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Dear Esteemed Readers, Authors, and Colleagues,

I hope this letter finds you in good health and high spirits. It is my distinct pleasure to address you as the Editor-in-Chief of Integrative Omics and Applied Biotechnology (IIOAB) Journal, a multidisciplinary scientific journal that has always placed a profound emphasis on nurturing the involvement of young scientists and championing the significance of an interdisciplinary approach.

At Integrative Omics and Applied Biotechnology (IIOAB) Journal, we firmly believe in the transformative power of science and innovation, and we recognize that it is the vigor and enthusiasm of young minds that often drive the most groundbreaking discoveries. We actively encourage students, early-career researchers, and scientists to submit their work and engage in meaningful discourse within the pages of our journal. We take pride in providing a platform for these emerging researchers to share their novel ideas and findings with the broader scientific community.

In today's rapidly evolving scientific landscape, it is increasingly evident that the challenges we face require a collaborative and interdisciplinary approach. The most complex problems demand a diverse set of perspectives and expertise. Integrative Omics and Applied Biotechnology (IIOAB) Journal has consistently promoted and celebrated this multidisciplinary ethos. We believe that by crossing traditional disciplinary boundaries, we can unlock new avenues for discovery, innovation, and progress. This philosophy has been at the heart of our journal's mission, and we remain dedicated to publishing research that exemplifies the power of interdisciplinary collaboration.

Our journal continues to serve as a hub for knowledge exchange, providing a platform for researchers from various fields to come together and share their insights, experiences, and research outcomes. The collaborative spirit within our community is truly inspiring, and I am immensely proud of the role that IIOAB journal plays in fostering such partnerships.

As we move forward, I encourage each and every one of you to continue supporting our mission. Whether you are a seasoned researcher, a young scientist embarking on your career, or a reader with a thirst for knowledge, your involvement in our journal is invaluable. By working together and embracing interdisciplinary perspectives, we can address the most pressing challenges facing humanity, from climate change and public health to technological advancements and social issues.

I would like to extend my gratitude to our authors, reviewers, editorial board members, and readers for their unwavering support. Your dedication is what makes IIOAB Journal the thriving scientific community it is today. Together, we will continue to explore the frontiers of knowledge and pioneer new approaches to solving the world's most complex problems.

Thank you for being a part of our journey, and for your commitment to advancing science through the pages of IIOAB Journal.

Yours sincerely,

Vasco Azevedo

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RESEARCH OPEN ACCESS

QUANTUM DYNAMICS FOR THE GENERALIZED CALDIROLA-KANAI OSCILLATOR IN COHERENT STATES

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ABSTRACT

A generalization of the Caldirola-Kanai Hamiltonian that describes dissipative systems can be fulfilled by replacing standard exponential function with the q-exponential one. The q-exponential function is a deformed exponential function that can be used, in more than one way, to develop a generalized formalism of statistical dynamics, so-called the non-extensive statistical dynamics. The quantum characteristics of the generalized Caldirola-Kanai oscillator are investigated with the help of a linear invariant operator of the system. It is shown that the eigenstate of the linear invariant operator is closely related to the Glauber coherent state. The fluctuations of position and momentum are illustrated and discussed for the different values of nonextensive parameter q.

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KEY WORDS

invariant operator; Caldirola-Kanai oscillator; coherent state; Hamiltonian; q-exponential function

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[I]INTRODUCTION

Though Boltzmann-Gibbs statistics has attained a remarkable success in theoretical physics, it has turned out that some of dynamical systems do not follow this statistics. As a matter of fact, this difficulty is related to nonextensive features of the system, which requires another statistical formalism. According to this, nonextensive statistical formalism is firstly suggested by Tsallis and, afterwards, successfully applied in many branches of dynamical systems, such as biology [1-3], chaotic systems [4], living systems [5], economics [6], hydrology [7], and nonlinear dissipative dynamical systems [8].

Ozeren has studied the effects of nonextensivity on the Caldirola-Kanai (CK) oscillator [9,10] via destruction and creation operators associated with the simple harmonic oscillator (DCOSHO) [11]. Caldirola-Kanai oscillator is a fundamental model of dissipative systems that is usually used to develop a phenomenological single-particle approach for the damped harmonic oscillator. It is well known that the Hamiltonian of CK oscillator is time-dependent. A useful method to solve quantum solutions of a time-dependent Hamiltonian system is invariant operator method [12-21] that have been firstly introduced by Lewis [12]. There are two kinds of invariant operators for a quadratic (time-dependent) Hamiltonian system, namely, linear invariant operator and quadratic invariant operator [15]. The quadratic invariant operator is broadly adopted by many researchers in studying quantum physics. However, the linear invariant operator is not yet extensively studied and, as a consequence, its properties are scarcely known. Notice that the destruction and creation operators that are necessary in developing quantum theory on the basis of the invariant operator method are different from DCOSHO. The linear invariant operator is useful in studying coherent states while on the other hand Schrödinger solutions based on the quadratic invariant operator correspond to the number states. After Glauber's research on coherence properties of the electromagnetic fields through coherent states [22], the concept of coherent states became important in quantum optics. A wave function in coherent states which follow minimum uncertainty relation is closest to the idealized classical wave. Nonclassical properties of SU(1,1) coherent states for the damped harmonic oscillator are studied in previous papers [23,24]. In the present work, we study the quantum dynamics for the generalized CK oscillator in the Glauber coherent state by employing linear invariant operator method.

[II] MATERIALS AND METHODS

2.1. Linear invariant operator

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The Hamiltonian of the CK oscillator is given by

$$\hat{H} = \frac{\hat{p}^2}{2m} e^{-\beta t} + \frac{1}{2} e^{\beta t} m\omega^2 \hat{x}^2, \quad (1)$$

where β is a damping constant. Through Tsallis thermostatics, a generalization of the exponential function appeared in the above equation can be fulfilled by replacing ordinary exponential function with a deformed one known as q-exponential function, such that [25]

$$e^y \to \exp_q y = [1+(1-q)y]^{1/(1-q)}, \quad (2)$$

where $1+(1-q)y > 0$. As a matter of fact, the q-exponential function is ubiquitous and beautiful. In case that $q \to 1$, $\exp_q y$ reduces to ordinary exponential function. A distinctive feature of q-exponential function we should bear in mind is that $[\exp_q y]^{-1}$ cannot be replaced by $\exp_q(-y)$ except for $q = 1$. In terms of the q-exponential, the CK Hamiltonian can be generalized in the form [11]

$$\hat{H}_q = \frac{\hat{p}^2}{2m \exp_q(\beta t)} + \frac{1}{2} \exp_q(\beta t) m\omega^2 \hat{x}^2. \quad (3)$$

From fundamental dynamics of Hamiltonian, it is not difficult to show that this Hamiltonian yields the classical equation of motion which is represented as

$$\ddot{x}(t) + \frac{\beta}{1+(1-q)\beta t}\dot{x}(t) + \omega^2 x(t) = 0. \quad (4)$$

Let us denote two homogeneous independent real solutions of the above equation as $s_1(t)$ and $s_2(t)$. Then, a little algebra leads to [26]

$$s_1(t) = \left(\frac{\pi\omega}{2\beta(1-q)}\right)^{1/2} \frac{s_0}{[1+(1-q)\beta t]^{\nu}} J_{\nu}\left(\frac{\omega}{(1-q)\beta} + \omega t\right), \quad (5)$$

$$s_2(t) = \left(\frac{\pi\omega}{2\beta(1-q)}\right)^{1/2} \frac{s_0}{[1+(1-q)\beta t]^{\nu}} N_{\nu}\left(\frac{\omega}{(1-q)\beta} + \omega t\right), \quad (6)$$

where s_0 is a constant, $\nu = q/[2(1-q)]$, J_ν and N_ν are the first and the second kind Bessel functions. The general solution of Eq. (4) is

$$x(t) = c_1 s_1(t) + c_2 s_2(t), \quad (7)$$

where c_1 and c_2 are arbitrary real constants.

Notice that the Hamiltonian, Eq. (3), is dependent on time. It is well known that the quantum solutions of a time-dependent Hamiltonian system can be derived by taking advantage of invariant operators of the system [13]. In general, the invariant operator $\hat{I}$ should satisfy the Liouville-von Neumann equation which is given by

$$\frac{d\hat{I}}{dt} = \frac{\partial \hat{I}}{\partial t} + \frac{1}{i\hbar}[\hat{I}, \hat{H}_q] = 0. \quad (8)$$

Let us suppose that the solution of the above equation for our system is of the form

$$\hat{I}(\hat{x}, \hat{p}, t) = A(t)\hat{x} + B(t)\hat{p}, \quad (9)$$

where $A(t)$ and $B(t)$ are time functions which should be determined afterwards. The substitution of Eqs (3) and (9) into Eq (8) yields

$$\dot{A} = B \exp_q(\beta t) m\omega^2, \quad (10)$$

$$\dot{B} = -\frac{A}{m \exp_q(\beta t)}. \quad (11)$$

From the above two equations, the differential equation for $B(t)$ is easily derived to be

$$\ddot{B}(t) + \frac{\beta}{1+(1-q)\beta t}\dot{B}(t) + \omega^2 B(t) = 0. \quad (12)$$

Since this is just the same as the classical equation of motion for coordinate given in Eq. (4), we can take the solution of $B(t)$ as $s_1(t)$ or $s_2(t)$. However, in this case, it may be more useful to consider a complex-number solution of the form

$$B(t) = B_0 s(t) \exp\left(i\Omega \int_0^t \frac{dt'}{s^2(t') m \exp_q(\beta t')}\right), \quad (13)$$

where B_0 is an arbitrary complex constant and $s(t)$ and Ω are given by

$$s(t) = \sqrt{s_1^2(t) + s_2^2(t)}, \quad (14)$$

$$\Omega = m[s_1(t)\dot{s}_2(t) - \dot{s}_1(t)s_2(t)] \exp_q(\beta t). \quad (15)$$

From a direct differentiation of Eq. (15) with respect to time, we have $d\Omega/dt = 0$. This implies that Ω is a time constant. Note that the complex conjugate of Eq. (13), $B^*(t)$, is also allowed as a solution of Eq. (12). Let us denote the invariant operator associated with $B(t)$ and $B^*(t)$ as $\hat{I}_I$ and $\hat{I}_{II}$, respectively. By inserting the time derivative of $B(t)$ given in Eq. (13) into Eq. (11), another time function $A(t)$ can also be obtained. Thus, we have

$$\hat{I}_I = \hat{a} \exp\left(i\Omega \int_0^t \frac{dt'}{s^2(t') m \exp_q(\beta t')}\right), \quad (16)$$

$$\hat{I}_{II} = \hat{a}^+ \exp\left(-i\Omega \int_0^t \frac{dt'}{s^2(t') m \exp_q(\beta t')}\right), \quad (17)$$

where

$$\hat{a} = B_0\left[s(t)\hat{p} - \left(m \exp_q(\beta t)\dot{s}(t) + i\frac{\Omega}{s(t)}\right)\hat{x}\right], \quad (18)$$

$$\hat{a}^+ = B_0^*\left[s(t)\hat{p} - \left(m \exp_q(\beta t)\dot{s}(t) - i\frac{\Omega}{s(t)}\right)\hat{x}\right]. \quad (19)$$

If we choose B_0 as

$$B_0 = \left(\sqrt{2\hbar\Omega}\right)^{-1} \exp(i\theta), \quad (20)$$

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where θ is an arbitrary phase, Eqs. (18) and (19) become dimensionless and satisfy the boson commutation relation such that $[\hat{a},\hat{a}^{\dagger}]=1$. Hence, we can conclude that $\hat{a}$ and $\hat{a}^{\dagger}$ are destruction and creation operators, respectively. The advantage of putting the solutions of Eq. (12) as Eq. (13) is that, by doing so, we can easily understand the relations between the linear invariant operators and the ladder operators. Let us take $\theta=\pi/2$ at this stage for convenience. Then, Eqs. (18) and (19) become similar to those of Ref. [26].

