of the *puruṣa* – the *jīva* and the *īvara*. The undiscerning *puruṣa* coming under the thrall of *prakṛti* and getting entangled in *samsāra* is the *jīva*. The discerning *Puruṣa*, on the other hand, controlling *prakṛti* and bringing about creation is called the *īvara* – *puruṣasca jīvesvarūpēpi bhīdīdhaḥ, tatra yoh prakṛtyavivēkena sampsarati sa jīvah, yastu prakṛtīm vaśikṛtya vīśvasyādyādi karoti sa paramēśvaraḥ*.<sup>14</sup>

Moreover in the 4<sup>th</sup> *skandha* of the *Bhāgavata* Dhruva has stated different features in characters of the *jīva* and the *īvara* thus emphasising the acceptance of two forms of *puruṣa*. *īvara* being unbound, pure, omniscient and immutable is different from the *jīva*.

*tvanti vyatiriktaḥ jīvanīlokaṇa ebasse tīṣṭhat*<sup>15</sup>

It is with the blessings of the *īvara* that *jīva* achieves salvation – *jīvestu tvat prajādānamucyate*<sup>16</sup>

*Jīva* is sullied, ignorant, somnolent, transient, exists under the auspices of the *īvara* and so the features of the *īvara* are reverse to those of the *jīva*. The difference between *jīva* and *īvara* is further clarified in the 11<sup>th</sup> *skandha*.

*suparṇavetau sadṛśīyau sokāyau yadrachaitan kṛtānīdau ca vṛkṣe /*

*ekasīyoh khūḍātī pippalānamamno niraṇno pi balen bhūyān //*

*āmānamanyāreca sa vedā vichānapippalāto na tu pippalālah /*

*yo vichāyā yuk sa tu nityabodhāo vichāmyo yoh sa tu nityamuktah // 17*

*Bhāgavata*'s contention follows Upaniṣadic thought in this regard. The *Munḍakopanishad* while talking about *jīva* and *īvara* states:

*dhvā suparṇā sayujā sokāyā somānān vṛkṣaḥ parīśvasvājāle /*

*teyoraṇyāḥ pippalān svādvanti amānamanyo avicākaṣṭī // 18*

In the *Sāṃkhyakārikā* Īśvarakṛṣṇa while stating about the plurality of the *puruṣa* never comments about its dual form – *jīva* and *īvara*. In contradiction, the *Bhāgavata* claims about its dual formal nature which, furthermore, is superseded by *bhāgavāna*, the ultimate entity. The cogitation of the *Bhāgavata* regarding the *ātmā* are deeply influenced by Vedānta. In the Vedānta the ultimate consciousness is recognised as *brahma*, *īvara* and *jīvātmā*. This idea is very much similar to *Bhāgavata*'s *paramapuruṣa bhāgavāna*, *īvara* and *jīvātmā*. This can be seen as a major difference between the approaches of the *Sāṃkhyakārikā* and those of the *Bhāgavata* regarding the *puruṣa*.

The division of the *puruṣa* as stated in the *Bhāgavata* raises the question whether it supports the existence of pluralism of *puruṣa* or the idea of a single one. A cursory glance would give the impression of it supporting the former idea. However, Prabhāda, while describing *ātmā* calls it the one (*eko*) and Śrīdhara further explains the term *eko* in his commentary quoting the *Śrauti* –

*ekah – ekamevādvitīya mīti śrauteḥ // 19*

This idea of oneness has been emphasised for several times in the *Bhāgavata* through the comments of Śukādeva in the 12<sup>th</sup> *skandha*:

*nahi satyaḥyo nānādvamānāvān yaḍi manyate /*

*namatām chidraoryachvijyotīśorvāyoraiva // 20*

Śrīdhara stresses this oneness further when he is saying 'upādhihṛta ityāha nānādvamīti'.<sup>21</sup>

It seems that the *Bhāgavata* intends to impose potentiality of *jīva*'s salvation by giving stress on the 25 principles of *Sāṃkhya* and the role of *prakṛti* and *puruṣa* in achieving consciousness i.e. the *vivēka-jñāna* without eschewing influence of Vedānta as well. Maybe the need of the bhakta for complete self-sacrifice at the feet of an individual deity pushed the *Bhāgavata* more towards Vedānta rather than *Sāṃkhya*, the latter asserting the existence of many *puruṣas*. This shows a fine differentiation between the *Bhāgavata* and the *Sāṃkhyakārikā* regarding the status and forms of *puruṣa*.

It appears that *Sāṃkhya*'s *puruṣa* in the *Bhāgavata Purāna* becomes enveloped by the idea of *avatāra*s. It should be mentioned here that *Sāṃkhya*'s idea of *puruṣa* is quite similar to *Bhāgavata*'s *avatāra-puruṣa*. In explaining the theory of creation the *paramatva* is always required for such creativity as the causative principle in all the *Sāstras* such as the *Upaniṣads*, *Darśana*, *Purānas* etc.. This causative principle has been termed as *brahma*, *paramātmā*, *puruṣa*, *bhagavāna* etc. in various texts. But as the *paramatva* is eternal, *nirguṇa* and passive, the act of creation requires the presence of another principle. This principle, a part of *paramatva*, is the *Upaniṣadic hiraṇyagarbha* or *kāryabrahma*, Vedāntic *śvara* and Puranic *puruṣavatāra*.

The idea of *avatāra* germinated in the *Purānic* texts has no relevance in the early Indian philosophical musings or *Upaniṣadic* thoughts -

*sa aikṣat bohūsyām prajāvyayam, tat sṛjtvā, tadābrahmapravāśat*<sup>22</sup>

Scholars are trying to find out that there are possibilities inherent in the *Upaniṣadic* and Vedic thoughts for existence of something akin to the idea of *avatāra* and their *filā*. The *Bhāgavata* defines *avatāra* as - *aprapñcāt prajāñce avataraṇam avatārah*<sup>23</sup>

It further notes that the creation of the universe is the result of the action of the *puruṣavatāra*, a part of the *paramatva* -

*jagathe puruṣeṣam rūpaṃ bhagavān mahadādibhūh |*

*śambhūtaṃ soḍaśakalāmādaṇi lokasīrṣṭyavā ||*<sup>24</sup>

While describing the nature of *bhagavāna* the *Bhāgavata* recounts that the presence of *Puruṣa* activates *Prakṛti* to create. This *Puruṣa* referred to as *bhūtmā puruṣa* is nothing but an *avatāra* of the *paramatva*.

*śūryo 'vatārah puruṣoḥ parasya*<sup>25</sup>

The idea of *Bhāgavata puruṣavatāra* in its role as the catalyst of *prakṛti*'s efforts to create is majorly similar to the ideas as expounded by the *Sāṃkhya*, especially *Sāṃkhyakārikā*. However, it can be stressed enough that in the *Bhāgavata*, *puruṣa* is not the independent principle as it is dependent on other principles. The *prakṛti-puruṣa tatva* is the ultimate principle in the *Sāṃkhya* system but this *tatva* is not of much importance in the *Bhāgavata*. This is emphatically postulated time and again in the *Bhāgavata*. Mahādeva in his dialogue to *Bhāgavāna* says that someone calls you *bhagavāna* while *parapuruṣa* of the *prakṛti-puruṣa* by others.

*tvām brahma keśīdānanyanyūta dharmameka eke paraṃ sadāśatoḥ puruṣaṃ parameṣam |*

*Śrīdhāra* in his commentary says something alike when he clearly states that the Vedāntics refer to *bhagavāna* as *śābha* while *Sāṃkhya* talks about it as *parapuruṣa*, who is, in fact, above the *prakṛti-puruṣa*.

*tvām brahma vedānitino 'vāñānta manvante |...prakṛtipuruṣayoh paraṃ pumaṅsam sāṃkhyub |*<sup>27</sup>

That the *Sāṃkhya* system accepts *bhagavāna* as a principle above the *puruṣa*, is admitted by the *Bhāgavata*. But the *Sāṃkhyakārikā* does not give recognition to the statement of the *Bhāgavata*. The existence of the *paramatva* at the top of the *puruṣa*, which moreover, is seen as a part of the former relegates the *Sāṃkhya-puruṣa* to dependence. *Puruṣa* in the *Sāṃkhya* system is glorious in its independence and unfettered. It is the *paramatva* and not the *bhagavāna*. Gauḍapāda in his commentary of '*tadviparītaśābha pumān*' explicates the term '*śābha*' of this *kārikā* thus -

*kiñ ca paratāntarāṃ vyaktiṃ svatantramavyaktiṃ lābhāca pūñānti svatantrāḥ*<sup>28</sup>

In conclusion it should be stated that though there are differences between the two texts regarding the status of *puruṣa* and the existence or non-existence of principles higher on the hierarchy than *puruṣa* its importance as well as its role in Creation is the common platform where *Bhāgavata* and *Sāṃkhyakārikā* completely agree with each other. Both agree to the theory that it is the unification of *prakṛti* and *puruṣa* that germinates the universe. Even *Bhāgavata* with its insistence of the supra-*puruṣa* principle of *paramatattva* or *paramātmā* complies with the existence of the *prakṛti-puruṣa* theory as the first condition of creation. The *Śrīmad Bhāgavata*, the scripture of eternal emancipation is full of devotional sentiment. Thus, in this devotional scripture the philosophical thought which is apparently less in sentiment, is germinated by the devotional sentiment and finally it is manifested in a new form in the world of philosophy.

