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COHERENCE

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The Bhawanipur Education Society College
Kolkata-700020

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FOCUS

This collection of referred articles is the first academic effort of the Science Faculty, The Bhawanipur Education Society College, to document research outputs of faculty from multidisciplinary backgrounds. In this collection, cross-cutting issues ranging from different kinds of mutualistic systems with varying stability properties, environmental concerns and other fundamental topics of social and academic interest have been discussed, analysed and critiqued.

Papers included here have deliberated on the trade-off between competing priorities such as short-term economic gains and long term environmental quality, thus bringing into focus the issue that market based economic benefits are not commensurate with the loss of environmental service flows. The book also includes contemporary debates on economic valuation and accounting of the natural environment. Space pollution, a matter of serious international concern, finds mention in this volume. Simultaneously, water pollution due to hazardous heavy metals and minerals, an important societal problem, has been discussed in numerous papers incorporated in this volume. One paper deals with pollution of water sources by dyes used in the textiles and mining industries, a topical issue that has become a serious environmental concern now-a-days. Mathematically, dynamic reactions of a predator-prey system is also studied in which, the predator is provided with an alternative food in addition to the prey species, the predator is harvested taking harvesting effort as a dynamic variable and a tax is imposed to regulate the system. This paper may have broad policy level implications in the field of biological mathematics.

The articles in this book fall under the umbrella of physical, biological and technological sciences which need not be confined to a single discipline because of its multi-faceted application and diverse yet mutually indispensable aspects. Hence, this volume of a heterogeneous collection of articles, provides the reader with a variety of interest areas and showcases the broad nature of research being conducted by young academicians in different colleges.

In presenting the volume, the team expresses its sincere gratitude for the support received from scholars from different disciplines, who have used their expertise and knowledge to bring the volume to an acceptable academic standard. The editorial board feels privileged to be able to publish a collection of contemporary readings that may be of academic and professional interest to the present and the future generations of scholars.

We are grateful to the UGC for funding the seminar which has been the point of initiation for this collection. The administrative and policy making body of The Bhawanipur Education Society College has contributed meaningfully to ensure that this volume of work by young academic professionals is published.

Kolkata
15 December 2015

Dr. Pradip Dutta Gupta

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Deterministic Ordinary Differential Equation Models in Population Ecology, with special reference to Symbiosis

Bindhyachal Rai,
Department of Mathematics, University of Allahabad, India
E-mail : brai@mri.ernet.in

Madhsudan Singh
Institute of Professional Studies, University of Allahabad, India
E-mail : smadhu_math@rediffmail.com

Piyush Khare
Ewing Christian College, University of Allahabad, Allahabad, India
E-mail : piyushkh53@gmail.com

Abstract Nature consists of qualitatively different kinds of mutualistic systems. Different types of mutualistic interactions have different stability properties. The main important factors which contribute to this diversity are: the mechanisms by which one species benefits the other and the number of species that must interact in order for there to be mutualism between two of them. In the second case, if the number of species is more than two, then the mutualism is called indirect mutualism and in this case the interactive dynamics is very complex. Thus the models, we shall consider in this paper will be at least three dimensional. We shall present a mutualist-prey-predator model, modelling facultative mutualism with the prey species and the existence of periodic solution will be discussed. We shall also consider a model when a mutualist can modify a competitive outcome of the interaction, leading to coexistence in a system of competing species. Two four species models will also be presented.

Key Words and Phrases: Mutualistic Systems, Facultative and Obligate Mutualism, Competition, Predation, Coexistence, Reversal of Outcome

1 Introduction

Ecology is a branch of science, which deals with the interaction of organisms with one another and with the physical environment in which they live. Basic interactions, we are concerned with are: predator-prey interactions, competition for resources and the mutualistic interactions. Scientific curiosity and understanding of species relations and their mutual interactions are not just an academic exercise, but are related to the essential need of organisms. Every organism depends on some resource for its survival. The capacity to utilize the resource, which enabled the primitive man to survive, gradually attained multiple dimensions, which in modern times tends to threaten the life support systems. In the course of evolutionary history, humans and their activities were having significant impacts on natural dynamics of the earth system. However, the various human activities such as : food production, international trade and

* Dedicated to the memory of Prof. A.B. Roy of Jadavpur University, Calcutta

commerce, energy production etc. are transforming the earth system on various scales, ranging from local to global. Population explosion and the economic growth have drastically increased the degradation of natural resources. If we draw our attention to contemporary situations of the ecosystem, a very critical situation of our ecosystem appears, alarming the future prospective. Although mutualistic interactions are very much important for conservation of biodiversity, yet mathematical models are rare in literature. The purpose of this paper is to highlight the importance of mutualistic interactions on the crucial ecological issue of extinction/persistence, through some mathematical models, governed by system of autonomous ordinary differential equations.

The occurrence of mutualism can arise in a great variety of ways in nature ([24, 1]). Some of the mutualistic benefits may be listed as; deterring predation, increasing prey availability, feeding on a predator, increasing or decreasing competitive outcomes, competing with a predator etc. All of these types of mutualistic benefits are well known to occur in nature. Early models of mutualism were two dimensional ([3], [6]). Three dimensional mutualistic models, where the mutualism arises due to presence of a third population, were first analyzed in Rai, et al. ([18]). Since then, until recently, there has been a fair amount of work, on three dimensional mutualistic models, ([13, 14, 15, 18]). There is very little work on four dimensional mutualistic models. Freedman and Rai ([12]) and Kumar and Freedman ([16]), did some work to analyse four dimensional mutualistic models, throwing some light into the complex mutualistic interactions. Different types of mutualistic interactions have different stability properties ([2]). Therefore, a diverse set of models of mutualism should be retained because conclusions based upon one type of mutualism need not apply to the other. We refer ([21, 22, 23]) for mathematical analysis of recent four dimensional mathematical models of mutualism.

In any mutualistic system there may be more species involved in the interaction, because a mutualist could simultaneously benefit its partners in more than one ways ([2, 3]). Ants as mutualist decrease predation on treehoppers, due to deterrence mechanism. Mutualism may arise indirectly where there is no contact among the species ([23]). Some systems may involve interactions of at least five species in order for there to be mutualism between two of them. For example, consider a plant- harbivores aphids which attract ants, which in turn deter both the herbivores of the plant and the predators of the aphids. Other types of mutualisms involving beneficial interactions among two-species may still be very complex if there is multiple form of benefit involved in the system. For example, in the Acacia system described by Addicott and Freedman (cf. [2]),at least five benefits are involved in the interaction between ants and acacias, including deterring predation and competition, ameliorating abiotic mortality, providing habitat and food. Among much qualitatively different type of mutualisms, we refer ([7, 9, 10, 11, 14, 15, 18, 24]) for detailed analysis of three dimensional mathematical models, involving mutualistic interactions in different aspects, and ([21, 22, 23, 16, 12, 19]) for four dimensional mathematical models.

A mutualist of prey may decrease the predation of its predators, or compete with its predators. A mutualist of a prey may help it to out compete its predators by aiding it directly, competing with competitors or predating on its predators. Ecologically, this could involve a variety of different mechanisms, but all would have the effect of decreasing the rate at which prey are captured by the predators ([17]). For example a mutualist might camouflage the prey making it less apparent to the predators, or the mutualist might make the prey harder to be captured, or it might directly deter the predators from feeding upon the prey.

In this paper, we are concerned with an important concept in theoretical ecology. Namely, does the introduction of a mutualist into an existing community of species serve to enhance the long term survival of the community? Here we address the question for the case in which existing community can be modeled by at least three autonomous differential equations. Often the consideration of a third species changes the commensional association into mutualism between the other two species. For example ants deter herbivores from feeding on plants ([2]), and ants deter predators from feeding on aphids ([1]). In the absence of herbivores and predators, the association between ants -plants and ants- aphids, respectively is surely commensal ([20]).

The organization of this paper is as follows. In the next section, we will present two three- dimensional mutualistic models, each of them presenting a particular aspect of mutualistic interaction. Section 3 deals with a brief presentation of two four dimensional mathematical models, each of them possessing a rich wealth of ecological informations. Proper references have been given in the end, with their citations in the text.

2 Three Species Models

In Addicott and Freedman ([2]),the authors have considered the interactions of predator- prey populations in competitive environment with a slow-growing mutualist. Here we consider the general case where the dynamics of all the three species must be considered. Details and proofs of the results mentioned here are found in Rai, et.al. ([18, 11]).

2.1 Predator-Prey-Mutualist Model

Here we propose a model of predator and prey populations interacting with a mutualist, to the prey species. Mathematically this model can be represented by the following system of autonomous differential equations

$$\begin{cases} \dot{u} = uh(u,x) \\ \dot{x} = \alpha xg(u,x) - yp(u,x), \\ \dot{y} = z[-s + cp(u,x)], \\ u(0) > 0, x(0) > 0, y(0) > 0. \end{cases} \tag{1}$$

where t represents time, u(t) the population of mutualist at any time t, x(t) population of prey at any time t, y(t) population of predators at any time t, and s > 0, c > 0, $\alpha > 0$, are parameters of the system.

Functions h(u, x), g(u, x), p(u, x), from $R_+ \times R_+ \to R$, are continuous and sufficiently smooth to ensure the existence and uniqueness of solutions of initial value problem (1) with initial conditions in R+ and to allow the stability analysis of any solutions of (1). We also require the solutions to be defined on some interval [0, T] where $0 \le T < \infty$ .we further make the following assumptions:

H1: The function h (u, x) represents the specific growth rate of mutualist in the absence of prey and satisfies:

$$(a) h(0,x) > 0,$$

$$(b) \exists L : \square_{+} \to \square \ \ such that\ h(L(x),x) = 0\ with \frac{\partial L}{\partial x} \geq 0,$$

$$(c) \frac{\partial h(u,x)}{\partial u} < 0,$$

$$(d) \frac{\partial h(u,x)}{\partial x} > 0.$$

Ecologically, the above assumptions impose the following conditions on mutualist population.

1. The mutualist can grow at low densities with or without the prey x. This indicates that mutualism is non-obligate for the mutualist.

2. The population of mutualist can not grow over a certain population size, which depends on population size of its partner prey; this means that it has carrying capacity L, which is a function of prey population.

3. The growth of population of mutualist is slowed by an increase in its own population, other populations remaining the same. This further implies that mutualist exhibits density dependent growth. Ecologically this is termed as "population effect".

4. Population of mutualist is enhanced by an increase in the prey population for any population of the mutualist.

H2: The function g(x, u) represent the specific growth rate of prey population. We propose the following hypotheses for this function:

$$(a) g(\mathrm{u},0) > 0,$$

$$(b) \frac{\partial g(\mathrm{u},\mathrm{x})}{\partial x} < 0,$$

$$(c) \exists k : \square_{+} \to \square \ , such that\ \ g(\mathrm{u}, k(u)) = 0$$

$$(d) \frac{\partial g(x,u)}{\partial u} \leq 0$$

Ecologically the above assumptions impose the following restrictions on specific growth rate of prey:

1. The prey can grow at low densities with or without the presence of mutualists, so the mutualism is also non-obligate for prey.

2. The population growth of prey is slowed by an increase in its own numbers, for a fixed population size of mutualist. In other words the prey exhibit density dependent growth pattern.

3. The population of prey can not grow over a certain size in any environment. In other words the environment has carrying capacity for prey, which depends on population size of the mutualist.

4. There may be a cost to prey associating with the mutualist. In other words the growth rate of prey is suppressed by an increase in the mutualist population.

H3: The function, $p(u,x)$, i=1,2 represent the predator's response function. We propose the following hypotheses on this function:

$$(a)\, p(u,0) = 0,$$
$$(b)\, \frac{\partial p(\mathrm{u},\mathrm{x})}{\partial x} \geq 0,$$
$$(c)\, \frac{\partial p(\mathrm{u},\mathrm{x})}{\partial u} \leq 0,$$
$$(d)\, p(x,u) \geq 0.$$

Ecologically, these hypotheses impose the following restrictions on the predators response function.

1. The predator's response to the prey density, which refers to change in the density of prey per unit of time per predator as the prey density changes, is assumed always to be non-negative. Also there cannot be any predation in the absence of prey.

2. For fixed population of other species, the predation is enhanced with the increase in the number of prey species.

3. The mutualist cuts down the effectiveness of predation on the prey. This may be termed as "Mutualist effect". This is the main effect incorporated in the model.

The death rate incorporated in the model is a combination of natural death and harvesting of predator by other enemies. Obviously our model is valid if a predator is harvested by other predators or they die a natural death. The above assumptions are ecologically reasonable and exemplified in nature as discussed in the introduction.

It is easy to show that our system is well behaved in the sense that all the solutions of the system (1) remain positive and bounded, with initial positive conditions ([18]).

2.1.1 Main Results

Various equilibrium points of the system are : E1(0, 0, 0), E2(0, k(0), 0),E3(L(0), 0, 0), $E_4(0,\tilde{\mathrm{x}},\tilde{y})$ $E_5(\tilde{\mathrm{u}},\tilde{\mathrm{x}},0)$, $E_6(\mathrm{u}^*,x^*,y^*)$ .The conditions for their existence have been given in detail in ([18]).The main results are:

Theorem 2.1 If the following conditions hold

1. $\frac{s}{c} \in$ Range $p(\mathrm{L(x)}, \mathrm{x})$,

2. $-s + cp(\mathrm{L(x)}, \mathrm{x}) = 0$ and

3. $x < K(\mathrm{L(x)})$

then there exists a unique interior equilibrium.

Theorem 2.2 Let (u^*, x^*, y^*) be the interior equilibrium state of the system.Further let the following two conditions hold

1. a1, a2, a3 > 0,

2. b1.b2 < 0,

then as the value of α (the bifurcation parameter) passes through $\alpha_0 (= -\frac{b_2}{b_1})$, small amplitude periodic solutions of the system appear, which bifurcate from the equilibrium state (u^*, x^*, y^*) (see ([18]) for the values of a1, a2, a3, b1, b2 and other details and proofs)

2.1.2 A Specific Example

Here we analyze a special case of the general model, incorporating all its important features, as mentioned in the model. We consider the following model

$$\begin{cases} \dot{u} = \gamma u[1 - \frac{u}{L_0 + lx}] \\ \dot{x} = \alpha x[1 - \frac{x}{K}] - \frac{\beta xy}{1 + mu}, \\ \dot{y} = y[-s + \frac{c\beta xy}{1 + mu}]. \end{cases} \qquad (2)$$

where the parameters α, β, γ l, L0, K, m, c, s all are positive. This particular model refers to the case, where in the absence of the predator y, the association between u and x is not mutualistic, but commensal. The mutualism occurs when we introduce the predator into the system. Possible equilibrium states are: E1(0, 0, 0), E2(0,K, 0), E3(L0, 0, 0), $E_4(0, \frac{s}{c\beta}, \frac{\alpha}{\beta}(1 - \frac{s}{Kc\beta}))$

5(L0+lK,K, 0). For the specific values of the parameters taken as c = l = m = s = L0 = 1, $\beta = 2, \gamma = 4$, K = 8, all the restrictions of the assumptions ate satisfied. With these values, conditions of the mathematical results are also satisfied and the value of α_0 comes out to be 8. Hence if 8 is in the range of the values of α, the equilibrium state (3, 2, $\frac{3}{2}\alpha$) bifurcates into periodic orbits.

2.1.3 Discussions

In this model a predator-prey-mutualist system has been modeled and mathematically analyzed. Conditions for equilibria were given, and the stability of these equilibria were determined. Conditions were also given for the existence of three-dimensional periodic solutions.A specific example was given. It was found that by adding a mutualist to the system, the prey equilibrium value is increased.

This was the effect in the case of a stable interaction of increasing the effective carrying capacity for the prey species. Further the carrying capacity of the mutualist is also increased. However, as expected, all populations remain bounded. Depending upon the parameters, adding a mutualist to the system could be either stabilizing or destabilizing, and therefore limit cycles could appear, where they were not before, or disappear. Finally, adding a mutualiat to a predator-prey system could cause the predator to go extinct, in which case the prey and mutualist population numbers approach equilibrium values.

2.2 Competitor-Competitor-Mutualist Model

We propose as a model, two competing species x1, x2 and a third species u, which acts as a mutualist to the species x1 ([11]). We shall assume that there is no direct interaction between u and x2. The dynamical behavior of a Competitor-Competitor-Mutualist community is represented by the following system of equations:

$$\begin{cases} \dot{u} = uh(u, x_1) \\ \dot{x}_1 = \alpha x_1[g_1(u, x_1) - q_1(u, x_1, \mathrm{x}_2)], \\ \dot{x}_2 = x_2[g_2(x_2) - q_2(x_1, \mathrm{x}_2)], \\ u(0) > 0, x_1(0) > 0, x_2(0) > 0. \end{cases} \tag{3}$$

where u, x1 form a mutualist pair. The hypotheses implicit in the system (3) are that the rate of increase or decrease of the populations does not depend upon time and that the populations are so large as to be measurable with real numbers and not subject to the random luctuations. The functions h(u, x1) and gi, i = 1, 2are as in system (1), and the competition functions qi, i = 1, 2, are increasing functions of x1 and x2, but in addition q1 is a decreasing function of u, which is the mutualist of x1.

2.2.1 Main Results

In addition to local and global stability behavior ([8, 5]),the following results have been proved.

Theorem 2.3 Let the following conditions hold, in addition to those mentioned in the assumptions

1. $\min[\{g_1(0,0)-q_1(0,0,K_2)\},\{g_1(0,L(0)-q_1(0,L(0),K_2)\}]>0,$

2. $\min[\{g_2(0,0)-q_2(K_1(0),0,)\},\{g_2(0)-q_2(x_1,0)\}]>0,$

3. $\dfrac{\partial g_1(u,x_1)}{\partial u}>0,$

4. $uh_u(u,x_1)+x_1 h_{x_1}(u,x_1)\le -\alpha_1<0; ug_{1u}(u,x_1)+x_1 g_{1x_1}(u,x_1)\le -\alpha_1<0,$

then the system (3) is persistent. (see ([11]) for other details)

Theorem 2.4 Let $(\bar{u},\bar{x}_1,\bar{x}_2)$ be an interior equilibrium state of the system (3), lying in positive octant of the phase space of the variables u, x1, x2. Also, let the following conditions hold

1. a1 > 0, a2 > 0, a3 > 0,

2. there exist $\alpha_0>0$ 0 such that $b_1\alpha_0^{\,2}+b_2\alpha_0+b_3=0,$ and $b_2^{\,2}>4b_1b_2$

then as the value of α (the bifurcation parameter) passes through, α_0 there appear small amplitude periodic solution of the system (3), bifurcating from the equilibrium $(\bar{u},\bar{x}_1,\bar{x}_2)$.

(see ([11]) for the values of a1, a2, a3, α and other details)

2.2.2 An Example

Here we give a numerical example to illustrate the appearance of small amplitude periodic solutions if the functions h, g1, g2, q1 and q2 are chosen properly. Consider the following system:

$$\begin{cases}\dot{u}=\dfrac{u}{10}[1-u+x_1],\\ \dot{x}_1=\alpha x_1[1-x_1-\dfrac{572}{1155}\dfrac{u}{1+x_1}]-\dfrac{\alpha x_1x_2}{1+u}\\ \dot{x}_2=x_2[1-x_2]-\dfrac{3x_1x_2}{2}.\end{cases}\qquad(4)$$

We find that $\bar{u}=\dfrac{11}{16},\bar{x}_1=\dfrac{1}{10},\bar{x}_2=\dfrac{17}{20}$

20 is an equilibrium state. Calculations at $E^*(\frac{11}{10}, \frac{1}{10}, \frac{17}{20})$ shows that a1 =.0096 + 00549α > 0, a3 =.0008α > 0, b1 = −.0002, b2 = −.0006, b3 =.0897 and the value of the parameter α comes out to be approximately 19.73. Thus all the hypotheses framed and the mathematical conditions are satisfied and we shall have perturbed periodic solutions in three dimensions (see [11] for details).

2.2.3 Discussions

In this model,a Competitor-Competitor-Mutualist system has been modeled and analyzed. Conditions for equilibria were given, and the stability of these equilibria were determined. Conditions were also given for the existence of three-dimensional periodic solutions. A specific numerical example was given to support the mathematical analysis.

It was found that the mutualist will play a very important role in such an ecosystem. For example, when the inhibitory effect of the species x2 on the species x1 is very high, the mutualist reduces the effectiveness of the competetion coefficient and thereby could cause the reversal of stability of the interior equilibrium state in both the cases and reverse competitive outcome. Also, in the absence of the mutualist, the competitive sub community, does not admit any interior equilibrium, but the introduction of muttualist into the system always guarantees an equilibrium state. This shows that the mutualist could change competitive exclusion to coexistence.

3 Four Species Models

In this section, we consider two four dimensional mutualistic models, reflecting different aspects of complex mutualistic interactions and their dynamics. We refer Freedman and Rai, ([12]) and Rai and Singh, ([22]) for details and proofs of the results mentioned here.

3.1 Competitor-Mutualist Model

We consider as a model of two competitors interacting with two mutualists ([12]). The dynamical behavior of the system under consideration is governed by the following system of autonomous differential equations:

$$\begin{cases} \dot{u}_1 = u_1 h_1(u_1, x_1) \\ \dot{x}_1 = x_1 g_1(u_1, x_1) - x_1 x_2 q_1(u_1), \\ \dot{u}_2 = u_2 h_2(u_2, x_2), \\ \dot{x}_2 = x_2 g_2(u_2, x_2) - x_1 x_2 q_2(u_2), \\ u_i(0) > 0, x_i(0) > 0. \end{cases} \tag{5}$$

where t represents time, ui(t)represent the mutualist population of xi(t) at any time t, i = 1.2, and xi(t) is the corresponding competitor. Corresponding to these interactions, we propose the following hypotheses for the functions occurring in the model.

H0: We assume that h_i, g_i, q_i are sufficiently smooth so that solutions to the initial value problem

exist and are unique.

H1: $h_i(0, \mathrm{x}_i) > 0, \dfrac{\partial h_i(\mathrm{u}_i, \mathrm{x}_i)}{\partial \mathrm{u}_i} < 0, \dfrac{\partial h_i(\mathrm{u}_i, \mathrm{x}_i)}{\partial x_i} > 0$; there exists $L_i(\mathrm{x}_i), L_i(0_i) > 0$ such that

$h_i(L_i(i_i, \mathrm{x}_i)) = 0, i = 1, 2.$

The above hypotheses impose the following properties on the hi, respectively. The mutualist population is capable of growing on its own, and hence the mutualism of xi on ui is facultative. The growth rate, however, is decelerated as its population numbers increase due to environmental limitations, xi is the mutualist of ui. There is a carrying capacity of the environment which limits the mutualist populations as a function of the number of xi.

H2: $g_i(\mathrm{u}_i, 0) > 0, g_{ix_i}(\mathrm{u}_i, x_i) < 0$; there exist $K_i(\mathrm{u}_i), K_i(0) > 0$ such that $g_i(\mathrm{u}_i, K_i(\mathrm{u}_i)) = 0$ and such that lim $K_i(\mathrm{u}_i)) = \tilde{K}_i < \infty$ as time tends to infinite.

These hypotheses are described as follows. Each competitor is capable of growing on its own, but the growth rate decreases as the population increases, limited by its carrying capacity, which is a function of the mutualist population.

H3: $q_i(\mathrm{u}_i) > 0, \dfrac{\partial q_i(\mathrm{u}_i)}{\partial \mathrm{u}_i} \le 0.$

It may be noted that the competition effect is reduced by the mutualist. In any case, competition is always increased by a rise in the either population. From the above hypotheses, it is straight forward to show that the system (5) is dissipative. In fact, we can describe a region A, which contains the region of attraction.

3.1.1 Main Results

There are a large number of possible equilibria for the system under consideration. First we note that E0(0, 0, 0, 0) always exist. As well, the following equilibria are obvious, E1(L1(0), 0, 0, 0), E2(0,K1(0), 0, 0), E3(0, 0,L2(0), 0), E4(0, 0, 0,K2(0)), E5(L1(0), 0,L2(0), 0), E6(L1(0), 0, 0,K2(0)),

E7(0,K1(0),L2(0), 0), $\bar{E}(0, \dfrac{56500}{271}, 0, \dfrac{45000}{271})$ and $E^*(1200, \dfrac{2375}{2}, 2413, \dfrac{875}{4})$

In addition to the assumptions, let the following conditions (From local stability analysis) also hold.

H4: $g_2(\mathrm{L}_2(0),0) - \mathrm{x}_1\,\hat{x}_1 q_2(\mathrm{L}_2(0),\hat{x}_1,0) > 0.$

H5: $\bar{M}_1, \bar{M}_2$ (see (cf. [12]) have no eigen values with zero real parts, and

H6:E˜i, if it exists, is globally asymptotically stable with respect to solutions initiating in the interior of the ui − x1 − x2 space for i = 1, 2. The following result has been proved.

Theorem 3.1 Let H(0)-H(6) hold, then the system (5) persists.

From the results in Butler et al. ([4]), the following corollary is obvious.

Corollary 3.1 Let the assumptions (H0)—(H6) hold, then the interior equilibrium E^* exists.

(See ([12]) for proofs and other details)

3.1.2 An Example

Here we give an example to illustrate our results. The numerical coefficients are for illustrative purposes and do not necessarily represent any real system. Consider the following system

$$\begin{cases} \dot{u}_1 = 400u_1[1-\dfrac{u_1}{1150+\dfrac{4x_1}{95}}], \\ \dot{x}_1 = 300x_1[1-\dfrac{x_1}{1500}]-\dfrac{14x_1x_2}{9(1+\dfrac{u_1}{270})}, \\ \dot{u}_2 = 450u_2[1-\dfrac{u_2}{2394+875}], \\ \dot{x}_2 = 250x_2[1-\dfrac{x_2}{1000}]-\dfrac{x_1x_2}{9(1+\dfrac{u_2}{475})}. \end{cases} \tag{6}$$

Various possible equilibrium points of the above system are:

E0(0, 0, 0, 0), E1(1150, 0, 0, 0), E2(0, 1500, 0, 0), E3(0, 0, 02394, 0), E4(0, 0, 01000, 0), E5(1150, 0, 2394, 0), E6(1150, 0, 0, 1000), E7(0, 1150, 2394, 0), $\bar{E}(0,\frac{56500}{271},0,\frac{45000}{271})$ and $E^*(1200,\frac{2375}{2},2413,\frac{875}{4})$.

We observe that all the conditions framed in the hypothesis are satisfied and the other conditions of the results are also satisfied. Hence the system (6) persists.

3.1.3 Discussions

In this model we have considered a system of four autonomous ordinary differential equations as a model of four interacting populations, two species competing with each other and two mutualists, one for each competitor. Our main interest was to give criteria for the persistence of all the four populations. We have been able to investigate such criteria in terms of parameters of the system. It has been shown that in the absence of one of the mutualists the corresponding three dimensional subspace has no interior equilibrium state but if the mutualist is allowed to interact, then we do have an interior equilibrium state in the four dimensional state, establishing the fact that the mutualist has altered the competitive outcome, and as a result all the four species could persist.

3.2 Four Species Prey-Mutualist Model

We propose as a model, the interaction of two competing predators y, z for the same prey x, which is in mutualistic association with u. We refer Rai and Singh, ([22]) for detail. The dynamical behavior of the system can be described by the following system of autonomous ordinary differential equations:

$$\begin{cases} \dot{u} = uh(u,x,y,z) \\ \dot{x} = \alpha x g(u,x) - y p_1(u,x) - z p_2(u,x), \\ \dot{y} = y[-s_1(y) - q_1(z) + c_1 p_1(u,x)], \\ \dot{z} = z[-s_2(z) - q_2(y) + c_2 p_2(u,x)], \\ u(0) > 0, x(0) > 0, y(0) > 0, z(0) > 0. \end{cases} \tag{7}$$

Where $. \equiv \frac{d}{dt}$ and t represents time, u=population of mutualist at any time t,x= population of prey at any time t, y= population of predators at any time t, z= population of predators at any time t, $s_i \geq o, c_i \geq 0,\ i = 1,2,\ \alpha \geq 0$ are parameters. Functions h, g, p_i, q_i, for i=1, 2 from $R_+ \times R_+ \to R$, are continuous and sufficiently smooth to ensure the existence and uniqueness of solutions of initial value problem (2.1) with initial conditions in R^+ and to allow the stability analysis of any solutions of (2.1). We also require the solutions to be defined on some interval [0.T] where $0 \leq T < \infty$.We further frame the following assumptions:

H1: The function h (u. x) represents the specific growth rate of mutualist in the absence of prey and satisfies the following assumptions:

$$(a) h(0,x) > 0$$
$$(b) \exists L : \square_{+} \to \square \quad such that\ h(L(x),x) = 0$$
$$(c) \frac{\partial h(u,x)}{\partial u} < 0$$
$$(d) \frac{\partial h(u,x)}{\partial x} \geq 0$$

Ecologically, the above assumptions impose the following conditions on mutualist population:

1. The mutualist can grow at low densities with or without the prey x. This indicates that mutualism is non-obligate for mutualists.

2. The population of mutualists can not grow over a certain population size, which depends on population size of its partner prey; this means that it has carrying capacity L, which is a function of prey population.

3. The growth of population of mutualist is slowed by an increase in its own population, other populations remaining the same.This further implies that mutualist exhibits density dependent growth. Ecologically this is termed as" population effect".

4. Population of mutualists is enhanced by an increase in the prey population for any population of the mutualist.

H2: The function g(x, u) represent the specific growth rate of prey population. We propose the following hypotheses for this function:

$$(a) g(0,u) > 0$$
$$(b) \frac{\partial g(x,u)}{\partial x} < 0$$
$$(c) \exists k : \square_{+} \to \square \ , such that\ g(k(u),u) = 0$$
$$(d) \frac{\partial g(x,u)}{\partial u} \leq 0$$

Ecologically the above assumptions, imposes the following restrictions on specific growth rate of prey:

1. The prey can grow at low densities with or without the presence of mutualists, so the mutualism is also non-obligate for prey.

2. The population growth of prey is slowed by an increase in its own numbers, for a fixed population size of mutualist. In other words the prey exhibit density dependent growth pattern.

3. The population of prey can not grow over a certain size in any environment, In other words the environment has carrying capacity for prey, which depends on population size of the mutualist.

4. There may be a cost to prey, associating with the mutualist, In other words the growth rate of prey is suppressed by an increase in the mutualist population.

H3: The function, $p_i(x,u)$, i=1,2 represent the predator's response function. We propose the following hypotheses on this function:

$$(a)\, p_i(0,u) = 0,$$
$$(b)\, \frac{\partial p_i(x,u)}{\partial x} \geq 0,$$
$$(c)\, \frac{\partial p_i(x,u)}{\partial u} \leq 0,$$
$$(d)\, p_i(x,u) \geq 0, \quad i = 1,2.$$

Ecologically, these hypotheses impose the following restrictions on the predators response function:

1. The predator's response to the prey density, which refers to change in the density of prey per unit of time per predator as the prey density changes, is assumed always to be non-negative. Also there can not be any predation in the absence of prey.

2. For fixed population of other species, the predation is enhanced with the increase in the number of prey species.

3. The mutualist cuts down the effectiveness of predation on the prey. This may be termed as "Mutualist effect".This is the main effect incorporated in the model.

H4: The functions $q_1(z)$ and $q_2(y)$ represent competition between predators y and z. We propose the following hypotheses on these functions

$$(a)\, q_i(0,) = 0; i = 1,2,$$
$$(b)\, \frac{\partial q_1(z)}{\partial y} > 0.$$
$$(c)\, \frac{\partial q_2(y)}{\partial z} > 0.$$

Ecologically, these hypotheses impose the following restrictions on the functions q_i, i=1, 2:

1. In the absence of competing predators there is no competition.
2. Competition increases with the increase in rival densities.

Here, in the present formulation, the word competition stands for both intraspecific and interspecific competitions. The terms q_i, i=1, 2 incorporate only interspecific competition, while intraspecific competitions has been incorporated as population effect, occurring with growth rate functions of all the species.

H5: The functions $s_1(y)$ and $s_2(z)$ are death rates of competing predators. We propose the following hypotheses on these functions:

$$(a)\ s_i(0) > 0,$$
$$(b)\frac{\partial s_1(y)}{\partial y} > 0,$$
$$(c)\frac{\partial s_2(z)}{\partial z} > 0.$$

Ecologically, these hypotheses impose the following restrictions on the death rates.

1. Initially death rates are positive.
2. Death rates remain positive for all the time.

The death rates incorporated in the model is a combination of natural death and harvesting of predator by other predators. Obviously our model is valid if a predator is harvested by other predators or they die a natural death. The above assumptions are ecologically reasonable and exemplified in nature as discussed in the introduction.

3.2.1 Main Results

Here we mention main results, and for details we refer to Rai and Singh ([22], [19]). First we observe that trivial equilibrium $E_1(0,0,0,0)$ always exists. As well the following one-dimensional and concerned two-dimensional equilibria are obvious, $E_2(L(0),0,0,0)$, $E_3(0,K(0),0,0)$, $E_4(0,\hat{x},\hat{y},0,0)$, $E_5(\tilde{u},\tilde{x},0,0)$, $E_6(0,x_2,0,z_2)$. On ecological point of view, there must exist equilibrium in u-x plane, for otherwise one of the populations would extinct contradicting the concept of mutualism. Hence, we assume that E_5 will always exist.

There are other three other possible equilibria, which are in relative three-dimensional subspaces. Criteria for existence may be found in ([18, 23]). If they exist, we denote them by $E_7(u_3, x_3, y_3, 0)$, $E_8(u_4, x_4, 0, z_4)$, $E_9(o, x_5, y_5, z_5)$. Finally, there may be a positive interior equilibrium denoted by $E_{10}(u^*, x^*, y^*, z^*)$. Apart from the stability analysis, the following theorem for coexistence for all the interacting species has been proved.

Theorem 3.2 Let the following conditions hold, in addition to those mentioned in the assumptions

1. $s_i(0) < c_i p_i(K(0), 0)$, i=1, 2
2. $s_2(0) < c_2 p_2(x_1, 0)$
3. $s_i(0) < c_i p_i(\tilde{u}, \tilde{x})$
4. $s_1(0) < c_1 p_1(x_2, 0) - q_1(z_2)$
5. $s_1(0) < c_1 p_1(x_2, 0) - q_1(z_2)$
6. $s_2(0) < c_2 p_2(x_3, u_3) - q_2(y_3)$,

then the system (7) is uniformly persistent. (see ([22, 23]) for other details)

From the results in Butler et al. (4]), the following corollary is obvious.

Corolary 3.2 Let the assumptions (H1)-(H5) hold and conditions of the theorem (3.2) are satisfied then the interior equilibrium $E_{10}(u^*, x^*, y^*, z^*)$ exists.

3.2.2 An Example

In order to illustrate the above analysis we consider the following example. All coefficients and functions are taken for mathematical convenience, not exactly from a real ecological system. In this illustration the occurrence of all the boundary equilibrium points for a particular system is shown. Also uniform persistence is demonstrated by the use of theorem. For this purpose we consider the following system

$$\begin{cases} \dot{u} = u[1 - \dfrac{u}{3+x}] \\ \dot{x} = 4x(1 - \dfrac{x}{1+4u}) - \dfrac{x}{1+4u} y - \dfrac{x}{1+4u} z \\ \dot{y} = y[-\dfrac{1}{3} - z + \dfrac{3x}{1+4u}] \\ \dot{z} = z[-\dfrac{1}{3} - y + \dfrac{5x}{1+4u}] \end{cases} \quad (8)$$

Various possible equilibrium points of the above system are listed as follows:

$E_0(0,0,0,0)$, $E_1(3,0,0,0), E_2(0,4,0,0), E_3(7,4,0,0), E_4(0,\frac{1}{9},\frac{35}{9},0), E_5(0,\frac{1}{9},0,\frac{35}{9})$,

$E_6(\frac{28}{5},\frac{13}{5},\frac{7}{5},0)$, $E_7(,\frac{28}{5},\frac{28}{5}0,\frac{7}{5})$, $E_8(0,\frac{2}{3},\frac{5}{3},\frac{5}{3})$, $E^*(6.8529,3.8529,0.0735,0.0735)$.

We obtain for the system (5.1)

$$H_1(x) = -\frac{79}{9} < 0,\ H_2(x) = \frac{35}{81} > 0,\ H_3(x) = \frac{1}{28} > 0,\ H_4(x) = -\frac{149}{9} < 0.$$

We also observe that conditions (H1)-(H5) are satisfied and all the conditions of theorem (3.2) are satisfied, thus the system (8) persists uniformly.