2.2. Quantum dynamics

Let us write the eigenvalue equation of $\hat{I}_I$ in the form

$$\hat{I}_I\,|\phi\rangle=\lambda\,|\phi\rangle. \tag{21}$$

If we consider that $\hat{I}_I$ is expressed in terms of $\hat{a}$, the eigenstate $|\phi\rangle$. is associated to the Glauber coherent state. From Eqs. (16) and (21), it is trivial to identify λ, which is

$$\lambda=\alpha\exp\left(i\Omega\int_0^t\frac{dt'}{s^2(t')m\exp_q(\beta t')}\right), \tag{22}$$

where α is an eigenstate of $\hat{a}$. By solving Eq. (21) in position space, we have the eigenstate such that

$$\langle x\,|\,\phi\rangle=\left[\frac{\Omega}{s^2\hbar\pi}\right]^{1/4}\exp\left\{\frac{1}{s\hbar}\left[\sqrt{2\hbar\Omega}\alpha x-\frac{1}{2}\left(\frac{\Omega}{s}-im\exp_q(\beta t)\dot{s}\right)x^2\right]-\frac{1}{2}|\alpha|^2-\frac{1}{2}\alpha^2\right\}. \tag{23}$$

According to the invariant operator theory, the wave function, $\langle x|\psi\rangle$, which satisfy the Schrödinger equation is different from the eigenstate of the invariant operator by only a time-dependent phase factor [13]

$$\langle x\,|\,\psi\rangle=\langle x\,|\,\phi\rangle\exp[i\varepsilon(t)]. \tag{24}$$

To derive the time-dependent phase $\dot{\varepsilon}(t)$, let us insert Eq. (24) in Schrödinger equation. Then, we get

$$\hbar\dot{\varepsilon}=\langle\phi\,|\left(i\hbar\frac{\partial}{\partial t}-\hat{H}_q\right)|\,\phi\rangle. \tag{25}$$

Execution of some algebra after inserting Eq. (3) into the above equation leads to

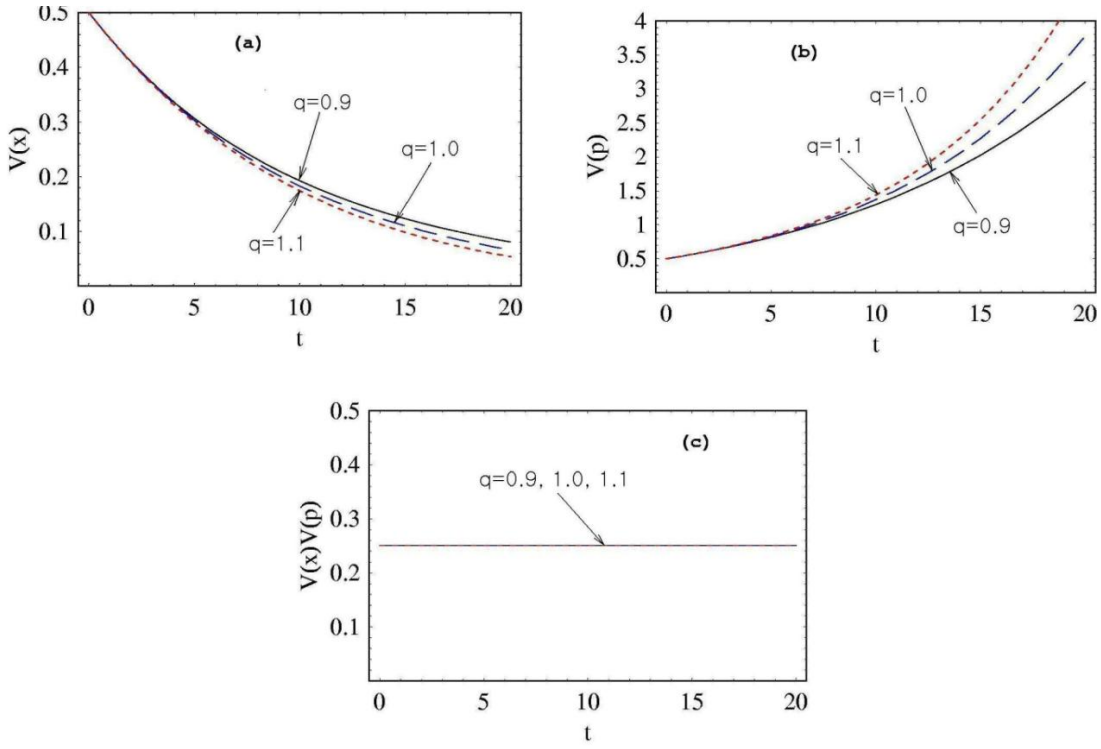

Fig: 1. Variances $V(x)$ (a) and $V(p)$ (b) and uncertainty product $V(x)V(p)$ (c) as a function of time, for various values of q. We used $\omega=1$, $\beta=0.1$, $m=1$, $\hbar=1$, and. $s_0=1$.

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$$\dot{\varepsilon} = -\frac{\Omega}{s^2(t) m \exp_q(\beta t)}\left(\alpha^*\alpha + \frac{1}{2}\right) + \frac{i}{2}(\dot{\alpha}\alpha^* - \dot{\alpha}^*\alpha). \quad (26)$$

If we consider that the absolute value of α is constant, $\varepsilon(t)$ in the above equation is easily identified to be

$$\varepsilon(t) = -\frac{1}{2}\Omega\int_0^t \frac{dt'}{s^2(t') m \exp_q(\beta t')}. \quad (27)$$

Thus, we confirm that the exact Schrödinger solution in the coherent state is represented as Eq. (24) with Eqs. (23) and (27). This solution is very useful when we investigate diverse quantum properties of the system.

As an example, let us see the variances of the canonical variables. The variance of an arbitrary quantum variable is in general defined as

$$V(y) = \langle \hat{y}^2 \rangle - \langle \hat{y} \rangle^2, \quad (28)$$

where $\langle \hat{y} \rangle = \langle \Psi | \hat{y} | \Psi \rangle$. Considering the wave function given in Eq. (24), the variances of the canonical variables are evaluated in the form

$$V(x) = s^2\hbar/(2\Omega), \quad (29)$$

$$V(p) = \frac{\hbar\Omega}{2s^2}\left[1 + \left(\frac{m \exp_q(\beta t) s\dot{s}}{\Omega}\right)^2\right]. \quad (30)$$

Variances $V(x)$ and $V(p)$ and their product (uncertainty product) $V(x)V(p)$ are illustrated in **Fig. 1**. Note that $V(x)$ decreases as time goes by while $V(p)$ increases. However, the uncertainty product $V(x)V(p)$ almost does not vary with time and is nearly $\hbar^2/4$. The uncertainty product in the coherent state is the same as the minimum uncertainty product in the number state, which corresponds to the case of $n = 0$ where n is the quantum number. The decrease of $V(x)$ and the increase of $V(p)$ with time are more rapid for large q.

The degree of correlation between the two conjugate canonical variables x and p is represented by correlation coefficient that is defined as [27].

$$r = \frac{1}{2}\langle \{\hat{x} - \langle \hat{x} \rangle, \hat{p} - \langle \hat{p} \rangle\}_+ \rangle \Big/ \sqrt{V(x)V(p)}, \quad (31)$$

where $\{\}_+$ means anti-commutator. A little algebra using Eqs. (24), (29), and (30) leads to

$$r = \frac{1}{\Omega} m \exp_q(\beta t) s\dot{s}\left[1 + \left(\frac{m \exp_q(\beta t)}{\Omega}\right)^2\right]^{-1/2}. \quad (32)$$

Then, the uncertainty product $V(x)V(p)$ in the Glauber coherent state for the time-dependent Hamiltonian system is represented in terms of r as [14]

$$V(x)V(p) = \hbar^2/[4(1 - r^2)]. \quad (33)$$

This becomes large as r approaches unity. We see from Eq. (32) that r is close to unity when $\dot{s}$ is sufficiently higher than $\Omega/[m \exp_q(\beta t) s]$, leading to high uncertainty product.

[III] RESULTS AND DISCUSSION

The ordinary CK oscillator has been generalized by replacing standard exponential function with the q-exponential function. The quantum dynamics of the generalized CK oscillator is investigated by introducing linear invariant operator. By means of the Liouville-von Neumann equation, two kinds of linear invariant operator $\hat{I}_I$ and $\hat{I}_{II}$ are constructed. We confirmed that $\hat{I}_I$, and $\hat{I}_{II}$ are represented in terms of the destruction operator $\hat{a}$ and the creation operator $\hat{a}^+$, respectively. By solving the eigenvalue equation of $\hat{I}_I$, the corresponding eigenstate $\langle x | \phi \rangle$ has been obtained as shown in Eq. (23). From Eq. (24), we can see that the solution of the Schrödinger equation $\langle x | \psi \rangle$ can be represented in terms of the eigenstate $\langle x | \phi \rangle$. Since $\langle x | \phi \rangle$ is not only an eigenstate of $\hat{I}_I$ but also an eigenstate of $\hat{a}$, we can conclude that Eq. (24) is the Glauber coherent state.

The Schrödinger solution, Eq. (24), is very useful when investigating diverse properties of the coherent state for the generalized CK oscillator. As an example, we evaluated variances of position and momentum by taking advantage of Eq. (24). It is shown in **Fig. 1** that $V(x)$ decreases with time while $V(p)$ increases. The degree of these decrease and increase is explicitly dependent on the nonextensive parameter q. The strength of correlation for position and momentum can be represented by correlation coefficient r defined in Eq. (31). We confirmed that there is a simple relation between $V(x)$ $V(p)$ and r, which is given in Eq. (33).