Note: BP in the endnotes stands for *Śrīmad Bhāgavata Purāna*

### Endnotes

- 1 Hulín, p. 127
- 2 *Basel*, p. 4
- 3 Larson, p. 15
- 4 BP 3.26.3, p. 1191
- 5 BP 7.7.19, p. 2811
- 6 *Isopanisad* 3, p. 5
- 7 Śrīdhara's Commentary, BP 3.26.3, p. 1191
- 8 Śrīdhara's Commentary, BP 7.7.19, p. 2811
- 9 *ibid*, p. 2811
- 10 *ibid*, p. 2811
- 11 *Sāṃkhyakārikā* 11, p. 117
- 12 Gauḍapāda's Commentary, *Sāṃkhyakārikā* 11, p. 55
- 13 *Yuktidīpikā, Sāṃkhyakārikā* 2, p. 55
- 14 Śrīdhara's Commentary, BP 3.26.4, p. 1191
- 15 Śrīdhara's Commentary, BP 4.9.15, p. 1468
- 16 *ibid*, Śrīdhara's Commentary, p. 1468
- 17 BP 11.11.6, p. 163-64
- 18 *Muṣkōkopaniṣad* 3.1.1, p. 165
- 19 Śrīdhara's Commentary, BP 7.7.19, p. 1191
- 20 BP 12.4.30, p. 499
- 21 Śrīdhara's Commentary, BP 12.4.30, p. 500
- 22 *Tribhāga-sāṃkhyasūtrī*, BP 1.3.1, p. 70
- 23 *ibid*
- 24 BP 1.3.1, p. 70
- 25 BP 2.6.42, p. 593
- 26 BP 8.12.9, p. 3074
- 27 Śrīdhara's Commentary, BP 8.12.9, p. 3075
- 28 Gauḍapāda's Commentary, *Sāṃkhyakārikā* 11, p. 57

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# Salun: A potters' village; Sociology of Pottery Making Culture in a Village in the District of Purba Bardhaman

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The history and development of ceramic art and industry is traced by an enquirer since remote antiquity till recent times. The development of ceramic art and industry is closely intertwined with the socio-cultural aspects of life led by those who devoted themselves throughout to the ceramics popularly known as potters, *Kumor* or *Kumbhakar*s. The ethno-archaeological study centering round the ceramics is spread over a vast territorial jurisdiction of this country. But at present I have concentrated only on the district of Purba Bardhaman. The areas surveyed by me in this district include rural, semi-urban, urban areas inhabited by a large number of potters' families, those who are divided among castes and sub-castes with their characteristic socio-cultural orientation. This study is an attempt to make an in depth study of the socio-cultural cum economic aspects of the ceramic artists' inhabiting in some parts of Purba Bardhaman District. The potters of these areas are found to follow their age-old or traditional techniques with some modern ones. My contention may be verified by the actual survey I have made in the village Shalun, in this district.

The district of Purba Bardhaman is geographically divided by river Damodar from the district of Bankura. On the southern part of the district we find a number of blocks. Khandogosh is one of such blocks that have a number of potters' dominated villages. On the northern part of this block we see a small village Salun. Salun is a Hindu dominated village with multi caste settlements grown in the village. Beside the large concentration of potters, we find here different Hindu caste groups such as *Brahmin*, *Kayastha*, *Goala*, *Kamar*, *Bene*, *Bagdi*, *Bouri* etc. Census 2001 confirms us that it encompasses an area of 280.0 hectares of land with a big population of 3060, of which 1552 are male and 1508 are female. This large section of people live in 7 localities divided into 644 households. This report enumerates that the village has a sizeable schedule caste population of 1486 and with 192 schedule tribe people.<sup>1</sup>

Salun is connected with Bardhaman town and with Bankura by a pacca road. The village has two Primary schools, one I.C.D.S. centre, one Adult Literacy Centre, one Sub- health Centre etc. The village stands nearer to river Damodar as well as to river Shali. So the village is enriched by alluvial soil of Damodar basin. The land of this area is much fertile for growing crops. The villagers have been enjoying wide spread irrigation facilities. A fair number of villagers directly or indirectly depend on agriculture.<sup>2</sup> Census 2001 records that, the total numbers of workers in the village is 1346 among which 172 are cultivators and 445 are agricultural labourers. The report also reveals that the number of household workers in the village is 92. Salun is well known in the district as a potters' village. The chief cottage industry in the village is pottery though the village has developed some brick industry as well.<sup>3</sup>

river-sand and kiln-ash as temper. Colour clay or pigment, another important raw material known as *Banak* and used as slip is obtained from a village field near Sonamukhi, Bankura. Two types of slips are used, red and white, known to the potters as '*Lal Banak*' and '*Kalo Banak*'. At present the potters go in a group to collect this colour clay and bring it jointly which costs nearly Rs. 3000/ per truck.

### Slip-

Like the *Radhi* potters of Bardhaman, Bankura and Birbhum the potters of Salun make slips of two colours stated above, through the process of decantation with the help of rain water.<sup>13</sup>The experienced potters maintain that a good quality of red slip could only be obtained from rain water. Slips are applied on both side of rim, neck, and on belly portion of the exterior side of a vessel. (Fig.-11)

### Kiln (*Poan*)

Kiln is of two types vertical and horizontal, both of which are used by the potters of West Bengal as well as of India.<sup>14</sup> The potters of Salun bake their vessels only in a vertical kiln (*Gol Poan*), unlike the potters of other districts in West Bengal. (Fig.-12) Kiln is known to them as '*Pon*,' '*Poan*' or '*Shal*'. There are 14 kilns in the village which are used by the 21 potters' families working in the village. All the kilns are of vertical type with two different shapes, rectangular and circular, though the former one being a few in numbers. It is learnt that previously they used horizontal kiln (*Kulo Pon*), but at present they use only vertical one with having a number of perforations on its girth. The size of this type of kiln varies between 8 feet to 10 feet in diameter in case of circular one and in case of rectangular; it ranges between 8 feet to 12 feet in length and 6 feet to 9 feet in breadth. The girth or the muffle stands almost 36 inches above the ground. The potters of this village make the kiln chamber wide enough. The size of the perforated girth indicates that at least 350 to 400 vessels of different sizes can be accommodated at a time for firing. The vessels are arranged inverted in a circular manner. (Fig.-13)

### Fuel (*Jal*)

The potters use saw dusts, hays, dry leaves etc. as fuel. While arranging the vessels, it is seen that they put pieces of woods in between the rows to make the pots baked well. They hold that it takes about 4 hours to bake the vessels well. Cost of firing as told by them is Rs. 900 to 1100 per firing. It is also learnt that at the initial stage of first two hours, fuels are supplied slowly and after that the intensity of supplying fuels is increased and are fed fast. The potters of Salun maintain that they bake 350 to 400 pots at a time in a kiln which worth about Rs. 3000 to 4000, of which Rs. 2000 to 2500 come as profit to them. It is also learnt that most of the potters fire their pots once or twice in a month, with the exceptions of Jaladhar Pal and Haladhar Pal (Two brothers) who can arrange the same once in a week. (Fig.-14)

### Throwing of vessels on wheel (*Bhiyano*)

In the process of manufacturing vessels throwing is the principal job or making of the vessel by wheel. Whether it is wheel made or hand made every vessel has to go through the process of manufacturing by a wheel. Throwing is the process rather different stages of manipulation of fingers by the potters to make a pot or vessel. (Fig.- 6,7) This stage actually exhibits their craftsmanship or excellence to make various pots wit different shapes and designs.

**Marketing** --It is well known to the people of Bardhaman, Birbhum and Bankura that Salun is famous for its traditional earthen ceramic or pottery. The potters sell their products through agents and by them from their houses as well. The aged potters hold that their products had a larger market in the districts of Purba and Paschim Bardhaman, as well as in Bankura too. It is learnt that they generally sell their product in different village *Hat*, such as in Khandogosh, Rasulpur and in Patrasayer etc and in various shops in Bardhaman town. They also hold that a number of male and female agents from neighboring villages as well as from different places



Fig.13. Arrangement of vessels on kiln



Fig.14. Firing in kiln



Fig.15. Wheel made vessels (Red Ware)



Fig.16. Wheel made vessels (Black Ware)





# THE STUDY OF TRADITIONAL POTTERY MAKING IN WEST BENGAL AND ITS CONNECTION WITH MEGALITHIC CULTURE

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## **Introduction**

The present paper is an attempt to explore the possibility for tracing the relationship of the pottery making activities between the potters of Megalithic culture and the others of eastern India. Though my basic knowledge about pottery making activities and the communities involved in such activities with reference to West Bengal, in this paper I have tried to trace the relationship of the above cultural matrix. We are aware about the fact that the Chhotanagpur plateau played an important role in the evolution of so called Megalithic Cultural tradition both informed as Sepulture and the non-sepulchral. It is also evident from the wide distribution of Dolman, Menhir and other types of memorial stones including Vir Sthambha (Hero stone) and other.<sup>1</sup> Pottery is also reported from such Megalithic site. In this context it is to be noted that Asura cultural sites of the core areas of Chhotanagpur plateau like Palamo, Ranchi, Santal Pargana, Singbhum areas had association with Megalithic tradition.<sup>2</sup> Hope my paper will also focus on the pottery making activities of Asura culture and its association with West Bengal pottery making activities. Excavation at Saratkhel (Ranchi) confirmed the pottery making activities of Asura culture bearing social groups and their association with so called Megalithic Culture. Therefore, I will also try to trace the relationship between the tribal communities and the non-tribal communities of Eastern India in the context of pottery making activities. This study is

**Forming** (*Garan Kara or Uchho Dewa*) –The stage of forming succeeds thinning the wall. In this stage we observe the use of a tool first in the process of throwing. The tool which helps to some extent to give the desired shape of the vessel is called *Uchho*. It is a bamboo shaper.

**Collaring-** It is the technical acumen of a potter that forms various types of rim and neck of a pot with his fingers and the bamboo shaper. Here is an interesting point to be noted that each and every wheel thrower of a village has got a distinct feature of his product so far the neck and rim of a vessel is concerned. **(Fig.-5)**

**Smoothing-** (*Nyata Dewa*) Smoothing of a vessel while on wheel, takes place after the stage of collaring. Smoothing is done generally either by a wet mop which the potters call as '*Nyata*' or by the bamboo shaper (*Ucho*).

**Cutting off-** (*Pagui Namano*) Once the act of smoothing is completed the potters get them ready to detach or cut off the vessel from the remaining clay. Here an important point is to be noted that thread is used only in cases of small vessels, which are made complete on wheel. On the other hand a needle or a small thin bamboo slice is used to detach those vessels which are made half or incomplete, keeping a hole on the lower portion for luting to make them complete. The *Konnoujia* and *Maghaiya* potters of Malda, the tribal potters and the traditional potters of Bengal use thread to detach pot since all of them make large and medium size vessels pots on wheel.

The megalithic vessels recovered from Ranchi District and from other sites of Jharkhand and Bihar are mostly wheel turned and medium to thick fabric. The bowls, dishes, large and deep basins, large and medium vase and Handi or other cooking vessels recovered from those sites must had required joining or luting as it is said earlier.

**Beating after throwing-**Beating of wheel thrown pots is entirely done by the potter himself or by any male member of his family. It is only in case of handmade vessels where female potters are seen to beat vessels to make them complete one. It is to be noted that the potters of various groups entirely depend on their women folk for manufacturing handmade pots. Beating is done to enlarge a vessel as well as to give it the required shape with the help of an anvil and beater. The *Konnoujia* and *Maghaiya* potters in the districts of Purba Bardhaman, Bankura and Birbhum do not require beating since they manufacture complete small pots.