(see ([23]) for the definition of $Hi(x), \mathrm{i} = 1,2,3,4.$ **)**

3.2.3 Discussions

In this model, we have proposed and analyzed a system of four autonomous differential equations as a model of four interacting populations, two species competing with each other for a single prey species which is in beneficial interaction with a mutualist. Our main aim was to obtain criteria for the persistence of all the four species. We have been able to obtain such criteria in terms of parameters of the system and have illustrated the results with a numerical example. It has been established that if death rates of the predator are less than a certain threshold value depending upon conversion efficiency of the individual predator and the intensity of competition of the competitor, then the coexistence is possible.

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A Hybrid Model for Marketing Renewable Energy Driven Air Conditioning Systems in India

Nimai Sundar Manna
Faculty – MBA, Vidysagar University, Midnapore, W.B., India, E-mail: nsmanna@gmail.com

Abstract Energy demand in India will increase by a factor of 1.5 to 2.5 by 2030 and minimum energy consumption of 2.3 toe/year/capita is needed today to achieve Human Development Index(HDI) of 0.9 where Less than 10% of the potential solar energy is utilized till date, and As per estimates, the demand for air-conditioning units has increased from about 25 million units (MU) in 1998 to more than 40 MU in 2006 and about 115370 GWh of electricity was used in India to meet the air-condition and cooling demand in the country in 2010-2011 and it is projected to increase by 40% in urban India and 21% in rural India by the year 2017. This is causing tremendous pressure on energy security and environment.

For the marketing of new innovative products researchers have identified two types of influences: External Influences like mass media, advertisement & publicity; and Internal Influences like word of mouth, recommendations from satisfied users. This paper derives market potential determination technique for the use of solar energy in cooling systems applying Hierarchically Adjusted Model and Bass Model. Hierarchically Adjusted Model has been used as the primary research methodology to develop the proposed tool and Bass Model is used to determine the future market potential for the solar energy driven vapour absorption Air Conditioning systems. There are nine steps in this Model including analysis of Cooling need and Solar radiation, Life cycle cost analysis, purchasing power parity, per capita roof space availability, measuring market potential for green energy driven devices (A.C.) using Bass Model, encoding the market potential, GIS plotting the market potential in the present map of India and Develop user-friendly web portal to measure feasibility of installing Solar A.C. for Indian locations.

A case study is taken to show the use of solar energy for cooling systems. The study reveals that about 69.23% respondents use Fans to meet their cooling need in summer & hot weather condition; 84.62% respondents feels more comfortable in Air Conditioned than fan & others; 61.54% respondents experience 11%-20% increase of electricity bill in summer season; 38.46% respondents agree to pay upto 150% over the cost of traditional A.C. for alternatives A.C. The findings show that the forecasted values using Bass Model is just similar in nature as that of the normal Product Life Cycle (PLC) of any product which shows that Bass Model is appropriate for estimating future sales of Solar Air conditioning systems in India. The outcome shows that the process can be effectively utilized as emerging marketing tool for other Renewable energy driven devices too.

Keywords Market Potential Mapping, Energy Security, Green Buildings, Bass Model, Hierarchically Adjusted Model

1. Background

The evolution of renewable energy over the past decade has surpassed all expectations. Global installed capacity and production from all renewable technologies have increased substantially; costs for most technologies have decreased significantly; and supporting policies have continued to spread throughout the world. Development in the early 2000s showed upwards trends in global renewable energy investment, capacity and integration across all sectors. Numerous scenarios projected levels of

renewable energy for 2020 that were already surpassed by 2010. Today renewable energy technologies are seen not only as a tool for improving energy security, but also as a way to mitigate green house gas (GHG) emissions and to provide direct and indirect social benefits. In much of the world, considerable time and household income are spent securing energy services. Energy poverty presents a significant hurdle for achieving development goals of improved health, prosperity, and a liveable environment. Renewable energy systems provide an unprecedented opportunity to accelerate the transition to modern energy services – displacing traditional biomass, carbon-based fuels, and fossil-fuel grid-based electricity and thereby lowering the hurdles to sustainable development.

Renewable also contribute climate mitigation efforts. The International Panel on Climate Change (IPCC), under the United Nations Framework Convention on Climate Change (UNFCCC), clearly states in its 2014 report that climate change is already having a sweeping effect on all continents and in every ocean. The problem will likely grow substantially worse unless green house gas emissions are brought under control. Renewable coupled with energy efficiency measure can help reduce emissions by providing low-carbon energy services. It is clear that renewable are becoming a mainstreamed energy resource. This is welcome news as we enter the Decade of Sustainable Energy for All (SE4ALL), which seeks to mobilise country action to ensure universal access to modern energy services, improved rates of energy efficiency and expanded use of renewable energy sources by 2030.

Markets, manufacturing, and investment expanded further across the developing world and it became increasingly evident that renewables are no longer dependent upon a small handful of countries. Aided by continuing technological advances, falling prices, and innovations in financing – all driven largely by policy support – renewable have become increasingly affordable for a broader range of consumers worldwide. In a rising number of countries, renewable energy is considered crucial for meeting current and future energy needs and that is true for a country like India too. As the space cooling is doubling in 5 years and exponential increase in cooling need, the energy security of the country is under threat.

The need of energy for refrigeration and air conditioning is very high, especially in the developing countries, but they are indispensable for food storage and for increasing the comfort of the people. The energy crisis and environmental regulations and laws enhance the use of energy-efficient and environmentally friendly systems. Unrestrained use of fossil fuel as an energy source has resulted in price hike, increasing pollution accompanied with global warming. Sustainable living requires that we adopt non-polluting renewable energy sources. One of the most cost-effective systems that can use renewable energy sources are desiccant. Asan alternative energy there are renewable sources available (solar energy, wind energy, geothermal energy and others) to drive the engines of refrigerator and air conditioning machines. The solar Energy is one of the best renewable sources, with is clean and environmental friendly. For supply with a certain refrigeration capacity there are several possibilities, for example: - Photovoltaic/vapour compression, Photovoltaic/thermoelectric, - Solar thermal- solid absorption (water /zeolite, ammonia/ calcium chloride etc.), - Solar thermal - liquid absorption (ammonia/water; water/lithium bromide etc.). Especially important is the use of solar thermal energy instead of electrical, oil or gas energy to drive the absorption refrigeration machines.

2. Introduction

F. M. Bass has developed a model of first-purchaser activity which seems to portray accurately the growth patterns for a large number of new products, such as durables, in this case solar energy driven vapour absorption air conditioning and cooling systems in which repeat purchasing is not a major factor

in early years of the product life cycle. The Bass model implies sales growth to a peak and then decline, and provides a framework for guessing the long-term sales pattern of a product based on early sales data. One of the advantages of the Bass model is that it permits a forecast of the timing of a turndown in sales during a period in which sales are growing rapidly, where naive forecasting models tend to project indefinite sales growth at rapid rates. Thus Bass in 1966 accurately predicted that a sales peak would occur in 1968 for colour television set sales at 6.7 million units, while the industry was building plant capacity for 14 million picture tubes. The overly optimistic industry projections resulted in rather severe economic dislocations which might have been avoided if forecasting technique through Bass Model be followed. In this paper the framework of the Bass model is used to develop a long-term forecast of solar energy driven vapour absorption air conditioning and cooling systems adoption in India and Asia-pacific market.

3. Literature Review

Since the publication of the Bass model in 1969, research on the modelling of the diffusion of innovations has resulted in a body of literature consisting of several dozen articles, books, and assorted other publications. Efforts have been made to re-examine the structural and conceptual assumptions and estimation issues underlying the diffusion models of new product acceptance by the target market. With the burning need for energy sustainability in line with the combating green house gas (GHG) emission and global warming, the possibility for market acceptance of renewable energy driven devices is of most important and in this area no such research work has not been reported till date.

The diffusion of an innovation traditionally has been defined as the process by which that innovation "is communicated through certain channels over time among the members of a social system" (Rogers 1983, p. 5). As such, the diffusion process consists of four key elements: innovation, communication channels, time, and the social system. As a theory of communications, diffusion theory's main focus is on communication channels, which are the means by which information about an innovation is transmitted to or within the social system. These means consist of both the mass media and interpersonal communications. Members of a social system have different propensities for relying on mass media or interpersonal channels when seeking information about an innovative product. Interpersonal communications, including nonverbal observations, are important influences in determining the speed and shape of the diffusion process in a social system. Since its introduction to marketing in the 1960s (Bass 1969; Robertson 1967), innovation diffusion theory has sparked considerable research among consumer behaviour, marketing management, operation management and marketing science scholars. Researchers in consumer behaviour have been concerned with evaluating the applicability of hypotheses developed in the general diffusion area to consumer research (Gatignon and Robertson 1985). The marketing management literature has focused on the implications of these hypotheses for targeting new product prospects and for developing marketing strategies aimed at potential adopters (Kotler and Zaltman 1976; McKenna 1985, Chap. 4). Researchers in management and marketing science have contributed to the development of diffusion theory by suggesting analytical models for describing and forecasting the diffusion of an innovation in a social system. More recently, this literature also has been concerned with developing normative guidelines for how an innovation should be diffused in a social system.

Focus has been given on the contributions of management and marketing science literature to the

cumulative understanding of the dynamics of innovation diffusion. The main impetus underlying these contributions is a new product growth model suggested by Bass (1969). The Bass model and its revised forms have been used for forecasting innovation diffusion in retail service, industrial technology, agricultural, educational, pharmaceutical, and consumer durable goods markets (Akinola 1986; Bass 1969; Dodds 1973; Lilien 2007; Nevers 1972; Tigert and Farivar 1981). Representative companies that have used the model include Eastman Kodak, RCA, IBM, Sears, and AT&T (Bass 1986). Since publication of the Bass model, research on the modelling of the diffusion of innovations in marketing has resulted in an extensive literature. Contributions of this literature through the 1970s were reviewed by Mahajan and Muller (1979). However, in the ensuing decade a plethora of studies has contributed to our understanding of the structural, estimation and conceptual assumptions underlying diffusion models. The present work is application of the model developed by Bass for the adoption of the solar energy driven air conditioning systems in India.

Justification of application of Bass Model:

Though renewable energy and renewable energy driven devices are the much discussed hot topics in present day scenario, but the market penetration of this alternative energy driven devices is not satisfactorically high. Moreover as the early sale data is very low therefore ARMA or ARIMA model of forecasting can't be used. In 1980, the U.S. department of Energy used the Bass model to forecast the adoption of solar batteries. It performed a survey of home builders to assess their perceptions of the marketplace to obtain reasonable values for p and q. Feeding them into the model, the researchers came to the conclusion that the technology was not far enough along to generate positive word-of-mouth. As a consequence, they decided to postpone wide scale introduction until the technology had improved enough so that users would be quite satisfied with it, resulting in a higher q and hence faster sales growth after launch. In the early 1990s, Direc TV planned the launch of its subscription satellite television service. It wanted to obtain prelaunch forecasts over a five-year horizon. The forecast were based on the Bass model, and the values for its parameters were obtained from a survey of stated intentions combined with the history of analogous products. The forecasts obtained in 1992 proved to be quite good in comparison with actual subscriptions over the five-year period from 1994 to 1999. Several firms have reported using the Bass model to their satisfaction. Often, they end up extending the simple model to further aid their decision making. In the mid-1980s, RCA used an extension of the Bass model to forecast the sales of music CDs as a function of the sales of CD players. The model was quite accurate in its predications. Some movie exhibitors in Europe now use an extension of the Bass model to forecast box office revenues for movies, and to decide on how many screens to show a movie. Therefore to use the Bass model for forecasting future adoption of the renewable energy driven devices such as air conditioning and cooling systems in India is apt, appropriate and just.

4. Objectives

For a new product coming into the market, the success of adaptation of that product by the customers i.e. the acceptance or rejection of the product largely depends on the level of awareness among the potential users and also the quality of that product to be introduced into the market. As per as the psychology of Indian consumers are concerned, they are generally having strong resistance to any kind of change in adopting new product. But as the rapid progress of the technology and with the passage of time people are

choosing more comfortable lifestyle and as such feeling more cooling need about 280 to 300 days in a year as a results the traditional Air Conditioning sales has been increasing exponentially. Solar energy driven air conditioning system is an innovative product and for the diffusion of this type of product two types of influences work in marketing management – i) External Influences (like Media communication etc.) and ii) Internal Influences (word of mouth etc.). Customer influenced by the internal influences are called ' Imitators' and those who are motivated by the external influences are called 'Innovators'. In this paper attempt has been made to apply the strength of this two types of influences to forecast the future sales i.e. adoption of solar A.C. in the Indian market. And at last some policy issues are also suggested for the smooth of the marketing of the renewable energy driven devices in India.

5. Sustainable Innovative Product :Solar Energy driven Air Conditioning Systems

To meet the growing demand for energy and to reduce environmental pollution, the solution should be asystems run on renewable energy particularly solar. Diagram (Fig-1) shows the whole set of technologies available to use solar energy for cooling. Thermally-driven cooling machines such as absorption chillers are driven by solar energy. A solar cooling installation consists of a typical solar thermal system made up of solar collectors, storage tank, control unit, pipes and pumps and a thermally-driven cooling machine. The high efficiency collectors namely double glazed flat plate collectors or evacuated tube collectors are used in solar cooling systems. New developments for the medium temperature range (100-250oC) could increase the overall efficiency of the cooling systems.

Solar assisted air-conditioning (SAAC) is one of the most widely used applications for solar cooling. The solar assisted air-conditioning systems are of two types- (i) Closed systems -These are thermally-driven chillers which provide chilled water conditioned air i.e. cooled, dehumidified air is supplied by air handling units or distributed through a chilled water network to the designated rooms. The absorption chillers (most common) and adsorption chillers are available in the market; (ii) Open systems -A complete air-conditioning is allowed by supplying cooled and dehumidified air in accordance with the comfort conditions. The refrigerant used for this purpose is water. Desiccant cooling systems using a rotating dehumidification wheel with solid sorbent is the most common system used for cooling purpose. A solar-assisted air-conditioning

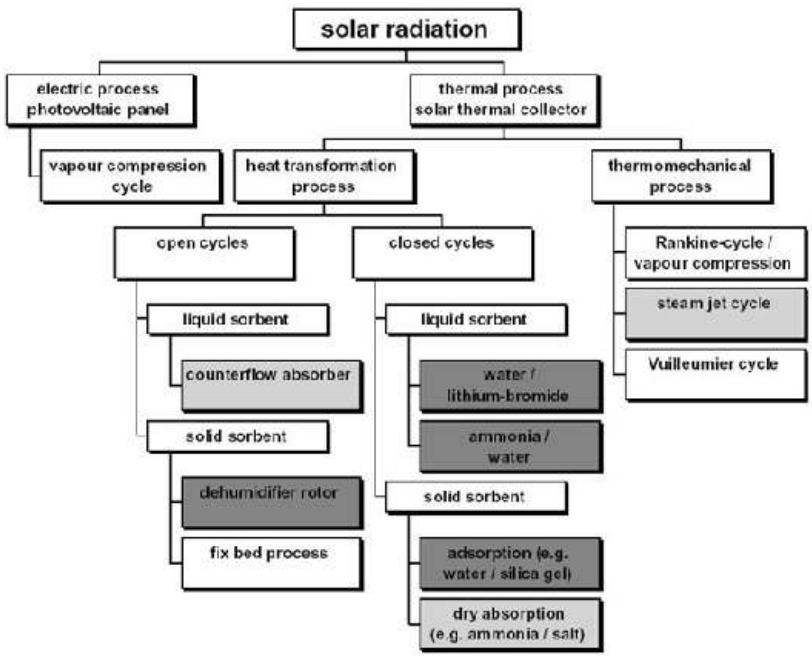

Figure 1 : Overview on Physical ways to convert solar radiation to cooling

system for a single-family residential building is composed of three major sub-systems:

- **The load sub-system:** This is the distribution system for the cold medium (supply and return). It is connected to the delivery terminals located at space to be air-conditioned in the building.
- **The cold production sub-system.** The heat released in this unit by the absorber and the condenser is discharged indirectly to the environment through a cooling tower.
- **The heat production sub-system:** It provides the high temperature heat to the thermally driven air-conditioning system. Besides the solar collector field, other key components are the thermal storage unit, the pumps and the thermostat controllers. Furthermore, depending on the system needs (insufficient solar radiation, inadequate collector area, etc.) a back-up heat source incorporated. In this paper, it is assumed that a gas heater provides the auxiliary thermal energy.

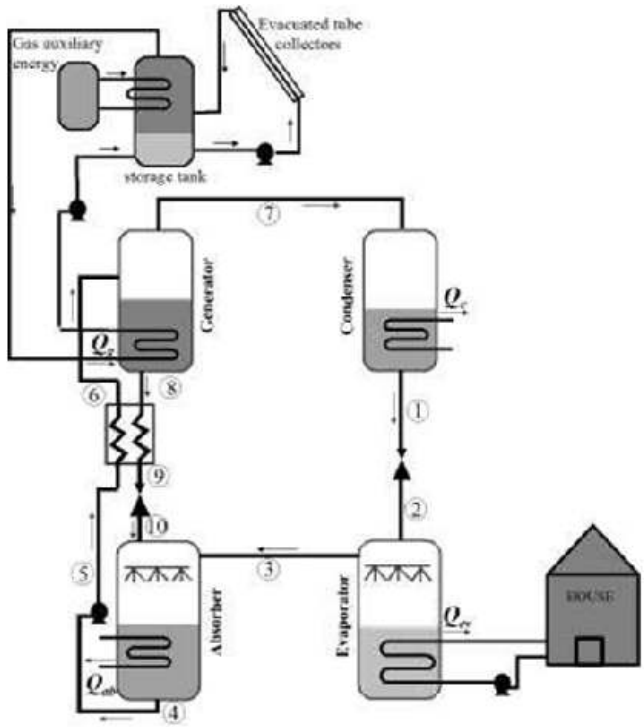

Figure 2 : Solar A.C. Water absorption Machine

6. Methodology

The process is Hierarchical model which starts with analysis of cooling need and analysis of solar radiation indifferent locations in India as shown in the diagram below. The model gradually judge and determine the acceptance of the new technology product in every stages and finally the future market potential is determined with the help of Bass Model.

The new product in this case is solar energy operated air conditioning and cooling systems and as this is very virgin category of product in India, it is at very nascent stage of adaptation and as such few secondary data are collected with the help of which parameters of Bass Model will be determined and the formulation of the diffusion model for solar energy driven air conditioning and cooling systems is done with these values.

The capacity of air conditioning system is expressed in term of Ton of Refrigeration (TR) and as the solar Air Conditioning system (Solar A.C.) is more economic and feasible in bulk space cooling, we have taken 1TR as one unit so that there would be no ambiguity to consider room A.C. and centralized A.C. for commercial purpose as a whole in term of cooling unit.

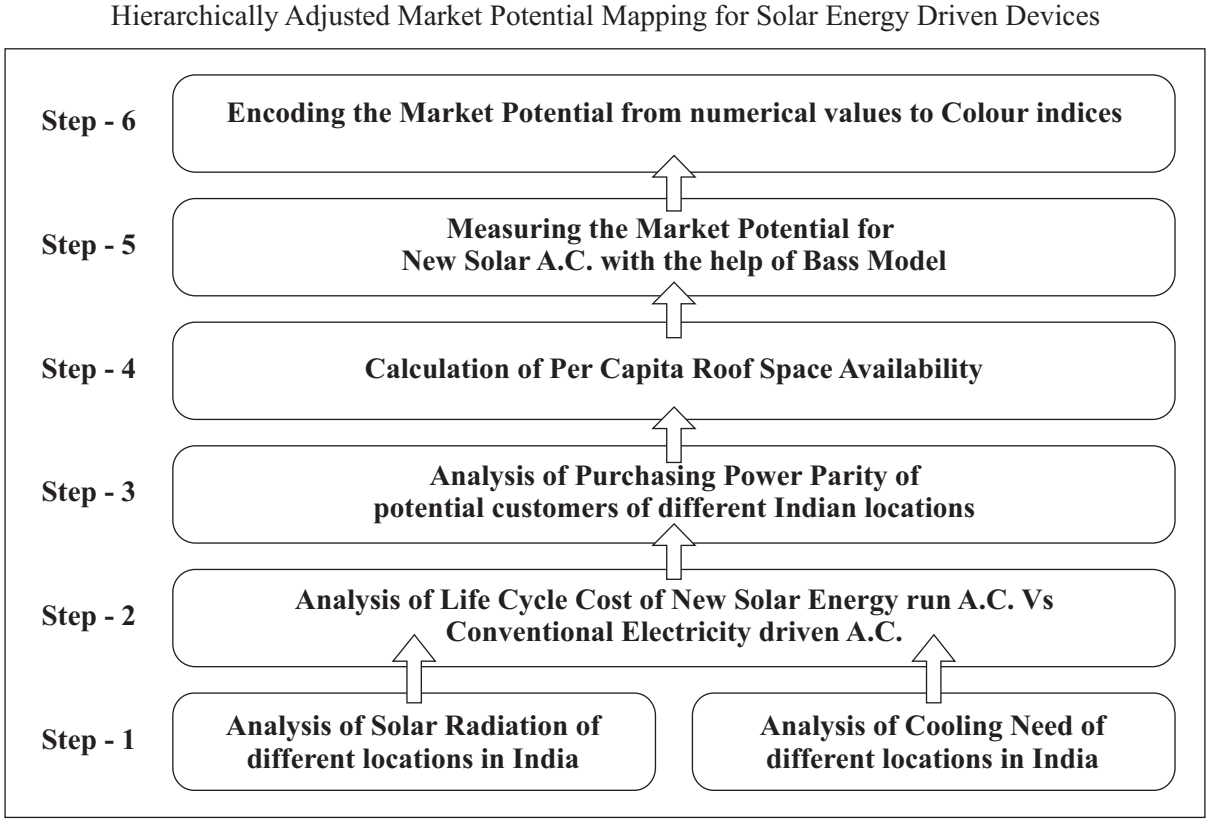

Figure 3 : Proposed Hierarchically Adjusted Market Potential Derivation Model for Solar Energy Driven Devices

8. Model for Deriving Market Potential for Solar Air Conditioning systems

We determine the market potential for solar AC using hierarchical model having six steps as – i) Life Cycle Cost analysis; ii) Calculation of Cooling Need; iii) Roof Space Availability; iv) Purchasing Power Parity of the Location (Affordability); v)Willingness to buy (Market Potential) using Bass Model; vi) Coding Market Potential. The diagram (Fig-3) shows the layout of our proposed model step by steps.

8.1 The first stage of buying process is recognition of need, here cooling need. India is becoming hotter day by day as yearly average temperature is gradually increasing and with rapid urbanization taking place in& around all major cities and towns. As for instance, Kolkata's air temperature varies between 12°C and 40°C and about 300 days/year are hot & sunny days and solar radiation varies between 3.5 -8.2 kWh/m2/d. Different locations have different temperature, humidity, wind speed & radiation and as such varying cooling need. We calculate cooling needs in terms of usage of energy for cooling and no. of devices used for the purpose. As estimated for Kolkata there is 1TR AC per 6 family. [see Annexure-A]

8.2 Transition from conventional to solar much depends on Life Cycle Costs(LCC) of the two types of systems composed of i) cost of acquisition ii) cost of operation iii) cost of maintenance iv) cost of disposal. These costs varies from place to place and time to time as electricity tariff, prices of systems, supply-demand ratio, purchasing power, temperature & humidity variation etc varies. Taking into consideration- a) Working time per year is 2000 hrs needed thermal energy for chillers is 96000 kWh; b)

The sun radiation in collector level per year is 1080kWh/ sq.m.a; c) Cost of vapour; d) cost of cooling water; e) costs of gas; f) costs of electrical energy. The equation to calculate refrigeration capital cost is $R = \frac{c*q^n(q-1)}{(q^n-1)}$ [Ajib, S.2001]. Where R – yearly capital costs, c- capital investment, q- rate of interest+1, n- depreciation years. Analysis shows that with same costs where conventional AC depreciates in 12 -15 years the new solar AC depreciates in 20-25 years, i.e., solar AC gives approximately double financial benefit.

8.3 After searching for alternatives, evaluation of alternatives also depends on price of the products ie, affordability to pay that. So in this step we segment the entire Indian demography in terms of purchasing power parity (PPP) based upon secondary data (NSSO, Census).

8.4 As the new solar AC requires rooftop space availability, we analysis the roof top area with the help of Web based GIS software (like Arc GIS). As for example with the Web GIS tool for Chandigarh we can easily find out the roof top area of any location or building and PV generated electricity potential (Figure 4).

To quantify the potential feasible place for installing Solar AC we calculate per family roof space available which is important input to its Market Potential. As typical 1TR solar AC needs $2m^2$ of rooftop space, so market potential at Chandigarh $4km^2/2m^2 = 2000000$ TR, i.e.,2000000 of 1TR solar AC.

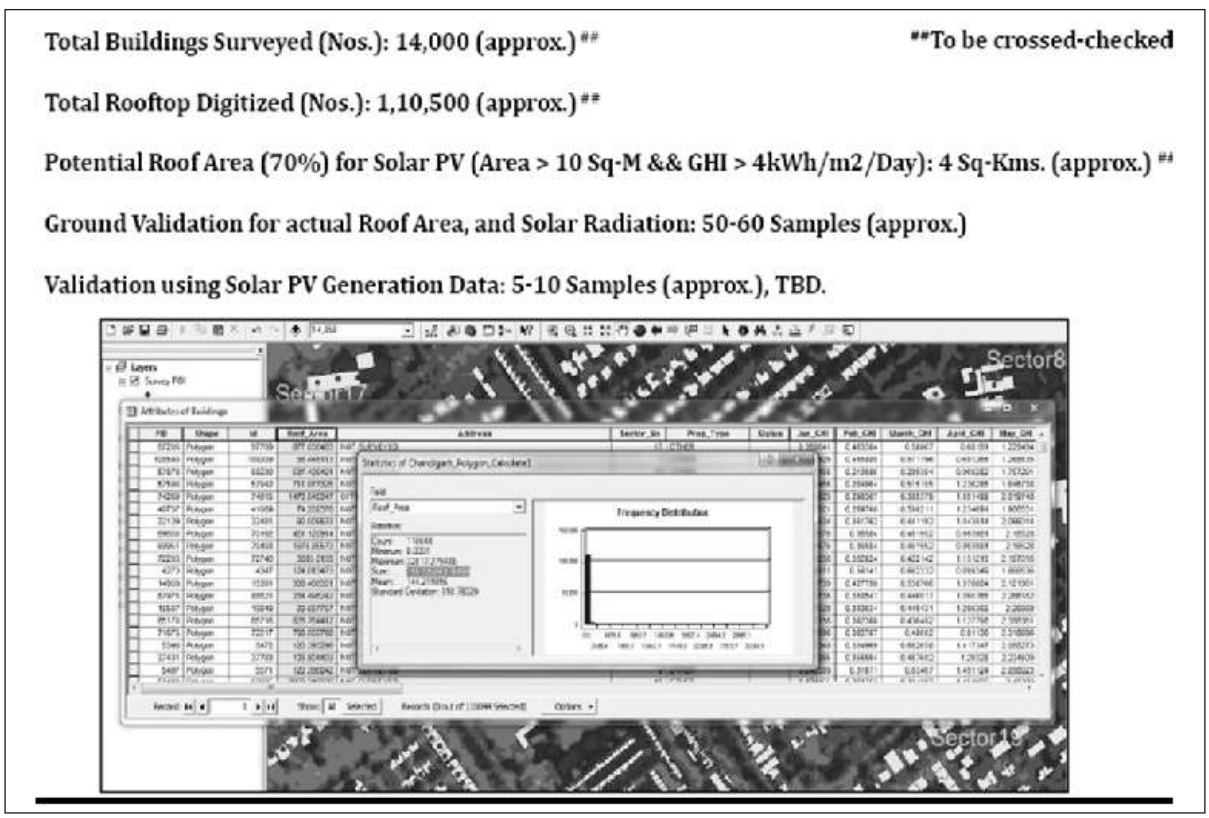

Figure 4: Rooftop area analysis by Web GIS tool at Chandigarh

8.5 Formulation of Bass Model for forecasting Market Potential of Solar energy driven A.C.:

The Bass model is a very useful tool for forecasting the adoption (first purchase) of an innovation (more generally, a new product, here Solar driven A.C.) for which no closely competing alternatives exist in the marketplace. A key feature of the model is that it embeds a "contagion process" to characterize the spread of word-of -mouth between those who have adopted the innovation and those who have not yet adopted the innovation. The model can forecast the long-term sales pattern of new technologies and new durable products under two types of conditions: (1) the firm has recently introduced the product or technology and has observed its sales for a few time periods; or (2) the firm has not yet introduced the product or technology, but its market behaviour is likely to be similar to some existing products or technologies whose adoption pattern is known. The model attempts to predict how many customers will eventually adopt the new product and when they will adopt. The question of when is important, because answers to this question guide the firm in its deployment of resources in marketing the new product.

The Bass Model:

The key behavioural and mathematical conceptions in Bass's model are as follows:

i) Over the period of interest there are m initial purchases of the product and there are no repeat purchases.

ii) The forces of innovative and imitative behaviour are assumed to operate in the market and exert different effects on the rate of initial purchases. These behavioural forces are represented by parameters p and q respectively in the model. Imitators are influenced in the timing of their adoption by social system pressures. This social force is captured in the Y(T) variable below (the number of previous adopters). Innovators, however, are not influenced by the number of previous adopters in the timing of their purchase.

iii) The probability of a purchase at T, given that no purchase has yet been made, is hypothesized then to be : $P(T) = p + (q/m)Y(T)$..... (1)

iv) Assuming sales are comprised entirely of initial purchases,

$S(T) = P(T)\,[m - S(T)]$,

or, using (1), $S(T) = pm + (q - p)Y(T) - (q/m)\,[Y(T)]^2$.....(2)

where: $S(T)$ = initial sales (adoptions) at T,

p = coefficient of innovation (a measure of external influence, viz, media communication) corresponding to the probability of an initial purchase $T = 0$,

q = coefficient of imitation (a measure of internal influences, viz, word of mouth),

m = number of initial purchases (adoptions) of the product (new technology) over total period, and $Y(T)$ = number of previous buyers at time T.

v) The assumptions of the theory are formulated in terms of a continuous model and a density function of time to initial purchase. The solution for this formulation yields an equation in which time is the only variable:

$S(T) = [m(p + q)^2/p] * \{e^{-(p+q)T}/[1 + (q/p)e^{-(p+q)T}]^2\}$..... (3)

vi) To estimate the parameters p, q, and m from discrete time series data, the following analog to the model (2) is employed in multiple regressions, where ordinary least squares estimates of a, b, and c are obtained:

$$S(T) = a + bY(T-1) + c[Y(T-1)]^2 T = 2, 3, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

vii) The parameters of the basic model (m, p, and q) are identified in terms of these regression coefficients and are:

$$q = -mc, \quad p = a/m, \quad m = \frac{-b - \sqrt{(b^2 - 4ac)}}{2c}$$

viii) Thus, to predict sales, these estimates for m, p, and q are substituted into the model solution (3).

ix. The peak (maximum) value of S(T) and the predicted time of this peak are shown to be:
$S(T^*) = m(q+p)2/4q$; where $T^* = (p+q)^{-1}\ln(q/p)$..... (6)

x) In the original work by Bass, the model was tested against series data for eleven different consumer durables. The period of analysis was restricted to include only that interval in which repeat purchasing was not an important contributor to sales. These data were found to be in good agreement with the model.

Also it is to be noted that the future sales as forecasted through the Bass model is just similar to the normal Product-Life-Cycle (PLC) curve of any new product introduce into the market and as such this model (Bass) has enough importance in marketing solar Air Conditioning and cooling systems in India.

EXHIBIT 1:

Graphical representation of the probability of a customer's adoption of a new product over time; (a) shows the probability that a customer in the target segment will adopt the product before time t, and (b) shows the instantaneous likelihood that a customer will adopt the product at exactly time t.

Using Bass Model Estimates for Forecasting Future Sales of Solar A.C.:

Once we determine the parameter values by estimating or by using analogous, we can put these values into a spreadsheet to develop forecasts (Exhibit 2) [Peter J. Lenk,1990]. The software has built-in options for sales forecasting using estimates either from the nonlinear least squares method (if there are sufficient

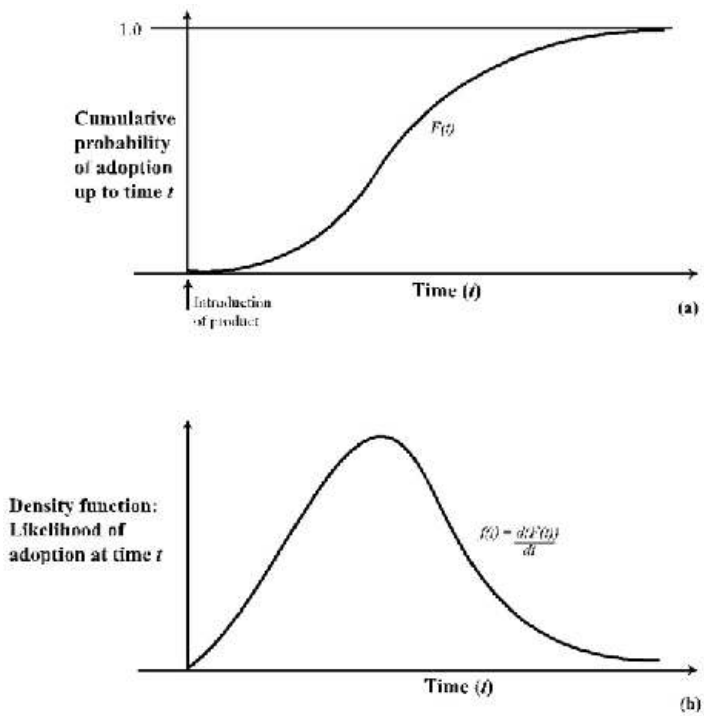

Figure 5 : Graphical representation of the probability of a customer's adoption of a new product over time t

market data for estimation) or by directly selecting p and q from analogous products.