In recent years, it turned out that nonextensive formalism of thermodynamics with q-exponential is important as an implement of biophysics. A universal function for the kinetics of complex biological systems, which unifies and generalizes several theoretical attempts for describing biological fractal phenomena, has been established with the use of nonextensive mechanics [2]. Useful informations for enzyme→ligand fluorescence energy transfer can be obtained from Tsallis statistics for fluorescence intensity decay in enzyme-ligand complex formation [3].

[VI] CONCLUSION

The time behavior of variances, $V(x)$ and $V(p)$, is affected by the degree of nonextensivity that is determined by the value of q. Fundamentally, $V(q)$ decreases with time while $V(p)$ increases, in response to the dissipation of quantum energy of the oscillator. The rate of decrease of $V(x)$ and the rate of increase of $V(p)$ become large along the increase of q. For q=1, these dynamical behaviors recover to those of standard CK oscillator. The effects of nonextensivity on some dynamical systems are important as a correction of Boltzmann-Gibbs statistics.

CONFLICT OF INTERESTS

The author declares that there is no conflict of interests.

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CERAMIC INDUSTRY WASTEWATER TREATMENT BY RHIZOFILTRATION SYSTEM – APPLICATION OF WATER HYACINTH BIOREMEDIATION

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ABSTRACT

In the present study, water hyacinth was used to treat ceramic wastewater that contains heavy metals such as Cadmium (Cd), Chromium (Cr), Copper (Cu), Zinc (Zn), Manganese (Mn), Iron (Fe), and Boron (B). A batch analysis (3 Columns) by continuous rhizofiltration system was used to remove heavy metals from ceramic wastewater. The metal removal efficiency was identified by evaluating the translocation of metals in roots, leaves and shoot of the water hyacinth. The heavy metal removal efficiency followed the order Fe > Zn > Cd > Cu > B > Cr during the treatment process, and water hyacinth had luxury consumption of those elements (up to 99.3% removal efficiency). In addition, water hyacinth length, weight, stem and leave width were also determined and showed some increment (up to 0.74cm in Column 2). Similar trend was also observed for the leave and stem, where it increased considerably from 5.61 to 6.01 and 2.37 to 2.91 cm in Column 1, respectively. Water hyacinth weight demonstrated some rise (e.g. 27.96 to 37.1 g in column 1), signifying growth of water hyacinth during the treatment of ceramic wastewater. The results of Scanning Electron Microscope (SEM) analyses indicated that most of the metals accumulated in the roots of the plants, suggesting that absorption were the main mechanisms in the treatment process. It can be concluded that phytoremediation of wastewater through rhizofiltration process has the ability to trap and filter contaminants such as metals and organic pollutant.

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KEY WORDS

Ceramic wastewater; water hyacinth; heavy metal removal; rhizofiltration

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[I] INTRODUCTION

The production of bricks, clay and sand as raw material for ceramic industry has contributed to certain extent in the field of engineering. It has excellent recycle function primarily in its wastewater usage, where cost has been reduced during formation of the final product and environmentally safe due to waste handling [1]. However, it should be pointed that the ceramic industry also produces a significant amount of wastewater that contains heavy metals. Studies have shown that the ceramic wastewater contains 15 mg/L of Boron and 2000 mg/L of suspended solids [2]. Boron is widely used in the ceramic industry during the development of mechanical strength of tiles. In general, ceramic material is defined as inorganic materials, with possible organic content as well as non-metallic compounds. In addition, it produces a product with a small portion of clay which can be glazed or unglazed, porous or vitrified [3]. A small amount of Boron and metallic elements in ceramic wastewater may affect plant tissues and human body. It is well known that water hyacinth has the capability to absorb mineral compounds. Previous study has shown that it can remove up to 70% of chromium in wastewater [4] and absorb heavy metals such as cadmium and zinc [5]. Water hyacinth is an exotic plant which can grow up to 3 feet and has green leave with sharp edges, circular to oval joined to a spongy reproduction.

Earlier study has shown that metal up-take time and detention area play an important role in phytoremediation, particularly its rhizofiltration [6]. Rhizofiltration is a filtration and absorption process of heavy metals by plant root over a period of time. Response of a plant to hydraulic retention time (HRT) is also considered due to availability of water to retain pollutant. Accordingly, the current treatment method was selected based on economic point of view, and this application may execute in situ plants which grow on ceramic wastewater surface. Even

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though a number of studies have been conducted on phytoremediation, there were not many studies on ceramic wastewater treatment using water hyacinth. Accordingly, the aim of this study was to investigate heavy metal removal from ceramic wastewater using water hyacinth. The heavy metals investigated were Cadmium (Cd), Chromium (Cr), Copper (Cu), Zinc (Zn), Iron (Fe), and Boron (B). A batch analysis using continuous rhizofiltration system was investigated to remove heavy metals from ceramic wastewater. In addition, psychological response of plant portion to heavy metals absorption and its synchronization to their food was also assessed.

[II] MATERIALS AND METHODS

2.1. Remediation using single plant

Water hyacinth was collected from a Nursery in Skudai, Johor Bharu, Malaysia. The seedling was cultivated using water in a Hydroponic basin (10 L) for a period of 3 days. Ceramic wastewater was collected from a local ceramic factory **[Table–1]**. For each batch analysis, around 400 ml of ceramic wastewater was used. The purpose of batch analysis was to ensure adaptability of the plant to ceramic wastewater and growth cultivation. Plant size and weight was determined regularly to choose the best plant for experiment. Later, primary study was performed in 20 L Hydroponic container to investigate heavy metal removal from the ceramic wastewater. In general, around 8 to 11 plants of water hyacinth were specified. The preliminary and primary studies were then performed at 12, 24, 48, and 72 hrs of retention time.

Table: 1. Characteristics of ceramic wastewater

Parameter	Unit	Concentration
pH	-	8.21 ± 0.15
Dissolved Oxygen	mgL^{-1}	0.17 ± 0.02
Chemical Oxygen demand	mgL^{-1}	822 ± 42.0
Total Suspended Solid	gmL^{-1}	0.181 ± 0.11
Boron	mgL^{-1}	14.4 ± 0.20
Copper	μgL^{-1}	20 ± 0.11
Zinc	mgL^{-1}	8.13 ± 0.25
Iron	mgL^{-1}	1.51 ± 0.10
Chromium	mgL^{-1}	19.25 ± 0.02

2.2. Experimental setup

The present study focused on adsorption by root and it is considered as a tertiary treatment of wastewater. A 3-phase cleaning system, with a constant flow rate passing through the 3 columns with different root lengths and distance from first holding tank was proposed for the study, in order to maintain suitable loading and flow rate which consisted a retention pond and rhizofilter. **Figure– 1** illustrates the experimental set-up of the study. All variables were identified initially, and wastewater was circulated in one direction in the container (0.28 x 0.19 x 0.46m). Arithmetic mean for the removal efficiency was used when deviation was within 30% of the mean [7].

The experiment was performed by first feeding the ceramic wastewater into a holding tank ($0.024m^3$). Subsequently, the wastewater was fed into Column 1, followed by Column 2 and 3 containing water hyacinth for 5 days. Finally, the effluent from Column 3 was fed back to a holding tank. Since Rhizofiltration focuses on the root system, it is vital to investigate metal accumulation in the root, shoot and leaves of the water hyacinth. Each water hyacinth plant was separated and washed 3 times using distilled water before drying in the oven for 2 days.

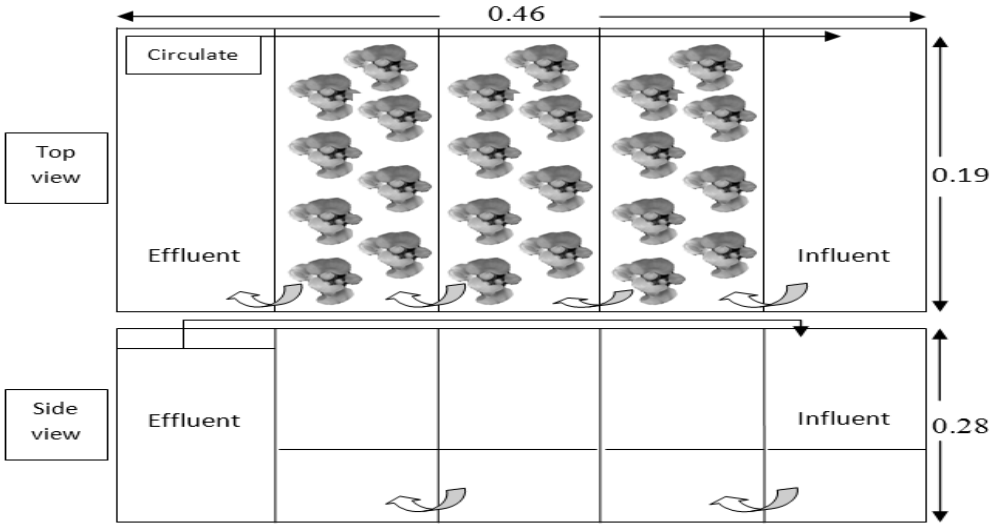

Fig: 1. Schematic diagram of experimental flow (units in m)

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[III] RESULTS AND DISCUSSIONS

3.1. The removal of metals with Rhizofilter circulation System

Laboratory experiments with Rhizofilter circulation system were conducted on samples taken from each basin for 5 days. Control tests without plant materials were carried out to reflect on the non rhizofiltration effect in batch experiments. The treatment process is without any circulation with free flow condition. The overall performance of the treatment system is shown in **Table– 2**.

3.2. The performance of metals

Results of heavy metal removal profiles are illustrated in **Figure– 2** to 7 for Boron, Copper, Zinc, Ferum, Chromium and Cadmium respectively.

3.3. Inorganic, Organic Chemical and Physical constituents

The chemical analysis in each column during the treatment of ceramic wastewater is shown in **Table– 1**. The chemical analysis included pH, DO, COD, and TSS.

3.4. Water Hyacinth Performance

Table– 4 indicates the measurement of water hyacinth portion (root, leave, stem and weight). The images of roots are shown in **Figure– 8**.