**Slip treatment-** Use of slip in earthen ceramics is a well known phenomenon in pottery manufacturing technology. It is important to note that categorization of ceramics in India is done according to the slips applied on them. For example, when we say Northern Black Polished ware, it presumes the slip of black applied to them. Archaeological excavations in Ranchi district as well as in other areas of Jharkhand, Bihar and in Chhotanagpur plateau areas unearthed kinds of potteries not only with various shapes and fabrics but



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## শ্রীমদ্ভাগবতমহাপুরাণ ও সাংখ্যকারিকার প্রকৃতি-ভাবনা :

### একটি তুলনাত্মক আলোচনা

মণিমালা মণ্ডল

#### সারসংক্ষেপ

ঈশ্বরকৃষ্ণের সাংখ্যকারিকা ও শ্রীমদ্ভাগবতপুরাণ - এই উভয় গ্রন্থে প্রকৃতিতত্ত্বের স্বরূপ নিরূপিত হয়েছে। প্রকৃতির স্বরূপ, ধর্ম, সৃষ্টি প্রক্রিয়ায় তার ভূমিকা, এই সকল গুরুত্বপূর্ণ বিষয় সমূহকে উভয় গ্রন্থের নিরিখে পর্যবেক্ষণ করে দেখা যায় অধিকাংশ ক্ষেত্রে তাদের পরস্পরের মধ্যে তেমন কোন মতপার্থক্য নেই, বরঞ্চ মতাদর্শগত সাদৃশ্যই বেশি চোখে পড়ে। প্রকৃতি অহেতুমৎ, ত্রিগুণাত্মক, অবিবেকী, বিষয়, সামান্য, অচেতন এবং প্রসবধর্ম বিশিষ্ট - সাংখ্যকারিকায় এই ব্যক্তব্য সম্পূর্ণ অবিকৃত রয়েছে শ্রীমদ্ভাগবতে। সেইরূপ জগৎ সৃষ্টিতে প্রকৃতির ভূমিকা উভয়ত্র প্রায় একই রকম ব্যাখ্যাত হয়েছে। পুরুষের সান্নিধ্যে প্রকৃতির সংক্ষোভের বিষয় নিয়েও কোন মতান্তর নেই। তবে আধারের প্রকৃতি আধেয় যেহেতু কিছুটা প্রভাবিত হয়ে থাকে তাই একই প্রকৃতিতত্ত্বগত চিন্তায় গ্রন্থদ্বয়ের নিজস্ব মৌলিক চিন্তার কিছুটা ঘটেছে। সাংখ্যকারিকায় প্রকৃতিতত্ত্ব সম্পূর্ণ স্বতন্ত্রতত্ত্ব রূপে প্রতিপাদিত হয়েছে, এখানে প্রকৃতি স্বাধীন। শ্রীমদ্ভাগবত প্রকৃতির স্বতন্ত্রতা সেইভাবে অক্ষুণ্ণ থাকেনি, প্রকৃতি এখানে পরাধীন।

শব্দসংকেত : সাংখ্যকারিকা, শ্রীমদ্ভাগবতপুরাণ, ঈশ্বরকৃষ্ণ, প্রকৃতি, গুণত্রয়, স্বতন্ত্র

সাংখ্যাচার্য্য ঈশ্বরকৃষ্ণ বিরচিত সাংখ্যকারিকা গ্রন্থটি সাংখ্যদর্শনের অন্যতম প্রামাণ্য গ্রন্থ রূপে প্রসিদ্ধ। এই গ্রন্থে সাংখ্যদর্শনের অন্যান্য তত্ত্বের সঙ্গে মুখ্যতত্ত্ব প্রকৃতির স্বরূপ প্রতিপাদিত হয়েছে। অন্যদিকে শ্রীমদ্ভাগবতমহাপুরাণ হল বৈষ্ণব সম্প্রদায়ের অন্যতম আকর গ্রন্থ। এই গ্রন্থেও ভগবত্তত্ত্বের আলোকে প্রসঙ্গে সাংখ্যদর্শনের অন্যান্য তত্ত্বের সঙ্গে প্রকৃতিতত্ত্বের স্বরূপ আলোচিত হয়েছে। সাংখ্যকারিকা দর্শন গ্রন্থ, শ্রীমদ্ভাগবত ভক্তিমূলক গ্রন্থ এবং গ্রন্থদুটি ভিন্ন ভিন্ন সময়ে রচিত। সাংখ্যকারিকার রচনাকাল আনুমানিক খ্রিস্টীয় চতুর্থ থেকে পঞ্চম শতক<sup>১</sup> এবং ভাগবতের রচনাকাল আনুমানিক খ্রিস্টীয় একাদশ থেকে দ্বাদশ শতক।<sup>২</sup> সেই কারণে দুটি গ্রন্থে প্রতিপাদিত একই প্রকৃতিতত্ত্বগত ভাবনা স্বাভাবিক ভাবে

- <sup>১০</sup> তত্ত্বকৌমুদী, সাংখ্যকারিকা - ৩, পৃ. ৩৬।
- <sup>১১</sup> সাংখ্যকারিকা - ৩, পৃ. ৩৫।
- <sup>১২</sup> তত্ত্বকৌমুদী, সাংখ্যকারিকা - ৩, পৃ. ৩৬।
- <sup>১৩</sup> মাঠরবৃত্তি, সাংখ্যকারিকা - ৩, পৃ. ১১২।
- <sup>১৪</sup> ভাগবত - ৩/২৬/৪, ১১৯১।
- <sup>১৫</sup> শ্রীধরটীকা, ভাগবত - ৩/২৬/১০, পৃ. ১১৯৪।
- <sup>১৬</sup> মাঠরবৃত্তি, সাংখ্যকারিকা - ২, পৃ. ১১২।
- <sup>১৭</sup> শ্রীধরটীকা, ভাগবত - ৩/২৬/১০, ১১৯৪।
- <sup>১৮</sup> গৌড়পাদভাষ্য, সাংখ্যকারিকা - ১০, পৃ. ৫২।
- <sup>১৯</sup> তত্রৈব।
- <sup>২০</sup> ভাগবত - ৩/২৬/৪, পৃ. ১১৯১।
- <sup>২১</sup> শ্রীধরটীকা, ভাগবত - ৩/২৬/৪, পৃ. ১১৯১।
- <sup>২২</sup> ভাগবত - ৩/৭/৪, পৃ. ৮৪৪।
- <sup>২৩</sup> তদেব - ৮/১২/৩৮, পৃ. ৩০৮১।
- <sup>২৪</sup> গৌড়পাদভাষ্য, সাংখ্যকারিকা - ২২, পৃ. ৯৪।
- <sup>২৫</sup> সাংখ্যপ্রবচনভাষ্য, সাংখ্যসূত্র - ১/৯২, পৃ. ৭০।
- <sup>২৬</sup> সাংখ্যসূত্র - ১/৯২, পৃ. ৭০।
- <sup>২৭</sup> তত্ত্বকৌমুদী, সাংখ্যকারিকা - ৫৭, পৃ. ৩৩৩।
- <sup>২৮</sup> সাংখ্যকারিকা - ৩১, পৃ. ২৪২।

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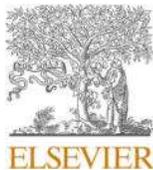
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## Immunotoxic role of organophosphates: An unseen risk escalating SARS-CoV-2 pathogenicity

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### ABSTRACT

Consistent gathering of immunotoxic substances on earth is a serious global issue affecting people under pathogenic stress. Organophosphates are among such hazardous compounds that are ubiquitous in nature. They fuel oxidative stress to impair antiviral immune response in living entities. Aside, organophosphates promote cytokine burst and pyroptosis in broncho-alveolar chambers leading to severe respiratory ailments. At present, we witness COVID-19 outbreak caused by SARS-CoV-2. Infection triggers cytokine storm coupled with inflammatory manifestations and pulmonary disorders in patients. Since organophosphate-exposure promotes necroinflammation and respiratory troubles hence during current pandemic situation, additional exposure to such chemicals can exacerbate inflammatory outcome and pulmonary maladies in patients, or pre-exposure to organophosphates might turn-out to be a risk factor for compromised immunity. Fortunately, antioxidants alleviate organophosphate-induced immunosuppression and hence under co-exposure circumstances, dietary intake of antioxidants would be beneficial to boost immunity against SARS-CoV-2 infection.

### 1. Introduction

With the advancement of scientific revolution, human beings have made the existing anthropocene more comfortable for their daily life. From agricultural field to the industrial sector, human populations are blessed with the use of modern technologies and equipments, which not only reduce energy for production but also enhance yield at the same time. But the darker side of such advancement includes consistent gathering of detrimental chemicals in the environment contaminating almost every component of biosphere. These chemicals have secured their apparent presence in several drugs, food stuffs, household products, drinking water, agrochemicals and so on. Organophosphates (OPs) are among such hazardous compounds that are being globally used on a

regular basis.

OPs are amides, esters, or thiol derivatives of phosphoric acid. These chemicals are extensively used in agriculture, horticulture, forestry, veterinary-medicine, domestic purpose and also for the control of vector-borne diseases. Certain OPs are being used to treat head-lice, scabies and crab-lice in humans (Idriss and Levitt, 2009). In agricultural sector, OPs are extensively applied to eradicate pests including locusts, aphids, leaf miners, fire ants, thrips and caterpillars. These pesticides augment both quantity and quality of agricultural products (Chang et al., 2017). OPs namely tris-(2-chloro, 1-methyl-ethyl) phosphate, tris-(2-chloroethyl) phosphate, tri-n-butyl phosphate, tri-iso-butyl phosphate, triphenylphosphate and tris-(butoxyethyl) phosphate are admired flame retardants and plasticisers at public places

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suppressor of cytokine signaling-3 (SOCS3) which acts as negative regulator of cytokine signaling. Results from a cytokine/chemokine secretion analysis revealed the proinflammatory properties of Tris (1, 3-dichloropropan-2-yl) phosphate, Triphenyl phosphate and Tris (2-butoxyethyl) phosphate (Li et al., 2020). These compounds reduce the production of anti-inflammatory cytokines (IL-10 and IL-13) and trigger the release of proinflammatory cytokine (TNF- $\alpha$ ). In another study, exposure to chlorpyrifos suppressed production of IFN- $\gamma$ , TNF- $\alpha$  and IL-6 following LPS stimulation in mice (Singh et al., 2013). *In vitro* study by Zhao et al. (2020) has claimed that, malathion can suppress the synthesis of IL-2, IFN- $\gamma$ , IL-4 and granzyme-B whereas chlorpyrifos is able to decrease the production of IL-6 in splenic lymphocytes.