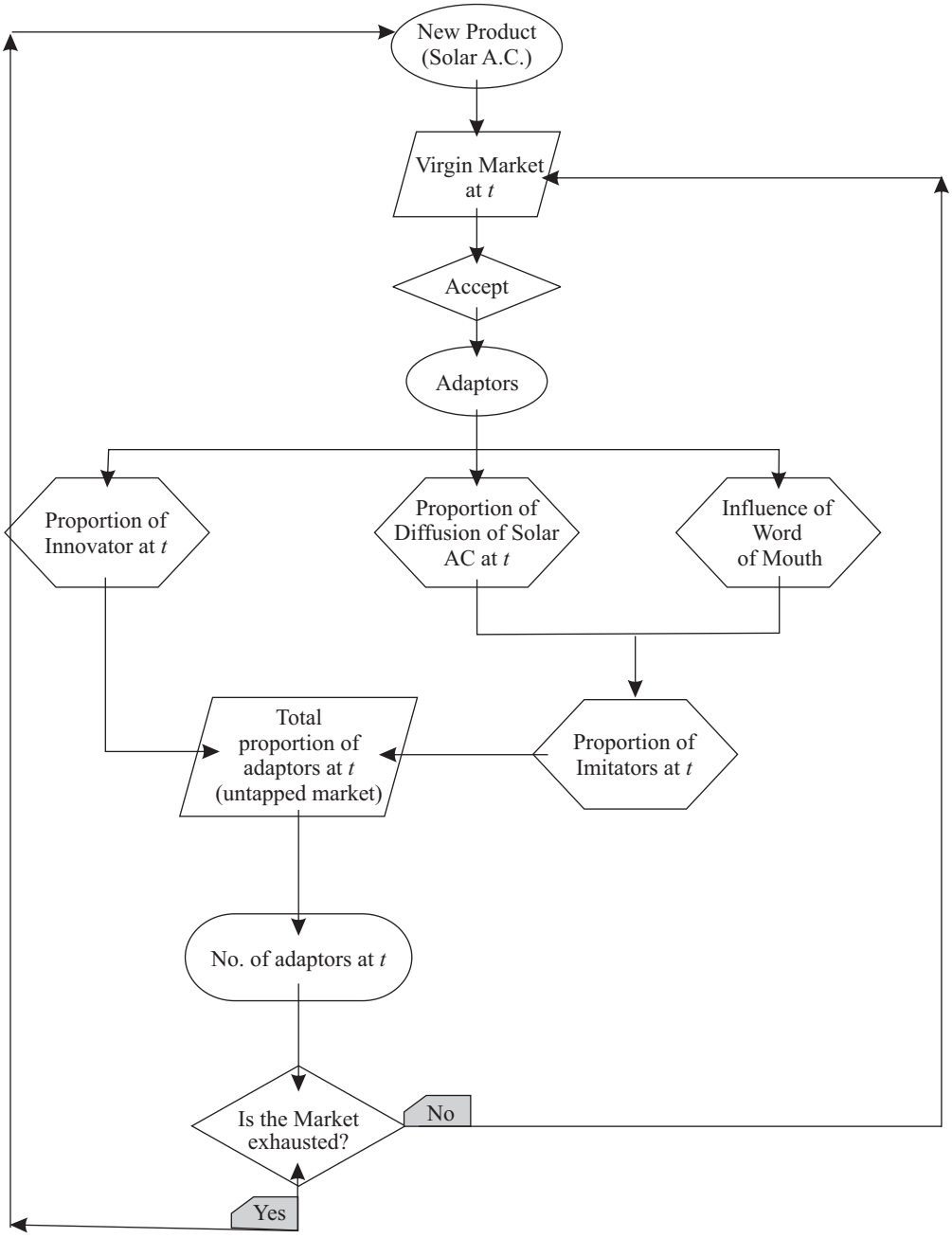

Figure 6 : Data Flow Diagram of the Bass Model for Solar Air Conditioning systems

An estimated forecasted table as per $S(T) = pm + (q - p)Y(T) - (q/m)[Y(T)]^2$.....eq^n (2)

Quarter	Sales	Cumulative Sales
0	0	0
1	160	160
4	425	1118
8	1234	4678
12	1646	11166
16	555	15106
20	78	15890
24	9	15987

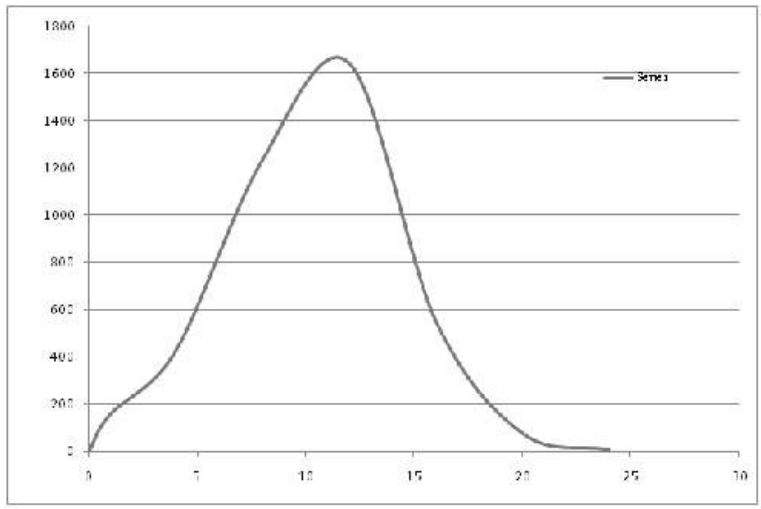

Figure 7 : Proposed forecasted sales of solar A.C.

EXHIBIT 2:

Example computations showing

how to use the Bass model to forecast

the sales of an innovation (Solar

Energy Driven Air Conditioning

Systems). The computations are based on the estimated values of p=0.1 and q=0.41, and market potential (N) = 160 units (in thousands).

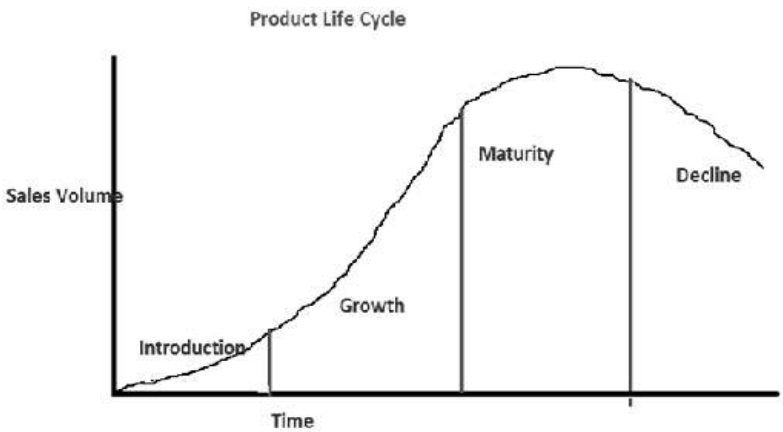

Fig 8: Normal Product Life Cycle graph

Assumptions in the Basic Bass model for applications in Solar A.C.:

The Bass model makes several key assumptions. We can relax many of these assumptions by using more sophisticated models for market potential determination of Solar energy driven Air Conditioning & cooling Systems; as below:

- **The market potential (N) remains constant:** This assumption is relaxed in models in which N– is a function of price declines, uncertainty about technology performance, and growth of the target segment. The software includes an option to specify the growth rate of the target segment.
- **The marketing strategies supporting the innovation do not influence the adoption process:** Considerable research has been devoted to incorporating the impact of marketing variables, particularly price, advertising, and selling effort. We described the generalized Bass model, which represents one way to relax this assumption.
- **The customer decision process is binary (adopt or not adopt):** This assumption is relaxed in

several models that incorporate multistage decision processes in which the customer goes from one phase to another over time:

awareness → interest → adoption → word of mouth → Imitator

- **The value of q is fixed throughout the life cycle of the innovation:** One would, however, expect interaction effects (e.g., word of mouth) to depend on adoption time, being relatively strong during the early and late stages of a product's life cycle. This assumption is relaxed in models that incorporate a time-varying imitation parameter.
- **Uniform mixing, i.e., everyone can come into contact with everyone else.** One way to relax this assumption is by incorporating the social structure of connections among the members of the target group. An appealing structure to include is the "small world network" with both "close" and "distant" ties among members.
- **Imitation always has a positive impact (i.e., the model allows only for interactions between innovators and non-innovators who favour the innovation):** Several models are available that allow for both positive and negative word of mouth. When word-of-mouth effects are likely to be positive (e.g., "sleeper" movies such as Ghost), it may be wise to gradually ramp up marketing expenditures, whereas when word-of-mouth effects are likely to be negative (e.g., the "mega-bomb" movie Water world), it may be better to advertise heavily initially to generate quick trials before the negative word of mouth significantly dampens sales.
- **Sales of the innovation are considered to be independent of the adoption or non-adoption of other innovations:** Many innovations depend on the adoption of related products to succeed. For example, the adoption of multimedia software depends on the adoption of more powerful PCs. Likewise such innovations as wide area networks and electronic commerce complement each other and have to be considered jointly to predict their sales. Several models are available for generating forecasts for products that are contingent on the adoption of other products.
- **There is no repeat or replacement purchase of the innovation:** There are several models that extend the Bass model to forecast purchases by both first-time buyers and by repeat buyers.

Conclusions:

For marketing managers, diffusion models such as Bass model have the potential to provide insights into the introduction and growth phases of new product life cycle. The possible benefits derived from the model based on innovation diffusion theory lie in the capacity of these models to predict the timing and magnitude of the sales peak for an innovation, as well as the general shape of the diffusion curve, with relatively little input data. This research has shown that for new innovative product the Bass model accurately reproduced the diffusion of an innovation of green device such as solar air conditioning systems when the data was appropriately aggregated. The graph for periodical values of sales forecast is just similar to that of an ideal product life cycle (PLC) which indicates that application of Bass Model for future market potential is just appropriate. The value of the Bass model lies in its claimed forecasting data to predict the remainder of the adoption process. The Bass model can be used to describe the diffusion process, to test specific diffusion based hypotheses, to determine whether sales targets represent a feasible adoption process, and to make limited forecasts to provide a basis for product marketing decision making.

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Annexure- A

Power consumption due to cooling need (fan and air cooler) = Total generated power X 15%

Total number of fan (NFAN) used in Kolkata= power consumption due to fans (W) / 75 (W)

(Because a typical ceiling fan may consume up to 75 watts of energy) ##

Total number of installed A.C. machines (NAC) in Kolkata

= total power consumed by A.C. machines / wattage of a typical A.C. machine

If there are 5 members per family (on an average), then the total number of families (NFAMILY) in Kolkata will be = population of Kolkata / 5

According to above data analysis we can calculate the total number of fans used in Kolkata for domestic purpose as, (1225 MW x 15%)/75 = 2.45 x 106 numbers of fans.

Total population of Kolkata (NPOP) is 14.96 million (as of census 2011)

So, the approximate per capita cooling need is (NFAN / NPOP) = (2.45/14.96) = 0.1638 number of fans.

** (Total power generating capacity of CESC is 1225 MW)

Total number of installed A.C. machines (NAC) in Kolkata = 500 MW / 1000 W = 5 lakhs.

Total number of families (NFAMILY) in Kolkata = 14.96 million / 5 = 2.992 million (approx)

So, the approximate per family Air-Conditioning machine distribution in Kolkata is

= 5 lakhs / 2.992 million = 0.167 number of A.C. machines. (i.e. 1TR AC per 6 family)

Dynamic Reaction Model of an Exploited Predator-Prey System

Ujjwal Kumar Pahari
Department of Mathematics, Netaji Nagar Day College, Regent Estate, Kolkata,
E-mail: upahari123@gmail.com

Abstract In the present paper, dynamic reaction model of a predator-prey system is studied in which (i) the predator is provided with an alternative food in addition to the prey species, (ii)the predator is harvested taking harvesting effort as dynamic variable and (iii) a tax is imposed to regulate the system. The existence of possible steady states along with their local as well as global stability is discussed. Boundedness of the system is also discussed. It is seen that the system undergoes a Hopf bifurcation by the addition of alternative prey and the criteria for the Hopf-bifurcation is also discussed. Optimal tax policy is discussed using Pontryagin's maximal principle. Finally some numerical simulations are given to show the consistency with theoretical analysis.

AMS Mathematics Subject Classification: 92D25, 34C23.

Key words Alternative prey, dynamic reaction, harvesting, global stability, bifurcation, taxation.

1. Introduction

Population dynamics has attracted interest from commercial harvesting industry and from many scientific communities including biology, ecology and economics. Research in the area of theoretical ecology was initiated by Lotka-Volterra. Since then, many mathematicians and ecologists contributed to the growth of this area of knowledge as reported in the treatises of Paul Colinvaux [12], Freedman [5], Kapur([7] and [8]), etc. Harvesting of multi-species fisheries is an important area ofstudy in fishery modelling. The issues and techniques related to this field of study and the problem of combined harvesting of two ecologically independent populations obeying logistic law of growth are discussed in detail by Clark [2]. Harvesting problems with taxation as a control instruement are studied by Kar and Chaudhuri [9], Dubey et.al. [4], Kar et.al. [10], etc.

2. The model formulation

We consider the model equations of two interacting species which are in prey-predator relationship and where both species have independent specific growth rate in the absence of the other. Whenever there is a large catch of the predator, there exists serious implications for production of both the species and therefore, it is necessary to regulate harvesting on the predator species. The rate equations of growth of two species are given by

$$\frac{dx}{dt} = rx\left(1 - \frac{x}{k}\right) - \frac{axy}{b+x},$$

$\frac{dy}{dt} = \frac{maxy}{b+x} + dy - cy^2 - h(t)$ (1)

with$x(0) > 0,\ y(0) > 0$

Here $x = x(t)$ = density of the prey population at time t,

$y = y(t)$ = density of the predator population at time t,

k = environmental carrying capacity of the prey,

r = average net per-capita growth rate of the prey, i.e. maximum specific growth rate of the prey,

a = maximal relative increase of predation,

b = half saturation level which is a constant,

d = growth rate of the predator due to availability of alternative food sources,

c = mortality rate of the predator population,

m = conversion factor,

$h(t)$ = harvesting rate of the predator at time$t$.

The term dy represents a growth rate of the predator due to the availability of alternative food sources. It is quite natural that when focal prey is low, the predators increase their feeding on alternative prey. But when the focal prey increases, the predator uses less alternative prey and as focal prey approaches to its saturation value$k$, the amount of alternative prey consumed by the predator tends to zero and then only predation of the focal prey occurs. For this reason, we modify the term dy by the factor$dy(1 - \frac{x}{k})$. Also, predator mortality is assumed to be a rate proportional to y^2 rather than y.

The amount of prey consumed by the predator is assumed to follow Holling type II [6] functional form. We assume that the predator population is harvested according to the catch-per-unit-effort (CPUE) hypothesis [2] which describes that catch per unit effort is proportional to the stock level. Thus we consider $h = qEy$ where E is the harvesting effort and q is the catchability coefficient.

To control exploitation of the fishery, regulatory agency imposes a tax $\tau(> 0)$ per unit biomass ofthe landed predator fish. Any subsidy to the fishermen may be interpreted as the negative value ofτ.

The net economic revenue to the fishermen (perceived rent) is given by$E[q(p - \tau)y - C]$ where p isthe price per unit biomass and C is the cost of unit harvesting effort.

In an open access fishery of a fully dynamic model, the level of fishing effort expands or contracts according as the perceived rent to the fisherman is positive or negative. A model reflecting this dynamic interaction between the perceived rent and effort in a fishery is called a dynamic reaction model. The harvesting effort E is, therefore, a dynamic variable governed by the differentialequation

$$\frac{dE}{dt} = [(p - \tau)qy - C]E$$

Thus, the final model becomes

$$\frac{dx}{dt} = rx\left(1-\frac{x}{k}\right) - \frac{axy}{b+x},$$

$$\frac{dy}{dt} = \frac{maxy}{b+x} + dy\left(1-\frac{x}{k}\right) - cy^2 - qEy, \quad (2)$$

$$\frac{dE}{dt} = [(p-\tau)qy - C]E.$$

The system (2) under investigation has six equilibria:

$$(i)P_0(0,0,0)\ (ii)P_1(k,0,0)\ (iii)P_2(0,d/c,0)\ (iv)P_3(0,\hat{y},\hat{E})$$

Where$\hat{y} = \frac{c}{(p-\tau)q}, \hat{E} = \frac{1}{q}(d-c\hat{y})$ (v) $P_4(\bar{x},\bar{y},0)$where $\bar{y} = \frac{r}{ak}(k-\bar{x})(b+\bar{x})$

and$\bar{x}$is the unique positive root of the equation

$$x^3 + \left(2b-k-\frac{ad}{cr}\right)x^2 + \left\{(k-b)\left(\frac{ad}{cr}-b\right) + k\left(\frac{a^2m}{cr}-b\right)\right\}x + bk\left(\frac{ad}{cr}-b\right) = 0$$

and (vi) $P_5(x^*,y^*,E^*)$where

$$y^* = \frac{c}{(p-\tau)q}, x^* = \frac{k-b}{2} + \sqrt{\left(\frac{k-b}{2}\right)^2 - \frac{aky^*}{r}}, E^* = \frac{1}{q}\left\{\frac{max^*}{b+x^*} + d\left(1-\frac{x^*}{k}\right) - cy^*\right\}.$$

We now study the different conditions under which these steady states exist.

The equilibria $P_0(0,0,0)$, $P_1(k,0,0)$ and $P_2(0,d/c,0)$ always exist. In the case of taxation, it is natural to assume that $p > \tau > 0$. Hence $\hat{y} > 0$ and $\hat{E} > 0$ if $d > \frac{c^2}{(p-\tau)q}$.

Therefore, the equilibrium point$P_3(0,\hat{y},\hat{E})$exists if$p > \tau > 0$ and$d > \frac{c^2}{(p-\tau)q}$.

The equilibrium point $P_4(\bar{x},\bar{y},0)$exists if$\frac{d}{c} < \frac{br}{a}$.

This means that the ratio of the rate of growth due to alternative prey and mortality of predator is always less than the ratio of the product of specific growth and half saturation level of the prey to its maximum capture rate due to predation.

Before studying the stability of the model, we see that the solutions of the system are bounded in a finite region initiating at $(x(0),y(0),E(0))$ by the following theorem.

Boundedness

Theorem1. All the solutions of the system (2) which start in $\Re_+^3$ are uniformly bounded.

Proof: Let $(x(t), y(t), E(t))$be any solution of the system with positive initial conditions. We definethe function$W = x + \frac{y}{m} + \frac{E}{m(p-\tau)}$.

It can be shown that for each $\mu > 0$, $\frac{dW}{dt} + \mu W \leq V$, where

$V = \frac{k}{4r}(r+\mu)^2 + \frac{1}{4mc}(d+\mu)^2$.

Applying the theory of differential inequality (Birkoff and Rota) [1], we obtain

$$0 \leq W(x,y,E) \leq \frac{V}{\mu}(1 - e^{-\mu t}) + W(x(0), y(0), E(0))e^{-\mu t}$$

Which upon letting $t \to \infty$, yields$0 \leq W \leq \frac{V}{\mu}$.

Thus all the solutions of the system (2) that starts in $\Re_3{}^+$are confined to the region

$B = \left\{(x,y,E)\, \epsilon\, \Re_3{}^+ : 0 \leq W \leq \frac{V}{\mu} + \varepsilon\right\}$, for any$\varepsilon > 0$.

Local Stability Analysis

The variational matrix of the system (2) is

$$M(x,y,E) = \begin{bmatrix} r\left(1 - \frac{2x}{k}\right) - \frac{aby}{(b+x)^2} & -\frac{ax}{b+x} & 0 \\ \frac{maby}{(b+x)^2} - \frac{dy}{k} & \frac{max}{b+x} + d\left(1 - \frac{x}{k}\right) - 2cy - qE & -qy \\ 0 & (p-\tau)qE & (p-\tau)qy - c \end{bmatrix}$$

The eigenvalues of the variational matrix $M(0,0,0)$are$r, d, -c$. So, the equilibrium point $P_0(0,0,0)$is unstable.The eigenvalues of the variational matrix $M(k,0,0)$are $-r, -c, \frac{mak}{b+k}$. So, the equilibrium point$P_1(k,0,0)$ is also unstable.

For the equilibrium point$P_2(0, d/c, 0)$, the eigenvalues are$-d, r - \frac{ad}{bc}, (p-\tau)\frac{qd}{c} - c$. .Therefore,$P_2(0, d/c, 0)$ is a stable node if$\frac{d}{c} > \frac{br}{a}and\tau > p - \frac{c^2}{qd}$.

For the equilibrium point$P_3(0, \hat{y}, \hat{E})$, one eigenvalue of the variational matrix is

$r - \frac{ac}{(p-\tau)qb}$, which is negative if $\tau > p - \frac{ac}{brq}$ .The other two eigenvalues are the roots of the quadratic equation

$\lambda^2 + \frac{c^2}{(p-\tau)q}\lambda + cd - \frac{c^3}{(p-\tau)q} = 0$,which has(a) sum of roots $= -\frac{c^2}{(p-\tau)q}$which is always negative and (b) product of roots $= cd - \frac{c^3}{(p-\tau)q}$ .Hence, the roots of the quadratic equation are real and negative or

complex conjugate with negative real part if$\tau < p - \frac{c^2}{qd}$. Therefore, the equilibrium point P_3 is locally asymptotically stable if $p - \frac{ac}{brq} < \tau < p - \frac{c^2}{qd}$. So it is observed that even in the absence of prey$x$, the predator may exists in its equilibrium level and this is happened due to alternative prey.

For the equilibrium point $P_4(\bar{x}, \bar{y}, 0)$, one of the eigenvalues of the corresponding variational matrix is $(p-\tau)q\bar{y} -$ cwhich is negative if $\tau > p - \frac{c}{q\bar{y}}$. The other two eigenvalues are the roots of the quadratic equation $\lambda^2 + u\lambda + v = 0$ where

$u = c\bar{y} - \frac{r\bar{x}}{b+\bar{x}}\left(1 - \frac{b}{k} - \frac{2\bar{x}}{k}\right)andv = \frac{a\bar{x}\bar{y}}{b+\bar{x}}\left\{\frac{mab}{(b+\bar{x})^2} - \frac{d}{k} - \frac{rc}{a}\left(1 - \frac{b}{k} - \frac{2\bar{x}}{k}\right)\right\}$.

The sign of real part of the eigenvalues are determined by$u$. Now $u > 0$ if$k < b + 2\bar{x}$.The equilibrium point $P_4(\bar{x}, \bar{y}, 0)$ is locally asymptotically stable if

$k < b + 2\bar{x}$and$\tau > p - \frac{c}{q\bar{y}}$.

At$P_5(x^*, y^*, E^*)$, we have

$$M(x^*, y^*, E^*) = \begin{bmatrix} \frac{rx^*}{b+x^*}\left(1 - \frac{b}{k} - \frac{2x^*}{k}\right) & -\frac{ax^*}{b+x^*} & 0 \\ \frac{mbr}{b+x^*}\left(1 - \frac{x^*}{k}\right) - \frac{dy^*}{k} & -cy^* & -qy^* \\ 0 & (p-\tau)qE^* & 0 \end{bmatrix}.$$

The characteristic equation corresponding to $M(x^*, y^*, E^*)$ is

$\lambda^3 + m_1\lambda^2 + m_2\lambda + m_3 = 0$ (3)

where$m_1 = cy^* - \frac{rx^*}{b+x^*}\left(1 - \frac{b}{k} - \frac{2x^*}{k}\right)$,

$m_2 = cqE^* - \frac{crx^*y^*}{b+x^*}\left(1 - \frac{b}{k} - \frac{2x^*}{k}\right) + \frac{ax^*}{b+x^*}\left\{\frac{mbr}{b+x^*}\left(1 - \frac{x^*}{k}\right) - \frac{dy^*}{k}\right\}$,

$m_3 = -\frac{cqrx^*E^*}{b+x^*}\left(1 - \frac{b}{k} - \frac{2x^*}{k}\right)$.

Routh-Hurwitz criterion gives a set of necessary and sufficient conditions so that all the roots of the characteristic equation have negative real parts. For the above cubic equation, these criteria are $m_1 > 0$, $m_3 > 0$ and $m_1m_2 > m_3$.

After a little manipulation it can be shown that these conditions are satisfied if

$$\frac{d(b+x^*)^2}{mab} < k < b + 2x^*. \qquad (4)$$

Therefore, by Routh-Huriwtz criterion, we say that (4) is the sufficient condition for local asymptotic stability of the non-trivial steady state$P_5(x^*, y^*, E^*)$.

Global Stability Analysis

Let us consider the the following Lyapunov function:

$$V(x,y,E) = k_1\left(x - x^* - x^* ln\frac{x}{x^*}\right) + k_2\left(y - y^* - yln\frac{y}{y^*}\right) + k_3\left(E - E^* - E^* ln\frac{E}{E^*}\right)$$

On $G\{(x,y,E): x > 0, y > 0, E > 0\}$, where k_1, k_2, k_3 are positive constants to be determined in the subsequent steps. It can be easily verified that the function V is zero at the equilibrium $(x^*, y^*, E^*)$and positive on G.

The time derivative of V along the trajectories of (2) is

$$\frac{dV}{dt} = k_1\left(\frac{x - x^*}{x}\right)\frac{dx}{dt} + k_2\left(\frac{y - y^*}{y}\right)\frac{dy}{dt} + k_3\left(\frac{E - E^*}{E}\right)\frac{dE}{dt}$$

$$= k_1(x - x^*)\left[r\left(1 - \frac{x}{k}\right) - \frac{ay}{b + x}\right] + k_2(y - y^*)\left[\frac{max}{b + x} + d\left(1 - \frac{x}{k}\right) - cy - qE\right] +$$

$$k_3(E - E^*)[(p - \tau)qy - c]$$

A little manipulation yields

$$\frac{dV}{dt} = -k_1\left[\frac{r}{k} - \frac{ay^*}{(b + x^*)(b + x)}\right](x - x^*)^2 - k_2 c(y - y^*)^2 + \left[\frac{k_2 mb}{b + x^*} - k_1\right]\frac{a(x - x^*)(y - y^*)}{b + x}$$

$$- \frac{k_2 d}{k}(x - x^*)(y - y^*) + [k_3(p - \tau) - k_2]q(y - y^*)(E - E^*)$$

If we choose $\frac{(b+x^*)}{mb}k_1 = k_2 = k_3(p - \tau)$

then we have, $\frac{dV}{dt} = -k_1\left[\frac{r}{k} - \frac{ay^*}{(b+x^*)(b+x)} + \frac{k_2 d}{2kk_1}\right](x - x^*)^2 - k_2\left[c - \frac{d}{2k}\right](y - y^*)^2 -$

$$\frac{k_2 d}{2k}[(x - x^*)^2 + (y - y^*)^2]$$

Clearly, if $c > \frac{d}{2k}$ and $\left[\frac{r}{k} - \frac{ay^*}{(b+x^*)(b+x)} + \frac{k_2 d}{2kk_1}\right] > 0$

i.e. if $\frac{d}{c} < 2k$ and $x > \frac{2kmaby^*}{(b+x^*)[2rmb + d(b+x^*)]} - b$ and$(x, y, E) \neq (x^*, y^*, E^*)$, then $\frac{dV}{dt} < 0$.

Hence, the equilibrium point $P_5$is globally asymptotically stable.

Bifurcation Analysis

Bifurcation for the parameter ′d'which is the growth rate of the predator due to alternative prey.

To study the effect of alternative resource on the system we consider the parameter'd' as bifurcation parameter.

The characteristic equation (3) has two purely imaginary roots if and only if

$m_1 m_2 = m_3$for some value of d, say d^*. We find that

$$d^* = \frac{k(b+2x^*)}{ax^*y^*}\left[-\frac{crx^*y^*}{b+x^*}\left(1-\frac{b}{2k}-\frac{2x^*}{k}\right)+\frac{mabrx^*\left(1-\frac{x^*}{k}\right)}{(b+x^*)^2}+\frac{c^2qE^*y^*}{m_1}\right]$$

Thus, there exist a unique d^*such that $m_1 m_2 = m_3$. Therefore, there is only one value of d, at which we have a Hopf bifurcation. Thus in the neighborhood of $d^*$the characteristic equation (3) cannot have real roots.

For$d = d^*$, we have $(\lambda^2 + m_2)(\lambda + m_1) = 0.$

This equation has two purely imaginary roots and a real root as

$\lambda_1 = i\sqrt{m_2}, \lambda_2 = -i\sqrt{m_2}\ ,\ \lambda_3 = -m_1.$

The roots are in general of the form

$$\lambda_1(d^*) = \mathrm{p}(d^*) + i\mathrm{q}(d^*),\ \ \lambda_2(d^*) = \mathrm{p}(d^*) - i\mathrm{q}(d^*),\ \ \lambda_3(d^*) = -m_1(d^*).$$

To apply Hopf bifurcation theorem as stated in Marsden and McCracken [11], we need to verify the transversality condition

$$\left[\frac{dp}{dd}\right]_{d=d^*} \neq 0.$$

Substituting $\lambda_1(d^*) = \mathrm{p}(d^*) + i\mathrm{q}(d^*)$ in the equation (3) and differentiating the resulting equation w.r.t. d and settingp $(d^*) = 0$ and $\mathrm{q}(d^*) = \sqrt{m_2} = q_1$, we get

$\frac{dp}{dd}(-3{q_1}^2 + m_2) + \frac{dq}{dd}(-2m_1q_1) = {m_1}'{q_1}^2 - {m_3}',$

$\frac{dp}{dd}(2m_1q_1) + \frac{dq}{dd}(-3{q_1}^2 + m_2) = -{m_2}'q_1\ ,$

Where m_1, $m_2$and m_3 are function of the bifurcation parameter d and

$${m_1}' = \frac{dm_1}{dd},\ \ {m_2}' = \frac{dm_2}{dd},\ \ {m_3}' = \frac{dm_3}{dd}.$$

Solving for $\frac{dp}{dd}$and $\frac{dq}{dd}$we have$\left[\frac{dp}{dd}\right]_{d=d^*} = -\frac{{m_1}'m_2 + m_1{m_2}' - {m_3}'}{2({m_2}^2 + {m_1}^2 m_2)}.$

To establish Hopf bifurcation at $d = d^*$, we need to show that

$\left[\frac{dp}{dd}\right]_{d=d^*} \neq 0$.i.e.$m_1{}'m_{2+}m_1m_2{}' - m_3{}' \neq 0.$

Here$m_1{}' = \frac{dm_1}{dd} = 0, \quad m_2{}' = \frac{dm_2}{dd} = cq\frac{dE^*}{dd} + \frac{ax^*}{b+x^*}\left(-\frac{y^*}{k}\right) = \left(c - \frac{rx^*}{k}\right)\left(1 - \frac{x^*}{k}\right)$

$$m_3{}' = \frac{dm_3}{dd} = cq(m_1 - cy^*)\frac{dE^*}{dd} + cqE^*\left(\frac{dm_1}{dd} - c\frac{dy^*}{dd}\right) = \frac{crx^*}{b+x^*}\left(1 - \frac{x^*}{k}\right)\left(1 - \frac{b}{k} - \frac{2x^*}{k}\right)$$

Therefore,

$$m_1{}'m_{2+}m_1m_2{}' - m_3{}' = \left(1 - \frac{x^*}{k}\right)\left[cy^*\left(c - \frac{rx^*}{k}\right) + \frac{r^2x^{*2}}{k(b+x^*)}\left(1 - \frac{b}{k} - \frac{2x^*}{k}\right)\right]$$

$$< 0 \text{ if } c - \frac{rx^*}{k} < 0 \text{ and} 1 - \frac{b}{k} - \frac{2x^*}{k} < 0\,.$$

Thus, if $k < min\left\{\frac{rx^*}{c}, b + 2x^*\right\}$, then $m_1{}'m_{2+}m_1m_2{}' - m_3{}' < 0$ and hence

$$\left[\frac{dp}{dd}\right]_{d=d^*} \neq 0.$$

Thus, we get a sufficient condition that whenever $k < min\left\{\frac{rx^*}{c}, b + 2x^*\right\}$,

Hopf-bifurcation occurs at $d = d^*$.

That is, the system is stable when $d < d^*$ and unstable when $d > d^*$.

Optimal Taxation Policy

The objective of the regulatory agency is to maximize the total discounted net revenues that the society derives from the fishery. Symbolically, this objective amounts to maximizing the present value J of a continuous time-stream of revenues given by

$$J = \int_0^\infty e^{-\delta t}(pqy - c)dt,$$

whereδdenotes the instantaneous annual rate of discount,c is the fishing cost per unit effort and p is the price per unit biomass of y .To solve this optimization problem, we utilize the Pontryagin'smaximal principle. We treat τ as the control variable and wish to determine a tax policy $\tau = \tau(t)$which maximizes J subject to the system (2).

The Hamiltonian of this control problem is

$$H = e^{-\delta t}(pqy - c)E + \lambda_1\left\{rx\left(1 - \frac{x}{k}\right) - \frac{axy}{b+x}\right\} + \lambda_2\left\{\frac{maxy}{b+x} + dy\left(1 - \frac{x}{k}\right) - cy^2 - qEy\right\} + \lambda_3\{(p-\tau)qy - c\}E \qquad (5)$$

where λ_1, λ_2, and$\lambda_3$are additional unknown functions called the adjoint variables. The Hamiltonian (5) must be maximized for τ. Assuming that the control constraints are not binding (i.e., the optimal solution does not occur at $\tau = \tau_{min}$or $\tau = \tau_{max}$), we have singular control given by$\frac{\partial H}{\partial \tau} = 0$.

Now $\frac{\partial H}{\partial \tau} = 0$ gives $\lambda_3 \lambda E q y = 0$.

We use a singular control and find the singular path. For this, we take $\lambda_3 = 0$.

The adjoint equations are

$$\frac{d\lambda_1}{dt} = -\frac{\partial H}{\partial x} = -\left[\lambda_1\left\{r\left(1-\frac{2x}{k}\right)-\frac{aby}{(b+x)^2}\right\}+\lambda_2\left\{\frac{maby}{(b+x)^2}-\frac{dy}{k}\right\}\right] \quad (6)$$

$$\frac{d\lambda_2}{dt} = -\frac{\partial H}{\partial y} = -\left[e^{-\delta t}pqE-\lambda_1\frac{ax}{b+x}+\lambda_2\left\{\frac{max}{b+x}+d\left(1-\frac{x}{k}\right)-2cy-qE\right\}+\lambda_3(p-\tau)qE\right] \quad (7)$$

$$\frac{d\lambda_3}{dt} = -\frac{\partial H}{\partial E} = -\left[e^{-\delta t}(pqy-c)-\lambda_2 qy+\lambda_3\{(p-\tau)qy-c\}\right] \quad (8)$$

Since $\lambda_3 = 0$, we have from (8) $\lambda_2 = e^{-\delta t}\left(p-\frac{c}{qy}\right)$ (9)

We seek to find optimal equilibrium solution of the problem so that x, y and E can be treated as constants.

Substituting λ_2 in (6) we get $\frac{d\lambda_1}{dt} = A\lambda_1 + Be^{-\delta t}$

Where $A = \frac{rx}{k} - r\left(1-\frac{x}{k}\right)+\frac{aby}{(b+x)^2}$

$B = \left\{\frac{dy}{k}-\frac{mab}{(b+x)^2}\right\}\left(p-\frac{c}{qy}\right)$ (10)

The solution of this linear equation is

$\lambda_1 = -\frac{B}{A+\delta}e^{-\delta t} + K_0 e^{At}$, where K_0 is a constant.

The shadow price $\lambda_1 e^{-\delta t}$ is bounded as $t \to \infty$iff$K_0 = 0$.

Therefore, $\lambda_1 = -\frac{B}{A+\delta}e^{-\delta t}$ (11)

Using (7) we get

$$\delta\left(p-\frac{c}{qy}\right) = pqE+\left(\frac{B}{A+\delta}\right)\left(\frac{ax}{b+x}\right)+\left(p-\frac{c}{qy}\right)\left\{\frac{max}{b+x}\,d\left(1-\frac{x}{k}\right)-2cy-qE\right\} \quad (12)$$

Now for the optimal equilibrium solution, we have from (2)

$r\left(1-\frac{x^*}{k}\right)-\frac{ay^*}{b+x^*} = 0,$

$$\frac{max^*}{b+x^*} + d\left(1-\frac{x^*}{k}\right) - cy^* - qE^* = 0, \quad (13)$$

$$(p-\tau)qy^* - c = 0.$$

Using these equations in (12), we get

$$\delta\left(p-\frac{c}{qy^*}\right)(cy^*+\delta) - \left(\frac{B}{A+\delta}\right)\left(\frac{ax^*}{b+x^*}\right) - pqE^* = 0, \quad (14)$$

Where, $$A = \frac{aby^*}{(b+x^*)^2} - r\left(1-\frac{x^*}{k}\right)$$

$$B = \left\{\frac{dy^*}{k} - \frac{mab}{(b+x^*)^2}\right\}\left(p-\frac{c}{qy^*}\right) \quad (15)$$

Equation (14) together with equations (13) gives the optimal tax $\tau = \tau^*$ and optimal equilibriumsolutionsx^*, y^*, E^*.

Numerical simulation

In this section, we present some numerical simulations of the system (2) to verify the analytical predictions obtained in the previous sections. Using numerical simulation instead of real world data, which of course would be of great interest, has some advantages. It may be noted that the simulations presented in this paper should be considered from a qualitative, rather than a quantitative point of view.

(i) Let us take $r = 6, a = 20, b = 10, c = 4, d = 10, k = 50, p = 10, q = 0.5, \delta = 0.01, m = 0.8$ in appropriate units. Then from eqn.(13) and eqn.(14), we find that for the optimal tax τ^*= 6.56075, the system (2) has a positive equilibrium

(42.6345, 2.32609, 10.2578) is globally asymptotically stable as seen from the Figure 1.

(ii) From Figures 2, 3 and 4 we observe that the prey population decreases and the predator population increases with the increase of tax whereas harvesting effort always decreases with the increase of tax when the other parameters remain same. This is realistic because whenever tax increases, the people are less interested to harvest predator and as a result, predator population increases and consumption of prey increases and prey population decreases.

(iii) For the values r = 5, a = 15, b = 5, c = 0.9, k = 50, p = 2.8, q = 0.7, δ = 0.01, m = 0.8, τ = 2 we obtain the critical value d^*= 20.9212 from section 6. The values of the parameters also satisfy the sufficient condition for the Hopf-bifurcation. From Figures 5 and 6, we see that when$d < d^*$, the system is stable and as d crosses its critical value d^* the system becomes unstable, i.e. a Hopf-bifurcation occurs at the critical valued^*.