Table: 2. Heavy metal removal rate (%) and amount reduced in each column containing water hyacinth

Parameter	Control		C1		C2		C3		Effluent	
		%		%		%		%		%
B, mgL^{-1}	3.40	23.6	10.37	72.0	10.90	75.7	10.47	72.7	10.83	75.2
Cu, μgL^{-1}	7.50	37.5	15.00	75.0	15.66	78.3	13.66	68.3	17.66	88.3
Zn, mgL^{-1}	5.13	63.1	7.92	97.4	7.72	94.9	7.92	97.4	7.96	97.9
Fe, mgL^{-1}	1.07	71.2	1.48	98.2	1.48	98.5	1.50	99.3	1.50	99.3
Cr, mgL^{-1}	13.24	68.8	16.53	85.9	16.26	84.5	16.01	83.2	13.24	68.8
Cd, mgL^{-1}	0.10	62.3	0.10	64.8	0.15	93.3	0.15	96.0	0.15	96.0

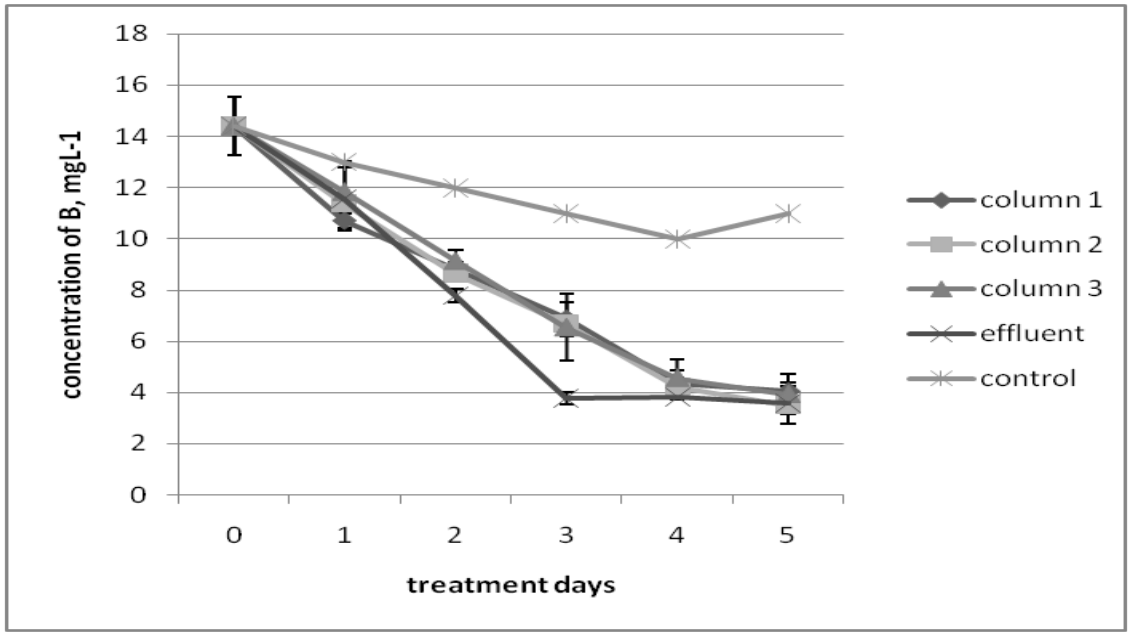

Fig: 2. Boron removal profile in each column during the treatment of ceramic wastewater using water hyacinth

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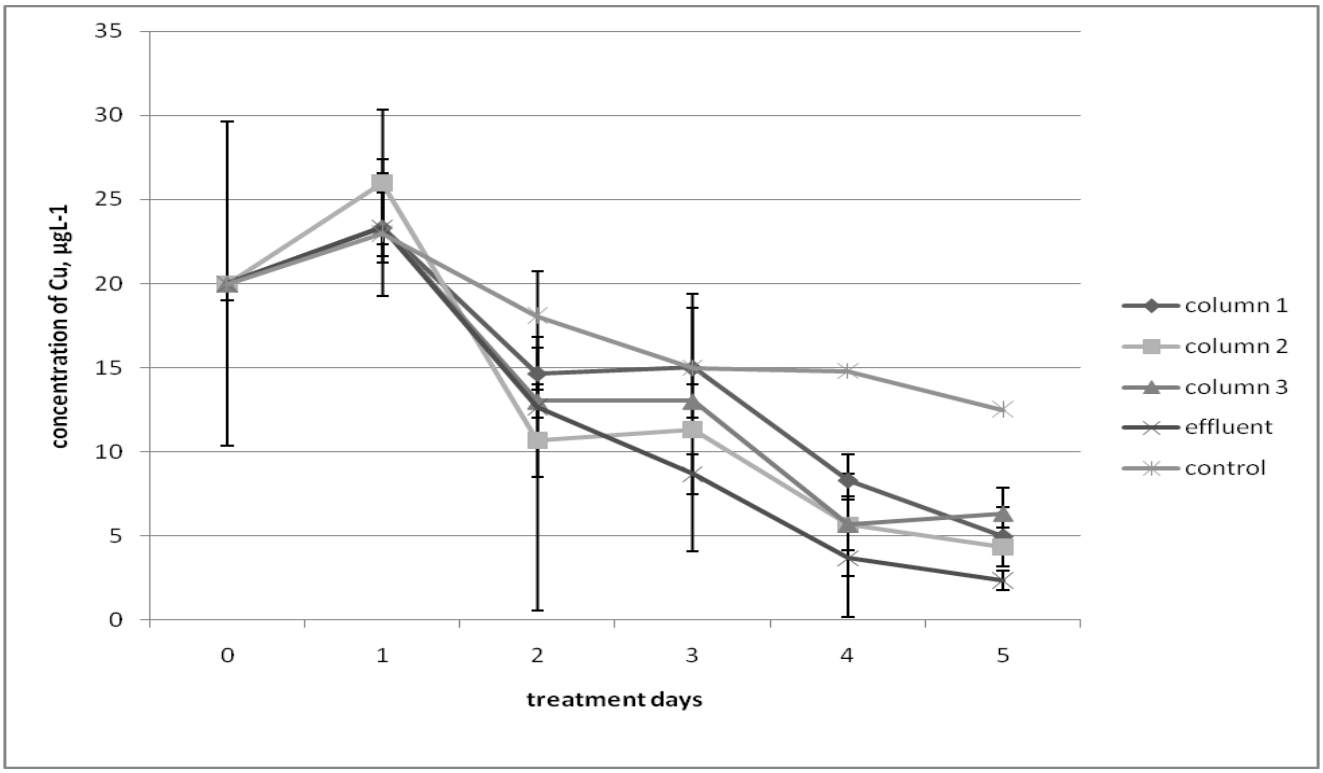

Fig: 3. Copper removal profile in each column during the treatment of ceramic wastewater using water hyacinth

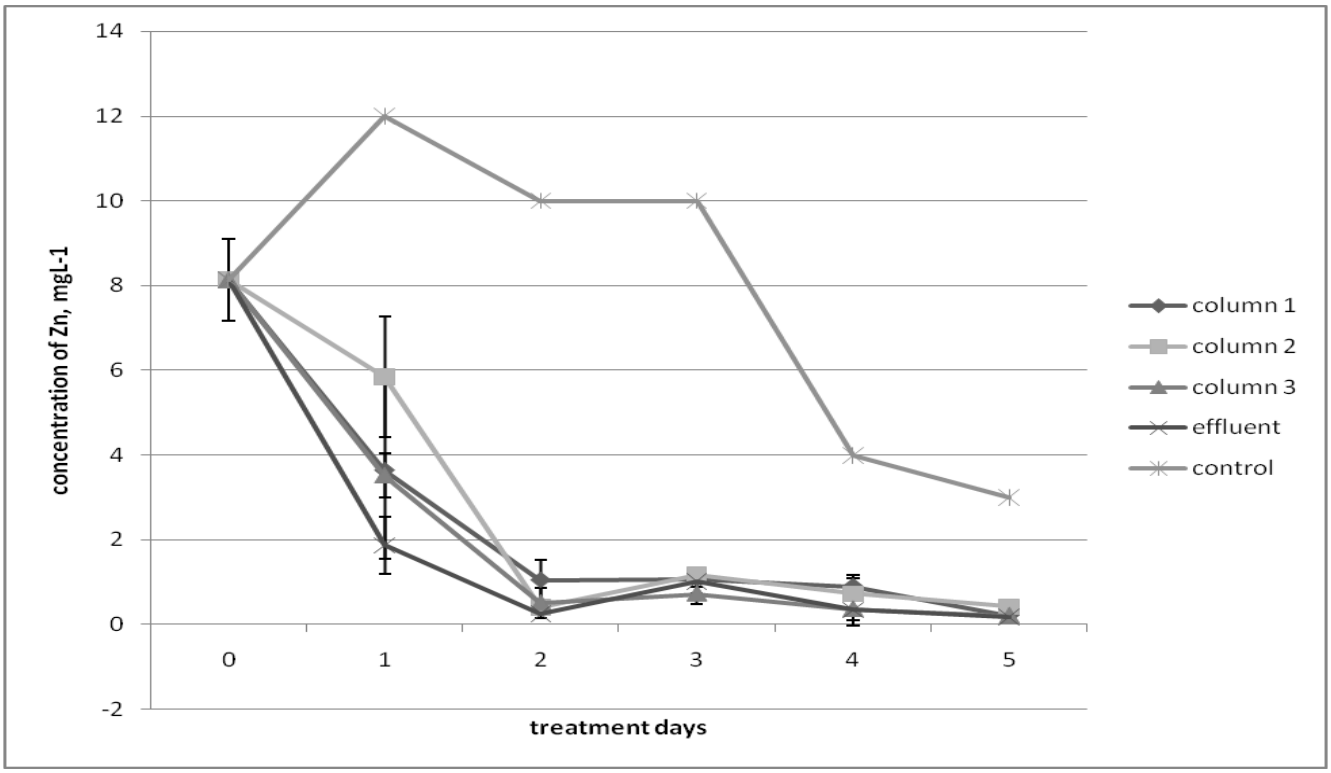

Fig: 4. Zinc removal profile in each column during the treatment of ceramic wastewater using water hyacinth