#### 4.6. Suppressed delayed-type hypersensitivity reaction

Delayed-type hypersensitivity (DTH) is a reflection of cell mediated immune response. Study conducted by Moon et al. (1986) revealed that, subchronic exposure of rodents to certain OP compounds viz. fenitrothion, fenthion and diazinon resulted in marked suppression of DTH and Arthus reaction. Malathion applied epicutaneously for 2 days or over 4 weeks failed to elicit DTH in female BALBc mice pointing towards impaired cell mediated immune response (Cushman and Street, 1983). Immunotoxicological investigation by Undeger et al. (2000) using footpad swelling assay revealed that, dimethoate at a dose of 28.2 mg/kg/day reduced DTH reaction in treated rats. A dose dependent decrease in DTH was also observed following exposure to phosphamidon. Ethephon, at a dose rate of 1995 ppm suppressed DTH response to SRBC as measured by thickness of edema in hind paw in mice (Abou-Zeid et al., 2018). Similar observation was recorded following exposure to diazinon at a dose of 10 mg/kg in male Wister rats (Ibrahim, 2014). In a recent study, acute intoxication of malathion (0.5 LD<sub>50</sub>) resulted in reduced function of Th1 lymphocytes, DTH reaction and production of IFN- $\gamma$  in random-bred albino rats. Monocrotophos suppresses DTH reaction, lymphocyte count and lymphocyte stimulation in sheep (Khurana and Chauhan, 2003). Low dose oral exposure to acephate can modulate humoral immune response and DTH response to SRBCs in rodents (Sankhala et al., 2012).

#### 4.7. Autoimmune responses

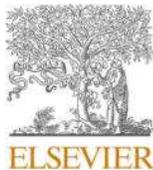
There is small but evolving body of literature that advocates OP induced autoimmune responses leading to several chronic manifestations. Systemic autoimmunity is measured by anti-nuclear antibodies. OP insecticide diazinon has been positively associated with serum antinuclear antigens in occupationally exposed male farmers (Parks et al., 2019). In another finding, farmers having experience of long-term exposure to diazinon, fenitrothion, methidathion, malathion, chlorpyrifos, parathion and profenofos had elevated level of blood antinuclear antibody. Rheumatoid arthritis (RA) is a systemic autoimmune inflammatory disease. Its incidence of occurrence was higher in fonofos applicators (Meyer et al., 2017). Koureas et al. (2017) conducted a cross sectional study among pesticide sprayers dealing with chlorpyrifos, phosmet and dimethoate in Thessaly (Greece). Multinomial analysis revealed that, frequencies for RA and allergic rhinitis were significantly higher in OP pesticide sprayers compared to control group. Rheumatoid factor (RF) is the autoantibody that targets healthy tissues in the body. Rodgers (1997) has reported that, malathion administration at non-cholinergical doses can potentially increase serum RF and anti-dsDNA antibodies. Moreover, it can exacerbate progression of systemic lupus erythematosus which is an autoimmune disease with diverse clinical and immunological manifestations. Long-term exposure to dichlorvos can promote development of autoimmune hepatitis (Zhao et al., 2015). Thus, OP compounds have certain implications for autoimmunity and organ damage.

### 5. Mechanism of immunotoxicity: OPs versus SARS-CoV-2

People with under-performing immune system may be at high-risk of receiving SARS-CoV-2 infection. They may also remain infectious for a longer duration than others. Numerous studies have claimed that, OP induced disruption of immune system may intervene antiviral immune responses. OP compounds are the promoters of apoptosis in lymphoid organs. Studies have shown that, OP mediated cell death is triggered by increased levels of pro-apoptotic proteins (Bax and caspase 3) and reduced levels of anti-apoptotic proteins (p-Akt and Bcl2) (Venkatesan et al., 2017). Moreover, OP triggers activation of NF- $\kappa$ B via p53 signaling pathway that further escalates tissue damage (Lee et al., 2014) in lymphoid organs. Cellular demise in thymus, spleen and lymph nodes results in reduced titer of neutralizing antibodies against viral infection (Matter et al., 2011). Immunocytes like NK cell, LAK cell and CTL play crucial role in clearance of virally infected cells by releasing serine proteases (granzymes). OP inhibits activity of these serine proteases to impair cell mediated anti-viral functions. In addition, FasL/Fas pathway is targeted by OP compounds to hinder the activity of killer cells (Li, 2007). OPs injure dendrites of DCs more likely through inhibition of protein kinases such as Akt family or ERK which are essential for cell proliferation and survival (Schäfer et al., 2013). Pro-oxidative impact is exerted via Cytochrome P450 based ROS production. ROS can overwhelm the cellular antioxidant status to manifest OS - a major trigger to necroptosis, pyroptosis, and parthanatos in immunocytes (Robinson et al., 2019). Alongside, ROS mediated disruption of mitochondrial membrane exposes cardiolipin and mtDNA to cytosol thus provoking NLRP3 to compose inflammasome (Iyer et al., 2013). C-reactive proteins are elevated following OP exposure and higher level of this inflammatory marker can contribute to immunosuppression (Yoshida et al., 2020; Taghavian et al., 2016). IFN constitutes the first line of defense against viral infections (Ivashkiv and Donlin, 2014). Inability to mount an effective IFN-response results in systemic infection (Baskin et al., 2009). Efficiency of a virus to evade IFN-response is crucial for viral replication, transcription and onset of pathologies (Iyer et al., 2017). Virions unable to escape IFN-response, usually fail to replicate in host (Iyer et al., 2017). OP promotes IFN-depletion (Singh et al., 2013) and therefore can rupture the protective-shield against viral-attack.

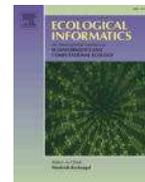
Similar to OPs, SARS-CoV-2 can be detrimental to immune machinery and convergence of both can worsen the outcome of COVID-19. Virions utilize ACE-2 receptors to invade target cells. However, certain essential oils like geranium and lemon strongly reduces expression of ACE-2 in epithelial cells that can subvert viral invasion (Senthil Kumar et al., 2020). Molecular docking and molecular dynamics studies have revealed that, hesperidin can distort the bound structure of ACE-2 and spike protein fragment that could have potential anti-SARS-CoV-2 implication (Basu et al., 2020). However, many structural, non-structural and accessory proteins of SARS-CoV-2 adopt multiples strategies to modulate cytosolic interactome and subsequent immune function (Fig. 1). For instance, ORF8 down-regulates MHC-I to disrupt antigen presentation by macrophages and DCs (Park, 2020). Indeed a recent literature has demonstrated that, ORF-8 can directly bind to MHC-I molecule at endoplasmic reticulum to drive auto-lysosomal degradation (Zhang et al., 2020a,b). NSP5 interacts with epigenetic regulator histone deacetylase-2 to modulate MHC-II expression and cytokine production (Gordon et al., 2020). SARS-CoV-2 infection promotes subverted IFN-I synthesis in patients (Acharya et al., 2020). Such response is facilitated by coronavirus PLpro that disrupts IFN genes such as STING-TRAF3-TBK1 complex (Báez-Santos et al., 2015). In addition, other SARS-CoV-2 proteins like NSP13, NSP14, NSP15 and ORF6 have been suggested to antagonize IFN function by suppressing nuclear localization of IRF3 (Yuen et al., 2020). Notably, viral M protein interacts with RIG-1/MDA-5/MAVS signaling pathway to hinder IFN-I and IFN-III production (Zheng et al., 2020). Interestingly, certain essential oil components such as (E,E)- $\alpha$ -farnesene, (E,E)-farnesol and (E)-nerolidol have better binding affinity for SARS-CoV-2 proteins like Mpro

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## Importance of benthic-pelagic coupling in food-web interactions of Kakinada Bay, India

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### ABSTRACT

Benthic components occupy the sediment layer of aquatic ecosystems and play a definitive role in overall system functioning and maintenance. The exchange of inorganic and organic materials between the sediment and water column through benthic-pelagic coupling plays a very important role especially in shallow water ecosystems. It is facilitated mainly by trophic interactions between the benthic and pelagic food webs, or specifically, between the coupling links i.e. the nodes that participate in coupling. Aquatic ecosystem models incorporating benthic food web in details have been few. In the present study, a food web model incorporating both benthic and pelagic food webs has been developed using EcoPath with EcoSim software, for Kakinada Bay ecosystem of Coastal Andhra Pradesh, India and has been analysed to get an idea about this system's functioning and integrity. Hypothetical perturbation scenarios (perturbation of biomass of two important benthic components – microphytobenthos and suspension feeding invertebrates) were applied to the model to study the effects of these two components on overall system robustness and integrity. The analysis of the base model revealed that while the bay system has not yet attained maturity, it also does not face much stress. While the system saw a decline in maturity with increase in microphytobenthos (MPB) biomass, increase in biomass of suspension feeding invertebrate (SFI) resulted in the exact opposite. Study of SFI biomass perturbation scenario also highlighted its role in coupling. Modelling studies incorporating benthic components as separate groups have been few. This work aims to provide a better insight into how benthic components may affect the whole system. Information regarding system health and resilience provided by such models can also be used as guidelines for fishery management and policy making.

### 1. Introduction

Benthic organisms, also called 'benthos', comprise of a community of organisms that occupy the sediment layers of intertidal coastal zones and open ocean or freshwater aquatic ecosystems. In shallow ecosystems where light reaches the sediment, i.e. in the euphotic zone, phyto-benthos (photosynthetic bacteria and benthic algae) can flourish and photosynthesize (MacIntyre et al., 2004). Though, macrophytobenthos are also present, microphytobenthos (MPB) (consisting primarily of microscopic photosynthetic algae) has a much higher contribution to the

productivity of the benthic system (Daehnick et al., 1992). It has been estimated that MPB assemblages can contribute up to 50% of the total estuarine autochthonous primary production (Underwood and Kromkamp, 1999). Thus understanding roles played by different benthic components in a system is of paramount importance when delving into sustainable management practices.

The benthic food chain predominantly comprises of detritivores and scavengers as primary consumers. Filter feeders such as sponges and bivalves (seen to occupy hard sandy bottom layers) and deposit feeders such as polychaetes (present on softer bottom layers) are other

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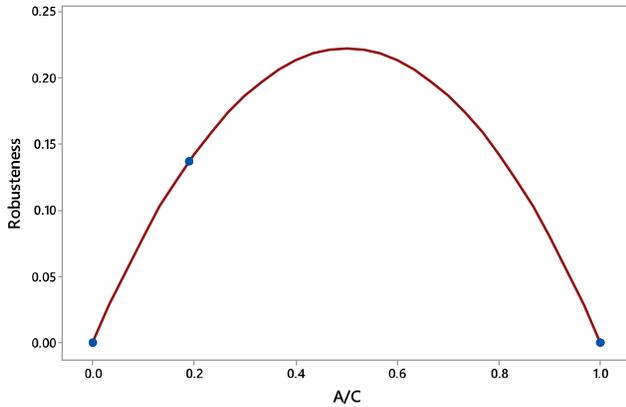


Fig. 3. Relation between degree of order and the corresponding robustness of the unperturbed system.