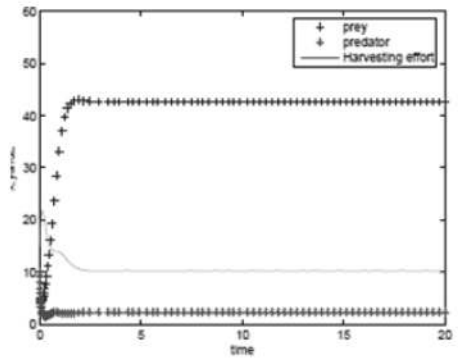

FIGURE 1. *Time evolution of populations for the model system (2)corresponding to the optimal tax* $\tau^* = 6.56075$.

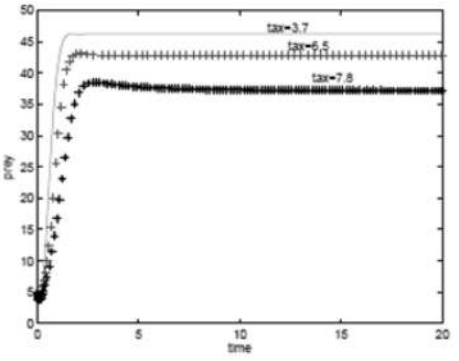

FIGURE 2. *Variation of prey population against time for different tax levels the other parameters remaining the same.*

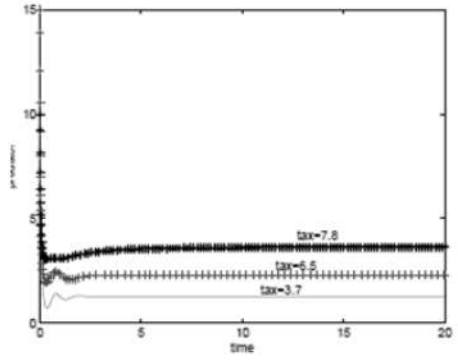

FIGURE 3. *Variation of predator population against time for different tax levels; the other parameters remaining the same.*

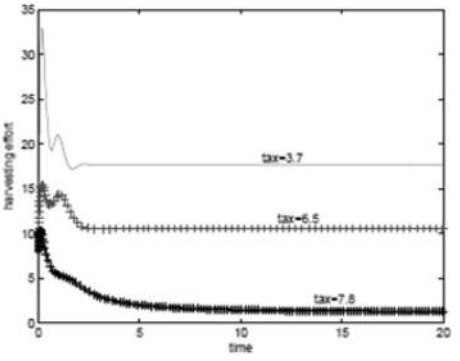

FIGURE 4. *Variation of harvesting effort against time for different tax levels; the other parameters remaining the same.*

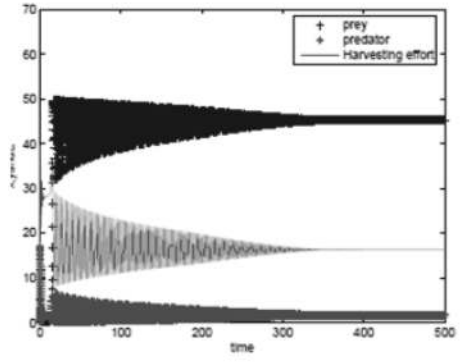

FIGURE 5. *This figure shows that when* $d = 20 < d^* = 20.9212$, *the equilibrium point* $(45.1975, 1.60714, 16.1133)$ *is stable.*

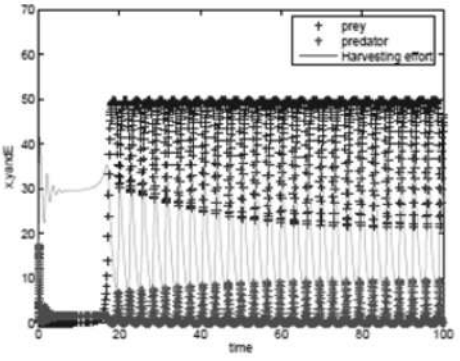

FIGURE 6. *This figure shows that when* $d = 22 > d^* = 20.9212$, *the system (2) becomes unstable.*

Conclusion

Now-a-days, the biological resources are mostly harvested with the aim of achieving economic interest. Thus, unregulated exploitation and extinction of many natural and biological resources is a major problem of present day. In this work, we consider a bio-economic prey-predator model with the provision of alternative food to the predator and only the predator species is harvested. We force the fishing effort to remain continuous over time and tax as a control instrument. From the model, it is seen that the alternative food plays an important role in stability of the system. Bifurcation analysis shows that under certain conditions, the system changes its state from stable to unstable whenever the growth rate of the predator due to alternative prey crosses its critical value. Also optimal taxation policy is discussed. Numerical simulations show the consistency of the theoretical results.

To maintain the length of the paper some dynamical behaviors such as persistent etc. are not given in this paper. However, these will be considered in my future research work.

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Indication of Habitat Quality Ad Environmental Health by Fiddler Crabs (*UCA*: Ocypodidae) : A Potential Bioindicator for Mangrove Ecosystems

Soumyajit Chowdhury
M.U.C. Women's College, Burdwan, West Bengal, E-mail : wildlifesc@gmail.com

Abstract Fiddler crabs (Uca: Ocypodidae: Decapoda) are small, semi-terrestrial burrowing crabs that play important structural and functional roles in the ecology of temperate salt marshes and tropical mangroves. Apart from their significant role as 'keystone species' in such ecosystems, fiddler crabs are also good environmental indicator by virtue of responding to both point and non-point pollution sources. Both their adult and larval forms are sensitive to environmental contaminants especially insecticides and fertilizers, that have been found to adversely affect their health through bioaccumulation as well as biomagnification of such toxins along the estuarine food chains. Oil pollution, a growing concern in the coast and seashore, also showed marked effect on fiddler crab health and activity – that have wider direct and indirect implications for salt marsh and mangrove ecosystems. Sundarban mangrove ecosystem in the Ganga-Brahmaputra-Meghna deltaic region, the only mangrove tiger-land of the world, is under an emerging threat from climatic stress and anthropogenic pollution due to rapid human settlement, tourist activity, deforestation, and increased agricultural and aquacultural practices. Fiddler crab populations and to a larger extent, the entire mangal community may be under threat from such activities. Wetland restoration, good water quality management and application of properly evaluated environmental contaminants (like pesticides) may show a positive response among fiddlers in this vulnerable ecosystem. Thus, they may be used as potential bioindicators for estimating the health of such sensitive ecosystems and as focal species for developing conservation programmes in the region.

Keywords Fiddler Crabs, *Uca*, Mangroves, Pollution, Sundarbans

Introduction

Crabs are the most abundant of the mangrove macro-fauna and are a valuable asset to the mangrove ecosystem. Burrowing crabs are particularly important and many should be considered 'ecological engineers' (Jones *et al.*, 1994). Fiddler crabs (*Uca* spp., Ocypodidae) are small, semi-terrestrial burrowing crabs that play important structural and functional roles in the ecology of temperate salt marshes and tropical mangroves (Katz, 1980; Lim & Heng, 2007). Almost all live in intertidal zones of sheltered bays and estuaries, feeding and digging burrows in the inshore muddy or sandy substratum. They are characterized by strong sexual dimorphism and male asymmetry. The males are easily recognized by their distinctively asymmetric claws: an oversized major claw or cheliped playing a role in courtship and signalling among conspecifics; while a small cheliped helping in feeding by scooping up organic deposits from muddy or sandy substratum.

Fiddlers ingest the sediment containing their food, burrow in it, and alter it in many physical and chemical ways.They also form an integral part of the food web and significantly influence the transfer of nutrients

and energy within these ecosystems (Montague, 1980). They are sensitive to pollutants and balance the salt marsh and mangrove ecosystems (Kwok and Tang, 2006; Grimes *et. al.*, 1989). Hence they have been stated to play the role of *keystone species* in many salt marsh and tropical mangrove ecosystems (Lim and Rosiah, 2007).

Fiddler Crabs are Significant Contributors to Mangrove Ecosystem Functions

The multifarious ecological roles played by the fiddler crabs in the salt marsh and mangrove ecosystems can be categorized into bioturbation (burrowing, feeding and reworking within the surficial sediment by animal forms resulting in sediment mixing), trophic interactions (as consumer and prey in a food web), symbiosis (close associations with different other life forms) and indication of habitat quality and environmental health(Chowdury *et. al.*, 2011; Chowdhury, 2013). These crabs are a significant component of the intertidal macrofaunal biomass of temperate and tropical estuaries of the world (Figure 2). Some prominent ecological roles played by these crabs are:

i) Increasing primary productivity, nutrient cycling, sediment biogeochemistry and transfer of energy within the ecosystem by their bioturbation activities,

ii) Active participation in mangrove detrital food web, thereby contributing to the nutrient cycling in the ecosystem by releasing dissolved (DOM) and particulate (POM) organic matters, and

iii) Forming an integral part of the food web and feeding guild (as deposit feeders), by being both a consumer as well as a prey in the salt marsh and mangrove ecosystems.

Mangroves and Pollution

Mangrove forests and other intertidal wetlands of the tropics and subtropics are key ecological habitats that link terrestrial and marine environments. Mangrove forests and adjacent mudflats are increasingly affected by urban and industrial development in the tropical coastal zone. They suffer pollution from multiple sources, both direct and indirect, including but not limited to municipal waste, aquaculture, mariculture and shipping as well as onshore industries and run-off from urban centres.

a) **Solid Waste Pollution in Mangroves:** This is primarily caused due to litter from land and sea from anthropogenic origin. Solid wastes, both in the form of bio-degradable (BDSW) and non-biodegradable (NBDSW) materials, may be dumped or simply accumulate in mangroves. The solid waste

Figure 1 : Two most common species of fiddler crabs in Indian Sundarbans, *U. rosea* and *U. triangularis* in the mangrove mudflats exposed during the low tide.

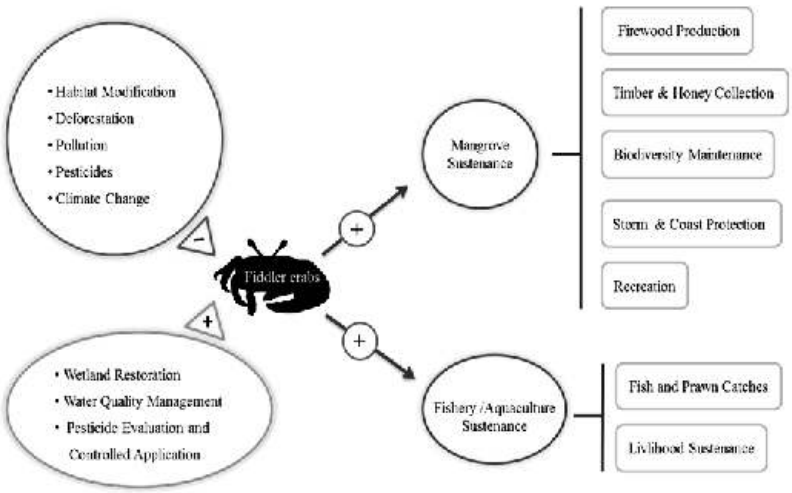

Figure 2 : Positive and negative influence on fiddler crabs in SBR that can serve as a keystone species in maintaining the ecosystem and sustenance of human lives.

pollutants from various point and non-point sources (industrial and domestic units) are affecting the mangrove ecosystem in various ways.

b) **Chemical Waste Pollution in Mangroves:** This is caused by fertilizers, pesticides, detergents and many other synthetic industrial chemicals those are released to waterways. Many of these chemicals are toxic to fish and other aquatic animals, including humans living in mangrove forested regions.

c) **Oil Pollution:** This is caused by oil and other petroleum products like gasoline, kerosene and methane that find their way into coastal water from mining activities, oil refineries, power plants, gas stations, streets and ships. Mangrove ecosystems all over the globe highlight their vulnerability to oil pollution as mangrove sediments behave like a sink, retaining the toxicity of pollutants (Brito *et al.*, 2009). Oil pollution can smother mangrove roots and suffocate the trees, as well as kill finfishes, shellfishes, birds and other faunal forms.

Response of Fiddler Crabs to Mangrove Pollution

Fiddler crabs are a good environmental indicator and sensitive to environmental contaminants especially insecticides. These crabs respond to both point and non-point pollution sources.

a) Response to Environmental Contaminants:

Contaminants, such as polychlorinated biphenyls (PCBs) and insecticide/fertilizer mixtures, adversely affect the

Figure 3 : Non-biodegradable Solid Waste (NBDSW) pollutionin the mangrove forested regions at Lac Bay, Bonair (*Photo Credit: Debrot, A.O., 2013*).

health of fiddler crab populations. Fiddler crabs apparently concentrate these toxins from seawater or food. They accumulate PCBs from contaminated sediments and detritus and can transfer them to aquatic, avian, and terrestrial food webs when preyed upon by fishes, birds, and small mammals. When Dieldrin was concentrated in crab tissues, it was found to cause impaired locomotion, killing crabs at the higher concentrations. Chemical contaminants can drastically reduce populations of fiddler crabs in the marsh (Krebs *et al.*, 1974). Fiddler crabs have been found to be sensitive to mercury (DeCoursey and Vernberg, 1972) and cadmium (O'Hara, 1973). Heavy metals such as mercury, copper, and zinc are toxic to fiddler-crab larvae, causing a significant delay in larval development as well as deformities.

Figure 4 : Oil coated the Shela River near Mongla, Sundarban mangroves in Bangladesh on December 12, 2014 (*Photo Credit: Getty Images, 2014*)

Spraying marsh habitats for mosquito control can also cause a significant decrease in the natural fiddler crab populations downwind of the pesticide application area. Studies in Florida have shown that the mortality of fiddler crabs can be markedly reduced when high-pressure nozzles are used in combination with the mosquito adulticide, Dibrom. Methods that reduce the size of the pesticide droplets not only improve the effectiveness of a pesticide to kill mosquitoes but also significantly reduce the amount of pesticide needed (Rookery Bay NERR, 1996).

b) Response to Oil Pollution:

There were significant differences between control and oil-exposed fiddler crabs for all behaviors measured including righting response, locomotion, ability to move up an incline, ability to grip an inclining plane, and aggressive or defensive behaviors (Burger *et. al.*, 1991). Fiddler crab, *U. pugnax* do not burrow as deeply in the areas still impacted by oil as they do in oil-free areas, as studied at Wild Harbor and Great Sippewissett Marsh respectively, in Florida (Figure 5). They not only detected the presence of oiled sediments in the affected area but also halted or turned laterally to avoid the oiled sediments, as evidenced from their burrow casts (Figure 6). Their inability to make normal deep burrows as well as their delayed escape responses, lowered feeding rates, and achieved lower densities have direct implications for the crabs and other biota in the marsh (Culbertson *et. al.*, 2007). All such events may lead to larger-scale ecosystem effects, as these crabs form an integral part of the salt marsh ecosystems.

c) Response to Non-Point Sources:

Nonpoint source runoff from residential areas, roads, and golf courses can have a negative impact on marsh creek ecosystems and impact water quality. Any one discharge may involve only small amounts of chemicals that are diluted by the receiving streams, but when combined with other chemicals from multiple other discharges, significant concentrations of pollutants may result.

Pollution may disrupt the food web in the salt marsh by killing off some species and prompting others to greatly increase in number. One such study was carried out regarding nitrogen pollution above a threshold level, inducing a eutrophication process in Bradley Creek ecosystem, adjacent to the Duck Haven Golf Course in southeastern North Carolina and a consequent impact on the water quality and density of the fiddler crab *U. minax* (George *et. al.*, 2001).

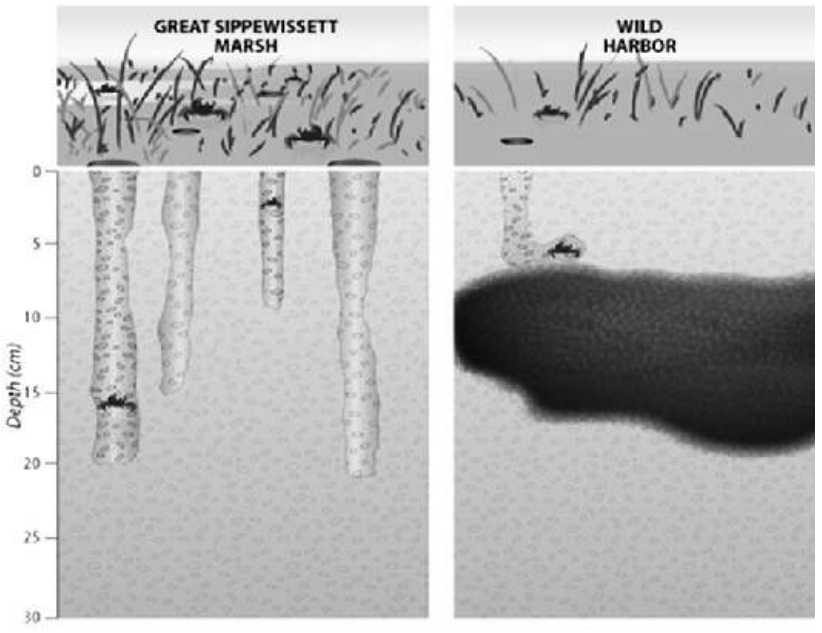

Figure 5 : U. pugnax burrowsat Great Sippewissett Marsh (A) and Wild Harbor (B) in Florida, showing straight (average depth of 14.8 cms.) burrows in oil-free and stunted (average depth of only 6.8 cms.) in oil-polluted areas respectively. The crabs appear to turn back when they encounter oil (*Picture Credit: Reddy, 2007*).

Fiddler Crabs in Sundarban Mangroves: A Potential Bioindicator

Mangroves are essential for maintaining coastal fisheries, protecting coastlines from the effects of cyclones and storms and coral reefs from deposition of sediments and pollutants. Throughout the World mangroves are being destroyed or degraded, especially due to anthropogenic reasons. They are one of the world's most threatened tropical ecosystems. More than 35% of the world's mangroves are already gone. The figure is as high as 50% in countries such as India, the Philippines, and Vietnam, while in the Americas they are being cleared at a rate faster than tropical rainforests (Oswell, 2015). Everywhere including the Sundarban mangroves in the Ganga-Brahmaputra-Meghna deltaic region of India and Bangladesh,threats are the same. Indian Sundarbans has been suffering from environmental

Figure 6 : Plaster of Paris casts demonstrate how fiddler crabs in healthy marshes dig deep and straight burrows (left side), while crabs in areas where oil is still buried in Wild Harbor dig shallow and erratic burrows. (*Picture Credit: Reddy, 2007*).

degradation due to rapid human settlement, tourist activity, deforestation and increased agricultural and aquacultural practices. Various industries have come up on both banks of the Hugli estuary. A considerable amount of organic contaminants and heavy metals from the industrial effluents are discharged into this estuarine system (UNEP, 1982). The ecosystem also receives huge waste load (domestic and industrial) of Kolkata municipal city through river Bidhyadhari.

In Sundarban mangrove ecosystem of India, crustaceans and fiddler crabs are most dominant and account for by far the largest proportion of animal biomass (Chakraborty and Chaudhury, 1992). Five species of *Uca* are found here: *U. rosea, U. dussumieri, U. vocans, U. triangularis* and *U. lactea*. Under the emerging scenario of climatic and anthropogenic stress (e.g. deforestation, habitat modification and pollution) in Sundarban mangroves, fiddler crab populations and to a larger extent, the entire mangal community may be under threat. They have been stated to play the role of keystone species in many salt marsh and tropical mangrove ecosystems (Lim and Rosiah, 2007). They influence the transfer of nutrients and energy from intertidal areas to estuaries in general (Montague, 1980; 1982), thereby sustaining the fisheries, among others in Sundarbans. As they are sensitive to pollutants, fiddlers variously indicate the health of the ecosystem and hence can be used as potential bioindicators for this vulnerable mangrove ecosystem.

Wetland restoration and good water quality management (Knott *et. al.*, 1997), as well as application of properly evaluated environmental contaminants (like pesticides) may show a positive response among fiddlers in this vulnerable ecosystem, thereby sustaining the same in this part of the world.

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Green Synthesis of Metal Nanoparticles with Environmental Issues

Ujjal Kumar Sur
Behala College, Kolkata-700060, E-mail : uksur99@yahoo.co.in

Balaprasad Ankamwar
Bio-inspired Materials Science Laboratory, Department of Chemistry,
Savitribai Phule Pune University, Ganeshkhind, Pune-411007,
E-mail : bankamwar@yahoo.com

Abstract Metal nanoparticles are of enormous significance owing to their interesting catalytic, electronic and optical properties and their potential application in sensing, catalysis, surface-enhanced Raman scattering (SERS) spectroscopy and biomedical engineering. Development of cost-effective and environmental-friendly biogenic protocols for the synthesis of metal nanoparticles has become popular among researchers in recent times. Nanomaterials especially, metal nanoparticles can also be synthesized using the extract of natural bioresources such as microorganisms, animals and plants as a source of reducing and stabilizing agents in laboratories even on large scale. This is considered as an eye-catching viewpoint for eco-friendly or so-called green synthesis. Development of eco-friendly synthesis of biocompatible nanoparticles and their potential biomedical applications introduces the concept of nanobiotechnology. The lower cost and lesser side effects as compare to chemical methods of synthesis are the main advantages of biosynthesis. This paper desribes briefly the green synthesis of metal nanoparticles using microorganisms, plant, fruit extracts as well as animal tissues with special emphasis on their applications.

Keywords Nanoparticles, Plant extracts, Microorganisms, Biosynthesis, Biomedical applications

Introduction

Nanotechnology refers to a field where there is control of matter on an atomic or molecular scale. Generally, it deals with structures of dimensions less than 100 nanometers (nm) and involves developing new materials or devices with dimensions on this scale. The word "nano" is Greek, which means dwarf. An atom can be divided into many fundamental particles: electrons, neutrons, meson, protons, quarks etc and it loses its property when it is divided into those particles. In terms of size, atom has the radius in the order of [1Å] = 10-8 cm = 10-10 m. One nanometer is about 8~10 atoms next to one another. Mathematically, 1 nm = 10-9 m. The concept in "nanotechnology" was first used by famous physicist Richard Feynman on his talk 'There is plenty of room at the bottom' given at the American Physical Society meeting at Caltech in 1959. He described a process by which individual atoms and molecules can be manipulated using precise tools. Nanotechnology began its journey in the early 1980's with two major developments; the introduction of cluster science and invention of scanning tunneling microscope.

Nanotechnology got a major boost after the invention of integrated circuit in 1958. The number of transistors in the computing hardware that can be placed inexpensively on an integrated circuit has increased exponentially, doubling approximately every two years. This is known as Moore's law as it was first observed by Dr. Gordon E. Moore, the co-founder of Intel in 1965.

Current computing-hardware technology hits a road block in about 2012 in terms of fabrication and device operation. Thus, alternative patterning techniques and computing schemes are needed (e.g., quantum, molecular and optical computers, carbon-nanotubes based devices). The invention of fullerenes in 1986 and carbon nanotubes a few years later has brought a new dimension in computing-hardware technology and it is expected that these carbon-nanotube based devices will replaced the existing silicon (Si)-technology based devices in the near future providing an improvement in computation speed and efficiency.

The term "nanotechnology" was coined by Professor Norio Taniguchi of Tokyo Science University, Japan in the year 1974. He approached nanotechnology from 'top-down' stand point. K. Eric Drexler introduced the term 'molecular nanotechnology' to the world in the year 1986 from the point-of-view of a physicist, and defines the term as "large-scale mechano synthesis based on positional control of chemically reactive molecules". Gerhard Binnig and Heinrich Rohrer of IBM institute, Zurich invented Scanning tunneling microscope (STM), a novel tool to image matter at atomic scale. This was a significant breakthrough and therefore had a great impact on the future development of nano-scale science. In 1990, D. M. Eigler placed Xenon atoms to a shape, reflecting the logo of IBM. In 1993, the first nanotechnological academic research centre was established at the Rice University, USA. Five years later, Zyvex, the first molecular nanotechnology company was established in USA. In the year 2000, Lucent and Bell labs, together with Oxford university created the first DNA motor, the first nano-biotechnological gadget. It is expected that global sales of nanomaterials could exceed $1 trillion by 2015, though today's descriptions of nanotechnology markets and trends contain a lot of estimates and guesstimates. In near future, "nanotechnology" will likely include building machines and mechanisms with nanoscale dimensions, referred to as Molecular nanotechnology. The other aspect deals with scaling down existing technologies to the nanoscale. Some of the most promising potential of nanotechnology exists due to the laws of quantum physics. Quantum physics laws take over at this scale, enabling novel applications in optics, electronics, magnetic storage, computing, catalysis and other areas.

Nanoparticles are typically smaller than several hundred nanometers in size, comparable to large biological molecules such as enzymes, receptors, and antibodies. With the size of about one hundred to ten thousand times smaller than human cells, these nanoparticles can offer unprecedented interactions with biomolecules both on the surface of and inside the cells, which may revolutionize cancer diagnosis and treatment. The most well-studied nanoparticles include gold nanoparticles, quantum dots, carbon nanotubes, paramagnetic nanoparticles, liposomes, and many others. Over the last decade, there have been many nanotechnology centers established worldwide. In the United States alone, more than six billion dollars have been invested in nanotechnology research and more than sixty centers, networks, and facilities, funded by various agencies, are in operation or soon to open. After establishing an interdisciplinary nanotechnology workforce, it is expected that nanotechnology will mature into a clinically useful field in the near future. One of the major applications of nanotechnology is in biomedicine. Nanoparticles can be engineered as nanoplatforms for effective and targeted delivery of drugs and imaging labels by overcoming the many biological, biophysical, and biomedical barriers. For in vitro and ex vivo applications, the advantages of state-of-the-art nanodevices (eg, nanochips and nanosensors) over traditional assay methods are obvious. However, several barriers exist for in vivo applications in preclinical and potentially clinical use of nanotechnology, among which are the biocompatibility, in vivo kinetics, tumor targeting efficacy, acute and chronic toxicity, and cost-effectiveness.

A new branch of nanotechnology is nanobiotechnology. Nanobiotechnology combines biological principles with physical and chemical processes to synthesize nanoparticles with specific functions. The development of eco-friendly cost-effective green protocol for the synthesis of nanomaterials is an important aspect of nanotechnology. More specifically, one can define nanobiotechnology involving nanomaterials synthesis using microorganisms, including bacteria, viruses, fungi as well as plant and animal based products. Synthesis of nanomaterials using bioresources can be classified into the following types : i)Use of microorganisms like fungi, yeast, or bacteria, ii) use of plant extract, fruit extract and honey iii) use of biological templates like DNA, membranes, viruses and diatoms, iv) use of animal tissues. Currently, there is growing need to develop eco-friendly synthetic protocols of various nanoparticles of different shapes and sizes for avoiding the adverse effects in comparison to traditional chemical methods. There is much scope of further improvement in the synthesis of nanoparticles by biogenic methods using different biological resources as the source of reducing and stabilizing agents and their potential applications. The aim of this paper is to provide an updated overview on the synthesis of metal nanoparticles using various biological methods both intracellularly and extracellularly and their potential applications in optics, optoelectronics, chemical and biosensors, biomedical applications and catalysis. Due to space limitations, a complete review of all recent work on this important subject is not possible. However, we only summarizes a few representative examples, including our own work.

Synthesis of gold and silver nanoparticles using microorganisms

Microorganisms are the organisms such as bacteria, fungi, yeasts etc. which can be detected under optical microscopes. These microorganisms are capable of interacting with metals when they come into contact with their cells and can form nanoparticles. Many microorganisms can produce inorganic materials either intra or extracellularly. Well-known example is magnetotactic bacteria which able to synthesize magnetic nanoparticles (Bazylinski and Frankel, 2004). Magnetotactic bacteria are motile, prokaryotes that move along geometric field lines. They produce magnetosomes, unique intracellular structure contains a magnetic particle, in narrow range of very low oxygen concentration. Magnetotactic bacteria usually mineralize either oxide magnetite Fe3O4 or iron sulfide Fe3S4–greigite. Extensive work is in progress using microorganisms for biosynthesis of nanoparticles. Here, some of the organisms exploited as the sources for reducing and stabilizing agents for the synthesis of nanoparticles are discussed along with their brief account of properties.

Metal nanoparticles can be extracellularly synthesized generally by the reduction of metal ions in solution. The formation of extracellular and intracellular silver nanoparticles by bacteria (*Pseudomonas stulzeri, Escherichia coli, Vibrio cholerae, Pseudomonas aeruginosa, Salmonells typlus*, and *Staphylococcus currens*) had been reported (Lengke *et al.*, 2007). Various microbes are known to reduce metal ions to the metals. The formation of extracellular silver nanoparticles can be extracellularly synthesized by photoautotrophic cyanobacterium *Plectonema boryanum*. The bioreduction of the Ag+ ions could be associated with metabolic processes utilizing nitrate by reducing nitrate to nitrite and ammonium ion (Lengke *et al.,* 2007).

Silver nanoparticles were synthesized using *Bacillus licheniformis* (Kalimuthu *et al.*, 2008). Saifuddin and coworkers reported the eco-friendly rapid biosynthesis of silver nanoparticles using a culture supernatant of bacteria *Bacillus subtilis* and microwave irradiation at the frequency of 2.45 GHz (Saifuddin *et al.*, 2009). Kalishwaralal reported the biosynthesis of gold nanocubes using *Bacillus*

licheniformis (Kalishwaralal *et al.*, 2009). Nair and Pradeep (Nair and Pradeep, 2002) have synthesized nanocrystals of gold, silver and their alloys by reaction of the corresponding metal ions within cells of lactic acid bacteria present in buttermilk.

The fungal systems are extremely good resources in the synthesis of metal nanoparticles. A novel biological method for the synthesis of silver nanoparticles using the fungus *Verticillium* has been reported (Mukherjee *et al.*, 2001). Exposure of the fungal biomass to aqueous Ag+ ions resulted in the intracellular reduction of the metal ions and formation of silver nanoparticles of dimensions ~ 25 nm. Electron microscopy analysis of thin sections of the fungal cells indicated that the silver particles were formed below the cell wall surface, possibly due to reduction of the metal ions by enzymes present in the cell wall membrane. The metal ions were not toxic to the fungal cells and the cells continued to multiply after biosynthesis of the silver nanoparticles. Bhainsa and D'Souza reported the extracellular biosynthesis of silver nanoparticles using the filamentous fungus *Aspergillus fumigatus* (Bhainsa and D'Souza, 2006). They studied the kinetics of synthesis including the spectroscopic and microscopic characterization of the synthesized silver nanoparticles. The extracellular synthesis of silver nanoparticles by a marine fungus *Penicillium fellutanum* has been reported by Kathiresan and coworkers (Kathiresan *et al.*, 2009). The fungus *P. fellutanum* was isolated from a coastal mangrove sediments.

Metal nanoparticles can also be synthesized by actinomycetes. Actinomycetes are microorganisms which can exhibit important characteristics of both fungi and prokaryotes such as bacteria. Focus on actinomycetes has primarily centered on their phenomenal ability to produce secondary metabolites such as antibiotics. Murali Sastry and his group were pioneer on the synthesis of metal nanoparticles using actinomycetes (Sastry *et al.*, 2003). Extremophilic Actinomycete *Thermomonospora* sp. were exploited (Ahmad *et al.*, 2003) by Ahmad *et al.* for the extracellular biosynthesis of monodisperse gold nanoparticles of dimension ~ 8 nm. Alkalotolerant Actinomycete, *Rhodococcus* species were used for the intracellular synthesis of gold nanoparticles (Ahmad *et al.*, 2003).

Synthesis of gold and silver nanoparticles using fruit extract

Fruit and plant extracts can be used to synthesize metal nanoparticles. The use of these extracts can eliminate the elaborate process of maintaining cell cultures using microorganisms for the nanoparticle synthesis. In addition to this, large-scale synthesis of nanocrystals can be carried out at lower cost. Ankamwar et al. had synthesized gold and silver nanoparticles using *Emblica officinalis* extracts (Ankamwar *et al*., 2005). Figure 1 shows the photograph of *Emblica officinalis* fruit.

Figure 1 : Photograph of Emblica officinalis fruit

Synthesis of gold and silver nanoparticles using plant extract

An important protocol for the eco-friendly biosynthesis of nanoparticles is the application of plant extract. Use of different plants in the synthesis is quite novel leading to true green chemistry. Figure 2 shows some popular plants which can be used for the extract preparation.

Murali Sastry and his group had used the leaves of geranium plant

(*Pelarogonium graveolens*) to synthesize gold nanoparticles (Shiv Shankar *et al.*, 2003). Biological synthesis of gold nanoparticles using *Magnolia kobus* and *Diopyros kaki* leaf extracts had been reported (Song *et al.*, 2009). There are reports about the synthesis of gold nanoparticles using *Murraya koenigi* leaf (Ankamwar, 2010), Lemon grass (Shiv Shankar *et al.*, 2004), Aloe vera leaf (Chandran *et al.*, 2006), Neem leaf (Shiv Shankar *et al.*, 2004), T*amarindus indica* leaf (Ankamwar *et al.*, 2005) and silver nanoparticles using *Murraya koenigi* leaf (Ankamwar *et al.*, 2012). Similarly, we find the synthesis of gold and silver nanoparticles using Krishna tulsi leaf extract (Daizy and Unni, 2011) and *Hibiscus rosa sinensis* (Daizy, 2010).

Triangular gold nanoprisms can be synthesized biologically (Shiv Shankar *et al.*, 2004) in high yield at room temperature by the reduction of aqueous chloroaurate ions (AuCl4-) by using the plant lemongrass (*Cymbopogon flexuosus*) extract.

Dr. Murali Sastry of Physical & Materials Chemistry Division, Dr. Absar Ahmed of Biochemical Sciences Division of National chemical laboratory (NCl), Pune and the team had demonstrated biological synthesis of large amounts of triangular gold nanoprisms by a single-step, room-temperature reduction of gold salt solution by the extract of the plant, lemongrass (*Cymbopogon flexuosus*). The lemongrass extract on mixing with gold salt solution exhibits a change of colour from pale yellow to a vivid ruby red. The reaction mixture is allowed to stand for six hours to yield a large number of triangular gold nanoparticles of 8 -18 nm thickness with an edge length of 200-500 nm. The scientists also enhanced the percentage of gold nanotriangles in the reaction medium up to ninety-five per cent of the nanoparticle population by repeated centrifugation. The reducing sugars (aldoses) present inside the lemongrass extract were found to reduce the Au^{3+} into nanoprisms (Shiv Shankar *et al.*, 2005). By simple variation in the concentration of the lemongrass extract in the reaction medium, it is possible to vary the size of the nanoprisms, thereby, the longitudinal SPR band in the NIR region can be easily tuned.

It has been reported that tamarind leaf extract can also be used as the reducing agent for making gold nanotriangles (Ankamwar *et al.*, 2005). On treating aqueous Au^{3+} solution with tamarind leaf extract, rapid formation of flat and thin single crystalline gold nanotriangles was observed. The effect of different organic solvent vapours such as methanol, benzene, and acetone on the conductivity of these gold nanotriangles was investigated by measuring the I—V characteristics. The results suggest that these nanotriangles can be used as vapor sensors. Nanoparticles of diverse shapes such as hexagon, truncated triangle, and triangle can also be synthesized by reducing aqueous chloroauric acid solution with the extract of seaweed, Sargassum *sp.*, at room temperature (Liu *et al.*, 2005).

Figure 2 : Photograph of some plant which can be used for extract preparation in metal nanoparticles synthesis

Synthesis of gold and silver nanoparticles using animal tissue

Animal tissue can be a potential source of reducing and capping agents for the biosynthesis of nanomaterials such as gold and silver nanoparticles. Recently, Jha and Prasad (Jha and Prasad, 2013) employed the use of cockroach (*Periplaneta Americana*) broth to synthesize gold nanoparticles. The synthesized nanoparticles were characterized by X-ray diffraction and transmission electron microscopic analysis to ascertain the formation of nanoparticles. The synthesis of nanoparticles might have resulted due to the activity of chitin, metallothioneine and tropomyosin to explain the possible mechanism of biosynthesis of nanoparticles. This work provides a new step for utilizing animal wastes in synthesizing different nanomaterials and subsequently addressing environmental issues.

Applications of gold and silver nanoparticles

The major intention of biological synthesis of nanoparticles is to develop eco-friendly and synthetic protocols with minimum cost of production and applications, specially in the biomedical field. Ankamwar et al. (Ankamwar *et al.*, 2005) had used biogenic gold nanotriangles films as vapour sensors. The high absorption coefficient of these gold triangles in the (Near-Infrared) NIR region make them useful in fabricating photonic devices such as optical sensors and NIR absorbers. Another application based on the large NIR absorption of the gold nanoparticles could be in hyperthermia of tumors (Hirsch *et al.*, 2003). The extremely flat nature of the nanoparticles would facilitate excellent thermal contact between the nanotriangles and tumor cells. The gold nanoparticles synthesized in aqueous medium using *Murraya koenigi* leaf extract can be used for cancer therapy due to anti-carcinogenic properties of biomolecules in the extract.