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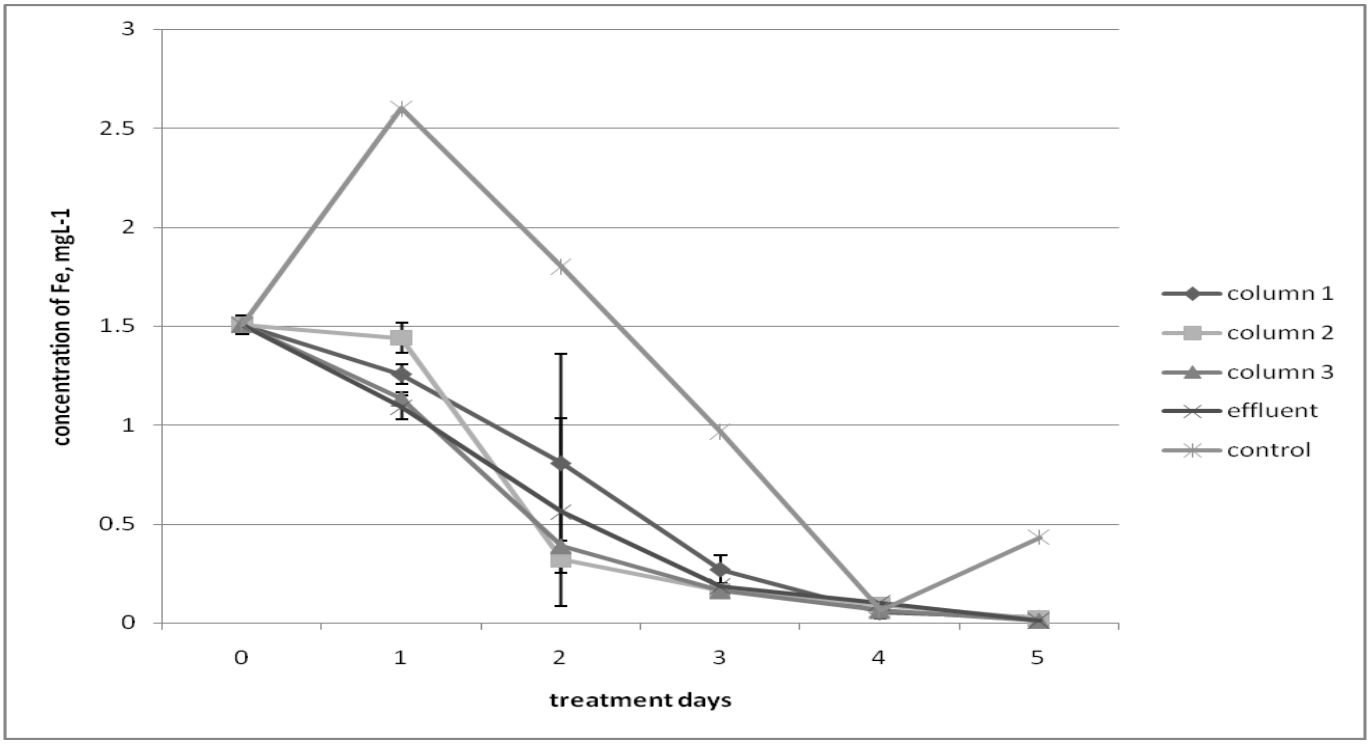

Fig: 5. Iron removal profile in each column during the treatment of ceramic wastewater using water hyacinth

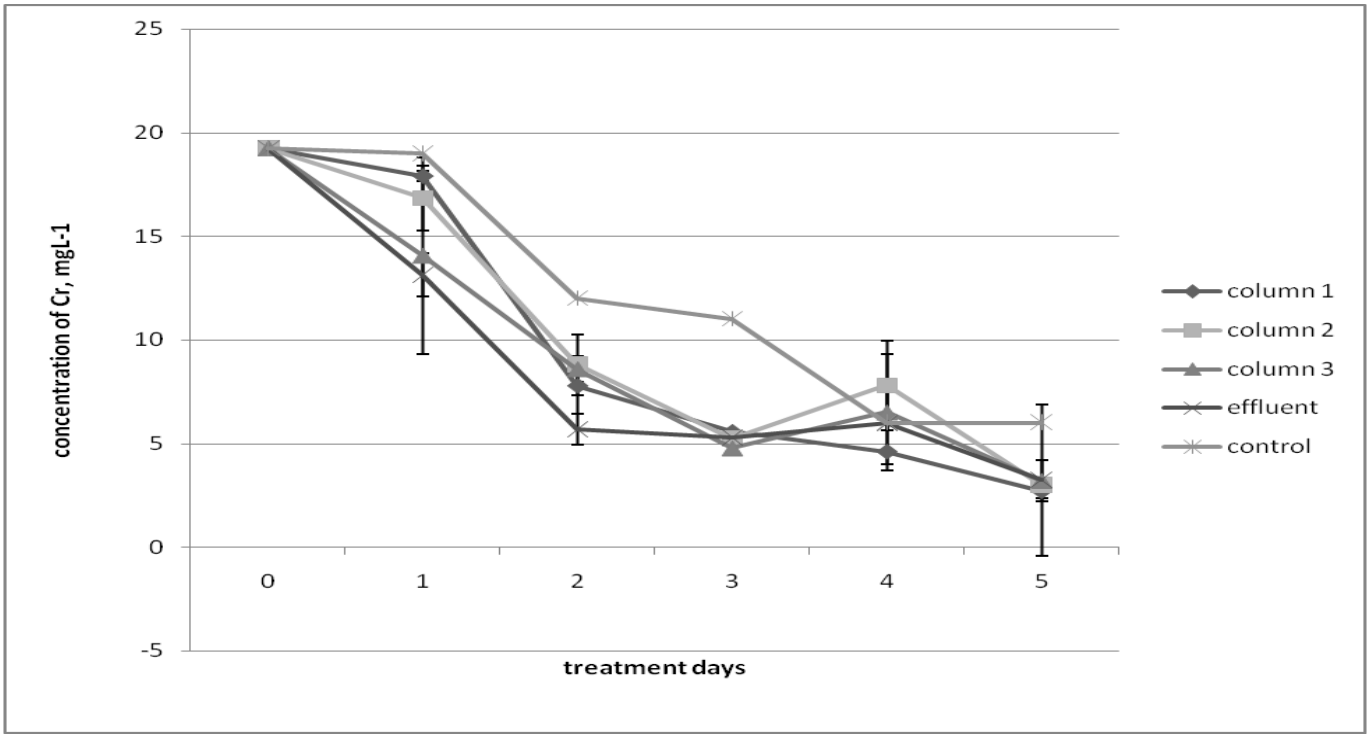

Fig: 6. Chromium removal profile in each column during the treatment of ceramic wastewater using water hyacinth

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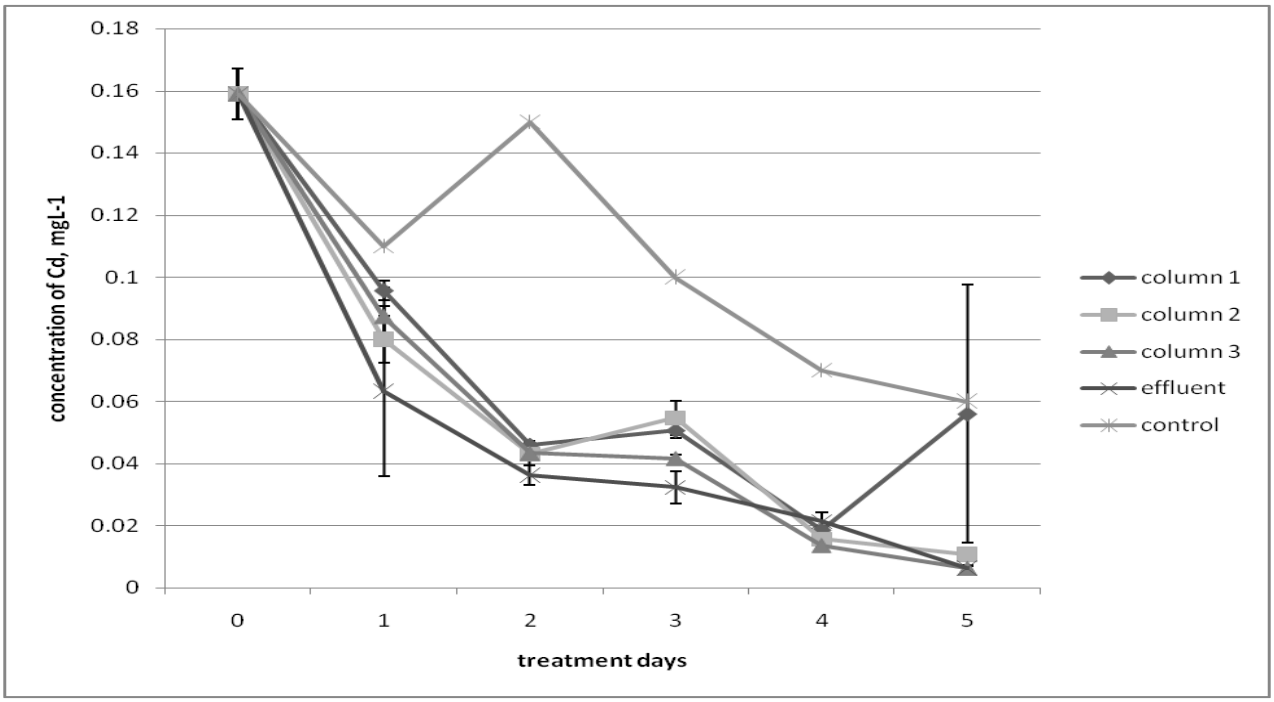

Fig: 7. Cadmium removal profile in each column during the treatment of ceramic wastewater using water hyacinth

Table: 3. Chemical analysis in each column during the treatment of ceramic wastewater

Parameter	Unit	C1	C2	C3	Effluent
pH	-	8.45 ± 0.1	8.49 ± 0.03	8.49 ± 0.20	8.49 ± 0.02
DO	mgL^{-1}	6.71 ± 0.07	6.82 ± 0.15	6.19 ± 0.01	6.52 ± 0.82
COD	mgL^{-1}	160 ± 8	135 ±9.0	124.7 ± 445	101.7 ± 9.35
TSS	gmL^{-1}	0.02 ± 0.01	0.04 ±0.01	0.02 ± 0.05	0.03 ± 0.01

Table: 4. Measurement of water hyacinth's portion

	Initial			5th Day		
	C1	C2	C3	C1	C2	C3
Root length, cm	6.12	4.23	4.35	6.73	4.97	4.73
Leave width, cm	5.61	5.78	5.32	6.01	6.15	5.83
Stem width, cm	2.37	2.11	2.02	2.91	2.56	2.32
Weight, g	27.96	15.97	17.83	37.1	17.25	22.18

[IV] DISCUSSION

4.1. The performance of metals

Figure– 2 illustrates boron reduction profile in each column during the treatment process. It can be seen that boron concentration decreased sharply from 14.4 mg/L to around 3.6 mg/L (75.2% removal efficiency), confirming the removal of boron by water hyacinth. Boron was successfully absorbed (10.83 mg/L, **Table– 2**) by water hyacinth through reaction for growth. It is known that plants need around 0.3 to 1.0 mg/L of boron for growth [8].

As for copper removal rate **[Figure– 3]** it can be seen that it was reduced tremendously, from 20 to 2.4 mg/L in the effluent, confirming the effectiveness of water hyacinth in removing heavy metals from ceramic wastewater. Around 17.66 mg/L **[Table– 2]** of copper was removed in the treatment system. Copper is absorbed by water hyacinth to strengthen its cell and encourages metabolism of nitrogen and carbohydrate in the photosynthesis process [9].

Figure– 4 shows zinc reduction profile, where 97.9% removal efficiency was noted during the operational period. The stem structure of water hyacinth promotes excellent absorption capacity for growth. Zinc activates enzymes for protein synthesis and can be used as starch production and root growth for water hyacinth [10].