(Fig. 5c). Detritivory to herbivory ratio ( $D/H$ ) however follows an opposite trend and decreases as MPB biomass increases (Fig. 5c).

System robustness value increased up to 5.91% of system base value with decrease in biomass and up to 4.67% of the same with increase in biomass (Fig. 5b & 6).

The exergy value followed an increase in the biomass of MPB and showed an increase of 15% from the system base value at the highest biomass of MPB (Fig. 7).

3.2.2. Suspension feeding invertebrates perturbation scenario

Both  $TST$  and  $FCI$  values show an increasing trend along with increase in biomass of SFIs (Fig. 8a). Unlike the MPB perturbation scenario, redundancy is directly proportional and  $A/C$  is indirectly proportional to biomass of the SFIs (Fig. 8b).

An increase in SFI biomass was accompanied by a decrease in  $TPP/TR$  and  $TPP/TB$  ratios and increase in  $D/H$  ratio (Fig. 8c).

System robustness was also indirectly proportional to SFI biomass and showed a range of  $-1.06\%$  to  $3.91\%$  of system base value (Fig. 8b & 9).

Exergy value showed almost 18% increase at the highest biomass

value of SFI (+99%) (Fig. 7).

4. Discussion

4.1. Unperturbed scenario →

The average ecosystem trophic level for the Kakinada Bay is 2.67 which is quite similar to the same for Hooghly-Matla estuarine system, India (2.72; Rakshit et al., 2017) but a bit higher than the average trophic level of Kuosheng Bay, Taiwan (2.35; Lin et al., 2004). The difference in the trophic level between Kakinada bay and Kuosheng bay may be attributed to the fact that the Kakinada bay model has higher number of carnivorous fish groups.

The Kakinada Bay trophic model comprised of ten discrete trophic levels and the mean transfer efficiency of 12.94% was found to be comparable with Chiku Lagoon (12%; Lin et al., 1999) and Tongoy Bay (14%; Wolff, 1994). The transfer efficiency is however quite higher than that of Kuosheng Bay (6.5%; Lin et al., 2004); the difference is due to the comparatively lower  $D/H$  ratio of Kakinada Bay which indicates that the flow to detritus is higher in Kuosheng bay than in Kakinada bay. This correlation between  $D/H$  ratio and trophic transfer efficiencies is evident in other systems as well (Table 5). Most of the transfer efficiencies of this system (Table 1) were found to be within the range of 10%–20% commonly reported in literature Odum and Barrett (1971).

Both  $TPP/TR$  (1.29) and  $TPP/TB$  (3.36) indicate the system is yet to attain maturity since  $TPP/TR$  approaches unity and  $TPP/TB$  ratio declines as the system approaches maturity (Christensen et al., 2005).

The total system throughflow of Kakinada Bay ( $169.17 \text{ t km}^{-2} \text{ year}^{-1}$ ) is quite low when compared to the  $TST$  of other similar systems (Table 5) even though the total biomasses of the different systems were comparable.  $TPP/TB$  ratio of Kakinada Bay is much lower than that of the other systems cited which accounts for the low  $TST$  (Heymans et al., 2002). The low  $TST$  value in turn results in low  $A/C$  ratio.

This is evident from the robustness value of the system which lies outside of the ‘windows of vitality’ towards the left-hand side (Fig. 2) indicating that while the system is resilient to stress it does not utilise maximum potential (Ulanowicz et al., 2009). The system has more alternate pathways between different compartments (which results in increased resilience to stress) than is necessary for efficient performance. As the system is still not mature, an increase in efficiency of the

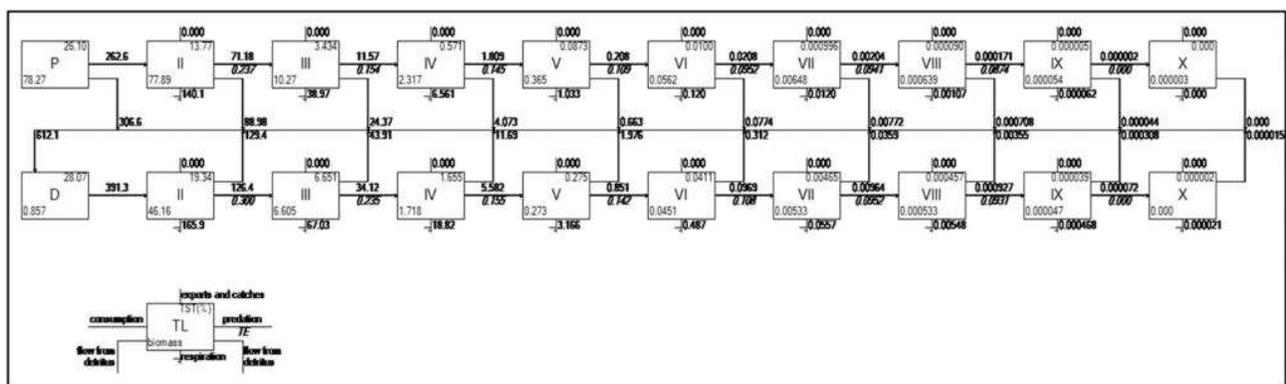


Fig. 4. Lindeman spine of Kakinada Bay; P represents producers and D represents detritus.

Table 4  
Transfer efficiencies for Kakinada Bay.

Source\Trophic level	II	III	IV	V	VI	VII	VIII	IX	X	%values
Producer	23.71	15.44	14.54	10.95	9.519	9.407	8.742			13.19
Detritus	29.97	23.52	15.47	14.2	10.81	9.517	9.307			16.11
All flows	27.37	20.77	15.23	13.42	10.56	9.497	9.214	7.783	2.597	12.94

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# Exactly Solvable Model of Classical and Quantum Oscillators of Time Dependent Complex Frequencies: Squeezing Properties of Coherent Field

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## Abstract

The exact analytical solution for a classical oscillator with time-dependent frequency is explored. We establish that the closed form solution for such an oscillator is possible provided the frequency is complex and obeying some stringent conditions. The complex nature of the frequency very often occurs in several physical problems. Therefore, the present model calculations are of relevant in fundamental and in practical situations. The solution of the classical oscillator of time-dependent complex frequency is used to obtain the solution of its quantum mechanical counterpart. The possibilities of getting the squeezed states and the nonclassical properties of the initial coherent radiation field coupled to the oscillator are discussed.

**Keywords** Quantum oscillator with complex frequency · Time-dependent frequency · Squeezing of coherent light · Wronskian

## 1 Introduction

The explanation of basic physics requires some simple models. The harmonic oscillator is perhaps the most useful one among them. A particle subject to a restoring force gives rise to the model of a harmonic oscillator. Interestingly, the model of a simple (one-dimensional) harmonic oscillator (SHO) with constant frequency and constant mass provides exact solutions both in classical and in quantum pictures. The situation becomes quite complicated if the parameters (mass and frequency) are time dependent. For example, the equations of motion corresponding to the classical harmonic oscillator with time-dependent complex frequency is given by:

$$\ddot{x} + \omega^2(t)x = 0. \quad (1)$$

Now, Eq. (1) does not have closed form analytical solution even when  $\omega$  is a real function of time  $t$ . Of course, for real frequency  $\omega(t)$ , Eq. (1) could be reduced to the so-called Ermakov equation [1–3]. Unfortunately, the Ermakov equation does not

give closed form exact solution. In spite of these, the Ermakov equation is well studied in various contexts [1–3]. Recently, by using the Ermakov-Lewis invariant appearing in KvN mechanics, the oscillator with time-dependent frequency is investigated [4]. Note that the oscillator with time-dependent mass and/or frequency are well studied by large number of researchers [5, 6, 8–14]. In all these cases [1–6, 8–19], the solutions are approximate and are involving real  $\omega(t)$ . It is already mentioned that the presence of real  $\omega(t)$  in Eq. (1) does not warrant the closed form solution since the differential equation is involving time-dependent coefficient. Of late, we obtain exact analytical solution for a quantum oscillator with time-dependent frequency  $\omega(t) = \omega(0)\sqrt{1 + \frac{\beta_0 t}{T}}$ , where  $\beta_0$  and  $\omega(0)$  are constant [19]. Of course the identical time-dependent frequency is investigated in the context of time-dependent harmonic oscillator in an electromagnetic field [20] and in the dynamics of Paul trap [5]. Interestingly, we also obtain the solution in terms of the elliptic function of second kind when the frequency  $\omega(t) = \omega(0)\sqrt{1 + \beta_0 \cos \Omega t}$ . Therefore, we are still in search for a closed form solution to Eq. (1) with few more functional dependence of  $\omega(t)$ . In this context, it is to be remembered that the real  $\omega$  corresponds the unitary evolution [16]. Now, the nonunitary evolution for  $\omega$  corresponds the presence of damping. The complex nature of the frequency  $\omega(t)$  in Eq. (1) is certainly unexplored to date. On the other hand, in different contexts, we find investigation where the complex nature of the frequency is considered [21–23]. The

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quantization of the oscillator is ensured since the Wronskian is time invariant. Now, we express the position and momentum operators in terms of the usual annihilation and creation operators  $a(t)$  and  $a^\dagger(t)$ . Therefore, we have

$$\hat{x}(t) = \frac{1}{\sqrt{2}}((a(t) + a^\dagger(t)), \tag{16}$$

and

$$\hat{p}(t) = -\frac{i}{\sqrt{2}}((a(t) - a^\dagger(t)). \tag{17}$$

Therefore, the annihilation and creation operators are expressed in terms of the position and momentum operators. Hence, we have

$$\begin{aligned} a(t) &= \frac{1}{\sqrt{2}}(\hat{x}(t) + i\hat{p}(t)), \\ a^\dagger(t) &= \frac{1}{\sqrt{2}}(\hat{x}(t) - i\hat{p}(t)). \end{aligned} \tag{18}$$