Conclusions

Various bioresources such as bacteria, fungi, actinomycete, plant leaves, fruits, honey as well as animal tissues can be used as a possible source of reducing and capping agents for the synthesis of nanoparticles. This review article demonstrates the role of various biological resources e.g. bacteria, fungi, actinomycetes, plant leaves, fruits and honey as well as animal tissues for the synthesis of nanoparticles mainly gold and silver with an overview of their potential applications. It is very difficult to find out the possible mechanism of these biosynthetic protocols.

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Problem, Policies and Management of Electronic Waste in India: A Review

Sanjib Halder and Siddhartha Roy
Department of Computer Science,
The Bhawanipur Education Society College

Abstract Over the past two decades, the manufacturing of electrical and electronic equipment (EEE) has emerged as one of the biggest global activities. Its production has grown exponentially, but the life span of these products has become very short. Increasing rates of consumption and planned obsolescence of electronic products have led to disastrous environmental consequences. More of these products are ending up with a dangerous addition to the ever-growing hazardous waste, posing a new challenge to policy makers. Developing countries like India are facing enormous problems related to the generation and management of E-waste which are either internally generated or imported illegally. Despite various laws and directives in India, the e-waste management is uncontrolled. In this paper we investigated the e-Waste problem, policy level initiatives and its implementation in India.

Keywords E-waste, environment, hazardous, management

Introduction

Electronic waste or E-waste is a latest and dangerous addition to the ever-growing hazardous waste. Obsolete and discarded electronic and electrical products and equipments constitute E-waste [1]. With the ever-advancing technology in today's society, electronic equipment of all forms have rapidly integrated themselves as a necessity in our everyday lives. From the TVs that entertain us, to the GPS systems that navigate us; from the headsets in our ears, to the smart phone on our hands and many more. These electronic products excel at enticing us with convenience, efficiency, accuracy, and more. The manufacturing of electrical and electronic equipment is one of the emerging global activities. The production of electronic equipment globally has grown from $225 billion in 1980 to almost $1 trillion in 2000, which is equal to 7.7 percent growth annually over the past 20 years [11]. But a huge shift in production of electronic equipment occurred over the last fifteen years. The main factors identified to be responsible for the increased consumption and productions of electrical and electronic equipment are rapid economic growth, urbanization and industrialization [3][5]. The Indian Information Technology (IT) sector is one of the major contributors to the global economy. Over the last five years, the Indian IT industry has recovered a compound annual growth rate of more than 42.4 %[11]. the size of India's consumer market is larger than that of many high-income countries and India is one of the fastest growing economies in the world. The domestic consumer durables demand in India has been skyrocketing over the last few years [17]. At the same time, it is also responsible for the generation of the bulk of E-waste in India. Developing countries like India are facing enormous problems related to the generation and management of E-waste which are either internally generated or imported illegally. The manufacturers and assemblers are producing around 1,050 tonnes of electronic scrap in a single calendar year [11]. However, the existing management practices related to E-waste in India are reasonably poor and have the risk to both human health and the environment. Moreover, the policy level initiatives are not being

implemented in an appropriate way. In India there is an urgent need to address the issues related to E-waste in India in order to avoid its detrimental future consequences.

Issues related to E-waste in India and its effect on Environment

Waste represents uncontrolled matter out-of-place, freely interacting and reacting, cultivating bacteria, fungi and toxins that may pose direct threats to our health. Waste is perhaps the most universal example of ecological risks in everyday life [6]. Nearly all ecological risks relate in one way or another to waste, more specifically to pollution. In case of E-waste, the problem arises as people in India do not know how to dispose their obsolete electrical and electronic gadgets. Normally, the unused electronic goods lie unattended at the Indian houses because of lack of knowledge about the proper disposal. Real problem begins when these obsolete gadgets are discarded with the regular municipal solid waste. Few people practice "extended producer responsibility". But most of the consumers do not pay attention to the processes through which the discarded electronic goods should follow. The effects of improper disposal of E-waste are observed relatively after a long period of time [4]. So the people are not very much bothered of disposing e-waste properly.

The major components related to E-waste in India, which should be taken care of, are Prime Sources of E-waste in India, Significance of the Problem in Indian context, effect on Health and Environment, Current Management practices of E-waste in India and Policy level initiatives in the country [5].

a) The Main Sources of E-waste

In India, the IT industry is the main contributor to the generation of e-waste. More over Indians upgrade or exchange their cell phones every 18 months, meaning there are approximately 16 million unused mobile phones are kept at home or in the office [16]. There are two main sectors of e-waste generation namely formal sector and informal sector. From the formal sector the sources are consumer, importers, etc. and from the informal sector the sources are Recyclers, Dissemblers or Dismantler. As about 90% of the e-Waste generated in India is being consumed by the informal sector [15].

b) Significance of the Problem with respect to the Indian context

The recycling of E-waste is a major concern in India. The workers in the recycling sector are dominated by the urban poor with very low literacy levels and hence they have very little awareness regarding the potential hazards of E-waste. Among the urban poor, there are a substantial number of women and children engaged in various recycling activities which further exaggerate the problem of E-waste as they are more vulnerable to the hazards from this kind of waste. One of the major concerns related to E-waste, particularly in developing countries like India and China, are dumping of E-waste from some developed countries. Large quantities of used electronics are typically sold to countries like India, China and other countries in the Asia Pacific region as in these areas the labours are cheap. These imported electronics are highly repairable. This can result in high accumulations of residue in poor areas without strong environmental laws.

c) Impact of E-waste on Environment and Health

E-Waste is an immediate and long term concern. Unregulated accumulation and recycling of E-waste can lead to major environmental problems endangering human health. Many components

contain toxic substance, Like Lead, Mercury, Cadmium etc and they have adverse effect on human health. Like, lead can be found on printed circuit boards or Television and computer monitor glass and it affects the kidneys and the reproductive system. Also have severely negative effects on mental development in children. Due to the improper recycling and disposal processes these components become hazards. These are in practice in most of the developing countries including India. Another major problem is landfilled of e-waste, which produces contaminated leachates which eventually pollute the ground water [7]. Almost 70 percent of the heavy metals like mercury and cadmium, found in landfills come from electronic equipments discarded by the users [11]. Open air burning of e-waste is very dangerous. Pollution from open air burning harms both the local environment and broader global air currents, depositing highly toxic byproducts in many places throughout the world [12,13]. Burning the isolating plastic cover of cables in open barrels produces 100 times more dioxins than domestic waste burning [14].

Management of E-waste in Indian Context

Apart from various toxic substances like lead, mercury and arsenic, electronic waste also contains valuable substances like gold, silver etc. When it comes to managing e-waste, India, a major portion is handled by the informal or unorganized sector using improper processes, which leads to environmental pollution and health hazards [9]. Most of the cases in India the obsolete electronics items are kept unattended and finally mixed with the house hold waste which are deposed on ground with other waste. So implementation of proper law is highly essential.

E-waste consists of different items. Many of which contain hazardous elements. Therefore, the target should be to reduce the concentration of these hazardous chemicals and elements through recycle and recovery. In Indian context, the major components of e-waste management are:

- E-waste collection, sorting and transportation.
- E-waste recycling; it involves dismantling, segregation of ferrous metal, non-ferrous metal and plastic recovery of valuable resource, sale of dismantled parts and export of processed waste for precious metal recovery and finally the materials of potential hazard are disposed of in landfill sites.

The stakeholders, i.e., the people who can help in overcoming the challenges posed by e-waste, are:

- Manufacturers
- Users
- Recyclers
- Policy makers

Advantage of incineration of E-waste is the reduction of waste volume and the utilization of the energy content of combustible materials. By incineration some environmentally hazardous organic substances are converted into less hazardous compounds. Disadvantage of incineration are the emission to air. Waste incineration plants contribute significantly to the annual emissions of cadmium and mercury. The assessment of E-waste recycling sector in India indicates that E-waste trade starts from formal dismantling sector and moves to informal recycling sector (Guidelines for Environmentally Sound Management of E-waste, 2008). The entire E-waste treatment is being carried out in an unregulated

environment, where there is no control on emissions. There are two E-waste dismantling facilities in formal sector in India. These facilities are M/s. Trishiraya Recycling facilities, Chennai and M/s E-Parisara, Bangalore [5]. The proper route of E-waste flow across different sectors can be represented by the chart in Fig.1.

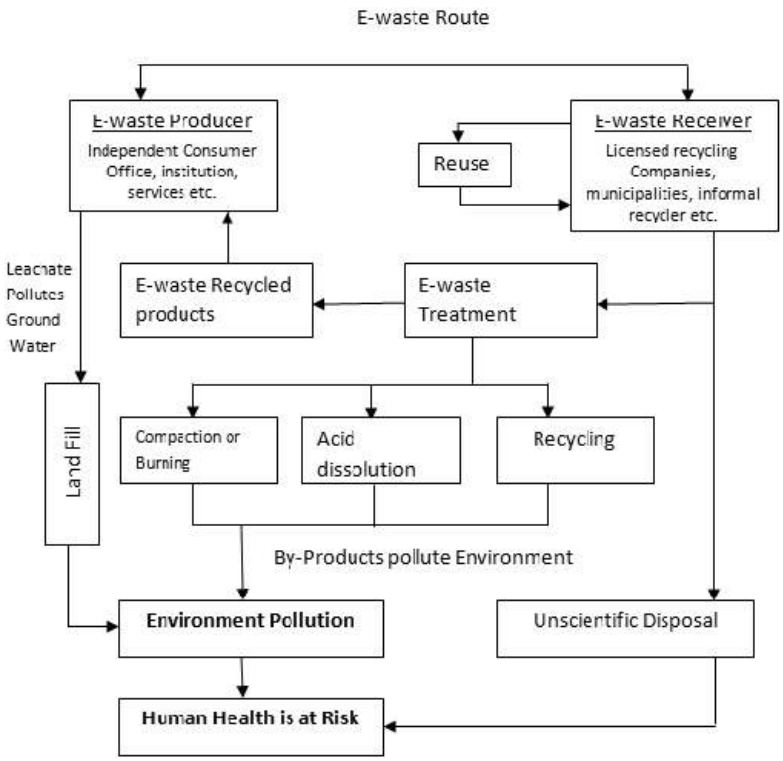

Figure 1 : E-Waste Route

Policy level initiatives in the country

The policy level initiatives regarding E-waste in India is good and needs more attention. But the implementation of those laws are quite rudimentary and demand immediate attention. Following are some of the policy level initiatives in India regarding E-waste.

a) The Hazardous Wastes (Management and Handling) Amendment Rules, 2003

Under Schedule 3, E-waste is be defined as "Waste Electrical and Electronic Equipment including all components, sub-assemblies and their fractions except batteries falling under these rules". The wastes generated from industry producing products that contain mercury such as thermometer, battery, fluorescent lamp, thermostats, etc., are not included in the list of waste containing mercury, which shows that Central pollution Control Board (CPCB) is not serious about the problem of waste containing mercury.

b) Guidelines for Environmentally Sound Management of E-waste, 2008

This guideline was a Government of India initiative and was approved by Ministry of Environment and Forest and Central Pollution Control Board. It classified the E-waste according to its various components and compositions and mainly emphasis on the management and treatment practices of E-waste. The guideline included a very good and effective concept named "Extended Producer Responsibility". Here the producer is a bit responsible for proper management of their product at the end of their life.

c) The e-waste (Management and Handling) Rules, 2011

According to this regulation, 'electrical and electronic equipment' means equipment which is

dependent on electric currents or electro-magnetic fields to be fully functional and 'e-waste' means waste electrical and electronic equipment, whole or in part or rejects from their manufacturing and repair process, which are intended to be discarded. These rules are meant to be applied to every producer, consumer or bulk consumer involved in manufacturing, sale purchase and processing of electrical and electronic equipment, collection centers, dismantlers and recyclers of e-waste. Responsibilities of producers, collection centers, consumers, dismantlers, recyclers etc. are defined and incorporated in these rules.

The Recycle route

* Call up manufacturer; if they don't pick up, complain to Pollution Control Board.

* Check with dealer, reseller about collection centres, if any.

* Check if local scrap dealer has an authorisation certificate from PCB.

* Check with manufacturer for incentives on offer, such as discounts on next buy.

d) E-Waste (Management) Rules, 2016

This is the very recent initiative. These rules are not implemented in India as yet and will only come into force from the 1st day of October, 2016. These rules shall apply to every manufacturer, producer, consumer, bulk consumer, collection centres, dealers, e-retailer, refurbisher, dismantler and recycler involved in manufacture, sale, transfer, purchase, collection, storage and processing of e-waste or electrical and electronic equipment listed in Schedule I, including their components, consumables, parts and spares which make the product operational but shall not apply to - **(a)** used lead acid batteries as covered under the Batteries (Management and Handling) Rules, 2001 made under the Act; **(b)** micro enterprises as defined in the Micro, Small and Medium Enterprises Development Act, 2006 (27 of 2006); **(c)** radio-active wastes as covered under the provisions of the Atomic Energy Act, 1962 (33 of 1962) and rules made there under.

Conclusion

India is becoming one of the largest electrical and electronic equipment consumer market in the world. Therefore the amount of E-waste generated is rising rapidly with the increasing demand and use of electronic and electrical equipment. However, the management of the same is a major challenge faced by the country. To handle the increasing generation of E-waste, more and more recycling units are required across the country. There is no large scale organized E-waste recycling facility in India and the entire recycling exists in unorganized sector and has a lot of health and environmental consequences. Involvement of urban poor, especially women and children and illegally imported E-waste from developed countries further exaggerate the problem of E-waste in India. The general public is not aware enough to dispose the obsolete electric and electronic equipments. The idea of recycling of e-waste needs to be popularized more to create awareness among the general public and small businesses so that they dispose of their electronic waste responsibly to prevent uncontrolled and dangerous scrapping of e-waste for a cleaner India. Lack of strict regulations and awareness makes dumping a preferred destination for E-waste. Proper implementation of the "e-waste (Management and Handling) Rules, 2011" and "*E-Waste (Management) Rules, 2016*" is extremely needed to address the ever growing E-waste in the country.

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Man Animal Conflict in Bhitarkanika, Odisha

Sanjukta Chatterjee
South Calcutta Girls' College, E-mail : sanjukta.chatterjee0@gmail.com

Abstract Situated at the estuary of Brahmani and Baitarani River at Kendrapada district of Odisha, Bhitarkanika is characterised by vibrant mangrove ecosystem and wildlife sanctuary of crocodiles and other reptiles. Gahirmatha beach is a marine sanctuary where nestling of Olive Ridley and many other species of sea-turtles are seen. Over 215 species of birds including winter migrants make this region geo-morphologically, ecologically and biologically significant. Increasing fishing activities in Dhamra port as well as growth of population in this region has ultimately led to a man-animal conflict which led the local people to be disinterested in protecting this bio-diversity. The spread of eco-tourism or iguana collection from bird sanctuaries may be the different ways to generate economic prospect to the local people and make them interested in conserving the second largest mangrove ecosystem in India.

Keywords bio-diversity, estuary, mangrove ecosystem, preservation and protection.

Introduction

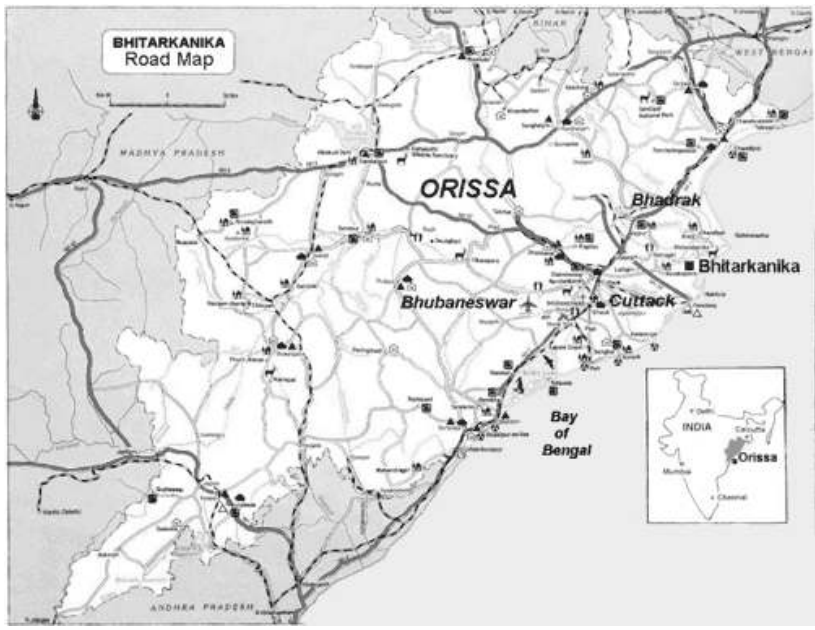
Bhitarkanika is situated in the estuarine region of Brahmani, Baitarani, Dhamra Pathasala and too many little creeks in the north-eastern corner of Kendrapara district, Orissa. There are nearly twenty five deltaic islands of various sizes, each of which are under active delta building process. It is the state's only and probably the country's second viable mangroves. The highest biodiversity of mangrove species in the world are identified in Bhitarkanika. It is the only sanctuary of Orissa having reptilian fauna for conservation. The unique phenomenon of mass-nesting of sea-turtles is witnessed here. It has a heronry of egrets, herons and storks. The newly formed islands offer shelters for migratory birds from October to February. It was designated "Ramsar Wetland of International Importance" in 2002.

Bhitarkanika is situated on 25'45" N and 87'0" E Coordinates and covers an area of nearly 672sq. km. The core area covers 145sq.km. Gahirmatha Beach Marine Sanctuary lies to the east of Bhitarkanika Sanctuary. This region is rich in mangrove species like sundari, thespian, casuarinas and grasses like the indigo bush and more.

Prior to 1971, the local people lived there in almost semi perfect harmony with nature. But due to increase in population, the mangroves, out of reach of regular inundation, experienced serious threat due to expansion of agricultural lands. Shortage of detritus was reflected on the shrinkage of fishing and more emphasis was given on coastal fishing. A program for conservation of estuarine crocodile and its habitat was mooted in 1975 with which a direct conflict between man and animal began. Rampant coastal fishing caused large scale mortality of Ridleys and estuarine dolphins.

Sustainable development might be initiated through the conservation of mangroves by laying emphasis on the establishment of small units of shrimp and prawn hatcheries and cultivation of salt-resistant variety of rice in tidal-mud flats. The deficit in earnings might be supplemented with the collection of

iguana and the generation of organic fertilizers out of it. Regulated eco-friendly tourism might pay the region an enormous monetary support.



Location of bhitarkanika in odisha

Bhitarkanika is situated in the estuarine region of Brahmani-Baitarani River systems between them are some islands, i.e. Bhitarkanika, Dangmal, Mahisbandha, Ranahasua, Angari, Salahipur and others. There are two large shoal formations: Kalibhanj in river Dhamra and Baguli in river Maipura. There are a number of islands in Bay of Bengal of varying sizes. Among them Defence Island, Shrott's Island, Wheeler's Island are noticeable. The whole region is under active delta formation. Therefore nearly twenty deltaic islands are there which remain under water in high tide.

The Mangroves of Bhitarkanika

The land, water, climate and biota of this region are quite distinct from adjacent fresh water or marine environment. The state's only and probably the country's second viable mangroves are located here. Nearly 650 square kilometers of area is covered with tidal, littoral or estuarine mangrove forests. Some plant species occurring outside the inter-tidal environment are also associated with mangroves. Out of seventy species of mangroves found in the world, fifty five are found in Bhitarkanika and were designated a "Ramsar Wetland of International Importance" in 2002.

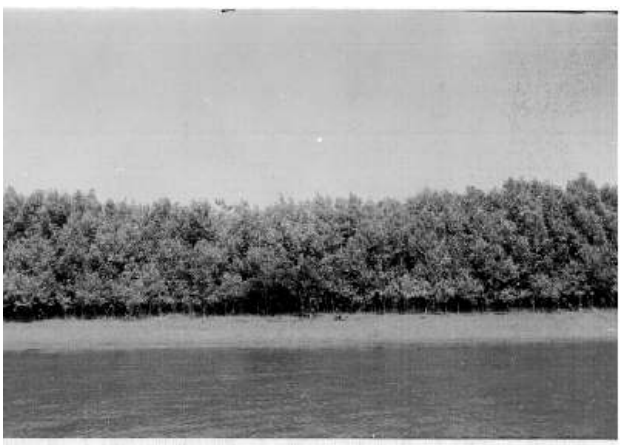


Plate 1 : Mangroves in Bhitarkanika

Mangroves modifies the course particles into fine ones and help in soil formation. Network of mangrove roots provide firm anchorage to the banks of tidal rivers, creeks and also the coast lines which effectively arrests river bank and coastal erosion. It supports a range of interconnected food webs which sustain the fisheries. Algae and detritus shrimps and prawns which provide food source for higher species (Chapman, & Reiss. 2006).

The mangrove is highly fragile ecosystem as the essential factors for the maintenance of this system are fresh water influx from adjoining land and tidal inflow from the sea. Changing the regime of either factors whether in quality or in quantity is likely to bring a corresponding change in the mangrove biota. As in Bhitarkanika, the water salinity exhibit a gradual change from near fresh water conditions to tidal water conditions. Thus most of the plants have evolved and adapted to withstand wide salinity gradients. However since the area contains older formations of tidal influence; newly accreting land mass subject to daily inundation; and not very old formations between the formers are subject to tidal influence only round full moon and new moon days, horizontal zonations of the plant formations are met with. Some consequently have specialized to thrive in narrow limits of both low and high salinities. It is therefore that the plant diversity will be fabulous here.

Detritus is the principal energy source in the mangrove ecosystems. A large number of detriblovores e.g. shrimps, prawns, nematodes, forage fish, mullets, mud skippers etc through several cycles of ingestion exhaust the nutrient laden detritus. Many fish and crabs feed on either directly on detritus or on detritus feeders. Common shore crabs are seen in abundance in this region. Large game fish (bhetki for example) feed on detritus feeding fish and so on. The off shore waters having a mangrove coastline also benefit through the out welling of nutrient laden detritus. Mangroves therefore have a great economic value through its contribution to the detritus food chain, supporting rich estuarine and adjacent marine fisheries. (Robertson & Alongi, 2013)

The Kanika Raja (Lepidochelys Olivacea)

To the east of mangroves, there is the world's largest nesting beach for Olive Ridley turtles or Kanika Raja as they are locally known. Gahirmatha Beach Sanctuary covers an area of nearly 1435 sq.km. And is rich in terminenalia, zizphus. Bija salaia sal, babul, teak, bamboo and many other varieties of common deciduous trees. The turtles migrate from coastal waters of Srilanka even as far as the Pacific Ocean in huge numbers from the beginning of November each year for mating and nesting in Gahirmatha region, a ten kilometer stretch of coast from Habalikhati to Ekakula. They usually select a suitable site, dig a hole in the sand with their flippers, lay nearly 120 eggs each, cover and sweep out all traces of their visit and crawl back to the sea. The nesting beach along this stretch was backed by the dense mangrove forests of Avicennia Marina, A.officinates, A.allea and many others. Since 1975, a high rate of forest destruction affected the mangrove population very badly. Then in 1989, a cyclonic storm swept across Orissa coast and Gahirmatha mass-nesting beach was fragmented. The Maipura River opened itself into Bay of Bengal cutting through Gahirmatha beach and the sand spit was separated from the main beach forming two elongated islands of around four kilometers in length, the Nasi I and Nasi II... This event seriously hampered the mass-nesting phenomenon. But afterwards they shifted their choice to newly formed Nasi Islands and gradually it has become a new rookery. But this island gets inundated almost every year and the hatching success rate of this new rookery is much less than the previous. It is quite difficult to give the exact reason for the non-arrival of turtles in some years. But beach erosion, bright light from missile test range at the Wheelers' Island near Gahirmatha, bad weather and illegal fishing are the main reasons (Dash & Chandrashekhar 1990).

In 27th September, 1995, Gahirmatha was converted into the only marine sanctuary and was notified such by the Government of Orissa, Forest and Environment Department. From there a census figure of nesting of sea turtles have been obtained.

Salt Water Crocodiles (Crocodylus Porosus)

Year	Nesting in lakhs	Year	Nesting in lakhs	Year	Nesting in lakhs
1993-94	6.945	2001-02	0.02	2009-10	1.12
1994-95	3.395	2002-03	2.44	2010-11	0.83
1995-96	2.90	2003-04	0.02	2011-12	0.00
1996=97	0.00	2004-05	2.44	2012-13	4.00
1997-98	0.00	2005-06	2.96	2013-14	3.39
1998-99	2.94	2006-07	2.85		
1999-2000	7.115	2007-08	0.00		
2000-01	7.40	2008-09	2.11		

Table 1: Year wise Mass nesting of Olive Ridley Turtles

Bhitarkanika is also the residence of salt water crocodiles and is globally unique in that 10% of adults exceed 6 M length. . Around mid nineteen seventies, the population of these salt water crocodiles had gone down to a critical level leaving only a small viable population in the main Bhitarkanika river systems and its associated creeks. The decline in population was mainly due to over exploitation of mangroves and indiscriminate poaching. A program for conservation of salt water crocodiles and its habitat was initiated in 1975 by Dr. H.R Bustard, the FAO/UNDP consultant. The project started at Dangmal. The practice of collection of eggs from wild and their subsequent incubation techniques was preferred to build up the depleted population. At present nearly 700 saltwater crocodiles inhabit the rivers and creeks. Around 3000 were born during 2014 annual breeding and nesting season.

Plate 2 : White crocodile in the sanctuary

Year	Hatching	Juvenile	Adult
2002-03	484	180	192
2003-04	525	210	220
2004-05	681	168	204
2005-06	637	196	197
2006-07	503	257	224
2007-08	538	227	252
2008-09	538	256	260
2009-10	510	298	270

Table 2 : Crocodile census, DFO Bhitarkanika

Man- Nature Conflict

Prior to early nineteen seventies, people lived there in semi perfect harmony with the nature. The entire region was little disturbed by the outsiders. But after that a good number of migrants from Midnapore, Sunderban and even Bangladesh had built their new home in this hitherto undisturbed territory. Much of the forest lying above regular inundation level had been cleared. A long stretch of embankments were made to restrict the inflow of salt water and lands behind them were reclaimed to put under cultivation of salt-resistant variety of rice instead of the wild variety previously cultivated. In this way active delta-building process was much hampered. The worst possible consequence could have been noticed by the

Plate 3 : Destruction of mangroves in estuarine region of river Dhamra

immense devastation of life and property due to the Super Cyclone of 29th and 30th October, 1991 in and around Bhadrak and Chandbali region in Kendrapara district (Chadha & Kar 2001).

The soil salinity throughout this region is quite high. So the land is arable only in Kharif season and the yield is not satisfactory. This is because the percentage of male cultivators to the total workers had gone down from 70% in 1981 to 63% in 1991 and only 54% in 2001. Thus it is clearly evident that agriculture alone can not provide them with subsistence. Fishing is the most common subsidiary occupation. Sheltered water of mangroves provided nursery grounds for commercially harvested prawns and shrimps. If mangroves were absent, there would be very little detritus and subsequent fall of the yield of fish. This is again reflected on the work-participation ratio of the region. According to 1991 census, about 30% of the total workers were dependent directly or indirectly on fishing. It is now only 21% in 2001 census. It would affect the general economy of the region. To encourage coastal fishing a large fishing harbour had been established in Dhamra. Thus the fishing operation has shifted from the hands of the local people to that of the organized sector.

Plate 4 : Fishermen's motor-boat in Baitarani Estuary

Plate 5 : Dhamra Port

There are other known pollution causing industries like Oswal and PPL etc. around Bhitarkanika which could affect the ecological soundness on prawn gharries which ultimately has some impact on the wildlife depending on the aquatic habitat. The porpoises, dolphins and marine turtles are being crushed by the trawlers. Five species of marine and estuarine dolphins had been recorded in this region of which only Indo-Pacific Humpback dolphin are found today (Nayak, Sahu & Dutta 2008).

Man-animal Conflict

Salt-water crocodile is stated to be most dangerous species of crocodilians from human standpoint. In Bhitarkanika some of the adult males particularly are of very big size. Frequently people intrude into the crocodile habitat for poaching, collection of wood, honey, nalia grass or set traps for deer, wild boar etc. and get caught by the crocodiles. The following table shows the casualty by crocodile in Bhitarkanika.

(Data source: D.F.O. Bhitarkanika range)

While writing this paper, a news had attracted my attention: a woman is killed in crocodile attack in Dangmal, Bhitarkanika (Zee News: 8th June, 2015).

Human attacks and more particularly cattle attacks increase the unpopularity of crocodile conservation and increase the pressures working against it.

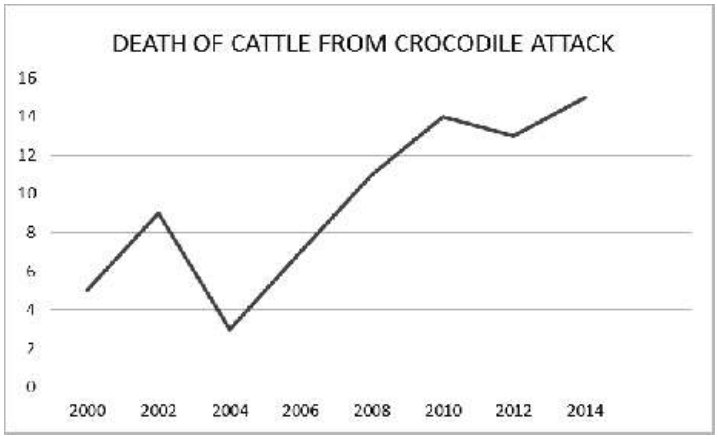


Chart 1 : Death of cattle from crocodile attack

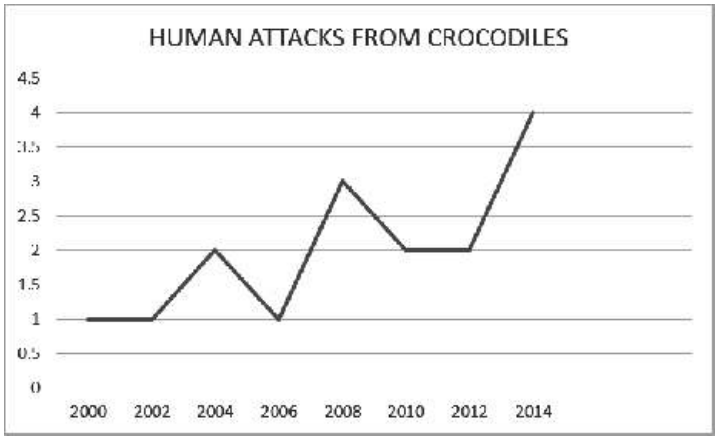


Chart 2 : Death of humans from crocodile attack

A Step Towards Sustainable Development

After a long persuasion of local environmentalists, zoologists and international agencies under UNDP, Orissa Govt. has restricted coastal fishing to some extent. With the recommendation of Gahirmatha Marine Turtle Research and Conservation Center, coastal trawler fishing is prohibited during the mass-nesting season of Olive Ridleys, i.e. from January to April. The extension of earthen embankments along the estuaries is also restricted with a view to save the mangroves and to stop the extension of agricultural areas.

But these measures possibly affected the working structure of local population. The percentage of main workers has gone down from 29.74% in '91 to 27.5% in 2001 and 26.9% in 2011 (PCA: Census of India). Percentage of male cultivators is only 54% compared to 73% for female (Census 2011). The sex ratio is 1055 females per 1000 male. All these data show an indication of out-migration of labour force from this region due to lack of opportunities of livelihood.

To provide the local people with employment, priority should be given to the conservation of mangroves,

which not only supplies the essential detritus for the estuarine fish culture but also acts as a wind breaker from frequent cyclonic storms. Mangroves also provide hogla, golpata, nalia grass for local housing. Small prawn hatcheries instead of large ones are to be maintained so that tidal water inflow is not hampered. A strip of undisturbed mangrove forest at least 100 meters wide along all rivers and creeks are to be maintained adjacent to cultivated land and human habitations inside the sanctuary so that the aquatic as well as reptilian life is not disturbed.

To develop the economic condition of the local people, two non-conventional sources may be tapped; the first one is regulated eco-tourism and the second one is iguana collection. Bhitarkanika had already proved itself as an emerging eco-tourism zone. Its unique scenic beauty and reptilian wild life can attract a good number of tourists from different states of India as well as from different countries. As here is no fear from ferocious land animals, so adventure tourism, nature trail may be encouraged to restrict unplanned tourism. This can generate a broad-base infrastructure and can add health to the local economy. The forest shelter to more than 2145 species of birds. Iguana collection from these heronries may be another new source of income. Organic fertilizers can be made out of it as in the case of Ecuador of Latin America. Thus the primary as well as secondary sectors of economy may get a boost and development and conservation can go side by side.

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Source of Information

1) DFO, Bhitarkanika, Dangmal Range
2) DFO, Bhitarkanika, Ekakula Range
3) Field Survey

Groundwater Arsenic Pollution in West Bengal: Causes, Impacts and Control

Abhijit Das
Vijoygarh Jyotish Ray College, Kolkata, E-Mail: abhijit.dasecon@gmail.com

Abstract Groundwater is the main source of drinking water in West Bengal. But arsenic contamination of groundwater detected in at least 79 blocks in 8 districts of the state has made a significant segment of its population vulnerable. Consumption of arsenic laced water beyond permissible limit has very serious health implications. Over Past three decades scientific studies have been undertaken in West Bengal to understand the sources and extent of the problem of arsenic contamination in groundwater. Possible impacts on human health have been studied through epidemiological investigation. Governments and other agencies are mainly attentive to identification, mitigation and supply of safe drinking water but little has been done to understand the pains the arsenic patients are going through. In this paper first we present a comprehensive assessment of these past studies and then we present our findings based on case studies to fill in partially the knowledge gap in literature on socio-economic impact.

Key Words Arsenic, Health effects, Socio-economic effects, West Bengal, Mitigation efforts.

Introduction

Over the last three decades, due to excessive exposure to high concentrations of arsenic in drinking water has been recognized as major public-health concern. Arsenic poisoning in drinking water has been reported in many parts of the World. Countries such as Afghanistan, Argentina, Australia, China, Taiwan, Thailand, Mexico, USA, Ghana, Hungary, United Kingdom, Chile, New Zealand, and Russia and so on in the world reported arsenic contamination problem (Rahaman et.al., 2006; Mukherjee et. al.,2006; Ravenscroft, 2009). From the view point of population at risk and extent of affected area, India (particularly West Bengal) and Bangladesh are the largest arsenic affected countries of the world (Das, 2012).

Detection in the 1983 of arsenic in the groundwater of West Bengal, the main source of drinking water, has added a new dimension to the already existing water related problems in the state (Chakraborty et.al., 2009). Experts considered the sources of arsenic in groundwater to be geogenic and opined that excessive withdrawal of groundwater was responsible for leaching of arsenic into the aquifer. Expert committee also disclosed that the intermediate aquifer (second aquifer 20-80 metre below ground level (mbgl)) of the affected areas have shown significantly above the 'World Health Organisation (WHO) guideline value', i.e. 10 µg/L (Gadgil at. el., 2012).

There is bulk of literature on the arsenic related health impacts, called arsenicosis (Saha and Chakraborti, 2001). International agencies dealing with health related problems like, International Agency for Research on Cancer (IARC), World Health Organization (WHO), US Environmental Protection Agency (US-EPA) and a few others consider arsenic in drinking water to be causing cancer in skin, lung, liver, urinary bladder and kidney. Various other non-carcinogenic health effects like dermal, cardiovascular,

neurological, respiratory, diabetic mellitus, gastrointestinal and reproductive and developmental effects are also caused due to chronic exposure to arsenic through drinking water (Das et. al., 2013).

There is no cure or medicine to provide permanent solution of the arsenicosis (Smith et al., 2000). The only approach to tackle the menace is to provide arsenic safe water in the affected areas as preventive solution rather than cure. West Bengal Government in collaboration with national and international organization adopted several measures which can at best be considered as short term and medium term to provide arsenic safe water

Social costs of arsenic pollution are varied: instability, superstition, ostracism, marital problem, discrimination against women, increased poverty, diminished work ability, and death (Nasreen, 2002). The Intelligence quotient (IQ) level and the cognitive functions of the children are also affected by the arsenic pollution. Various reports and observations show that due to arsenic pollution healthy relation between different persons within a family and between different families in the villages are being disturbed. The infected persons become mentally sick and physically incapable of doing any economically meaningful work (Das and Roy, 2013).