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Iron is an important element for plant growth, and it is absorbed by roots by rhizofiltration process. Plants have fibrous root, which makes the rhizofiltration process easier [11]. Plants needed this element for enzyme formation that can help photosynthesis. As illustrated in figure 5, the iron removal efficiency increased uniformly from day 3 to 5, with up to 99.3% removal rate.

As for the chromium removal, water hyacinth showed promising results as a hyper-accumulator. The water hyacinth appeared to be a good choice for removing chromium from polluted water. Around 13.24 mg/L **[Table– 2]** of chromium was removed during the treatment process with overall removal efficiency of 68.8%.

One of the main toxic effects of cadmium in plants is growth reserve in size and dry weight of tops and roots [12]. Water hyacinths showed only a minimal adverse impact from cadmium exposure, because of the needs and necessary of nutrient source. Cadmium removal efficiency was 96% **[Table– 2]**.

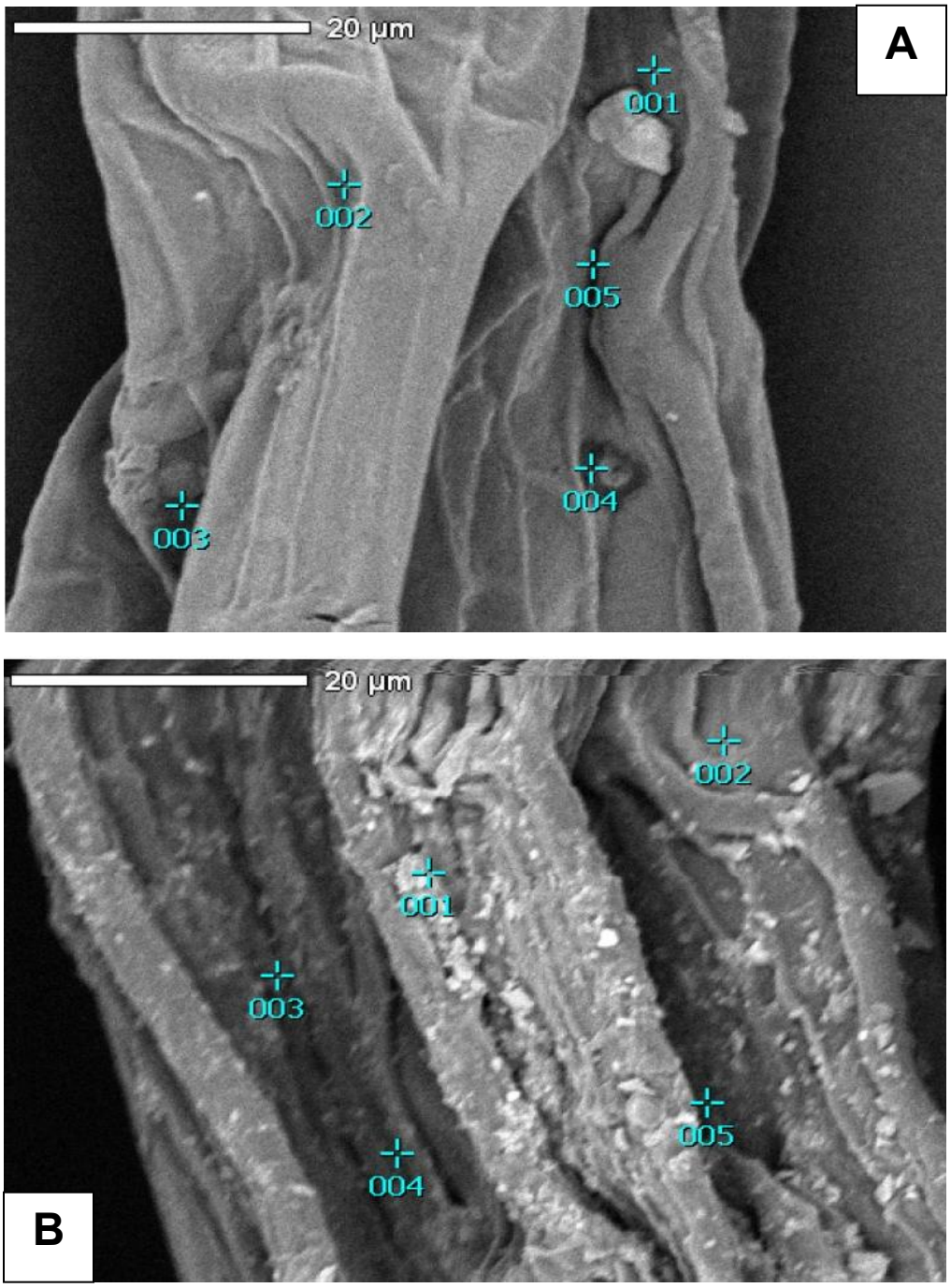

Fig: 8. Scanning Electron Microscope (SEM) images of the surface of the sunflower root (A) before and (B) after rhizofiltration

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4.2. Inorganic, organic chemical and physical constituents

Table– 3 illustrates chemical analysis in each column during the treatment of ceramic wastewater using water hyacinth. It can be seen that the pH in the effluent was stable (pH=8.49), confirming the treatment using water hyacinth did not affect the pH profile. However, there was a minor increment in the pH profiles, in all the columns compared to influent pH (pH=8.21), due to chemical reactions that occur during the retention period.

COD removal efficiency can be decreased if a wastewater contains substrates that can be broken [13]. It should be pointed here is that during initial treatment (1st day), the COD in the effluent was around 853 mg/L (data not presented) mainly because of the admixture with existing organic material on the process of wastewater sample and plants relocation. However, the COD removal efficiency increased gradually from day 2 onwards until only 101 mg/L of COD left in the effluent [Table– 3]. As for the Dissolved Oxygen (DO), the levels were gradually increased to 6.52mgl^{-1}, due to air supply during the treatment. Oxygen in the sample is used for the decomposition of organic matter by bacteria in the process of aerobic respiration. In addition, the roots played an important role in the aerobic decomposition of organic waste efficiently [14]. Total suspended solid (TSS) for the three sets of water samples were shown in Table– 3, and demonstrated some reduction (from 0.181 to 0.03gml^{-1}), probably due to the solid sediments at the base sample. Thick plant roots and high total surface area of water hyacinth promoted sedimentation of suspended solid.

4.3. Water hyacinth performances

Water hyacinth length, weight, stem and leave width was determined [Table– 4], in order to investigate its growth rate. Long heavily roots were seen to increase up to 0.74cm within 5 days of treatment (Column 2). Previous study has shown that the length varies from 4 to 15cm in small plants, 10 to 36cm in medium plants, and 12 to 22cm, in large plants [15]. At certain situations, its populations could be doubled within two weeks. The growth rate of water hyacinth was limited to a certain extent, due to copper contaminations in the ceramic wastewater. Similar trend was also observed for the leave and stem, where their widths increased considerably (e.g. from 5.61 to 6.01 and 2.37 to 2.91 cm in Column 1, respectively). Weight of water hyacinth also showed some increment (e.g. 27.96 to 37.1 g in Column 1) signifying growth of water hyacinth during the treatment of ceramic wastewater. Scanning electron microscope (SEM) [16] showed that the roots were covered with large fragments of heavy metals [Figure– 8b], suggesting that absorption were the main mechanisms in the treatment process containing ceramic wastewater by rhizofiltration.

[V] CONCLUSION

Phytoremediation of wastewater through rhizofiltration has the ability to trap and filter contaminants such as metals and organic pollutants. The circulation process in the current study contributed to the best innovation for the treatment of heavy metals in the ceramic industry. Water hyacinth is appropriate and suitable hyper accumulator for the treatment of ceramic wastewater containing iron, cadmium, chromium, zinc, and boron. Water hyacinth is the best plant because of its luxury consumption with the circulation flow.

CONFLICT OF INTERESTS

Authors declare no conflict of interest.

FINANCIAL DISCLOSURE

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FATTY ACID COMPOSITION OF NEW HYBRID VARIETIES OF MINOR MILLETS SEED

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ABSTRACT

Minor millets are important food crops of a large group of people in rural, tribal and hilly areas in India. Nine hybrid varieties of minor millets seeds viz., Ragi ((Eleusine coracana variety FM & HR), Kodo (Paspalum scrobiculactum variety 41,48 & 439), kutki (Panicum sumatrense variety 8 & LMCO-2), Sanwa (Echinochloa frumentacea variety VL-29 & VL-172) have been studied for their fatty acid composition by gas chromatography. The Kodo-48 has highest (86.5%) total saturated fatty acid content whereas variety kutki-8 has 79.1% total unsaturated fatty acid content with better storage quality. The Sanwa BMVL-29 has highest content (46.9%) of linoleic acid (PUFA).

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KEY WORDS

Minor millets; fatty acid composition; Gas chromatography; Ragi ; Kodo; Kutki ; Sanwa varieties.

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[I] INTRODUCTION

Millets are a group of small-seeded species of cereal crops or grain like food that has been used by large group of people in rural, tribal and hilly areas in India. Millet is a cereal crop plant belonging to the grass family, Graminae. The term "millet" is used loosely to refer to several types of small seeded annual grasses, belonging to species under the five genera in the tribe Paniceae [1-9] . Moreover these plants are less prone to diseases and pests in the field and store. The advantage of millets lies in the fact that they can be grown in infertile soil, intense heat, and scanty rainfall. For millions of people in the semi-arid tropics of Asia and Africa, millet has been the most important staple food for centuries. They are sometimes known as the "poor man's cereal" because given choice, people go for other cereals such as wheat or rice. Millet is considered as the sixth crop in the world after wheat, rice, corn, barley and sorghum [10].

Fat is one of the major nutrients which provide energy, promote body growth, maintain and repair body tissue, promote reproduction and lactation and regulate body process. Fats are carriers of fat soluble vitamins. Dietary fat must also provide essential fatty acids (EFA) which are the functional components of membrane lipids and have other important metabolic function. Fats are made up of fatty acids which include saturated fatty acids like palmitic and stearic, monounsaturated fatty acids (MUFA) like oleic and polyunsaturated fatty acids (PUFA) like linoleic acid and linolenic acid [11, 12]. Lipids are relatively minor constituents in cereal grains, however, they contribute significantly to diet as a source of invisible fat and essential fatty acid [13, 14]. The lipid also have an important role in storage quality and processing of cereal, among minor millets account for about 1% of good grains produced in the world and they are useful as food crops in their respective agro-eco systems [15], rural people used millets as an important staple food and also an alternative for alcoholic beverages.

[II] MATERIALS AND METHODS

2.1. Collection of samples

The healthy, authentic and new hybrid varieties of minor millets seed of Ragi variety FM and HR, Kodo variety 41, 48 and 439, Kutki variety 8 and LMCO-2, Sanwa variety VL-29 and VL-172 under investigation were collected from Agriculture Research Station of Jawaharlal Nehru krishi Vishwavidyalaya, Dindori (M.P.).