Now, it follows

$$[a(t), a^\dagger(t)] = 1, \tag{19}$$

where Eq. (15) is used. Instead of defining annihilation and creation operators as function of time, it is also possible to define those operators as function of cavity length [27]. Now, we claim that the solution of the quantum mechanical oscillator of time-dependent frequency might be useful for investigating various quantum optical phenomena. These include squeezing, photon antibunching, higher ordered squeezing, and the nonclassical photon statistics. In order to substantiate the claim, we calculate the second-order variances involving the position and momentum operator available through Eqs. (13) and (14). Assuming the initial coherent radiation field coupled to the oscillator, we have

$$\bar{x} = \langle \alpha | \hat{x}(t) | \alpha \rangle = \frac{A_1 - iA_2}{\sqrt{2}} \alpha + \frac{A_1 + iA_2}{\sqrt{2}} \alpha^*, \tag{20}$$

where  $\alpha = |\alpha| e^{i\theta}$  is a complex eigenvalue of the annihilation operator corresponding to the coherent state. The parameters  $|\alpha|^2$  and  $\theta$  are the photon numbers and the phase angle respectively of the coherent radiation field. The average momentum can be obtained by differentiating Eq. (20). Now, the second-order variance of the position and momentum operator follow as:

$$\begin{aligned} (\Delta x)^2 &= \langle \alpha | \hat{x}^2 | \alpha \rangle - \langle \alpha | \hat{x} | \alpha \rangle^2 = \frac{1}{2}(A_1^2 + A_2^2), \\ (\Delta \dot{x})^2 &= \langle \alpha | \dot{\hat{x}}^2 | \alpha \rangle - \langle \alpha | \dot{\hat{x}} | \alpha \rangle^2 = \frac{1}{2}(\dot{A}_1^2 + \dot{A}_2^2). \end{aligned} \tag{21}$$

Now, we obtain the Heisenberg uncertainty relation  $(\Delta x)(\Delta \dot{x}) = \frac{1}{2} \sqrt{(A_1^2 + A_2^2)(\dot{A}_1^2 + \dot{A}_2^2)}$ . For  $t=0$ ,  $A_1(0)=1$ ,  $A_2(0)=0$ ,  $\dot{A}_1(0)=0$ , and  $\dot{A}_2(0)=1$ . Hence, for  $t=0$ , the minimum uncertainty condition  $(\Delta x)(\Delta \dot{x}) = \frac{1}{2}$  is achieved. Now, the

squeezing in  $x$ -quadrature ( $\dot{x}$ -quadrature) is obtained at the cost of  $(x$ -quadrature) if  $(\Delta x)^2 < \frac{1}{2}((\Delta \dot{x})^2 = \frac{1}{2})$ . By knowing the functional form of the time-dependent frequency  $\omega(t)$ , it is possible to calculate  $A_1$ ,  $A_2$ ,  $\dot{A}_1$ , and  $\dot{A}_2$  and hence to investigate the squeezing. The solutions (16) and (17) can also be used to investigate other nonclassical properties of the radiation field coupled to the oscillator with time-dependent frequency.

### 4 Conclusion

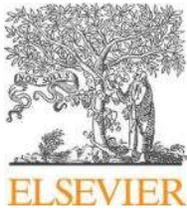
The classical harmonic oscillator with time-dependent frequency is investigated. We establish that the exact analytical solutions of the oscillator with time-dependent frequency are possible if the frequency is complex. The complex frequency of the oscillator is expressed as the sum of real and imaginary parts with suitable parameter which is of dimension of frequency. The exact analytical solutions of the time-dependent oscillator are obtained when the defined parameter is integrable with respect to time. In order to substantiate our claim, we give few examples for which the oscillator with time-dependent frequency is analytically solved in an exact manner. The solution of the classical oscillator with time-dependent complex frequency is exploited to obtain the solution of the quantum mechanical counterpart of the oscillator. The analytical solution of the quantum mechanical oscillator of time-dependent frequency is used to discuss the possibility of getting squeezed and other nonclassical phenomena of the input coherent radiation field coupled to the oscillator. We hope that the solutions of the oscillator with time-dependent complex frequency will be of use in wide range of applications.

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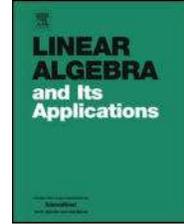
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# Linear Algebra and its Applications

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## Orthogonality of bilinear forms and application to matrices <sup>☆</sup>



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### ABSTRACT

We characterize Birkhoff-James orthogonality of continuous vector-valued functions on a compact topological space. As an application of our investigation, Birkhoff-James orthogonality of real bilinear forms are studied. This allows us to present an elementary proof of the well-known Bhatia-Šemrl Theorem in the real case.

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$v \in C_1$ . Similarly, assuming  $\mu > 0$ , it can be shown that  $v \in C_2$ . Therefore,  $C_1 \cup C_2 = \mathcal{M}_f$ , as desired.

Next, we claim that both  $C_1, C_2$  are non-empty. Indeed, following the same arguments used in the proof of Theorem 2.1, one can easily verify that  $C_1, C_2 \neq \emptyset$ . Finally, we claim that  $C_1, C_2$  form a separation of  $\mathcal{M}_f$ . To establish our claim, we observe that  $\bar{C}_1 \cap C_2 = \emptyset$  and  $C_1 \cap \bar{C}_2 = \emptyset$ , as otherwise we can find  $u_0 \in \mathcal{M}_f$  such that  $f(u_0) \perp_B g(u_0)$ . However, this is a contradiction to the fact that  $\mathcal{M}_f$  is connected. This completes the proof of the theorem.  $\square$

The above theorem may not be true if  $\mathcal{M}_f$  is not connected. We furnish the following example in support of this fact.

**Example 2.2.1.** Let  $\mathcal{U} = [0, 2] \subset \mathbb{R}$  and  $\mathbb{X} = \mathbb{R}$ . We define  $f, g \in \mathcal{C}(\mathcal{U}, \mathbb{X})$  by  $f(u) = \sin \pi u$  and  $g(u) = 1$  for all  $u \in [0, 2]$ . Clearly,  $\mathcal{M}_f = \{\frac{1}{2}, \frac{3}{2}\}$ . Now,  $f(\frac{1}{2})g(\frac{1}{2}) > 0$ , i.e.,  $g(\frac{1}{2}) \in f(\frac{1}{2})^+$  and  $f(\frac{3}{2})g(\frac{3}{2}) < 0$ , i.e.,  $g(\frac{3}{2}) \in f(\frac{3}{2})^-$ . Then from Theorem 2.1, it follows that  $f \perp_B g$ , however,  $g(v) \neq 0$  for any  $v \in \mathcal{M}_f$ , i.e.,  $f(v) \not\perp_B g(v)$  for any  $v \in \mathcal{M}_f$ .

Our next theorem, in some sense, assimilates the above two theorems. This turns out to be an important tool in our further developments. We omit the proof as it is trivial in view of Theorem 2.1 and Theorem 2.2.

**Theorem 2.3.** *Let  $\mathcal{U}$  be a compact topological space and let  $\mathbb{X}$  be a normed linear space. Let  $f, g \in \mathcal{C}(\mathcal{U}, \mathbb{X})$  be non-zero. Let  $\mathcal{D}_f \subseteq \mathcal{M}_f$  be such that  $\mathcal{D}_f$  is connected. Then the following conditions are equivalent:*

- (i) *There exist  $u_1, u_2 \in \mathcal{D}_f$  such that  $g(u_1) \in f(u_1)^+$  and  $g(u_2) \in f(u_2)^-$ .*
- (ii) *There exists  $u_0 \in \mathcal{D}_f$  such that  $f(u_0) \perp_B g(u_0)$ .*

As mentioned in the introduction, we obtain some of the earlier results on the Birkhoff-James orthogonality of linear operators as simple corollaries to Theorem 2.1 and Theorem 2.2.

**Corollary 2.3.1.** [7, Theorem 2.2] *Let  $\mathbb{X}$  be a finite-dimensional real Banach space. Let  $T, A \in \mathbb{L}(\mathbb{X})$ . Then  $T \perp_B A$  if and only if there exist  $x, y \in M_T$  such that  $Ax \in Tx^+$  and  $Ay \in Ty^-$ .*

**Proof.** The proof of the sufficient part is trivial. To prove the necessary part, we first observe that

$$\|T + \lambda A\|_{S_{\mathbb{X}}} = \|T + \lambda A\| \geq \|T\| = \|T\|_{S_{\mathbb{X}}},$$

for all  $\lambda \in \mathbb{R}$ . In other words,  $T, A \in \mathcal{C}(S_{\mathbb{X}}, \mathbb{X})$  (by considering the respective restriction operators on  $S_{\mathbb{X}}$ ) with  $T \perp_B A$ . Therefore, it follows from Theorem 2.1 that there exist

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# Atomic-Ordering-Induced Modulated Properties of Zigzag ZnTe Nanotubes

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In this work, zigzag ZnTe nanotubes of various diameters are constructed from a ZnTe sheet and are optimized geometrically through density functional theory based energy minimization calculations. The energetically optimized nanotubes are then used to examine their electronic properties. It is found that the band gap of a nanotube may be adjusted over a wide range from 0.5 to 2.3 eV and the work function of a nanotube may be adjusted in the range from 4.7 to 5.8 eV by choosing a nanotube of appropriate diameter. Thus, zigzag ZnTe nanotube may serve as an important band gap material for technological purposes.

## 1. Introduction

Basic investigation of the electrical, magnetic, optical, and catalytic properties of materials with the variation of their shapes, sizes, and compositions has become a predominant area of research to meet contemporary technological demands. For instance, nanostructures of diverse shapes such as quantum dots, nanorods, nanocones, and nanotubes have proven to exhibit interesting properties. However, 1D nanostructures, namely, nanowires and nanotubes, are expected to take a leading role in practical applications due to their unique structural features. In fact, the synthesis of carbon nanotubes<sup>[1]</sup> triggered enormous research activity in the domain of 1D nanomaterials. Intriguing features of carbon nanotubes encouraged further investigation of the formation of nanotubes composed of various other elements. Accordingly, a large number of experiments were performed and nanotubes of several binary compounds, such as BN, SiC, ZnO, ZnS, CdSe, CdS, GaN, and HgSe were successfully synthesized.<sup>[2–9]</sup>

Among noncarbon materials, ZnTe, a group II–VI semiconductor, exhibits some remarkable features such as relatively small resistance, bandgap of 2.2–2.3 eV and a very high photoabsorption coefficient of  $\approx 3 \times 10^4 \text{ cm}^{-1}$  under 540 nm.<sup>[10–13]</sup> Because of these intriguing features, ZnTe nanostructures were

shown to be useful in solar cells, green LEDs, photovoltaic devices, thermoelectric devices, and photodetectors.<sup>[14–18]</sup> ZnTe nanostructures were also used in nonlinear optics, generation and detection of terahertz signals.<sup>[19–22]</sup> In another study, Minegishi et al. observed superior incident-photon-to-current conversion efficiency using ZnTe-based photocathodes and obtained hydrogen from water using sunlight by the process of photoelectrochemical water splitting.<sup>[23]</sup> Such a possibility of wide range of applications led to

several experiments for the synthesis of various ZnTe nanostructures such as quantumdots, nanoplates, thin films, nanowires, nanoribbons, and nanotubes.<sup>[24–32]</sup> For example, Zarei et al.<sup>[33]</sup> synthesized ZnTe thin films by glancing angle technique and observed that they were useful in optoelectronic devices. In a study, Das et al.<sup>[34]</sup> synthesized various ZnTe nanoparticles and reported their size-dependent structural, optical, and vibrational properties. Again, ZnTe nanomaterials may be doped easily and therefore, their properties could be tuned to the desirable level.<sup>[35,36]</sup> For instance, transition-metal-doped ZnTe nanostructures have shown appealing magnetic and fluorescent properties.<sup>[37–42]</sup> From this discussions, it is clear that various ZnTe nanostructures are important for practical applications due to the emergence of important properties.