In this backdrop the specific objectives of the proposed research are

(a) To assess physical impacts and socio-economic implications of presence of arsenic in groundwater of West Bengal,

(b) To understand nature of public investment made towards mitigation actions undertaken.

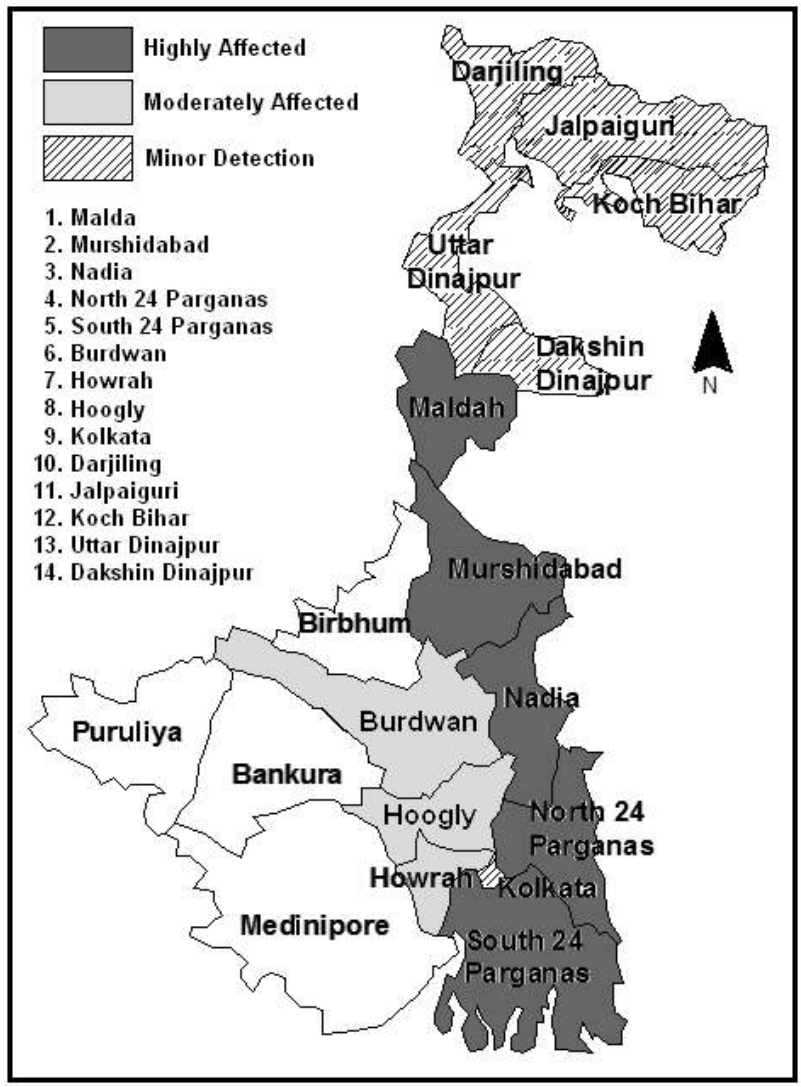
Methodology

The data for this study has been collected from both primary and secondary sources. Government reports, Media coverage on arsenic victims, research reports and articles have been utilized as a secondary source. To assess the socio-economic conditions of arsenic affected rural poor people of West Bengal four different arsenic affected districts (viz. Murshidabad, Nadia, North 24- Parganas and South 24- Parganas) were selected. We visited total 20 (4x5) villages selected on the basis of arsenic concentration level reported by Public Health Engineering Department, West Bengal[PHED (WB)] and School of Environmental Studies, Jadavpur University [SOES (JU)]. In-depth interviews and focus group discussions (FGD) were used to explore people's own understandings about the impact of arsenic on social as well as economic issues. Socio-economic impact on arsenic victim specially male bread winner, young male, married female and young female going to be married as well as arsenic affected family and their interactions with non-arsenic victim of the society was investigated.

Arsenic Pollution in West Bengal

In West Bengal approximately 79 to 111 blocks in 8 to 12 districts are detected with groundwater arsenic pollution. Around 24-26% of the total tubewell water samples have arsenic concentration above 50µg per litre. Despite mismatch in reported statistics, due to the difference in coverage of their study areas, from different sources there is, however, unanimity over the fact that eight districts of the state have arsenic levels in ground water above 50µg/L. These are Nadia, Murshidabad, Malda, South 24-Parganas, North 24-Parganas, Howrah, Hoogly and Burdwan. In these nine affected districts, around 49.7% of the total

hand tubewell water samples have arsenic concentration above 10µg per litre (WHO Standards), 24.7% of the total tubewell water samples have arsenic concentration above 50µg per litre (National Standards), 3.4% samples had arsenic above 300µg per litre (Chakraborti et. al., 2009).The current PHED status report (2013) of arsenic in West Bengal (on the basis of 1,32,219 water samples) concluded that at present the total population at risk in the state is approximately 28.7 million, 36% out of the total population. About 16.26 million population (35.48% of the total population of the State) covering 17533 number of habitations are located in the potential risk zone of groundwater arsenic related threat and diseases (NIH & CGWB, 2010). The variation in number of people at risk from various sources emerges from the variation in coverage of their water samples tested and year of reporting.



Map I : Arsenic Affected Areas in West Bengal

Various theories have been postulated on the sources and mobilization mechanism of arsenic. There is unanimity regarding the major source of groundwater arsenic in the Ganga-Meghna-Brahmaputra Plain. It's released from iron oxy-hydroxides under reducing conditions; however, the exact nature of this mobilization process is still unknown (Chakrobarti et. al., 2004).

Varied opinions are expressed on the cause of arsenic pollution in groundwater. Till 2000 it was thought that Rajmahal hill is the source of arsenic in ground water. But now new researches reveal different findings. Arsenic, more than the danger level, is found in the catchment area of Ganga-Bhramhaputra-Meghna. The survey report prepared by a group of specialists of School of Environmental Studies (SOES), Jadavpur University, Calcutta Medical College and Hospital and Institute of Post Graduate Medical Education and Research (I.P.G.M.E.R) under Seth Sukhlal Karnani Memorial (S.S.K.M) Hospital suspect that not Rajmahal hill, but the Himalaya is the source of arsenic and the entire catchment area of Ganga river will be severely polluted by arsenic (Sengupta, 2006).

Health Implications of Arsenic Problem in West Bengal

People drinking arsenic contaminated water for a couple of years could cause arsenical skin lesions (Guha Mazumder et.al., 2001; Saha 2004). However, nutrition and diet have a considerable influence on the prevalence of skin lesions. Various types of skin manifestations are diffuse melanosis, spotted melanosis, leucomelanosis, diffuse keratosis, spotted keratosis, hyperkeratosis, dorsal keratosis, gangrene, Bowens and skin cancer (Chakraborti et al. 2004). According to toxicologists these skin lesions are external manifestations of severe internal damage. Other than dermal effects arsenic may cause cardiovascular effects, respiratory effects, gastrointestinal effects, endocrinological effects, neurological effects, reproduction and developmental effects. SOES medical group examined 96,000 individuals from nine arsenic affected districts of West Bengal and 9356 (9.7%) of them had arsenical skin lesions (www.soesju.org). Increased risks of spontaneous abortion, stillbirth, preterm delivery, and infant mortality were also reported from the arsenic affected areas (Milton, 2003). Dermatological survey (Saha and Chakraborti, 2001) found that population drinking the same contaminated water, may not at all show arsenical skin lesions, but their hair nail and urine contain high concentration of arsenic. Thus for many of the villagers there is a possibility that they are sub-clinically affected. This implies morbidity. Infants and children are often considered more susceptible to the adverse effects of toxic substances than adults (NRC 1999).

A recent follow-up study (January 2009 and January 2010) on arsenic patients registered during 1995-2000 on 33 villages in 16 blocks-thanas of 9 arsenic affected districts from West-Bengal, India and Bangladesh shows 169 (14%) of the registered patients died between our 1st (1995-2000) & 2nd (Jan, 2009 - Jan, 2010) survey. Re-examination of 454 patients (44%) in the 2nd survey out of 1025 (1194- 169) alive patients registered during 1995-2000 reveals that 220 (48.5%) are at present having suspected Bowens, Non-healing Ulcer/Cancer, Ascites. In some villages 80-100% of the patients re-examined have suspected Bowens (SOES-JU, 2010).

Media has occasionally reflected on the morbidity and mortality incidents (published in different issues of reputed print media in West Bengal). Editorials, expert interview etc. has been used to draw Government's attention and raise public awareness about the health impacts of the particular water quality emphasizing the need for special action towards public provision of safe water. Researchers started informing government and raising public awareness much earlier about the possible health impacts of arsenic pollution in the drinking water in different parts of West Bengal.

Socio-economic Implications of Arsenic Problem in West Bengal

Arsenic is not only a physical but also an economic as well as social phenomenon. Because Arsenicosis (due to taking of arsenic contaminated water) contributed adverse effects on economic variables in the form of lowering labour productivity, lowering income earning capacity, loss of lifetime income, intergenerational poverty, impoverishment, welfare loss etc as well as a number of social taboos like social instability, social isolation, ostracism, superstition, marriage related problems and family problems etc. (Das and Roy, 2013). Besides these problems, arsenicosis diseases may cause psychological harms and affect mental health. These issues based on our field visits and FGD in West Bengal are mentioned below:

- Many families in North 24 Parganas or in South 24 Parganas are ostracized within their own

villages. Villagers socially boycott the patients of arsenicosis assuming that they are affected by leprosy once the external signs of the disease become visible on their body. With this, a new tradition of untouchability has emerged in the contemporary society. This certainly leads to social unrest.

- Consumption of arsenic contaminated water has led to a critical situation in which most of the families of Haringhata, Nonaghata and Uttarpara in Nadia district face immense difficulty in getting their daughters married.
- Naseda, a 21 year old young lady of Noakhali who got married recently, has been left by her husband within a few days of their marriage as he had misconceived the skin lesions on her body to be the signs of leprosy. Naseda who was a resident of Purbasthali in Burdwan district had shifted her base to her in-laws' house at Lohar village in Katwa. After being abandoned by her husband, she has come to stay again at her father's residence.
- As many married women have been deserted by their husbands along with their children for this disease of arsenicosis, many young unmarried women like the 18 year old Champa Gayen of Ramnagar village in South 24 Parganas are not willing to get married for the fear of being left alone in the same way.
- There are hundreds and hundreds of young women who became quite helpless and destitute after the premature death of their husbands. Some of the arsenic- afflicted villages have been named 'Village of Widows'.
- Being unable to bear the pain, Abul Kalam Azad, resident of Panjrapara village under Khoyramari Gram Panchayat of Jalangi block in the district of Murshidabad tried to commit suicide by hanging himself. But eventually he was rescued by the villagers. His family faced a great financial crisis having spent a huge amount of money in procuring his treatment facilities. However, he could not recover from the disease and day by day his pain increased beyond the level of tolerance. Seeing him suffer so much, his youngest daughter also tried to commit suicide by hanging herself. Fortunately she was also rescued by the villagers.
- The arsenic afflicted people are offered the work only when there is a shortage of healthy labourers, complained Asadul Sheikh, Obaidul Sheikh and many others. Once they had worked with full stamina and vigour. Now they cannot undertake any hard work or heavy task. Thus due to arsenic poisoning, the number of unemployed people is constantly on the rise.
- In Kadamtala village (one of the severely arsenic affected villages in Katlamari-I GP of Murshidabad), villagers reported that they are facing problems to sell their cultivated products in the neighbouring villages, because people in the neighbouring villages do not want to buy from them for the fear of arsenic poisoning. For this reason they have to go a long distance to sell their products (like vegetables, milk etc). The affected villagers often resort to lying to sell their goods.
- The arsenic patients had been suffering from mental agony because of their skin lesions. Factors mentioned were mental anxiety and depression, the fear of a premature death, no remedy is known to anyone, constant physical weakness, loss of natural appearance or physical condition, fear of getting gangrene because of prolonged suffering from arsenic.
- Demand for government action to provide arsenic safe water to attain better health standards for people has been expressed through various forms of public grievances, mass media, social conflicts

between local inhabitants and governments. The locals have staged mass deputation to the government officials, hunger strike, rally, polio boycott etc.

Controlling the Menace

Water being the state subject state government undertook mitigation efforts. There is no 'One Technology' solution for providing access to arsenic safe water (Susan et. al., 2014). A wide range of technologies have been tried in rural West Bengal over couple of decades for the removal of arsenic from drinking water. Most of the existing efforts concentrate on ex-situ remediation of arsenic. Technologies so far available are based on either treating arsenic contaminated groundwater or by treating arsenic safe surface water. Hand- pump attached Arsenic Removal Units (ATUs), Arsenic Removal Plants (ARPs), Dugwell, Deep Tubewell, Surface water (after scientific treatment), Swajaldhara,[1] rainwater harvesting are considered as the alternative safe water options in the arsenic affected areas. All these options are good provided they are well maintained. Considering the gravity of the situation, several arsenic mitigation measures/schemes in the rural areas of the West Bengal with a strategy for ensuring at least one safe source of drinking water for each habitation has taken. Upto April 2013, public expenditure has been incurred to set up 166 dugwells, 8037 hand fitted tubewells at deeper aquifer, 394 groundwater based PWSS and 12 surface water (river water) based PWSS for supplying arsenic safe water. Through different measures now there exist as per official statistics 129.81 million people (77% of the total affected population) with access to arsenic safe water. In view of the Bharat Nirman Programme, a Master plan is prepared on future mitigation measures in consultation with the Arsenic Task Force, Govt. of West Bengal (PHED,2006) in order to cover all the arsenic affected habitations so far identified on long term basis.

The total spending for implementation of water supply schemes in arsenic affected blocks till 31 March 2013 have been Rs. 2,509.38 crores. The central government has provided Rs.1278.01 crores under Arsenic Sub Mission and the balance amount of Rs.1231.37 crores has been provided by the state (PHED 2013).

Performance of the Mitigation Measures - A Case Study

A number of case studies have been conducted in Murshidabad in order to experience on level of success of technologies to supply safe water through alternative safe water options installed in the arsenic affected areas. Our field experiences based on technology specific case studies show that a large number of installed technologies are not working and the reasons ranged from socio-cultural-political to economic (Das 2012).

During our field visit what we have observed that most of the options are not working due to the lack of operation and maintenance and due to the lack of active participation of the people. Evidences obtained from the Swajaldhara project show that many projects have not been commissioned due to the lack of

1 Sectoral Reform Programme (SRP) in the rural water supply programme of the Ministry of Rural Development, GoI was introduced in April, 1999. The SRP initiative was scaled up throughout the country by launching 'Swajaldhara' in December, 2002. Under the SRP and Swajaldhara framework, individual water supply schemes are expected to be planned designed, implemented, operated and maintained by the community through Village and Sanitation Committees (VWSCs). Once the plant installed, beneficiary group contribute a monthly subscription for the O & M purpose of the plant. Collected money will be maintained by the committee and spent for electric bill, salary of the operating person etc.

availability of electricity in the local area. Areas where pipe water supply schemes are installed, we could not found any stopcocks in many of the stand posts leading to wastage of costly water. This means that the sustainability issue is completely ignored. Though we are putting more emphasis on the demand side management criteria, in the field level it is not observing. Whereas in some places projects are functioning well where there are champions (like educated young man, local Bazar Committee) who take the risk of initiating and leading the programmes. We also observed that the villagers are suffering less where they are well informed and aware about the arsenic toxicity.

Conclusion and Recommendations

The approach so far taken to tackle the situation in West Bengal is dominated by technological solution. Easy money flow and easy technology flow were there but the management aspect, economic aspects were silent and hence failure. Cost-effectiveness, economic valuation never figured in the agenda. As a result, financial sustainability, technical sustainability, participatory approaches never come in forward. Demand management had never been the goal. Supply management which dominated was also not planned with long term vision or within cost-effectiveness.

The concept of mass participation that leads to success is as old as humanityTo do away with the arsenic menace, it is the primary responsibility of the government, aid-agencies and the researchers to educate and motivate the common masses about this issue of serious concern. It is only when the multitude realizes the havoc that arsenic can unleash in their lives that our aim will be fulfilled in the true sense.

Comprehensive assessment in this dissertation helps in bringing out many important policy implications for addressing the issue of sustainable access to safe water in habitations with arsenic contaminated ground water. Given the progress of efforts towards arsenic mitigation at various levels in past almost three decades there is now enough evidences for designing pro-active action plans towards sustainable service delivery and access security. Given the progress achieved in knowledge on source, extent and manifestation of the problem and infrastructure design the next stage of action should emerge more on service delivery design and innovation in sustainable water access model design where community is not seen as victim or beneficiary but as an agent for change. Our suggestions/recommendations are summarized below:

1. Social hopelessness created by disease incidence and technology failure needs immediate intervention. This needs action and sustained reliable service delivery towards cure as well as prevention.
2. Immediate need is to provide public health service for cure/pain alleviation to suffering population to stop growing indebtedness. Destigmatisation is also simultaneously needed to stop social exclusion that is increasing.
3. Very alarming finding is arsenic patients are the highest in age group 20-40, the most productive age in human life. This means in these villages dependency ratio will increase and productivity will be less and will make life expectancy lower in near future. Millennium development goals will slip more in these villages.
4. Given the information base about district level population at risk the intensity of action can be prioritized to get equitable and efficient outcome.

Acknowledgement

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Cobalt Nanoparticles as Recyclable Catalysts for Treatment of Water Effluents Contaminated with Organic Dyes

Arijit Mondal, Asish Mondal and Debkumar Mukherjee*
Ramsaday College, Amta, Howrah 711 401, India

Abstract Cobalt nanoparticles were prepared from cobalt sulphate using tetra butyl ammonium bromide as surfactant and sodium borohydride as reductant at room temperature. The cobalt nanocolloids in aqueous medium were found to be efficient catalysts for the degradation of toxic organic dyes. Our present study involves degradation of Methylene Blue using cobalt nanoparticles and easy recovery of the catalyst from the system. The recovered nanoparticles could be recycled several times without loss of catalytic activity. The cause of the dye colour discharge by nanocolloids has been assigned based on our experimental findings.

1. Introduction

In recent years considerable attention has been paid to the environmental problem involving water treatment (Sanchez-Martin *et al.* 2010). The pollution of water sources by dyes from the textiles and mining industries has become a serious environmental concern now-a-days. The textile dyes with high aromatic content and low biodegradability have emerged as major environmental pollutants (Arslan *et al.* 2000, Sauer *et al.* 2002). Nearly 10-15% of the dye is lost in the dyeing process and is released in the waste-water. The waste-water from textile mills causes serious impact on natural water bodies and in the surrounding lands. As dyes are designed to be chemically and photolytically stable, they are highly persistent in natural environments. The improper handling of hazardous chemicals in the textile water also has some serious impact on the health and safety of workers. Skin diseases, chemical burns, irritation, ulcers and respiratory problems are common among workers involved in water treatment plants (Arslan I 2001). Various physical, chemical and biological pre-treatment and post-treatment techniques have been developed over the last two decades for the treatment of textile waste-water. Although most of them were found to be effective, the cost involved in the process is rather expensive (Kositzi et al. 2004, Patil et al. 1988, Mondal 2014). Shao et al (Shao 2009) and Zhang et al (Zhang 2007) employed Pd nanoparticles deposited on silicon nanowires to degrade Eosin Y and Methylene blue, respectively. During the degradation of Eosin Y or Methylene blue in presence of sodium borohydride, the Si/Pd nanoparticles offer several advantages such as rapid reaction rate, high catalytic activity, and reuse. However palladium chloride, the raw material required for preparing the Pd nanoparticles, is very expensive. Liu et al (Liu 2005) employed silver nanoparticles supported on silica spheres to reduce eosin and methylene blue. Jana *et al* (Jana 1999) produced silver particles in aqueous surfactant media and studied their catalytic properties toward the reduction of a number of dyes. Unfortunately, silver nitrate the raw material for production of silver nanoparticles is also expensive. There are very few reports about use of cobalt materials for the purpose of dye degradation mainly because of their difficulty in preparation and stabilization.

Herein, we used tetrabutyl ammonium bromide stabilized cobalt nanoparticles, prepared at room temperature, as an adsorbent in aqueous solution. Aqueous solution of methylene blue (MB) can be completely degraded within 2 minutes by the Cobalt nanoparticles. We have selected Methylene blue as our study material because it has absorbance maxima well within the visible range suitable for spectral studies. The used cobalt nanoparticles can be recovered by applying a magnet from outside to the aqueous solution. TEM studies before and after the dye degradation process reveals no aggregation or disintegration of particles. Our endeavour to use cobalt nanoparticles in the field of dye degradation may become important in the treatment of industrial effluents.

2. Experimental

2.1 Chemicals and materials

All chemicals were of reagent grade and used without further purification. Cobalt sulphate ($CoSO_4$), tetrabutyl ammonium bromide (TBAB), Sodium borohydride ($NaBH_4$), Methylene Blue (MB), acetone were purchased from Sigma-Aldrich. Cobalt nanoparticles and palladium particles have been abbreviated as CoNPs and PdNPs respectively in the manuscript.

2.2 Preparation of TBAB stabilized cobalt nanoparticles reduced by $NaBH_4$

To a screw-capped glass bottle equipped with a stirring bar were added 64 mg of cobalt sulphate (225 μmole), 100 mg tetrabutyl ammonium bromide (300 μmole) and 8 ml of deionized water. After adding deionized water solution of $NaBH_4$ (0.1M) dropwise, the mixture was stirred at room temperature for 15 minutes and then aqueous solution was decanted off. The TBAB-stabilized CoNPs (132 mg) were washed with water (5×2.0ml) and acetone (5×2.0ml) and dried under vacuum. The particles thus prepared can be stored at room temperature for several days.

2.3 Dye degradation process

In a representative degradation experiment, 5 mg of TBAB-stabilized CoNPs and an aqueous solution of $NaBH_4$ (2ml, 2×10^{-2} M) were rapidly added one by one into an aqueous solution of MB (2 ml, 4×10^{-5} M). The whole mixture was then subjected to UV-Vis spectral analysis at room temperature. The concentrations of Methylene Blue were quantified by measuring the absorption intensities at λ_{max} 664 nm.

2.4 Characterization

High Resolution Transmission Electron Microscopy (HRTEM) images of cobalt nanoparticles were obtained using CM30 microscope operating at 200 kV and expanded to 470 Pixels/cm resolutions. HRTEM samples were prepared by dispersing CoNPS in acetone for 45 minutes in a sonicator. The solution was withdrawn using hypothermal syringe and one drop of the solution was put in a carbon-coated copper grid and left to dry. The UV-Vis absorption spectra were measured at room temperature on INTECH spectrophotometer using solutions in 1 cm quartz absorption cell at wavelength 300-750 nm.

3. Result and discussion

The formation of cobalt nanoparticles during the reaction of cobalt(II) sulphate and sodium borohydride

could be easily followed by dramatic colour change from pink to black as soon as the reducing agent is introduced. The overall reaction proposed for this process is-

$$2Co^{2+} + BH_4- + 2H_2O \; ? \quad 2Co(s) + 2H_2(g) + 4H+ + BO_{2-}$$

? surfactant

Co-particles stabilized by surfactant

These cobalt nanocolloids are generally stabilized by TBAB against aggregation by electrostatic or steric protection. The presence of the surfactant on the surface of cobalt nanoparticles can be explained by comparing their FTIR data.The morphology and size of the as-synthesized particles on the carbon coated Cu grid were characterized by HRTEM (Fig. 1). The size distribution of Co nanoparticles fall between 80-100 nm estimated on the basis of studying 32 such particles. EDX (Energy Dispersive X-ray spectroscopy) spectrum shows 18.6 % cobalt (weight %) present in the isolated nanoparticles.

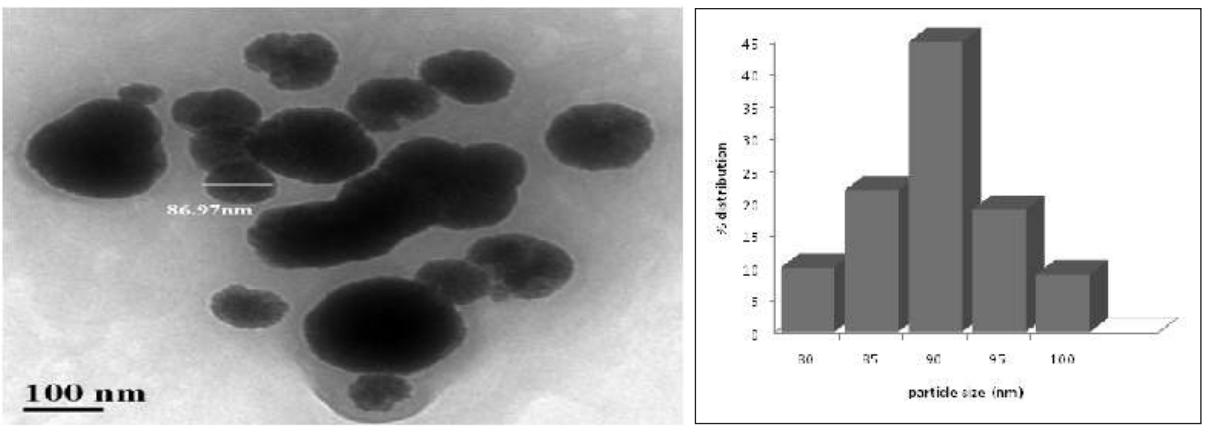


Figure 1 : TEM of as-synthesized cobalt nanocolloids and their particle size distribution

The progress of the catalytic degradation of MB can be easily monitored by the decrease in its optical density at the wavelength of the absorbance maximum of MB. Figure 2 shows the UV-Vis spectra of the degradation of MB (2×10^{-5}M) at sodium borohydride concentration of (2×10^{-2}M). It can be seen that the absorption band of MB at 664 nm decreases gradually with the reaction time and the blue colour of the mixture vanished in 120 seconds when the spherical cobalt nanoparticles were used. In the control experiment without any catalyst, an intense absorption peak at 664 nm was still observed even after 100 minutes (Fig.4B). The reaction rate of MB degradation with cobalt catalyst is at least 50 times faster than

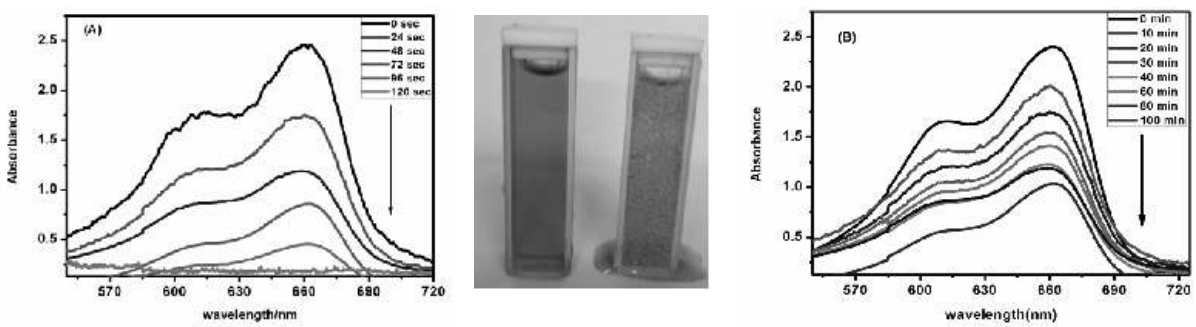
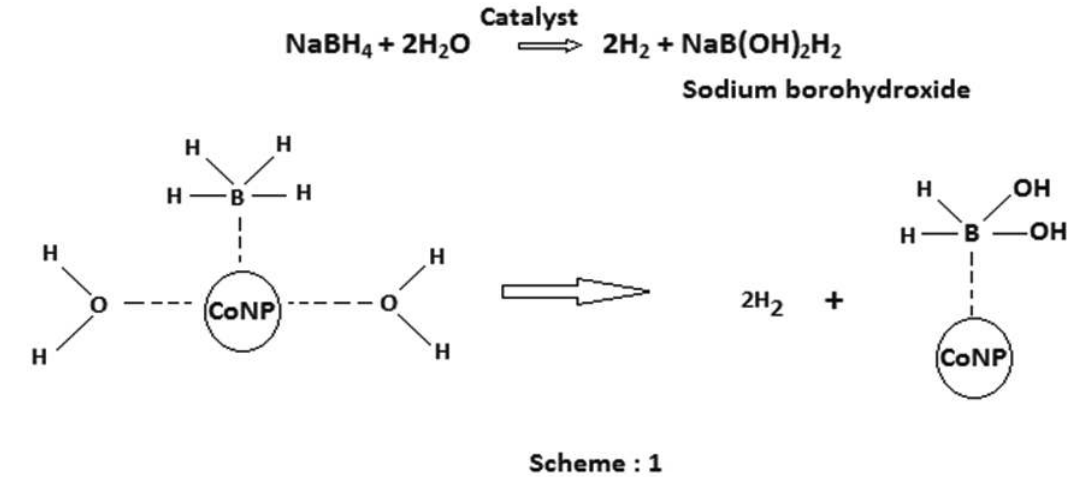


Figure 2 : UV-Vis spectra, (A) MB degradation in presence of CoNPs (B) MB degradation without presence of CoNPs

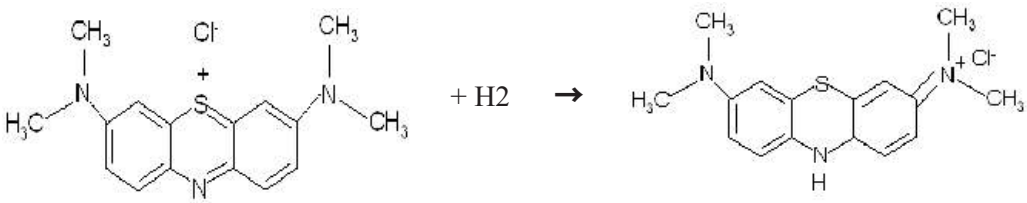
the results of the control test. This clearly indicates that the spherical cobalt nanoparticles have high activity in degradation of MB. Cobalt sulphate used as catalyst in place of nanoparticles has no effect and the spectrum is almost similar to that obtained in Fig 2B.

3.1 Reason of colour change of dye molecules

Dyes are coloured because of the presence of chromophores which are part of the conjugated system in the molecule. In addition to one or more chromophores (examples are Nitro-, Azo, Anthraquinone or Phthalocyanine moiety, Anthracene, Phenanthrene etc.) most dyes contain colour enhancing groups like carboxylic, sulphonic or hydroxyl groups classified as auxochromes. If any of the features mentioned above are missing or altered, the colour of the dye is lost or weakened. The research group of Kojima (Kojima et al. 2002) has shown that an aqueous solution of sodium borohydride in presence of a catalyst liberates hydrogen. The hydrogen thus liberated in our case by reaction of cobalt nanocolloids and borohydride in aqueous medium by virtue of scheme 1 is responsible for change of structure of methylene blue dye to its nonconjugated structure and hence loss of colour is observed.



Scheme : 1



methylene blue dye

3.2 Separation of CoNPs and recyclability study

The catalyst can be easily separated from the reaction medium. As cobalt nanoparticles possess magnetic property, they get stuck into the magnetic stirrer used in the system. Aqueous solution was slowly decanted from the reaction vessel and cobalt nanocolloids containing the magnetic stirrer were dispersed in deionised water using a sonicator. The solution was centrifuged when all nanoparticles settled at the bottom of the centrifuge tube. The aqueous solution was finally decanted out. The process was repeated

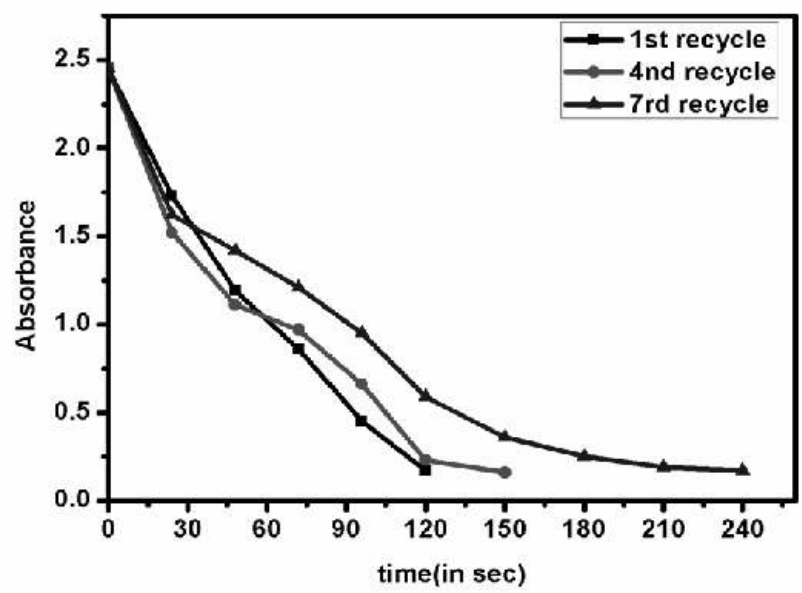


Figure 3 : Recyclability of CoNPs for Degradation of methylene blue dye

two times when finely dispersed black particles were obtained. Recycling experiments were then performed to test the reuse of the spherical Co nanoparticles. Catalytic experiments under similar conditions suggest that the regenerated particles still possess relatively good activity even after 7 cycles. The time of degradation of methylene blue dye with every cycle however increases and gets doubled during the 7th recycle experiment (Fig 3). After 4 consecutive cycles the cobalt nanoparticles were collected for HRTEM image to study their particle size distribution and to verify whether agglomeration or further degradation of particles has occurred. TEM image (Fig 4) of the recycled particles clearly show that no such phenomena have happened.

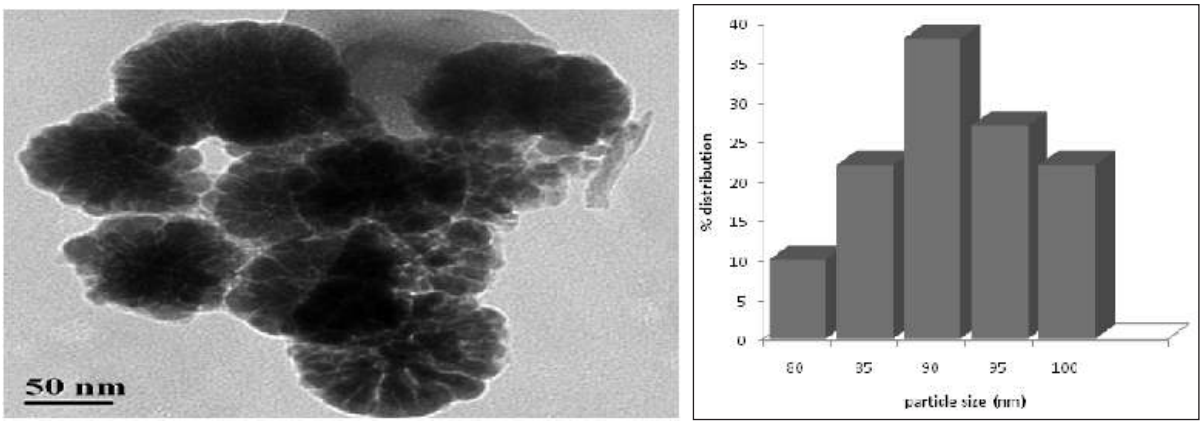


Figure 4 : TEM of recovered cobalt nanoparticles after 4th recycle

Conclusion

It is evident that the spherical cobalt nanoparticles can catalyze the degradation reaction of dyes in the presence of sodium borohydride and produces a remarkable enhancement in the reaction rate. It is highly air stable and represents an inexpensive, eco-friendly alternative noble metal catalyst suitable for waste water treatment. Another common belief that smaller particles behave as good catalysts because of their high surface area and more active centres has been proved wrong in the present case as palladium particles of much smaller size distribution were found to be inactive compared to larger cobalt particles as far as their catalytic behaviour is concerned. Further degradation reactions of organic dyes involving

various functional groups will be undertaken in future to elucidate the degradation mechanism using the cobalt nanoclusters.