2.2. Extraction and GLC analysis

Powdered sample of experimental seeds were subjected to solvent extraction in Soxhlet Apparatus for 20h, using petroleum ether (40-600C) as solvent. Lipids were then estimated gravimetrically by the method of

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Colowick and Kaplan 16]. Methyl esters of the lipids were prepared by the method of Chowdhary et al, [17] and analyzed by gas liquid chromatogram (GLC). Gas chromatograms were recorded using Flame Ionization Detector (FID) with split ratio 1:50.

[III] RESULTS

The results of saturated and unsaturated fatty acid composition of minor millets seeds are reported in [**Table -1 and Table -2**] respectively.

Table: 1. Saturated fatty acid composition of hybrid variety of minor millets

Seed	Saturated fatty acid %							
	Caprylic acid	Lauric acid	Myristic acid	Palmitic acid	Stearic acid	Arachidic acid	Bahenic acid	Total saturated fatty acid(%)
Ragi-FM	4.6	0.4	0.7	23.8	3.5	0.8	0.7	34.5
Ragi-HR	3.9	0.2	0.6	20.4	3.7	0.3	1.5	30.6
Kodo-41	1.7	0.2	0.3	25.7	4.2	1.0	1.1	34.2
Kodo-48	76.6	-	-	2.8	5.3	0.2	1.6	86.5
Kodo-439	1.3	0.1	0.2	16.5	2.4	1.1	0.7	22.3
Kutki-8	0.5	-	0.1	15.6	2.5	1.1	0.4	20.2
Kutki LMCO-2	0.5	0.1	0.1	17.8	1.8	1.8	0.3	22.4
Sanwa BMVL-29	2.1	-	0.1	15.8	5.0	0.9	0.3	24.2
Sanwa BMVL-172	1.1	0.1	0.1	17.1	6.1	1.1	0.4	26.0

Table: 2. Unsaturated fatty acid composition of hybrid varieties of minor millets

Seed	Unsaturated Fatty acid (%)				
	Oleic acid (MUFA)	Linoleic acid (PUFA)	Linolenic Acid (PUFA)	Ecosenoic Acid (MUFA)	Total Unsaturated fatty acid
Ragi-FM	48.8	13.3	0.8	2.6	65.5
Ragi-HR	48.4	19.3	1.1	0.5	69.3
Kodo-41	42.7	17.9	1.8	3.1	65.5
Kodo-48	6.7	5.8	0.1	0.2	12.8
Kodo-439	37.2	38.8	0.8	0.9	77.7
Kutki-8	38.8	38.8	1.0	0.5	79.1
Kutki LMCO-2	43.2	32.7	0.5	0.9	77.3
Sanwa BMVL-29	27.0	46.9	1.0	0.5	75.4
Sanwa BMVL-172	29.5	42.9	0.7	0.4	73.5

[IV] DISCUSSION

[Table-1 and Table -2] showed the variation of fatty acid content amongst different hybrid varieties of minor millets seeds viz., Ragi (FM ,HR), Kodo (41,48,439), Kutki (8,LMCO-2), Sanwa (VL-29,VL-172) .

The saturated fatty acid, Caprylic acid was found to be highest (76.6%) in variety Kodo-48 and lowest (0.5%) in variety Kutki (8, LMCO-2). The Palmitic acid content was reported higher (25.7%) in variety kodo -41, while It ranges from 2.8% (Kodo-48) to 23.8% (Ragi-FM) in the other variety of minor millets under the study.

The percentage of Stearic acid was to be found maximum (6.1%) in the variety Sanwa BMVL -172 and minimum (1.8%) in the variety Kutki LMCO-2. The Arachidic acid ranges from 0.2% (Kodo-48) to 1.8% (Kutki LMCO-2). The variety Kodo -48 has maximum (1.6%) Bahenic acid content while varieties Kutki LMCO-2 & Sanwa BMVL-172 have minimum Bahenic acid content (0.3%).The total saturated fatty acid (TSFA) content was to be greater (86.5%) in the variety Kodo-48 than the variety Kutki-8 (20.2%).

The unsaturated fatty acid, Ragi variety (FM) contain maximum amount (48.8%) of Oleic acid. Whereas, the Linoleic acid was found to be highest (46.9%) in the variety Sanwa-29. The Linolenic acid and Ecosenoic acid content was found to be greater (1.8% and 3.1% respectively) in the variety Kodo-41 than the variety Kodo-48 (0.1 & 0.2 respectively). The variety Kodo-48 contains minimum value of mono unsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA). Total

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unsaturated fatty acid (TUFA) content was found to be highest (79.1%) in the variety Kutki-8 and lowest (12.8%) in the variety Kodo-48.

Sanwa BMVL -29 variety found to be superior than the other hybrid varieties of minor millet seeds, under investigation and the other variety of millets, as it contains highest content of linoleic acid (46.9%). The amount of linoleic acid in millet oil is higher in comparison with most other types of vegetable oils[18]. The linoleic acid is one of the most important polyunsaturated fatty acid in human food, because of its prevention of distinct heart vascular disease[19]. This acid is most important essential fatty acid required for growth, physiological function and maintenance, which cannot be synthesized by the human body and one has to depend on dietary source for their adequate supply [20]. The body metabolizes linoleic and linolenic acid into arachiodonic acid and docosahexaenoic acid (DHA) respectively which are essential to the normal development of central nervous system [21, 22]. Various developmental problems including attention-deficit/hyperactivity disorder (ADHD) in children have been linked to biological deficiencies in polyunsaturated fatty acids. Additionally, there is evidence that symptoms may be reduced with PUFA supplementation [23].

[VI] CONCLUSION

Millets are a major food source in arid and semi-arid parts of the world. Millets are good sources of nutrients. Minor millet lipid contains high quantity of essential fatty acids especially the grains are rich in polyunsaturated fatty acid (PUFA). PUFA (Omega-3 and omega-6) are necessary in the normal functioning of all tissues of the body. Their deficiencies exhibit the symptoms of disorders especially abnormalities in the liver and kidney, changes in the blood, reduced growth rates, decreased immune function, depression, and skin changes, including dryness and scaliness.The comparatively high amounts linoleic acid which is an omega 6–fatty acid, is highly significant because this acid is easily converted to n–6 eicosanoids, n–6 prostaglandin and n–6 leucotriene hormones. This provides targets for drug development in arthrosclerosis (B.P), asthma, arthritis, immunity development etc. Linoleic acid is also very popular in beauty products as helping in moisture retention, acne reduction, and anti–inflammatory. Lack of linoleic acid causes dry hair, hair loss, and wound healing. Therefore, the consumption this millet containing oil will yield the same advantages to the consumer. Oleic acid, which is an omega–9 fatty acid as the major fatty acid also is equally important having all the health benefits of linoleic acid. In cases of reduced availability of omega–6– fatty acids, omega–9–fatty acids are converted to omega– 6–fatty acids. Adequate intake of the minor millets results in numerous health benefits.

CONFLICT OF INTERESTS

None

FINANCIAL DISCLOSURE

NIL

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STUDY ON DIFFERENT ASPECTS OF STEPHANOFILARIAL DERMATITIS INFECTION IN CATTLE POPULATION OF WEST BENGAL

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ABSTRACT

In the present study, prevalence, transmission, characteristics of the parasite Stephanofilaria assamensis and pathology of the disease caused by S. assamensis, commonly known as 'humpsore' were studied in two different eco-climatic zones of West Bengal (India) i.e. in coastal plain (Bay of Bengal) of South Bengal and in Himalayan foot hills of North Bengal respectively. Irrespective of the regions, out of total 1250 cattle randomly examined, 332 (26.56%) showed lesions of Stephanofilariasis caused by S. assamensis. The prevalence of the disease in South Bengal was found to be 17.12% in which the mentioned parasite not only affected the hump but also the dewclaw, hooves, abdomen and other parts of the body. While in North Bengal, the prevalence was quite higher (38.37 %) and infection was mostly limited to the hump region causing the so called real 'humpsore' in cattle. As per the breed of cattle is concerned, 22.60% infections recorded in indigenous cattle and 36.64% recorded in crossbred and exotic cattle. The prevalence was highest among the animals of 4 to 5 years age group (28.01%). Infection rate in males animals (29.25%) was more than in females (21.84%). Influence of season on prevalence indicated that it was highest in rainy season (47.13%) followed by summer (21.64%) and winter (8.76%). The isolation and characterization of adult and microfilariae was found to be identical with no differences in their morphology. In South Bengal and North Bengal regions Musca conducens and Haematobia sp. were identified as intermediate hosts. The histopathology of the biopsy materials revealed almost identical changes like hyperplasia, fibrosis, acanthosis with huge number of adult parasites and microfilariae in dermis layer of cross sections of skin.

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[I] INTRODUCTION

Skin of cattle is often affected by Stephanofilarial infection in the Indian subcontinent and is commonly known as 'Humpsore'. Nine species of the Stephanofilarial parasites have been reported from different parts of the world, but only *Stephanofilaria assamensis* has been reported as the causal agent of hump sore in eastern India. Though the name 'Hump sore' implies appearance of sore in the hump region but the stephanofilarial dermatitis also occurs in other parts of the body. The disease is transmitted by the fly Musca conducens and is prevalent in tropical countries like India [1, 2] and other countries. The disease is widely prevalent in West Bengal, India. The presence of the parasite *Stephanofilaria sp*. which affects domestic animals may harm human health [3]. Hence, keeping in view of its prevalence in West Bengal as well as its economic importance, a fresh initiation has been undertaken to investigate the present status of prevalence, transmission dynamics and pathology of the disease.

II] MATERIALS AND METHODS

2.1. Prevalence study

The study was carried out in two different eco-climatic zones of West Bengal, India, the northern foot hills areas of North Bengal and southern coastal plains of Bay of Bengal. A total of 1250 indigenous, exotic and cross bred cattle irrespective of skin lesions recorded, were examined for the presence of hump sore lesion. Out of 1250 cattle, 695 were from West Midnapur district of South Bengal and 555 were taken from Coochbehar district of North Bengal. The prevalence was recorded in three major seasons like summer (March to June), rainy (July to October) and winter (November to February) and in respect of age, sex and site of infection.

2.2. Recovery of parasites

For the identification of parasitic agent from the hump sore affected cattle, standard techniques related to recovery of adult worms and microfilaria from blood, impression smears and tissue materials of the affected regions were applied. For isolation of adult parasite, deep scrapings and pieces of healthy tissues were taken with a scalpel from the suspected lesions and treated with lukewarm (37oC) normal saline for 2 hours. The tissue debris was separated by decantation and actively motile adults were recovered by fine needles. The worms thus wriggled out were collected and preserved in 70% alcohol, cleared in lacto phenol and the morphologically characterized with light microscope. The tissue debris contents were centrifuged @ 1000 rpm for 5 minutes, for recovery of microfilaria. The sediment was mixed well with one drop of 0.1% methylene blue and examined under microscope for presence of microfilariae.