As the tubular structures of different materials are known to exhibit useful properties, it is inspiring to explore the features of ZnTe nanotubes. It is also known that the properties of the nanotubes are sensitive to the chirality of the nanotubes; i.e., the zigzag nanotubes may show distinct properties from armchair nanotubes. In a previous work, we extracted the properties of ZnTe nanotubes in the armchair configuration.<sup>[43]</sup> However, the properties of ZnTe nanotubes with zigzag configuration are yet to be examined. Apart from chirality, atomic positioning also plays a distinct role in directing the characteristics of a nanotube.<sup>[44,45]</sup> In this article, we probe the properties of zigzag ZnTe nanotubes by changing the atomic configurations. We assume two classes of zigzag ZnTe nanotubes on the basis of the atomic ordering, namely, class-1 and class-2. In the class-1 pattern, every Zn atom is directly connected by three Te atoms and in class-2, each Zn atom is directly connected by two Te atoms and one Zn atom. In the next section, we narrate the procedures along with the essential parameters. The outcomes are discussed in Section 3 and finally we abridge our findings in Section 4.

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wrinkled-surface structure emerged as a result of the radially outward displacement of the Te atoms (more electronegative) and radially inward displacement of the Zn atoms (less electronegative). More electronegative atoms possess extra electronic charges and therefore, they try to move far off the tube axis to minimize the electron–electron repulsion. In any molecular structure, it is observed that the less electronegative atom occupies the central position to minimize the electron–electron repulsion. An analogous wavy surface was also noted in CdS, ZnS, and CdSe nanotubes.<sup>[50–52]</sup> Because of the relative displacements of the Zn and Te atoms, such a relaxed nanotube resembles a coaxial cylindrical structure: The external one is built up with Te atoms, while the internal one is made up of Zn atoms. We may approximate the diameter of a tube by calculating the average of the external and internal diameters. We may further evaluate the wall width of the tube by subtracting the internal radius from the external radius. We have computed the diameter and wall width of the nanotubes and display the results in **Table 1** and **2**. It is perceived that in the class-1 pattern, the deviation in diameters of the nanotubes due to energy optimization ranges from 2.04% to 2.51% and in the class-2 pattern, deviation ranges from 3.04% to 4.35%. We have shown the variation of wall width with respect to diameter in **Figure 4**. This figure conveys that the wall becomes thinner with an enlarging diameter of the nanotube.

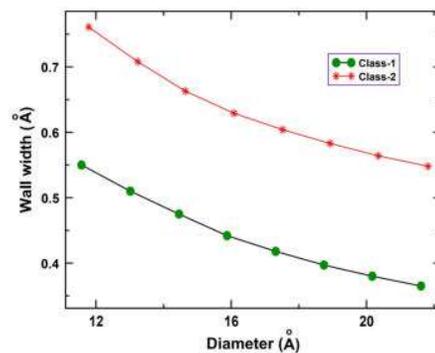
For understanding the energetic stability of the nanotubes, we have estimated their cohesive energy per atom.

**Table 1.** Estimated structural parameters of class-1 nanotubes. Here,  $D$ ,  $d$ ,  $N$ , and  $E_c$  represent the diameter, wall width, atom number in the supercell, and cohesive energy per atom, respectively.

System	$D$ [Å]	$d$ [Å]	$N$	$E_c$ [eV]
ZnTe (8,0)	11.571	0.550	32	2.292
ZnTe (9,0)	13.015	0.510	36	2.298
ZnTe (10,0)	14.454	0.475	40	2.304
ZnTe (11,0)	15.876	0.442	44	2.310
ZnTe (12,0)	17.315	0.418	48	2.315
ZnTe (13,0)	18.742	0.397	52	2.318
ZnTe (14,0)	20.171	0.380	56	2.321
ZnTe (15,0)	21.613	0.365	60	2.323

**Table 2.** Various structural parameters of class-2 nanotubes. Here,  $D$ ,  $d$ ,  $N$ , and  $E_c$  denote the diameter, wall width, atom number in the supercell, and cohesive energy per atom, respectively.

System	$D$ [Å]	$d$ [Å]	$N$	$E_c$ [eV]
ZnTe (8,0)	11.782	0.761	32	1.951
ZnTe (9,0)	13.234	0.708	36	1.958
ZnTe (10,0)	14.642	0.663	40	1.964
ZnTe (11,0)	16.085	0.629	44	1.970
ZnTe (12,0)	17.521	0.604	48	1.974
ZnTe (13,0)	18.924	0.583	52	1.978
ZnTe (14,0)	20.352	0.564	56	1.981
ZnTe (15,0)	21.824	0.548	60	1.983



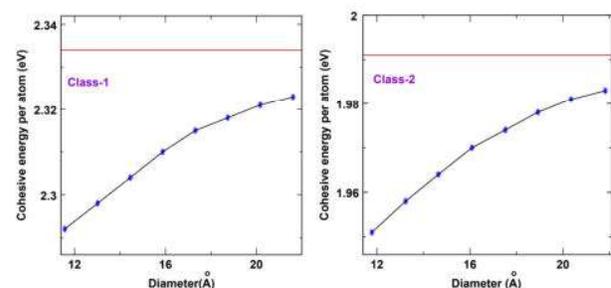
**Figure 4.** Dependence of the wall width on diameters of the both classes of zigzag ZnTe nanotubes.

Cohesive energy per atom,  $E_c$ , can be calculated by utilizing the expression

$$E_c = - \frac{E(\text{Zn}_x\text{Te}_y) - xE(\text{Zn}) - \gamma E(\text{Te})}{(x + \gamma)} \quad (2)$$

where  $E(\text{Zn}_x\text{Te}_y)$  is the energy of the relaxed system made up of  $x$  numbers of Zn atoms and  $\gamma$  numbers of Te atoms.  $E(\text{Zn})$  and  $E(\text{Te})$  represent the energy of isolated Zn and Te atoms, respectively. We realize that the cohesive energies of class-1 and class-2 sheets are 2.334 and 1.991 eV, respectively. However, for a class-1 nanotube the cohesive energy ranges from 2.292 to 2.323 eV (refer to Table 1). In case of class-2, the cohesive energy rises from 1.951 to 1.983 eV (see Table 2). We have plotted the cohesive energies with respect to the diameter in **Figure 5**. This figure exhibits that for both classes of nanotubes the cohesive energies increase with diameter and approach the values of the corresponding two dimensional sheets. It is recognized that the cohesive energies of class-1 nanotubes are slightly higher than those of the class-2 nanotubes; i.e., class-1 nanotubes are more favorable over class-2 nanotubes. We obtain a similar trend in case of armchair ZnTe nanotubes.<sup>[43]</sup>

The knowledge of bandgap and its variation with respect to tuneable parameters is important for designing new nanoscale devices with desired applications. To judge the significance of ZnTe nanostructures in various technological applications, we have determined the bandgaps of various ZnTe nanosheets



**Figure 5.** The cohesive energy per atom versus diameter plot for different zigzag ZnTe nanotubes. The red straight lines denote the cohesive energies of the ZnTe sheets.

## Data Availability Statement

Research data are not shared.

## Keywords

nanotubes, band gap, density functional theory, work function

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### **অতিমারী কোভিড ও ভারতীয়-দর্শন প্রসঙ্গ**

**মণিমালা মণ্ডল**

সহকারী অধ্যাপক, সংস্কৃত বিভাগ, গুসকরা মহাবিদ্যালয়, পশ্চিমবঙ্গ, ভারত

#### **Abstract:**

*The human world faces its greatest threat of disaster in the form of the COVID-19 pandemic. Infected by the virulent coronavirus the daily life of humans is under severe risk. The continuity and severity of this asymmetric warfare against the virus has tested the limits of human resilience. However, the extended struggle has been further prolonged asking for more struggles from us. Economic, psychological, physical and more such difficulties have not able to stop our fight against this disaster. We have presented a largely unflinching face to this adversity. Texts and traditions of the various societies, facing the danger as it is, have played an essential part in the building of the character of the people. The same is the case for India's populace. Indian philosophical traditions have provided the people here with clues to keep themselves both mentally and physically robust. Analysis of the well-accepted traditions such as that of Sāṃkhya, Yoga, Vedānta show that their deep interpretations assist us in the path of achieving physical and mental equilibrium.*

**Keywords: Pandemic, philosophy, Upaniṣads, Sāṃkhya, Yoga, Vedānta, disaster**

যখন কোন সংক্রামক ব্যাধির সংক্রমণ সীমিত পরিসর অতিক্রম করে বৃহৎ পরিসরে বিস্তারলাভ করে অর্থাৎ ক্ষুদ্র অঞ্চলে সীমাবদ্ধ না থেকে ক্রমবর্ধমান সেই ব্যাধি ভৌগোলিক সীমা ছাড়িয়ে অন্যত্র দেশ দেশান্তরে ছড়িয়ে পড়ে তখন সাধারণভাবে তাকে অতিমারী রূপে চিহ্নিত করা হয়।<sup>1</sup> যে কোন প্রাকৃতিক বিপর্যয়ের ন্যায় জনজীবনে এটাও একপ্রকার ভয়ানক বিপর্যয়, তবে অন্যান্য প্রাকৃতিক বিপর্যয়ের সঙ্গে এর মূল পার্থক্য হল এর স্থায়ীত্বকাল তুলনামূলকভাবে অনেক বেশি তাই এর সঙ্গে মোকাবিলা করাটাও স্বাভাবিকভাবেই অনেক বেশি কঠিন হয়ে থাকে। বর্তমান সময়ে সমগ্র বিশ্ব তেমনই এক ভয়ানক বিপর্যয়ের সম্মুখীন। 'কোরোনা' নামক ভাইরাস ঘটিত ব্যাধি যা 'কোভিড-১৯' নামে পরিচিত, এখন তার প্রথম আবির্ভাব স্থলের সীমা লঙ্ঘন করে বিভিন্ন দেশে অনুপ্রবেশ করেছে। সমগ্র বিশ্বের অনূন্য ২০০টি দেশের প্রায় প্রতিটি দেশই এই মারণ ব্যাধির দ্বারা আক্রান্ত। তদুপরি অতি সংক্রামক আগন্তুক এই রোগের নিরাময়যোগ্য প্রতিষেধক মানুষের কাছে নেই বললেই চলে, স্বল্প পরিমাণে যা আছে তাও প্রায় দুর্লভ হয়ে উঠেছে। মানুষ একপ্রকার বিনা অস্ত্রেই কোভিডের বিপক্ষে যুদ্ধে অবতীর্ণ হয়েছে। বিশেষ করে তৃতীয় বিশ্বের দেশ ভারতবর্ষের অবস্থা সেই প্রকারই বলা চলে। মানুষ আজ বড় অসহায়। একরাশ আতঙ্ক, শঙ্কা আর অনিশ্চয়তা নিয়ে দিনযাপন করছে যা মৃত্যুরই নামান্তর। অপ্রতিরোধ্য এই রোগের প্রকোপে কেবলমাত্র বিশ্বস্বাস্থ্যই ভেঙে পড়েনি তার