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Agriculture Related Pollution and its Impact on Environment in Nadia District, West Bengal

Susmita Mandal
South Calcutta Girls' College, 72, Sarat Bose Road, Kolkata- 700025.
E-mail: susmitascgc@gmail.com

Abstract Indigenous agriculture is a natural process that hardly harms to land. Postmodern practices without proper application techniques have altered the situation. Various studies have shown that there are only few landscapes which have remained unaltered due to human interference at least in West Bengal. The landuse as well as cropping pattern is changing over time due to rapid increase in population. The intensity of cropping has also changed over time and it has a great impact on the natural environment. Nadia is one of the highest crop intensive districts in West Bengal and even in India also (year 2005-06). The Cropping pattern of the district is changing gradually due to availability of modern agricultural advantages such as HYV seeds, pesticides, insecticides, irrigation facilities, fertilizers, machineries and so on. Indiscriminate overuse of these facilities to ensure production ultimately caused pollution of agricultural land and subsequently it had affected the agricultural production too. Excessive withdrawal of ground water for irrigation purpose, causes lowering of the water table which again leads to contamination with arsenic. This arsenic is eventually deposited in crops and causes serious health hazards to man and animal. Agriculture induced chemical pollution of river-canals and water bodies are another source of irrigation, which causes adverse effect on crops. Jute being the most important cash crop of this area causes pollution of surface water due to processes of retting washing and cleaning of jute fibre. Checking agricultural pollution is much harder than it seems. Many farmers are moving back, partly to traditional ways of cultivation, such as using organic manure and pesticides to reduce land pollution. Rainwater harvesting is another process to stop ground water contamination. A complete shift in the way of agricultural practice can impose a rational control over pollution.

Key words agriculture, water pollution, productivity, irrigation, environment, arsenic.

I. Introduction

The majority of the population of West Bengal lives in rural areas and most of them depend on agricultural practices for their livelihood. Change of mode of agricultural practice is essential to feed the rapidly growing population. Increasing productivity of crops is not an easy task. The task is more challenging for developing country like India. Here the farmers use huge amounts of chemical fertilizer, insecticide-pesticide, irrigation water, HYV seeds for production without proper education and knowledge. They use these as per their common knowledge higher the inputs the higher the yield, (Banerjee and Sanyal, 2011).

II. Study area

The study area is the Nadia district of West Bengal, which is surrounded by Bangladesh in the East and Bardhaman District in the West, Murshidabad district to the North and South 24 Pargana and Hoogly in the South. Nadia district bounded by 22^{O} 53'' N to 24^{O}11'' N latitude and 88^{O} 09'' E to 88^{O} 48'' E longitude and covered an area of 3927 sq km..

According to Oldhum (1870) the area is a part of Ganga Brahmaputra Delta. Major soils are deep loamy soils and deep clayey loamy soils and fall under new alluvium agro-climatic zone. Main rivers are Bhagirathi, Jalangi and Mathabhanga. The area enjoys the tropical monsoon type of climate with hot humid summer and mild winter.

III. Objectives

The objectives of the study are to make an attempt to analyse the

1) Use of increasing rate of fertilizers, irrigation water and HYV seeds and their impact on local environment.
2) Over utilization of ground water and its impact on environment.
3) Introducing new varieties of crops and their effects.
4) Jute cultivation and related environmental problems.
5) Impact of agricultural pollution on animal and human health.

IV. Changing agricultural scenario of Nadia district

In the last four decades the development in the agriculture sector has grown rapidly in Nadia district with the help of development in irrigation and availability of HYV seeds. As a result the agricultural fields remain evergreen with seasonal crops. The crop intensity is very high in this district. According to NATMO in the year 2005-06 the national average of crop intensity was 135.88% and in Nadia district it was recorded as 278% which was the highest in India.

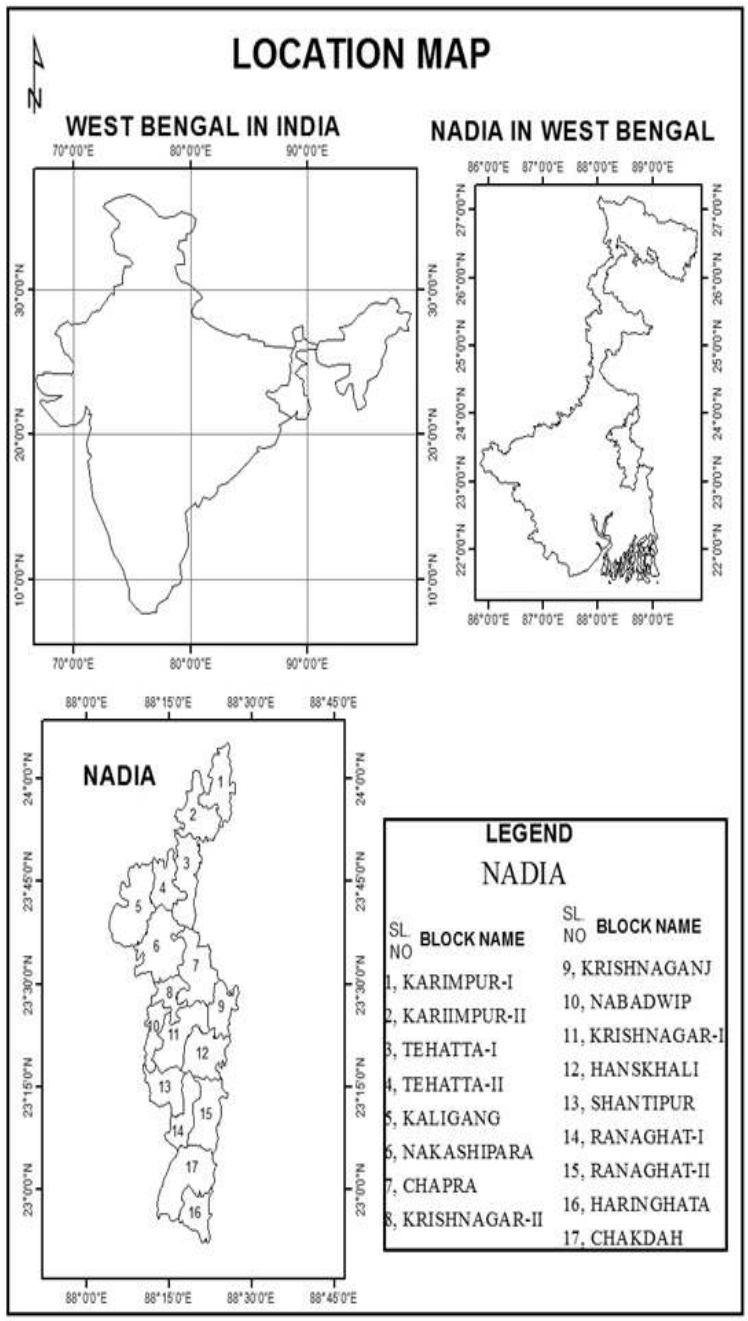

Figure 1 : Location map of the study area

Although the net cropped area is decreasing slowly due to landuse change, by growing population, but the total production is not affected. The main crops of the district are paddy, pulses, oilseeds, jute, sugarcane

and potato. Different types of vegetables, fruits and flowers are also grown. Main vegetables are brinjal, cauliflower, cabbage, peas, tomato, cucurbits, okra, chili, etc. Important fruits are banana, mango, guava, jackfruit, papaya, etc.. The flowers are Marigold, Rose, Gladiolus, Tuberose, Chrysanthemum etc.. The cropping pattern is determined by climatic condition, soil type, irrigation facility and market.

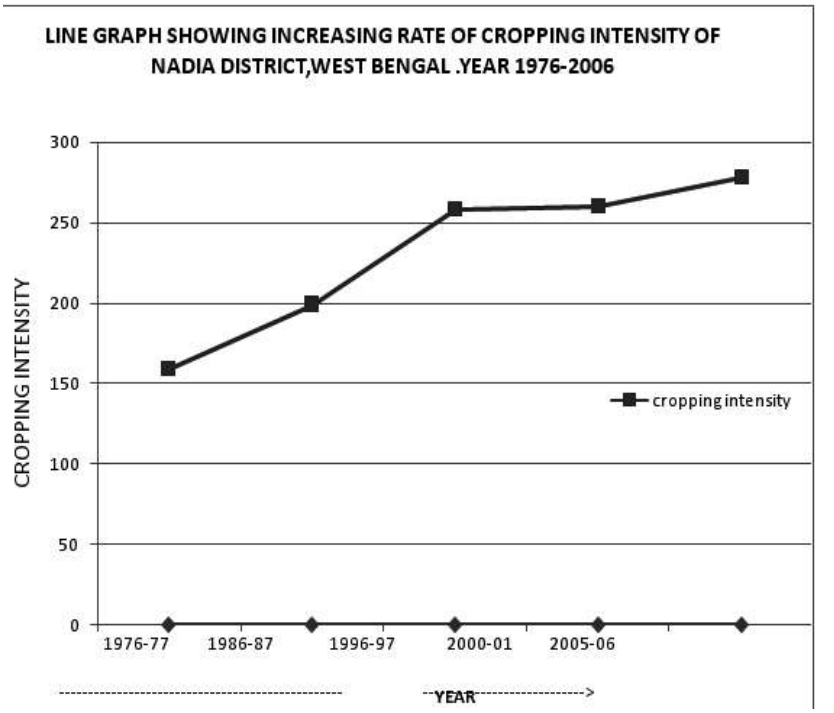

Figure 2 : Year wise variation of cropping intensity in the study area. Data source: Economic review 2011-12, Atlas of agricultural resource of India. District Statistical Handbook, Nadia. (Data compiled by the author)

4.1 Irrigation facility

Agriculture is not possible during the non monsoon season without the irrigation facility. Minor and small irrigation projects are the main source of irrigation water. Till 1967-68 the net irrigated area was only around 3% in 1976-77 the area under irrigation was 30.37 % of total agricultural land, which rose to 79.48 % in 2007-2008 in this district. Mainly deep tube wells and shallow tube wells are used for irrigation purpose, River lift irrigation (RLI scheme) facility is available only limited villages which are located near rivers. Significant amount of surface and ground water resource is exploited in this district, which is still continuing.

Figure 3 : Deep tube-well is one of the important sources of irrigation. (Photo by author)

4.2 HYV seeds

Over the last four decades from present the district witnessed an impressive growth in crop production due to the adoption of semi dwarf high yielding varieties coupled with the adoption of intensive input based management practices HYV seeds encourage a positive shift from single cropping to continuous cropping. The seeds are easily available from the Government farms or procured from district level agricultural authorities or in the open market. Almost the entire area under paddy, wheat and jute are occupied by HYV seeds. The common HYV seeds

of paddy are IR50, IR36, IET-2815, IR1009, Bhasamanik etc.

The jute varieties are Sabuj sona, IET 2830, IET 2707, Shyamali (JRC-7447), JRO-6321, JRO 7835 etc.. Wheat varieties are UP 262, H. P. -1209, Sonalika etc.. Not only that, even vegetables, fruits and flower seeds belong to High Yielding varieties. Huge amount of fertilizer and water are required for the success of the use of these seeds.

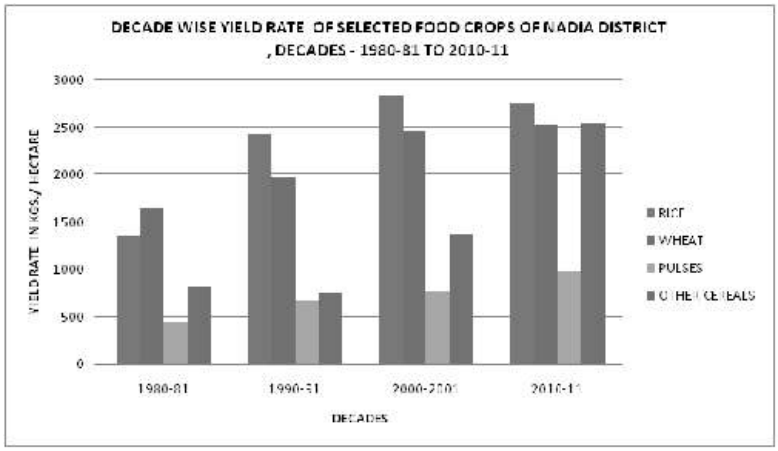

Figure 4 : Decadal variation in selected food crop production in the study area.
Data Source: District Statistical Handbook, Nadia.

4.3 Fertilizers, insecticides and pesticides

To achieve the target of the crop production huge amount of fertilizers, insecticide and pesticides are used in agricultural fields in Nadia district. Fertilizer compounds are added to promote plant growth. There are two types of fertilizers used in the agricultural fields, i.e. organic and inorganic. Organic matter like cow dung and parts of the plants are used. The inorganic fertilizers are nothing but chemical fertilizers. The common nutrients are Nitrogen, Phosphorous and Potassium (NPK). There are also some other nutrients such as calcium, magnesium, manganese, iron, zinc, copper, etc.. The consumption of fertilizers in the year 1976-77 was only 7850 metric tonnes, which has increased to 100.9 thousand metric tonnes in 2010-11. It's very important that the farmers must know about the combination of fertilizer, which are used for the particular crop to avoid damage through over or improper use.

Figure 5 : Cultivation of High Yielding Variety of paddy. Krishnanagar-I block. ***(Photo by author)***

Pesticides, insecticides are applying for safeguarding against pests and insects. Mainly chemical substances are used as a pesticide and insecticide. Chemical pesticides are poisonous to animals and human being. Indiscriminate use of these also very harmful to the environment.

V. Impact on physical environment and human health

- Excessive withdrawal of ground water may cause of arsenic leaching from the source, a huge number of the population of the study area is suffered by the toxicity of arsenic. All 17 blocks of Nadia district contain arsenic above the WHO guideline value of arsenic in drinking water. Arsenic effected patients

mainly found in Karimpur I and II, Tehatta I and II, Nakashipara, Nabadwip, Santipur, Chakdaha and Haringhata block.

- High doses of arsenic and other chemicals in drinking water causes characteristic skin manifestation, heart disease, renal disease, neurological effect, chronic lung disease, gastrointestinal infection and cancer of the skin, liver, lung, kidney and bladder (Singh et al.,2007).
- Pesticide pollution is one of the most serious problems of the area. Soil is contaminated by spraying of pesticides on the crop or direct soil treatment by using this. Later it washes out with water and pollute pond and river water, sometimes it reaches to ground water by leaching.
- Pesticides and insecticides are used against pests and insects, but most of the time non –target species also get harmed. Every year huge number of aquatic animals, including fishes and snakes are dying from the poisonous effect of pesticides.
- Jute is the one of the important cash crop of Nadia district. Harvesting is done in the July, August month; the fully grown plant cut and keeps the whole plant in ponds or stagnant water for 12-16 days for retting. After retting is complete the raw jute is peeled from the plant. The whole process pollutes the water completely which is harmful to aquatic life, sometime common ponds are used for retting thus the polluted water spread skin diseases rapidly among the villagers.
- Due to water pollution, water born diseases and skin problems are very common problem in the area.
- During dry season part of the river bed of Jalangi is used for cultivation purpose; and it causes siltation within the river. Thus the depth of the river decreases gradually and it hampers aquatic life. The Ganges dolphin found in Jalangi River in the upstream area in the eighties of last century, but now a few of them only found near the mouth of the river.

Figure 6 : Jute retting process is another source of water pollution in Nadia district. ***(Photo by author)***

VI. Suggestions

- Use alternative sources of drinking water or remove arsenic by using low cost, affordable, useful instrument or technology.
- Safe arsenic free drinking water and high protein diet are important remedial steps to prevent toxicity of arsenic.
- Popularization of bio-fertilizer to increase the production at the same time controls the adverse effect of chemical fertilizers.
- Give emphasis on crop rotation with leguminous crops to increase the soil fertility naturally.
- Sustainable exploitation of ground water resource.

- Widely introduce rain water harvesting process where possible.
- Maximum water-bodies, oxbow lakes are in derelict and the semi derelict condition in this district to use surface water for irrigation purpose. These are the other source of water pollution. So, large water body management is necessary.

VII. Conclusion

The agricultural practice in Nadia district developed with remarkable pace during the last four decades. However The indiscriminate use of fertilizer, insecticide, irrigation puts the environment in danger and it has the adverse effect on human health also. Researcher, planner, administrator has very clear views about the present environmental problem of this district. But the general people has not the proper awareness of the situation, who suffering from the problems. So that not only the Government but the NGOs also has great responsibility in this field. Agricultural development is necessary in this area, but in a sustainable manner.

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Alluvial Micro-Fungi: A Repository for Lignolytic Enzyme

Ipsita Roy, Sowptika Pal, Anindita Chakrabarty, Arnab Mandal, Rumki Sarkar, Madhuri Toppe, Dr. Sudeshna Shyam Chowdhury
St. Xavier's College, Kolkata

Rupa Chakrabarty
New Alipore College, Kolkata, E-mail: ipshi.micro@gmail.com

Abstract The Gangetic alluvium is a suitable site for bamboo leaching for its preservation and this very site contains the moulds which, if given a chance, can degrade bamboo. The soil is also contaminated with heavy metals coming from toxic chemicals of idol paint and mixed industrial/municipal slag. Two prominent moulds were isolated from the soil and identified as *Penicillium* sp. and *Pythium* sp. on the basis of their spore character. Their in-vitro activity on bamboo chips showed that they reduced bamboo around 25% in 21 days of time and produced the enzymes like lignin peroxidase, manganese peroxidase, laccase, cellulose exoglucanase, pectin lyase, polygalactouranase with manganese peroxidase (0.69U/ml in *Penicillium* sp. and 0.52 U/ml in *Pythium* sp.) showing highest activity followed by lignin peroxidase. *Penicillium* sp. showed better enzymatic activity of the two and further investigation revealed it to be tolerant to heavy metals like Cadmium and Lead obtained in high amounts from the soil. This shows that extremophilic are produced which can be used in biodegradation of materials of plant origin. Thus, these moulds help in biomining and enzymatic recycling of complex lignin enriched substrate.

Keywords Gangetic alluvium, *Penicillium* sp., *Pythium* sp., extremophilic, biomining

I. Introduction

Bamboo is botanically classified as a woody grass with increasing importance for sustainable production of materials with many applications for structures and industrial utilization. However, bamboo has a low natural durability and is attacked by fungi during storage, transport, processing and final use (Schmidt *et al*. 2011). There are several reports on its degradation by fungi. The behaviour of bamboo against decay fungi is an important parameter in bamboo establishment and use. Most investigations revealed that bamboo degradation is due to white and soft rot fungi, whereas brown-rot species are less aggressive. The degradation of lignin is brought about by fungi mainly belonging to Basidiomycetes (Rao, N.S.S. 2008). Over 600 species of Basidiomycetes have been found to be lignolytic, converting lignin to CO_2, by secreting extracellular lignin peroxidase and manganese –dependent peroxidase isozyme (Kumar, D. and Guptha, R.K., 2006). The important lignin degrading fungi are *Clavaria, Clitocybecollybia, Flammula, Hypholoma, Lepiota, Mycena, Pleurotus, Agaricus, Polyporus, Fusarium, Arthrobotrys, Poria, Pholiota, Cephalosporium, Collybi,* and *Humicola* (Atlas, R.M. and Bartha, R. 1998). Lignin degrading enzymes can also be used in soil bioremediation (Duran, N. and Esposito, E., 2000). The solid state fermentation treatment using lignin degrading soil fungi improves the nutritive value of paddy straw (Reddy et. al., 2008). The biological degradation of lignin is critical to the biospheric carbon and oxygen

cycle and is responsible for much of the natural destruction of wood in use. Applications utilizing lignin-degrading organisms or isolated enzymes provide environmentally friendly technologies for the pulp and paper industry and for the treatment of many xenobiotic compounds and dyes. Despite the resistance of lignin to degradation, a number of fungi are able to breakdown lignin. The best characterized degraders are white-rot fungi, in particular *Phanerochaete chrysosporium* and *Phlebia radiata* although brown-rot and soft-rot fungi are also able to degrade lignin. White-rot fungi secrete phenol oxidases, including lignin peroxidase, manganese peroxidase, and laccase, that attack lignin. These enzymes act through radical reactions, but there is as yet no commercial biocatalytic process for lignin depolymerisation (Chai Liyuan, Shi Yan et al., 2013).

Environmental problems associated with heavy metals are very difficult to solve in contrast to organic matters because incineration or biodegradation can transform the latter. As a fact, most of heavy metals have toxic effects on living organisms when exceeding a certain concentration. Furthermore, some heavy metals are being subject to bioaccumulation and may pose a risk to human health when transferred to the food chain (Rajendran et. al., 2003). Lead (Pb) is one of the heavy metals that have been recognized as a potent human toxin. According to the water standards used by the World Health Organization, levels of heavy metals such as lead ions in wastewater must be controlled and reduced to set value (USEPA, 1986). It has been known for a long time that various living and dead microorganisms can remove heavy toxic ions from solutions. In addition, their applications are important in the general environment and in areas where potential exists for both clean wastewater and heavy metals recovery. The methods are now recognized not only as viable alternatives but a desirable alternative and/or addition to the traditional remediation technologies. The biosorption of heavy metals ions by microorganisms is a promising property with a great potential for industrial applications.

This study was undertaken to understand the different lignin and cellulose degrading enzymes found in fungi and also to study the uptake and tolerance of different heavy metals, found in the soil sample, by these microorganisms.

II. Materials & Methods

1. **Sample Collection:** The soil sample was collected from the banks of the river Ganga in Kutighat, Baranagar. In these ghats, the alluvial soil deposited by the Ganga is used to leach bamboo. Firstly, the soil sample was collected in a sterile plastic conical. Physiological characterisation of soil was done.

2. **Isolation of microorganisms:** The soil was serial diluted in sterile water upto 10^{-3} concentration. 10^{-2} and 10^{-3} was pour plated in nutrient agar plates and kept in the incubator at 30ºC for 48 hours. Two prominent small fungal colonies were observed and pure culture was done on Sabouraud agar and one was incubated for 7 days and the other for 14 days to get visible spores. On the basis of spore character and mycelia, as observed under the microscope, the possible organisms were identified.

3. **Lignin Content:** 2gm sample of oven-dried extractive-free bamboo was used for determination of lignin composition, following TAPPI Method T 264 om-88.

4. **Bamboo Degradation:** Bamboo degradation was carried out in in-vitro and in-vivo conditions. Under in-vitro conditions, previously autoclaved bamboo chips were dispensed in 60ml Sabouraud broths in two separate flasks of same volume. Another flask was kept as control with sterile water. In

one of the Sabouraud broth flasks, tablets bored from *Penicillium* sp. pure culture was given and in another flask, *Pythium* sp was given. The flasks were plugged with sterile cotton and incubated at 30°C for 21 days.

In in-vivo condition, a previously autoclaved and weighed bamboo chip was inserted in 300gm of soil in a flask and incubated at room temperature for 21 days. About 100gm of the same soil was sterilized in a beaker and to it another autoclaved and weighed bamboo chip was given and incubated at room temperature for 21 days.

After 21 days of incubation, the fungal mesh was harvested from the in-vitro setup and its fresh weight was noted down. The bamboo chips were cleaned of fungal mesh and air dried. Then they were put in hot air oven for 1 hr at 90°C and weighed again, after which they were kept in the hot air oven for drying for 4 days at 60°C. The weight was again taken after 4 days. The bamboo chips collected from the in vivo setup was also dried and weighed in the same way as aforementioned.

5. Enzyme Assay: The enzyme activity of some of the lignolytic enzymes were found out by assaying the enzymes from the fungal mesh.

   (i) Lignin peroxidise: The assay was done based on the oxidation of vetryl alcohol to vetraldehyde in the presence of H_2O_2. The increase in absorbance was measured at 310nm.

   (ii) Manganese peroxidise: The activity of this enzyme was determined spectrophotometrically at 270nm by following the formation of Mn^{3+}-malonate complex at pH 4.5 in 50mM sodium malonate buffer with 0.5nM manganese sulphate. The reaction was initiated by adding H_2O_2 to the final concentration of 0.1mM.

   (iii) Laccase: This enzyme was assayed by monitoring the oxidation of 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid (ABTS) by the enzyme extract at pH 4.5 & 35°C. Laccase activity assay was performed in 2.1ml reaction mixture containing 1ml of 50mM malonate buffer (pH4.5), 1ml of 1mM ABTS & 0.1ml of enzyme solution. ABTS oxidation was measured at 420nm.

   (iv) Cellulose exoglucanase: Exoglucanase activity was measured using a reaction mixture containing 1ml of enzyme solution with 1ml of carboxymethyl cellulose (CMC) in Mcllvaine's buffer (pH 5) and incubated at 40°C for (Nitisinprasert and Temmes,1991).

   (v) Pectin Lyase: The enzyme solution was analyzed by continuous spectrophotometric rate determination method (Albersheim P.,1996) at 235nm under 40°C and pH 5. When the crude enzyme solution is added to pectin solution in the above said conditions, the enzyme starts to break the glycosidic bonds of pectin by β elimination.

   (vi) Polygalacturonase: It is a depolymerise that catalyses the hydrolysis of 1,4-glycosidic linkages in linear homogalacturonan regions of pectin polymers. Activity of this enzyme was measured at 540nm.

6. Determination of presence of metals in the soil: The metals present in the soil were determined on the basis of atomic absorption spectroscopy.

7. Determination of metal tolerance by fungi: Metal tolerance of *Penicillium* sp. for each metal was carried out using metal salts like lead chloride, calcium chloride and cadmium sulphate in different

concentrations of 100ppm, 20,000ppm, 10ppm respectively. Tolerance of the fungus was also observed in cadmium-calcium and lead-calcium interaction. These setups were incubated at 30°C for 10 days. After 10 days, the fungal biomass was harvested and fresh weight was noted down and reduction in growth was calculated.

8. Metal uptake by fungi: Dried fungal mass was treated with 70% Nitric acid for acid hydrolysis test and sent for determination of metal uptake by the principle of atomic absorption spectroscopy.

III. Results

1. The soil was found to have a pH close to neutrality, a very high electrical conductivity and high moisture content (Refer table 1).
2. According to the report provided by SGS India Pvt. Ltd. quiet an elevated amount of the heavy metals cadmium and lead are obtained along with a high concentration of calcium. (Refer table 2).
3. The possible fungal organisms were noted as *Penicillium* sp. and *Pythium* sp. on the basis of their spore and mycelial structure observed under microscope.
4. Lignin content was calculated to be 24.12% for 1.8 gram of bamboo chip.
5. Using the data of table 4 and table 5 it could be calculated that 100gm biomass of fungi could degrade 100gm of bamboo by 25.87% for Pythium sp and by 25.44% for *Penicillium* sp.
6. The enzyme activity of all the enzymes that were assayed showed greater activity for Penicillium sp than Pythium sp. (refer Graph 2).
7. From the result it can be seen that calcium shows less % of reduction in growth of fungi in broth (37.6%) as compared to lead (67.6%) and cadmium (95.3%). While in interaction of lead and calcium it is seen more % reduction in growth (61.7%) in comparison to only calcium salt. Even in case of cadmium and calcium interaction, growth is reduced in comparison to only calcium salt. Less % of reduction means more metal tolerance. Hence, we can conclude that calcium enhances growth of fungi as compared to individual metal concentration but in interaction because of cadmium and lead the growth is suppressed to some extent (refer table 5).
8. From the results it can be concluded that in presence of calcium along with both cadmium and lead the fungi has shown vigour in growth as compared to its growth in individual cadmium and lead.(refer table 6)

IV. Discussion

This project was aimed to study the properties of lignin degrading microorganisms obtained from soil where bamboo leaching is done.

Initially the soil characterization is done to obtain the pH (6.8),electrical conductivity (106.7μS at 25°C) and moisture content (32.5%) which gives us an insight about the type of microorganisms that can be found in the soil and also that the soil contains a lot of metal ions. Bamboo leaching is a process wherein the freshly cut bamboo are placed near running water so that the starch present in them is removed and the

bamboo becomes durable against pathogen or pest attacks. The starch released in the soil from the bamboo can increase the presence of such microbes which are starch utilizing and even the bamboo presence can do the same. *Pythium* shows vigorous growth in presence of starch (Shipton WA,1987) and that it can degrade Bamboo has been reported. Similar reports have been obtained in case of *Penicillium* sp (Fangli et. al., 2011) where its infection on Bamboo has been reported and the presence of alpha amylase in it has been informed (Metin et. al., 2012). In this project these two fungi were very prominently isolated from soil dilution of 10^{-2} and 10^{-3} respectively.

The inner part of Bamboo is mainly prone to attack by microorganisms which are soft and delicate. During leaching process due to the continuous flow of water the microbes do not get stability to colonize but if given a chance or favourable condition these rapidly grow on bamboo to degrade it. During this project both the bacteria as well as fungi were isolated from the soil but work is mainly done with fungi where it was found that both the fungi separately showed almost similar percentage of degradation (*Pythium* 25.87% and *Penicillium* 25.44%) but from the enzymatic assay it was proved that *Penicillium* had more enzymatic activity than did *Pythium* sp and so its tolerance and uptake capacity for heavy metals were conducted, the heavy metal presence in the soil sample was checked by atomic absorption method done in SGS. The presence of a number of heavy metals has been reported (Aktar et al., 2012) in Ganga water and as is the location of this sample lead, cadmium could be found in probable amount (9.89ppm and 1.35 ppm respectively). Even calcium was found in high amount (20397.21ppm).

In order to analyze the stamina of the fungi in increased metal amounts than in which they are isolated from, metal tolerance and uptake is studied at an elevated amount of heavy metals. It is reported that calcium has slight inhibitory action in fungal growth in very high concentration but if given in presence of metals which inhibit the growth of fungi, their growth normally enhances (E.B.G. Jones and D. H. Jennings, 1964). Similar results are obtained in this project where in such high concentration of calcium the fungi growth did reduce in comparison to the control where there was no metal ions added and showed a considerable increase in growth in presence of cadmium and lead suggesting that calcium helped fungi survive the high concentration of cadmium and lead which would otherwise have reduced fungal growth (refer table 5).

In case of metal uptake results suggest that more of calcium is taken up in presence of these toxic metals and this suggests that there might be a mechanism of fungi to cause detoxification of itself from the heavy metals by use of calcium hence showing growth. Though lead uptake is less in salt mixture in comparison to when it is only applied but still the growth of fungi is more so fungi can bear lead uptake.

From the observations of the project it could be concluded that Penicillin has higher enzyme activity than *Pythium* in Degrading Bamboo and the growth enhancement by calcium of fungi might also increase the degradation property of it on bamboo. This calcium has helped maintain the growth of fungi even in 10 times elevated amount of heavy metal which gives a possible reason as to why the fungi could survive and even retain its activity in such extreme conditions.

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Tables and graphs:

Characteristics	**Results**
Colour of soil	Deep Grey
Texture	Clayey
Odour	No significant odour
pH of soil	6.8
Electrical conductivity	106.7µS at 25°C
Moisture content	32.5%

Table 1: Physical properties of soil

Metals	Limit of reporting	Results obtained
Cadmium (Cd)	1.00 mg/kg	1.35 mg/kg
Lead (Pb)	1.00 mg/kg	9.89 mg/kg
Calcium (Ca)	1.00 mg/kg	20397.21 mg/kg

Table 2 : Concentration of metals obtained from soil

Bamboo chip inoculated in	Initial weight of Bamboo chips (x)	Weight after 4 days of drying (y)	Net weight (x-y)	% reduction in Bamboo chip weight
Water contol	1.8 gms	1.6818gm	0.1182gm	6.5%
Broth containing Pythium sp.	1.8 gms	1.662gm	0.138gm	7.67%
Broth containing Penicillium sp.	1.8 gms	1.6276gm	0.1724gm	9.58%
Sterile soil	1.8 gms	1.716gm	0.084gm	4.67%
Soil	1.8 gms	1.5328gm	0.2672gm	14.84%

Table 3: Percentage reduction in bamboo weight

Fungi type	Total fresh weight obtained (gm)	Fresh weight of fungi kept for drying(gm)	Dry weight after 4 days (gm)	Total dry weight (gm)
Pythium sp	4.5824	1.1834	0.1378	0.5336
Penicillium sp	2.909	0.401	0.0934	0.6776

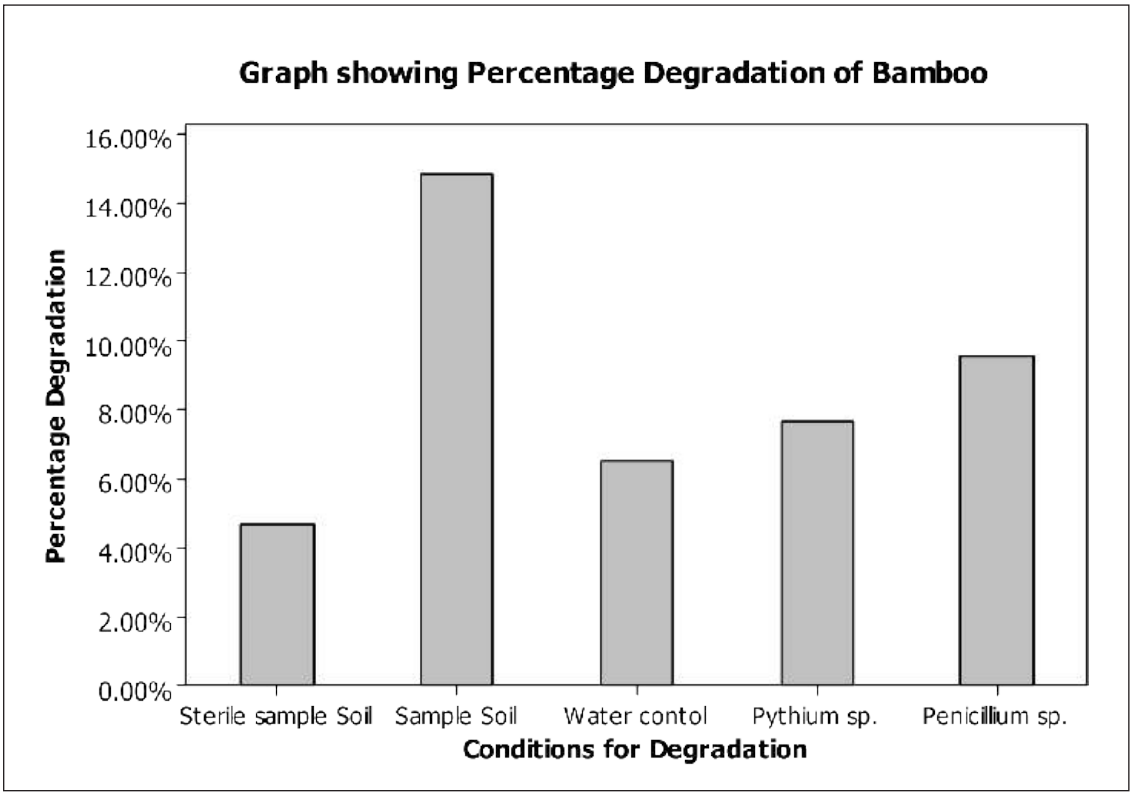
Table 4 : Fungal Dry weight Calculation

Sample	Average Weight (gm)	% of Reduction in Fungal Growth	Standard Error
Lead	0.23	67.6%	0.23±0.03
Calcium	0.43	37.6%	0.43±0.14
Cadmium	0.033	95.3%	0.033±0.0084
Cadmium + Calcium	0.265	50.6%	0.265±0.013
Lead + Calcium	0.343	61.7%	0.343±0.013

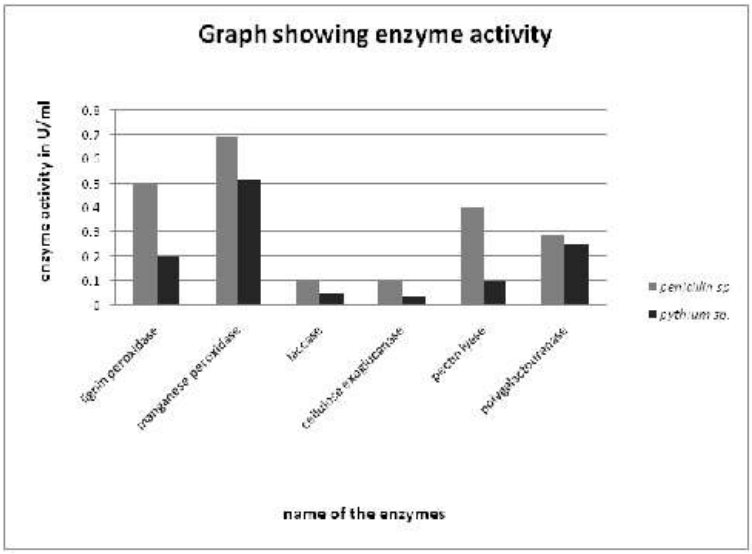
Table 5 : Percentage reduction in fungal growth

Sample	Concentration of metal ion	Sample volume	Metal uptake (mg/l)	Average fresh weight of biomass
Calcium	20,000 ppm	10 ml	88.18	0.433gm
Cadmium	10 ppm	10ml	0.23	0.0325gm
Lead	100ppm	10ml	2.49	0.225gm
Cadmium+ calcium	1:2000 ppm	10 ml	230.84 for Ca and 0.4 for Cd	0.3425gm
Lead + calcium	1:200 ppm	10 ml	176.59 for Ca and 1.0 for Pb	0.265 gm

Table 6 : Metal uptake results



Graph 1: percentage degradation in bamboo



Graph 2: Graph showing enzyme activity

Hazardous Metals and Minerals Pollution of Water in West Bengal

Dr. Maitrayee Basu Roy
Vidyasagar College for Women, Kolkata-700 006, E-mail: maitrayeebr@gmail.com

Abstract Worldwide, just under 900 million people lack reliable access to safe water. Water pollution particularly due to hazardous heavy metals like Lead and minerals such as fluoride and arsenic salts is an important societal problem. Many of these elements are dangerous as they tend to bio-accumulate. Contamination of underground water by such elements as arsenic, lead etc and the related health hazards is of considerable concern throughout world. This article discusses the status of pollution of water by some hazardous metals and minerals, particularly, arsenic, lead and that of fluoride ions in West Bengal.