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Detection of microfilaria was also made in impression smears prepared on a glass slide from oozing blood and fluid of deep scrapings of encrusted lesions and blood smears. The dried slides were fixed with methanol and stained with Giemsa stain (1:20) for 45 minutes. Peripheral blood was collected in vials containing heparin (0.2 mg/ml) from the suspected animals and thick and thin smears were prepared, fixed, stained with Geimsa stain and examined. Haematocrit test technique and Knott's techniques were applied for recovery of microfilaria from blood. For Knott's technique 9 ml of 2% formalin was mixed with 1 ml heparinized blood. The mixture was then centrifuged at 1500 rpm for 5 minutes. One drop of 0.1% methylene blue was added to the sediment and a drop of stained sediment was examined under microscope.

2.3. Vector study

The flies from the lesions / body were caught by net and thorax and salivary gland were dissected and tissues were squashed between slides and searched for presence of typical blunt crescent shaped microfilaria.

2.4. Pathological examination

Skin biopsies were taken from sites of those affected lesions by using 'Skin Biopsy Punch'. These were preserved in 10% buffered neutral formalin solution for histopathological examination as per standard technique.

[III] RESULTS AND DISCUSSION

Irrespective of the regions, out of 1250 cattle, 332 (26.56%) showed lesions of Stephanofilariasis caused by *S. assamensis*. But the prevalence of the disease in South Bengal was 17.12% **[Table-1]**, not only affecting the hump but the dewclaw, hooves, abdomen and also other parts of the body, while in North , the prevalence was quite higher (38.37 %) and mostly limited to the hump region causing the so called real 'hump sore' in cattle. As per breed of cattle is concerned, 22.60% were found affected among indigenous cattle and 36.64% crossbred and exotic cattle. The incidence was highest among the animals of 4 to 5 years age group (28.01%) followed by 5 to 6 years, 6 to 7 years, and 7 years and above age group, 3 to 4 years, 2 to 3 years and 1 to 2 years (1.80%). Males (29.25%) were found to be affected more than females (21.84%). As regard to site of lesions, the percent prevalence was recorded 27.40% in neck region, 18.67% in hump region, 17.16% at the base of dewclaws region, 13.85% in the hoof region, 4.51% in the prescapular area, 2.40% in the lateral abdominal region, 1.50% at the inner canthus of eye, and 14.45% on the other parts of the body.

Table-1: Prevalence (%) of *S. assamensis* infection in cattle population in different zones of West Bengal (India)

Zones	Ecological character	Number of cattle examined	Number of cattle affected	Percentage (%)
South Bengal	Coastal plains	695	119	17.12
North Bengal	Himalayan foot hills	555	213	38.37
Total		1250	332	26.56

It was observed that the prevalence of the disease increased from the month of May (20.66%) till it reached the peak in August (66.96%) and declined thereafter, lowest in winter till December. Thus, influence of season on prevalence indicated that it was highest in rainy season (47.13%) followed by summer (21.64%) and winter (8.76%).

Adult parasites and/or microfilariae were recovered from skin scrapings impression smears of tissue sections. Microfilariae in peripheral blood were also recovered only from 12 cases. Small, slender and whitish adult worms were collected. The male parasites ranged from 3 to 5 mm and females 7 to 11 mm. Under light microscope, a crown like cephalic structure was noticed; at a short below there was a row of cephalic spines. Except the cephalic structures, the cuticle was finely serrated at regular intervals throughout the body length and the serrations became gradually faint towards the posterior region. In males the body was almost of uniform thickness except the anterior end and posterior end, which was slightly bent ventrally. Whereas, both the ends of females were tapered, but the thickness increased gradually towards the posterior part and the tail was straight.

The centrifuged sediment and extractives of tissues in physiological saline revealed slender microfilaria, of which anterior end was blunt and the posterior end was pointed. Examination of impression smears revealed that most of the microfilariae were sheathed; only a few were unsheathed. Above to the nerve ring, the cephalic portion was narrow and ends somewhat rounded; on the other hand towards the posterior end, the microfilariae were narrow and tapered posteriorly. Most of the microfilariae were in open 'C' posture or coiled, while undulating forms and straight forms of the microfilariae were also observed in few cases. The length of the microfilaria was varied between 120 µm to 150 µm. In the present study, some immature worms with 'knob head' appearance and comparatively smaller size were also recovered. In the present study microfilariae could not be recovered in both thin and thick Giemsa stained blood smears. Only a few numbers of microfilariae were observed in micro-haematocrit and Knott's methods of examinations.

Two different haematophagus flies were recovered from the body of the affected cattle in two different eco-climatic zones. In coastal South Bengal *Musca conducens* and *Stomoxys calcitrans* flies were caught during feeding on the lesions of stephanofilaria. On dissection unsheathed crescent shaped infective larvae were recovered from the *Musca conducens* flies

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only and no larvae from *Stomoxys calcitrans*. In North Bengal, plenty *Haematobia sp.* and a few *Stomoxys calcitrans* were caught from the body of the host. On dissection of both the flies and thorough examination revealed a few larvae in the thorax and salivary gland of *Haematobia sp.* but not in *Stomoxys calcitrans.*

The gross and histopathological changes in different stages of stephanofilarial dermatitis of cattle were almost same irrespective of the site involved. The diameter of the gross lesions varied from 2 to 10 cm. Exudation of serum and oozing of blood leading to crust formations, acanthosis, proliferation and annular zones of leukoderma surrounding the lesions were noticed. Raw eroded ulcerated red areas were observed at around the junction of skin and hoof. Scab, dry crust formation and acanthosis were common. In dewclaw region, lesions with excoriation proliferation and complete loss of hairs and tumorous growth up to hen's egg size were quite common.

The histopathological sections prepared from skin biopsies revealed hyperkeratinization of cornified layers of the epidermis, stratum granulosum and stratum spinosum of the epidermis were hyperplastic and micro-cavities filled with tissue debris and inflammatory cells in the epidermis. Some of the retepegs of epidermis showed proliferation and extended deep into the dermis. Transverse and longitudinal sections of adult *Stephanofilaria sp*. parasites were found in the dermo-epidermal junction, just beneath the tips of retepeg and the parasite sections were surrounded by a zone of inflammatory cells. Longitudinal sections of adult parasites were also seen in the superficial layer of dermis near the epidermis along with the infiltration of inflammatory cells. Coiled and slender microfilariae without egg capsule were noticed amidst the granulation tissue in the superficial dermis and vicinity of that microfilaria was infiltrated with few inflammatory cells. The dermis showed extensive inflammatory reaction consisting of formation of granulation tissue, especially at the superficial part of dermis and deeper part of dermis showed fragmentation of tissue. The infiltrating cells of dermis consist of neutrophils, eosinophils and mononuclear cells. Increased activity of fibroblasts with hypertrophy and atrophy of the hair follicles were observed.

The highest prevalence among the animals of 4 to 5 years of age group with gradual increase in rate of prevalence with the advancement of age up to five years and there after gradual decrease was observed in the present study. The increased percentage of clinical cases in adult male cattle (4 to 5 years) might be due to their various exposure like ploughing, pulling carts and other drought purposes and chaining with iron-chain, thick ropes etc. These lead to external injury to hump, which attracts the vector flies and is one of the predisposing factors of Stephanofilariasis.

The highest prevalence 47.13% during rainy season might be due to high temperature, humidity and rainfall resulting into increased population of transmission vectors by their increased breeding performance during rainy season. During rainy season majority of the animals are utilized for ploughing of lands for agriculture and the hump and other parts of the body are exposed to injury which attract flies. When animals are reluctant for ploughing in the field, farmers often beat them with whip or sticks etc. to make them active which makes scratches over the skin thereby attracts the flies and might be the cause of stephanofilarial dermatitis in these sites.

The small slender and whitish parasites as observed in the present study and the 'C' shaped microfilariae with a slightly bent knob like cephalic and a sharply pointed tail in deep skin scraping were recovered earlier. Sheathed and unsheathed microfilaria were recovered in the present study where as only unsheathed microfilariae were recovered by earlier workers.

The dewclaws are pushed out and might be shed completely leaving behind a crater like ulcer. Acanthosis, thickening of the epidermis as a result of hyperplasia of the malpighian layer, especially the prickle cell layer, is a common feature in chronic inflammatory condition. Parakeratosis might be due to rapid cell turnover.

The presence of inflammatory cells and tissue debris in the micro-cavities of epidermis was observed in the present study. It is suggested that these are degenerating Stephanofilariae and the inflammatory reaction is against those parasites. Changes in typical hump sore were identical affecting mostly the hump region of the cattle in North Bengal while in South Bengal the sores in other parts of the body particularly the legs were quite common.

Endemicity of *S. assamensis* in India is well established and information about its prevalence, epidemiology, transmission and pathology are available [1]. But it was found that the incidence and character of the disease in hilly area (Himalayan foots) is not same with coastal plains of South Bengal. In the present study, it was observed that in contrast to 17.12% prevalence in coastal plain, it was 38.37% in North Bengal. It was further observed that in cattle population of South Bengal the lesions were distributed through out the body like hump, neck, hooves, dewclaws, and also other parts of the body. It was assumed that some factors in relation to the host parasite relationship and genetic variation in strains of the parasite are related to the limitation of the disease mostly to the hump region of the cattle of foot hills area. This type of observation in relation to variation in sites of infection in respect of eco-climatic variation has never been reported so far.

Various characteristics lesions as observed in the present study are in agreement with the findings of earlier workers [3, 4]. Exudation of serum and crust formation continuous as the lesion advances; subsequently, when the lesion becomes old and chronic, there is a granulomatous swelling on the area. Section of skin revealed acanthosis, hyperkeratosis and parakeratosis of

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epidermis which has been also been observed earlier [5].

There were spongiotic changes in the epidermis and epidermal retepegs proliferation and penetration in the dermis was noticed and this epidermal retepegs proliferation may be due to chronic parasitic infection. These parasitic sections suggest that the pathological tissue changes and inflammatory reactions are brought by the parasites [6, 7]. In bulls, chronic eosinophilic dermatitis in the scrotal area associated with stephanofilariasis has been reported [8].

[V] CONCLUSION

The differences in prevalence and characteristics of Stephanofilarial dermatitis in the present study between North Bengal and South Bengal (West Bengal, India) were proposed to be due to eco-climatic differences between these two zones, difference in the intermediate hosts and also due to differences in the genetic character of strains prevalent in these areas.

CONFLICT OF INTERESTS

None

FINANCIAL DISCLOSURE

NIL

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