সঙ্গে তীব্র ধাক্কা খেয়েছে রাষ্ট্রব্যবস্থা, অর্থনীতি, কর্মজীবন। স্বাভাবিক জীবনধারার গতি প্রায় রুদ্ধ হয়ে গেছে। সর্বোপরি মানুষের মানসিক স্বাস্থ্যের অবস্থা তথৈবচ। এইভাবে জীবনধারণের মূল স্তম্ভগুলি দুর্বল হয়ে পড়ায় মানুষ আজ দীশাহীন। তবুও এই তীব্র প্রতিকূল পরিস্থিতিতে সর্বশেষ জীবনশক্তিটুকু নিয়ে বেঁচে থাকার আশ্রয় চেষ্টা চালিয়ে যাচ্ছে। বহু বিষয়ই আছে যা প্রত্যক্ষভাবে তাদেরকে বিগত এক বছরের অধিক সময় ধরে নিরবিচ্ছিন্ন এই লড়াইয়ের শক্তি যোগান দিচ্ছে। তবে তাদের মধ্যে ভারতীয় দর্শনের ভাবনা-প্রসূত জীবনদর্শন সেক্ষেত্রে পরোক্ষভাবে হলেও অনেকখানি পুষ্টিবর্ধকের ভূমিকা পালন করে চলেছে বলে আমার মনে হয়।

যে কোন যুদ্ধ জয়ের অমোঘ অস্ত্রগুলি হল নিজের প্রতি আস্থা, নির্ভিকতা এবং অবশ্যই ধৈর্য্য। আমাদের কারো অজানা নয় যে ভারতের স্বাধীনতা আন্দোলনের যোদ্ধারা তাদের আন্তরশক্তিকে অটুট ও মজবুত রাখতে বার বার শরণ নিয়েছে গীতা, উপনিষদের। এখানে বলে নেওয়া দরকার যে, গীতা, উপনিষদ প্রভৃতি বেদান্ত-দর্শনের অন্তর্গত। বেদান্তের লক্ষণে বলা হয়েছে - ‘বেদান্তো নাম উপনিষৎ-প্রমাণং তদুপকারীণি শারীরক-সূত্রাদীনি চ’।<sup>2</sup> বস্তুজগতের কোন উপকরণ তাদের সেই বলবৃদ্ধিতে সহায়ক হতে পারেনি। এই মুহূর্তে বিশ্বের প্রতিটি মানুষ তদপেক্ষা ভীষণ এক যুদ্ধে সামিল হয়েছে টিকে থেকে জয়লাভের লক্ষ্যে। আর সেই লক্ষ্যে পৌঁছে দেওয়ার চালিকাশক্তিরূপে এই পরিস্থিতিতে ভূমিকা পালন করছে অন্তরের গভীরে প্রচ্ছন্ন থাকা দর্শনভাবনা। এই বিষয়টিকে কেন্দ্র করেই আমার বর্তমান প্রবন্ধের আলোচনা। এখানে উল্লেখ্য যে ভারতীয়-দর্শনের কথা বললেও বাহ্যিক বর্জন করতে কতিপয় দর্শনের প্রাসঙ্গিকতা আলোচনা করা হয়েছে।

বিগত একশো বছর ধরে মানুষের মহামারী এবং অতিমারী সম্পর্কে অর্জিত যা কিছু জ্ঞান তা সবই প্রায় ইতিহাস, উপন্যাস বা গল্প নির্ভর। বাস্তব অভিজ্ঞতা লাভের তেমন কোন সুযোগ প্রায় আসেনি বললেই চলে। কিন্তু একবিংশ শতকের এই দ্বিতীয় থেকে তৃতীয় দশকের সন্ধিক্ষণে গ্রন্থ নিহিত সেই সকল গল্প-কাহিনী যেন কোন দুর্দৈবের করস্পর্শে এক লহমায় জীবন্ত হয়ে উঠেছে। এই মুহূর্তে রক্তমাংসের মানুষ বাস্তবের মাটিতে অত্যন্ত নগ্নভাবে তাকে প্রত্যক্ষ করছে। কোন প্রকার পূর্বাভাস ছাড়া অতিমারীর আকস্মিক আগমনের এই ধাক্কা বিশ্বের জীবনধারার স্বাভাবিক সরল গতির ছন্দকে সম্পূর্ণভাবে বিনষ্ট করে দিয়েছে। এই রোগ অতি সংক্রামক, অন্যদিকে একে প্রতিরোধ করার মত ঔষধিবিষয় চিকিৎসাশাস্ত্রে প্রায় নেই বললেই চলে। তাই মানুষের জীবনরক্ষার একমাত্র উপায় হল সাবধানতা অবলম্বনের মাধ্যমে সংক্রমণের গতিকে যথাসম্ভব স্তিমিত করা ও অবরুদ্ধ করা। সেই উদ্দেশ্যকে সফল করার জন্য বিশ্ব স্বাস্থ্য সংস্থার স্বাস্থ্যবিধি মেনে মানুষকে হতে হয়েছে গৃহবন্দী। বন্ধ হয়েছে যানবাহন, দোকানপাট, অফিস আদালত সহ সরকারি-বেসরকারি সকল কর্মক্ষেত্র। এমনকি পারস্পরিক সাক্ষাৎকারটুকুও বন্ধ রাখতে হয়েছে। এর ফলে তৈরী হয়েছে অর্থসংকট, কর্মহীনতা, খাদ্যাভাব, নিসঙ্গতা, একাকীত্ব। ধনী থেকে দরিদ্র সর্বস্তরের মানুষ কমবেশি এই সমস্যাগুলির দ্বারা অহরহ পিড়িত হয়ে চলেছে। এককথায় বলা যায় মানুষের স্বাভাবিক জীবনধারা আজ বিপরীত মুখে বহমান। তবুও এহেন প্রতিকূল স্রোতের বিরুদ্ধে মানুষ সর্বশক্তি প্রয়োগ করে নিজেকে টেনে নিয়ে চলেছে বাঁচার লক্ষ্যে। লড়াইটা অসম লড়াই। সব যুদ্ধে প্রতিপক্ষের প্রতি প্রবল বিরুদ্ধ শক্তি প্রয়োগ করাটাই জয়লাভের একমাত্র উপায় নয়। কখনো কখনো শত্রুর সামনে টিকে থাকাটাও যুদ্ধজয়ের কৌশল হয়ে থাকে। আজ মানুষ সেই কৌশলই অবলম্বন করেছে। শতকষ্ট সহ্য করে সমস্ত রকম পরিবর্তিত পরিস্থিতির সঙ্গে নিজেকে মানিয়ে নেওয়ার চেষ্টা করে চলেছে। এই যে তার হারতে হারতে হার

- <sup>2</sup> বেদান্তসার, পৃ. ১৯
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- <sup>5</sup> ছান্দোগ্যোপনিষদ, ৩.১৪.১, পৃ. ৪২৮
- <sup>6</sup> ছান্দোগ্যোপনিষদ, ৬.৮.৭, পৃ. ৫২৭
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#### পরামৃষ্ট গ্রন্থপঞ্জী

সংস্কৃত:

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## Assessment Of The Novels With Special Reference To Chetan Bhagat

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### ABSTRACT:

The basic historical perspective of Indian English literature attempts to contextualize the genre's development and rise from its inception to its current popularity. British colonialism in India coincided with the rise of Indian English literature and history. Although academics agree that the first good Indian English work dates from the early 1800s, opinions differ. The adoption of English literature and language by the Indian upper-response class, as well as educational reform by the British administration and missionary efforts, all contributed to its rise. This article highlights about the assessment of the novels with special reference to Chetan Bhagat.

**Keywords:** Chetan Bhagat, Novels, Assessment.

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## EFFICACY OF PERFORMANCE METHOD OVER LECTURE METHOD: TEACHING SHAKESPEARE AND MAHESH DATTANI IN RURAL INDIAN CLASSROOM

Dr. Tanu...

### ABSTRACT

The proposed paper aims to compare and contrast the learning outcomes of two tests of drama from the UG syllabus of Honours (BU University), in an attempt to examine how far performance teaching can be successfully adapted in rural Indian classroom to teach Shakespeare and simultaneously the relevance of this adaption so far as teaching Indian writing in English (Mahesh Dattani) is considered on the basis of a survey. The author has reached some interesting findings that on the one hand accepts the performance method of teaching over lecture method but on the other hand doesn't wholly accept the performance of lecture method particularly when teaching Indian literature in English is considered. More interesting findings of those aspects where even performance method fails to address the limitations of lecture method process.

**Keywords:** Performance method, Lecture method, Shakespearian drama, Mahesh Dattani, Variation index

The English Honours syllabus of UG level (CBCS) is a multidimensional one. The problems of learning and teaching English literature at rural colleges are so multi-faceted that it is really puzzling to decide what should be the beginning point of this discussion. Putting aside the question of so called 'completing' [a very vague terminology] the due portion of the syllabus within a fixed period (here a semester), the problems can be categorized likewise – (i) orientation of a rural Indian student (ii) confused goal of learning English (iii) confused aims of traditional evaluation system (iv) non-availability of trained teachers in a changed scenario and their relevant confusion regarding the aims and methodology of teaching. Low language proficiency levels, lack of reading, writing and speaking skills, low motivation level, poor self-confidence and cultural prejudices can be assigned to the first-category. About

ninety percent of the students studying at school levels. As second language, English them learning a set of rules. When they college level, still then they do not have the idea of proper pronunciation, spelling and grammar (Bhandari, 2009). Besides, the huge gap between the students for whom the subject and the decoded subject matters of the syllabus, as rightly pointed out by Sarkar (www.cje.ids.czest.), is not. Secondly, there is confusion about the supposed goal of learning English. For the students, it seems to be, passing. As Bhandari puts it, "the sole objective and the learner remain to clear the exam and never realize the importance of learning

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