A large number of people dwelling in the deltaic regions of West Bengal use water with arsenic in excess of the limit prescribed suitable for human health. The affected areas, confined within the Ganga–Brahmaputra Delta (GBD), expose nearly 6 million people in West Bengal to such high arsenic concentrations. Fluoride and lead contamination in drinking water is also a burning environmental issue of the world today. The people of nearly 29 countries are affected with 'fluorosis' due to intake of fluoride-rich water. In India, the menace of this deadly poison is being reported from some parts of West Bengal too. As per various surveys and investigations, lead contamination in water in some pockets of West-Bengal is also a matter of grave concern.

For many rural areas in West Bengal, where hand-pumps and tube-wells are the only source of safe drinking water, these contaminants have emerged to cause a serious crisis threatening public health.

Key words water pollution, arsenic, fluorosis, lead, West Bengal

I. Introduction

Arsenic pollution

Arsenic contamination in groundwater in the Ganga- Brahmaputra fluvial plains in India and Padma-Meghna fluvial plains in Bangladesh and its consequences to the human health have been reported as one of the world's biggest natural groundwater calamities to the mankind [1]. In India, many areas from West Bengal have been shown to be affected whereas Bihar is an emerging area with high Arsenic contamination. Newer areas are suspected to be Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Nagaland, Uttar Pradesh and Tripura. Outside of India within GMB (Ganga-Meghna-Brahmaputra) basins, the southern parts of Bangladesh are long affected from Arsenic just as in West Bengal. According to a recent survey, the number of affected villages in the state is around 3417 in 107 blocks in some nine districts [2]. A brief review of the situation in West Bengal is discussed.

Brief Background

Groundwater arsenic contamination and its health effects in South-East Asian countries came to limelight during the last decade [3]. Bangladesh, India and China [4] are the worse arsenic-affected nations. In India some areas of all the states (Uttar Pradesh, Bihar, Jharkhand, West Bengal) in Ganga plain are arsenic affected and thousands are suffering from arsenic toxicity and millions are at risk [1]. Officially, arsenic poisoning in West Bengal was first diagnosed by a dermatologist K.C. Saha of School of Tropical Medicine (STM), Kolkata, to an outdoor patient of village Ramnagar of Baruipur police station in the district of South 24-Parganas on 6th July, 1983 [5]. Later it came out that many arsenic patients existed in

many villages well before 1983 but they could not be clinically diagnosed, so were not highlighted. Garai et al.[6] reported the first scientific paper published on Arsenic toxicity in West Bengal where he had warned of malignancy of the hyperkeratotic spots and liver if diagnosis is delayed.

The first Steering Committee was constituted by the Govt. of West Bengal in 1988, which conducted the multi centric study to find out the cause of the problem. This study was supported by Rajiv Gandhi Drinking Water Mission. Thereafter a number of Task Forces were constituted by the State Govt. during the 90s and the present reconstituted Task Force is functioning since 2001[7]. Almost all academic and research institutes working in Arsenic and ground water quality related problems are represented in the Task Force. The School of Environmental Studies (SOES), Jadavpur University joined the arsenic work at the beginning of 1988. The State Govt. has developed a master plan for long term mitigation for the problem in consultation with the task Force.

II. Sources of arsenic in ground water

1. The principle sources of arsenic are from arsenic bearing geologic material. The presence of sulphide mineral deposits in the field and the association of arsenic with such types of minerals suggest very strongly that these are the origin for the near field arsenic sources.
2. The problem of groundwater pollution by arsenic is found in the interfluvial region of the Bhagirathi-Hugli and the Jalangi-Ichamati rivers lying mostly in the eastern part of the Bhagirathi-Hugli river of West Bengal. The arsenic contamination in ground water beyond permissible limit of 0.05mg/l has been found within the shallow aquifer (20-60m below ground level). Apart from this area, other areas where higher incidence of Arsenic has been reported are four blocks (adjacent to the river Ganga) in Malda district, Purbasthali block of Bardhaman district and Balagarh block of Hugli district.[8]
3. Groundwater with higher concentration of arsenic generally occurs within 20-80m depth zone, commonly known as shallow aquifers. The principal source of arsenic is the arsenic sulphides minerals deposited along with clay, peat, with iron in the reducing environment. The lowering of groundwater at rapid rate during summer season causes aeration of aquifer oxidized the arsenic sulphides, makes it water soluble. It percolates from the subsoil into water table during monsoon. The deeper aquifers are by and large free from arsenic, except at a few places where no perceptible clay layer separates the lower one from the upper aquifer.

However, the cause of arsenic contamination in groundwater is still a debatable topic. Hence, it is necessary to study extensively the groundwater reservoir condition, mode of recharge-discharge relationship, groundwater movement characteristics in time and space and to determine dissolved oxygen and oxidation reduction potential in ground water to appreciate the cause of such arsenic concentration in ground water.

III. Extent of problem in West Bengal

In West Bengal, during 1980s, some cases of arsenical dermatosis in the districts of North 24 Parganas, South 24 Parganas, Nadia, Murshidabad and Burdwan were reported. By the end of December 2001, this problem had spread from few villages to 2065 villages of 75 blocks in 8 districts. About 10 % of the total population of the State is exposed to the above risk. It can be observed from the map below, Fig-1 [9] that there is increase in number of incidences with the time. Table 1 shows the district-wise distribution of arsenic concentrations from all the 19 districts of West Bengal based on analyses from 140-150 samples

from hand tube well; 48.1% had arsenic concentrations above 10 µg/L and 23.8% above 50 µg/L. Importantly, 3.3% of the analyzed tube wells had arsenic concentrations above 300 lg/L, a concentration predicting overt arsenical skin lesions [10]. A total of 187 (0.13%) hand tube wells were found highly contaminated (1000 µg/L). The maximum arsenic concentration (3700 µg/L) was found in Ramnagar village of GP Ramnagar II, Baruipur block, in South 24 Parganas district. The map below demonstrates the groundwater arsenic contamination status of Ganga-Meghna-Brahmaputra plain and all 19 districts of West Bengal. Most of the highly arsenic-affected districts of West Bengal are on the eastern side of the Bhagirathi River (Fig. 1). Table-1 [2] shows an overview of arsenic contamination and its health effects situation in West Bengal up to November 2007. Based on the intensity of arsenic concentrations in West Bengal, three zones have been demarcated (Table 1): highly affected, mildly affected, and unaffected. Nine districts (Maldah, Murshidabad, Nadia, North-24-Parganas, South-24-Parganas, Bardhaman, Haora, Hugli and Kolkata), in which an arsenic concentration of A300 lg/L was found in some tube wells, are considered as highly affected. Out of 135 555 samples analyzed from these nine districts 67306 (49.7%) had arsenic concentrations above 10 lg/L, 33470 (24.7%) above 50 µg/L, and 4575 (3.4%) above 300 µg/L. Out of these nine highly affected districts, five (Maldah, Murshidabad, Nadia, North-24-Parganas, South-24-Parganas) are widely affected. In three districts (North-24-Parganas, Nadia, Murshidabad) more than 95% of the blocks had arsenic above 50 µg/L (Table 1). At present, of these nine highly arsenic affected districts, three (Haora, Hugly, Bardhaman) are on the western side of River Bhagirathi, but once the highly arsenic-affected blocks of these three districts lay on the eastern side of Bhagirathi River which then changed its course. For this reason, these three districts are highly (particular blocks) but not widely affected.

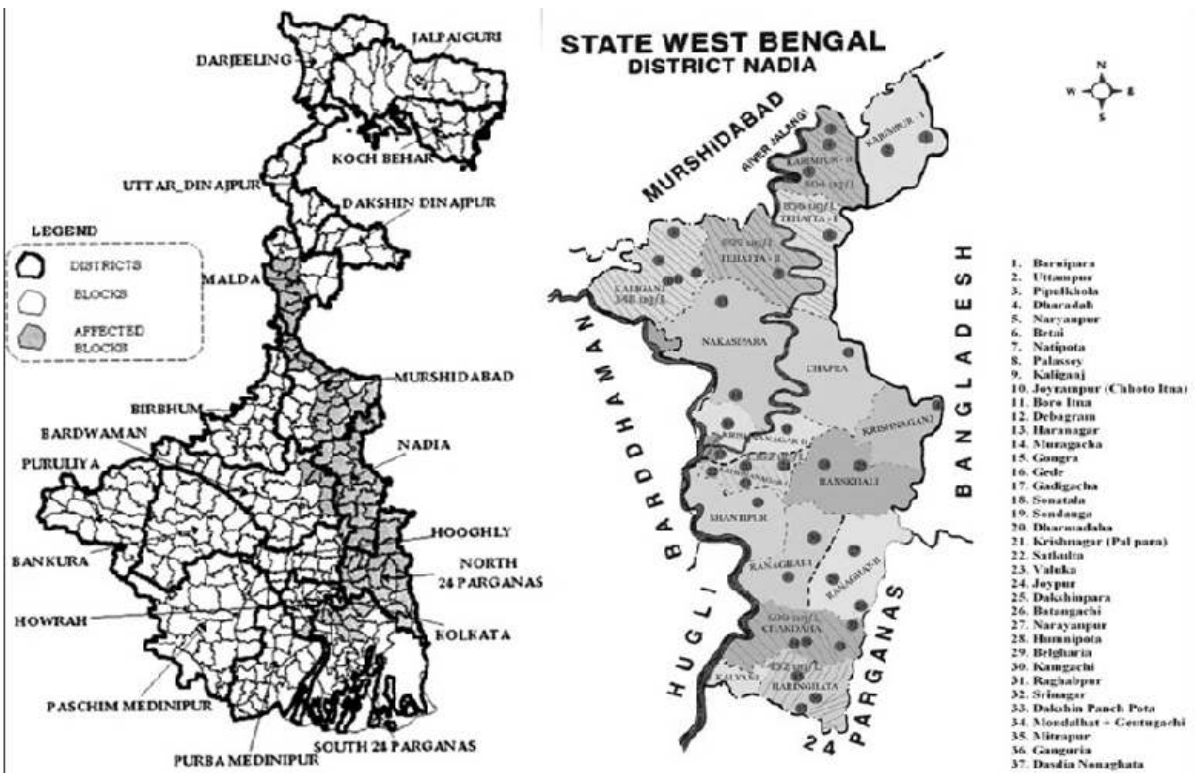


Fig-1. Arsenic affected blocks of West Bengal [Ind. J. Community Med_2010_35; http://medind.nic.in]

Five districts (Koch Bihar, Jalpaiguri, Darjiling, Dinajpur-North and Dinajpur-South), showing concentrations mostly below 50 µg/L (only a few above 50 µg/L but none above 100 µg/L), are considered mildly affected. The five other districts (Bankura, Birbhum, Purulia, Medinipur East and Medinipur West) are considered unaffected or arsenic safe (Table-1) [11].

Methods to combat Arsenic pollution

Several methods have been developed to remove arsenic from groundwater by the Public Health and Engineering Department (PHED), Govt of West Bengal, All India Institute of Hygiene and Public Health (AIH &PH), Tropical School of Medicines (S.T. M.), Calcutta and School of Environmental Studies, Jadavpur University which are indicated as follows [11].

i) Arsenic Removal Plant (ARP) fitted directly with Hand Pump

.ii) Arsenic Removal Plant for piped water supply scheme.

ii) Filtration of water: Various types domestic filters have been developed by the AIH &PH, PHED. These filters are fitted with sand as well as candle [2].

iii) Encouraging Surface Water schemes and Rain water harvesting.

Districts	Population	Total No. of Blocks	No. of Blocks surveyed	No. of Blocks with As>10µg/L	No. of Blocks with As>50µg/L	Distribution of total samples (in%) in different As conc. µg/L ranges.									Max. As Conc. µg/L
						≤3	4-10	11-50	51-100	101-200	201-300	301-500	501-1000	> 1000	
Highly affected															
North 24 Pgs	8934286	22	22	22	21	40.9	5.75	23.9	11.77	10.3	4.12	2.4	0.87	0.07	2830
South 24 Pgs	6906689	29	17	12	11	52.88	5.12	13.7	8.91	8.89	3.92	3.66	2.54	0.36	3700
Murshidabad	5866569	26	26	25	24	38.66	7.56	27.1	11.01	7.97	3.17	2.98	1.29	0.24	3003
Nadia	4604827	17	17	17	17	39.7	9.07	34.07	7.86	5.27	2.19	1.25	0.527	0.045	3200
Maldah	3290468	15	14	13	9	39.42	8.38	18.2	10.97	12.56	4.11	3.66	2.18	0.49	1904
Haora	4273099	14	12	12	7	60.43	15.36	13.05	5.91	2.79	1.495	0.815	0.068	0.068	1333
Hugli	5041976	18	17	16	11	66.41	15.64	11.34	3.48	2.35	0.633	0.0904	0.045		600
Kolkata	4572876	141[b]	100[b]	65[b]	30[b]	61.33	23.58	9.51	2.34	2.07	0.744	0.276	0.138		800
Bardhaman	6895514	31	24	12	7	79.38	2.99	9.26	3.26	3.38	1.02	0.417	0.227	0.038	2230
Mildly Affected															
Koch Bihar	2479155	12	5	4	1	85.02	12.02	2.74	0.2109						54
Darjeeling	1609172	12	4	3	0	89.3	8.89	1.78							19
NorthDinajpur	2441794	9	7	6	2	82.52	5.75	11.31	0.404						68
SouthDinajpur	1503178	8	6	2	1	88.05	10.4	1.327	0.221						51
Jalpaiguri	3401173	13	7	4	0	79.77	16.62	3.595							27
Unaffected															
Bankura	3192695	22	17	0	0	100									<3
Birbhum	3015422	19	11	0	0	100									<3
Purulia	2536516	20	15	0	0	100									<3
Mednipur East+West	9610788	25+29	10+10	0	0	100									<3

Table-1 : District-wise distribution of arsenic concentration in West Bengal (D. Chakraborti et al. Mol. Nutr. Food Res. 2009, 53, 542 – 551)

iv) Govt. plans and Programmes to supply arsenic free drinking water to the rural mass: Only the deep 3rd aquifer should be tapped for drinking water supply.

v) The water in new tube wells should be tested for Arsenic prior to commissioning.

Fluoride Contamination

Ingestion of excess fluoride in the human body may cause dental, skeletal and non-skeletal fluorosis. Again, low fluoride less than 0.5 mg/l causes dental caries. Proper safeguards are, therefore, required to be taken to ensure safe fluoride level in drinking water [12]. According to Bureau of Indian standards (BIS) [13] and ICMR [14], the highest desirable limit of fluoride is specified at 1.0 mg/l and the maximum permissible limit is 1.5 mg/l. In spite of this, fluoride contamination of groundwater is reported to be endemic in as many as 15 states in India.

In West Bengal, excess fluoride in groundwater has been detected so far in 43 blocks spread over seven districts, viz. Purulia, Birbhum, Bankura, Malda, South Dinajpur, North Dinajpur and South 24-Parganas [15]. As the problem spreads day by day, a scientific inquest to find out the source and cause of fluoride in groundwater of Purulia has become the need of the hour. For example, in the Purulia District instances of fluorosis are on the rise. The rural population is the worst affected because of the absence of centralized water-treatment system in these areas. Outbreak of media reports on this issue has become a matter of grave concern for the Government in view of the strategic location of Purulia, its poor socio-economic status and the tribal-dominated demography.

Source of fluoride in ground water

A review of the geological literature in Purulia has revealed that fluoride exists as a complex ion in a naturally occurring mineral called 'apatite', which is a fluorinated calcium phosphatic compound [16]. From experiments conducted in the laboratory, it has been found that a wide array of physico-chemical factors operating under different hydro geological regimes are responsible for fluoride enrichment to take place from the fluoride- bearing host (country) rock into the saturated zone of groundwater [17]. Although rock–water interaction seems to play a major role behind the enrichment process, fast recession of the water table (due to excessive groundwater withdrawal) and long spells of drought (as a fallout of climate change) have triggered the gradual leaching of fluoride into the circulating water[14]. Prevalence of physical and chemical weathering under arid to semi-arid conditions in high-alkaline groundwater zones further favours quick dissolution of fluoride into the circulating water. Industrial Fluoride pollution may arise from the manufacture of steel, aluminium, and fertilizers, where fluorapatite is used as a source of phosphorus. The intrusion of F into streams may result from nearby uneven joints, fractures, and faults in pipes carrying domestic, agricultural and industrial effluents. Moreover, hot springs near the Bakreswar and Birbhum regions may be responsible for F pollution in the adjoining areas [18].

The villagers who thrive on this nonpotable, fluoride-rich water bear the brunt of fluorosis and are clearly witnessed to suffer from yellow cracked teeth, joint pains, crippled limbs and quick ageing.

Remedial Methods

There could be various systems for the supply of fluoride-safe water to the community. However, such supply systems must be appropriate for the area-specific conditions. The option for fluoride-free safe water supply system could be the following:

i) River or lake water-based piped water supply.

ii) Big diameter tube well-based piped water supply (selecting the fluoride safe aquifers).

iii) Installation of deep tube wells attached with hand pumps (selecting fluoride safe aquifers, if available).
iv) Hand pump-attached excess fluoride removal units.
v) Use of traditional water sources (lakes/ponds) after treatment.
vi) Rainwater harvesting.
vii) Household treatment for excess fluoride removal

Lead pollution

Lead is the most significant toxin of the heavy metals, and the inorganic forms are absorbed through ingestion by food and water, and inhalation. Lead poisoning also causes inhibition of the synthesis of haemoglobin; dysfunctions in the kidneys, joints and reproductive systems, cardiovascular system and acute and chronic damage to the central nervous system [19].

Incidents of high content of lead have been found in ground water (bore well / well water), where as high as 41% samples were unfit for drinking. What is also shocking is that over 15% of Municipal Water had a high content of lead. Bengal has more than 27 highly polluted areas, including one in the heart of the city. An area in Picnic Garden, where used batteries are dumped, has been listed among the worst-affected places of the world in terms of lead pollution [20].

Sources of lead contamination of potable water supplies & groundwater

Lead Contamination due to PVC pipes is one of the major contributing factors of groundwater pollution in India [20]. The use of lead-based stabiliser in PVC pipes by Indian manufacturers is random. PVC pipes used in sanitation, plumbing & agriculture, manufacturing of PVC pipes & products, of PVC fittings and attachments play a vital role. Besides, lead acid batteries, paints, waste, Smelting operations, coal- based thermal power plants, ceramics and bangle industry are also sources of lead pollution.

Methods to combat lead pollution

i) Banning the use of lead and cadmium-based plasticisers or stabilisers in India is the best solution to eradicate lead pollution
ii) Removal of PVC pipes with high lead content from buildings and structures which have direct and indirect impact on the intake of drinking water.
iii) Ensuring only good quality PVC pipes are used in the farming Industry and banning the use of PVC pipes with high lead content.
iv) the government should give the highest priority to banning lead-based plasticisers from the PVC Industry.

IV. Conclusion & Suggestion

Water pollution could be a bigger threat than malaria or diarrhoea in a country like India. Managing the problem of water pollution needs an understanding of the process creating the contamination. It also needs effective planning, smooth operation of the administrative machinery and institutionalized expenditure. Tailings dumps and process wastes lying in locations close to the processing units need to be remediated on priority. Recycling/reprocessing of wastes containing toxic metals needs to be given greater emphasis not only from environmental and health considerations but also as a resource

conservation measure. Water supplied by urban municipalities and rural panchayats, should be free of (or contain within safe levels) of biotic and abiotic toxicants including heavy metals and minerals. Inexpensive devises for purifying water at household level have to be developed.

Creation of public awareness is very important. Greater interaction between scientists, technologists and media is needed to achieve that. School education can be a mechanism for creating awareness.

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Air Pollution Accounting for Sustainable Development Policy Decisions

Maniparna Syamroy
Asutosh College, Kolkata, E-mail : maniparnasr@gmail.com

Abstract Air quality is one of the important environmental issues in sustainable development as well as in public perception. The spurt of the developmental activities over the last decade has led to high level of emission and air quality deterioration. The conventional System of National Accounts (SNA) deals only with changing stock and flow of manmade capital but not of natural capital such as land, water, air, forest etc., and of its depleting stock as used up through its present economic activities. The indicator of sustainable development needs to be such so as to reflect the realities of economic growth and development. Continuous effort to find the right indicator as appropriate signaling mechanism of sustainable development, green accounting emerged as one of the possible indicators of sustainability. Appropriate quantification of natural asset would help in the assessment of stock and flow.

Air pollution levels and their impacts vary significantly from region to region. Greater Kolkata(KMDA area) being an important mega city has a good combination of industrial activity, large pollution density and high motor- vehicle use and therefore can give a good picture of the severity of air pollution for appropriate policy prescriptions in order to secure a better world for tomorrow.

This paper concentrates on how the air pollution accounting can be executed based on secondary data in order to monitor the sustainable development path way of the state. It can guide policy makers to make a standardised information system with regards to resource use and over-use, fill inconsistencies as well as data gaps and may ultimately lead to more efficient and consistent data collection system and policy planning.

Key words sustainable development, air quality, air pollution, environmental accounting, SEEA

I. Introduction : Air Quality-an important natural resource

The quality of air we breathe is one of the vital life support system. In fact air pollution is now a serious problem for most urban agglomerations. Rapid industrial developments, sharp increase in automobile fleet and huge combustion of fossil fuels have aggravated the situation of air pollution. The trade-off between competing priorities such as short-term economic gains and environmental quality brings forward the issue that market based economic benefits are not commensurate with the losses on the environmental service flow. It is important to note that the economic accounting is done almost entirely in monetary terms and although the economy operates within the natural environment; the inputs like air, water etc. used in production are taken to be "free" and not considered in the accounting framework. Keeping in view the notion of sustainable development, pollution accounting for these natural resources can be used an indicator that can guide the nations to consume without impoverishing itself. This could contribute to major decisions which have to be taken to check environmental degradation.

II. Resource accounting and the case of air accounts

The concept of resource accounting evolved in 1970s when the energy crisis led to energy measures. The Rio Earth Summit (1993) recognized the importance of environmental assessment and recommended that all nations along with United Nations in particular develop a System of Integrated Environmental and Economic accounting (SEEA). The UN System of National Accounts (SNA 93) had, therefore, included a set of guidelines for the preparation of a set of satellite accounts that will complement the conventional national income accounts. Thus, the United Nation Statistical Division responded to the need of the situation and came up with the system of Integrated Economic and Economic Accounting – a handbook on environmental accounting which set out a methodology to be followed for the valuation of natural resources and environmental degradation caused by anthropogenic approach. However, the methods and the concepts in this handbook are not the final conclusions and accordingly the handbook was issued as an interim version of the work in progress. In 2003, the revised handbook was published jointly by United Nations, the International Monetary Fund, the Organization of Economic Cooperation and Development, the Statistical Office of the European Communities (Eurostat) and the World Bank.

The System of Integrated Environmental and Economic accounting (SEEA) aimed at integrating environment and social dimensions in the accounting framework at least through satellite system of accounts. The satellite system of natural resource account is a modified system of income accounting showing environmental related sectoral activities separately along with their physical account flow changes valuation and possible link to main SNA.

Therefore the different resources such as air, water, forest must be separately accounted for through the satellite system of accounts. In case of air accounts, Air is a flow concept and not a stock, the quality of air needs to be preserved and protected for healthy survival of man and the other partners of the ecosystem. For this, the different air pollution parameters are to be monitored to get an idea of the quality.

III. Air Pollution Accounting

In case of Air accounts, the UN Handbook SEEA (2003) does not provide any guideline in the preparation of the account. So we have reviewed various literatures which considered air accounting. ESCAP (Volume II) , 1997 Chapter 2 shows how to prepare the air quality account in a step by step manner. It also highlights the point that air pollution levels and impact vary from place to place and, therefore, it is advisable to go in for a region specific approach.

The major air pollutants include Suspended Particulate Matter (Total and Respirable), Sulphur Dioxide (SO2), Hydrocarbons (HC), Nitrogen Oxides (NOx), Carbon Monoxide(CO), Photochemical Oxidants (Smog), Sulphates and Lead (Pb). The air pollutants are classified as primary and secondary pollutants depending on the process of formation. The primary air pollutants are generated directly from the source whereas the secondary pollutants are produced from primary pollutants by complex chemical reactions. The pollutants may be again categorised into local pollutant and global pollutants:

Local Pollutants are those pollutants which affect the air quality at the local level eg. RPM, SPM, SOx, NOx. On the other hand global pollutants are those long lived gases which affect the global atmosphere eg. Green House gases. Air quality of a region depends on the concentration of the above mentioned pollutants.

The West Bengal Pollution Control Board places importance in maintaining the desired level of standards for the above mentioned pollutants. The Industrial and Residential area will have to abide by the standards fixed for their areas. The standard levels for the pollution parameters we have considered is given in table below.

Pollutants	Time weighted average	Concentration in ambient air		
		Industrial Area	Residential Area	Rural & other Areas
1	2	3	4	5
Sulphur Dioxide (SO2)	Annual Average 24 hours	80 µg/m3 120 µg/m3	60 µg/m3 80 µg/m3	15 µg/m3 30 µg/m3
Oxides of Nitrogen as NO2	Annual Average 24 hours	80 µg/m3 120 µg/m3	60 µg/m3 80 µg/m3	15 µg/m3 30 µg/m3
Suspended Particulate Matter(SPM)	Annual Average 24 hours	360 µg/m3 500 µg/m3	140 µg/m3 200 µg/m3	70 µg/m3 100 µg/m3
Respirable Particulate matter (size less than 10 µm)(RPM)	Annual Average 24 hours	120 µg/m3 150 µg/m3	60 µg/m3 100 µg/m3	50 µg/m3 75 µg/m3

Table1 : Standard set for ambient Pollutant Concentration in West Bengal
Source: West Bengal Pollution Control Board Website

In this case of air quality accounting, we have tried to identify the possible areas of the high pollution concentration within the city based on the data of West Bengal Pollution Control Board and tried to evaluate whether there has been any change in status over two time points in the two consecutive years. The change was also observed over a gap of 10 years period. We have also done monetary valuation of air quality impact based on secondary information to find out the cost that is being imposed on the society. The assessment of the contribution of air pollution from various sources is another important part of air pollution accounting because it helps to formulate policy but this part is not taken up in this paper.

a) Air Quality Accounting : Air quality scores

We have tried to prepare a simple air quality score by ranking the maximum concentration levels for the four months – December, July, May and March for which the data is collected. We have assigned least numerical score to the best i.e. for the least concentration reported and maximum value to the worst. We have followed the Spearmen's ranking procedure i.e. when there is a tie we have assigned the average value. Thus we have the following table (Table2) which shows the relative ranking position of the different monitoring stations in terms of pollution concentration.

Stations/Score	RPM 04	RANK RPM 05	CHANGE in score for RPM	SPM 04	SPM 05	CHANGE in score for SPM	score N02 04	Score N02 05	CHANGE in score for NO2
Dunlop	15	15	0	15	11	4	10	14	-4
Ultadanga	12	14	-2	13	9	4	8	11	-3
Shyambazar	10	13	-3	10	15	-5	9	8	1
Saltlake	2	2	0	2	2	0	3.5	2	1.5
Beliaghata	3	6	-3	3	5.5	-2.5	7	4	3
Moulali	11	9.5	1.5	12	13	-1	15	15	0
Hyde Road	8	9.5	-1.5	5	10	-5	5	10	-5
Topsia	13	12	1	11	14	-3	12	12	0
Mominpore	9	7	2	9	7	2	3.5	6	-2.5
Minto Park	6.5	4	2.5	6	4	2	2	7	-5
Gariahat	6.5	11	-4.5	7	12	-5	13	13	0
Picnic Garden	5	8	-3	4	5.5	-1.5	6	3	3
Baisnab Ghata	1	1	0	1	1	0	1	1	0
Behala Chowrasta	14	5	9	14	8	6	14	9	5
Tollygaunge	4	3	1	8	3	5	11	5	6

Table 2 : Air Quality Rank and change in Rank for ambient air quality across wards in Kolkata city 2004, 2005
Source: Author's estimate based on the data collected from WBPCB

From the above table we can see the relative scores and changing value for different stations locations for the year 2004 and 2005. The change in score shows the relative change in the position from the year 2004 to 2005. If change is positive it indicates that air quality in that locality has improved, if the change is negative it shows that quality has deteriorated and if change is 0, it implies that air quality has not changed.

The observations that we can draw from the above table is presented in the following table (Table3):

Stations	Quality change with respect to RPM	Quality change with respect to SPM	Quality change with respect to NO2
Dunlop	No change	Improved	Deteriorated
Ultadanga	Deteriorated	Improved	Deteriorated
Shyambazar	Deteriorated	Deteriorated	Improved
Saltlake	No change	No change	Improved
Beliaghata	Deteriorated	Deteriorated	Improved
Moulali	Improved	Deteriorated	No change
Hyde Road	Deteriorated	Deteriorated	Deteriorated
Topsia	Improved	Deteriorated	No change
Mominpore	Improved	Improved	Deteriorated
Minto park	Improved	Improved	Deteriorated
Gariahat	Deteriorated	Deteriorated	No change
Picnic Garden	Deteriorated	Deteriorated	Improved
Baisnabghata	No change	No change	No change
Behala Chowrastra	Improved	Improved	Improved
Tollygaunge	Improved	Improved	Improved

Table 3: Observed changes in Air Quality over the year
Source: Author's estimate

In the next table (Table 4), we have tried to show the air

quality index considering all the pollutants. Since the SO2 concentration is much lower than the standard in Kolkata we have not taken SO2 into our consideration. Thus Air quality score for the year 2004 and 2005 is given below.

Stations	AIR QUALITY rank 2004	AIR QUALITY rank 2005	Change in Status
Baisnab Ghata	1	1	No change
Saltlake	2	2	No change
Beliaghata	3	5	Deteriorated
Minto Park	4	4	No change
Picnic Garden	5	6	Deteriorated
Hyde Road	6	9	Deteriorated
Mominpore	7	7	No change
Tollygaunge	8	3	Improved
Gariahat	9	12	Deteriorated
Shyambazar	10	11	Deteriorated
Ultadanga	11	10	Improved
Topsia	12	14	Deteriorated
Moulali	13	13	No change
Dunlop	14	15	Deteriorated
Behala Chowrasta	15	8	Improved

Table 4 : Air Quality score wise ranking
Source: Author's estimate

We can see from the above Table 4 that the air quality is best in Baisnabghata in both the two years, Saltlake occupies the second position in both the two years. The positive change is observed in Ultadanga, Behala Chowrasta and Tollygaunge Dunlop which was worse in 2004 has become the worst with respect to air quality. The ranking of these regions may act as one of important parameters of property price assessment. It can give a good indication of selection of housing projects as places with better indices are preferred for safer living. These can also help in prioritising policy for re-locating or managing pollution emitting activities. Such scores are of immense use for policy making. However, even a better view of spatial spread of air quality can be found by interpolation method which can be useful for city ward councils.

The change is the level of air pollution parameters was also observed after a 10 years point, 2014. But a major problem while executing this study is that the data set became smaller. Data was not available for a number of monitoring stations such as Beliaghata, Hyde Road, Topsia, Mominpore, Gariahat, Picnic Garden and Tollygaunge. But after these 10 years, Baisnabghata became worse primarily because of the increase in NO2 concentration and Saltlake became the best with respect to air quality. But we have tried to study the relative picture based on the data that is available as presented in Table 5.

b) Cost of Air Pollution

In the next part we have tried to make an assessment of the abatement cost associated with air pollution. A rough estimate suggests that 80% of the Kolkata population suffers from various degrees of respiratory disorders which are aggravated during winter period. (Green Governance, April, 2001. Table 6 relate air pollution with the associated diseases:

The high prevalence of air borne diseases is also confirmed in the studies related to air pollution in the city. According to a study by Dasgupta, 2005, 95% of the population in Kolkata believe that asthma attacks may be attributable to air pollution in the city and 85% concluded that eye/nose/throat irritations

Stations	Air Quality Rank 2014	Air Quality Rank 2005	
Dunlop	5.5	15	Improved
Ultadanga	5.5	10	Improved
Shyambazar	4	11	Improved
Saltlake	1	2	Improved
Moulali	8	13	It was 13th out of 15 in 2005 and now the last position.
Minto Park	3	4	Improved
Baisnab ghata	2	1	Deteriorated
Behala Chowrastra	7	8	Not much improvement as it was 8th out of 15 in 2005 and 7th out of 8 in 2014
Picnic Garden	NA	6	
Hyde Road	NA	9	
Beliaghata	NA	5	
Mominpore	NA	7	
Tollygaunge	NA	3	
Gariahat	NA	12	
Topsia	NA	14	

Table 5: Relative Ranking of Air Quality 2005 and 2014 of some monitoring stations

Pollutants	Short-term health effects	Long-term health effects	Source
Suspended Particulate Matter (SPM)	Sneezing, coughing, eye irritation, increase asthma attack	Many components of SPM are toxic and carcinogen	Motor vehicle use, Combustion products from space heating, Industrial processes, Power generation.
Respiratory particulate matter (RPM or PM10)	coughing, wheezing, shortness of breath, agravated asthma	lung damage, premature death of individual with agravated heart and lund disease	burning of fossil fuels in vehicles, power plants and various industrial processes
Sulphur Dioxide (SO2)	Increased asthma attack	Reduced lung function	fossil fuel combustion, smelting, manufacture of sulphuric acid, conversion of wood pulp to paper, incineration of refuse and production of elemental sulphur
Oxides of Nitrogen (NO2)	Eye and Nasal irritation, cough	Increased susceptibility to respiratory infection and adverse changes in cell structure of the walls of lungs	nitrogen dioxide is a traffic-related pollutant, emissions are generally highest in urban rather than rural areas

Table 6: Air Pollutants and related health impacts

Source: Complied from http://en.wikipedia.org/wiki/Air_pollution, WBPCB, Green Governance, West Bengal Pollution Control Board, (2004): Air Quality Status of West Bengal – A State of Environment Report

Perception of Diseases	% of population who concluded it to be responsible for air pollution
Head ache	88.6
Eyes/nose throat irritation	85.5
Runny nose/cold	66.8
Influenza and/or fever	19.9
Skin infection and rashes	83.2
Asthma attacks	95.3
Shortness of breath	68.7
Respiratory allergy to dust	85.5
Dry scratchy throat	40.2
Chest pain	47.6
Cough and phlegm	25.0
Dry cough	59.7
Bronchitis	29.7
Drowsiness	26.9
Pneumonia	12.1
Diseases of the heart	76.7
Cancer	26.2

Table 7 : Perception of people about disease due to air pollution
Source: Dasgupta, Mitali, 2005: Economic Analysis of Health Benefits from Air pollution Reduction: A Comparative Case study of Delhi and Kolkata

as well as allergy to dust are consequences of air pollution. The following table 7 shows in detail the perception of people in the city about the diseases that are outcome of air pollution:

Thus we see that deteriorating air quality is responsible to a large extent to the air borne diseases. And there proper mitigation policies are required to protect the air quality for healthy survival of mankind.The economic valuation of welfare gains in terms of health benefit if reduction in SPM and NO2 to the standard level can be achieved. How it can be achieved is not being probed here. The annual marginal benefit of reducing 1 microgram in SPM ad NO2 is known to be Rs17.68 and Rs20.05 for a representative household per month in Kolkata (Dasgupta, 2005). Based on this we tried to estimate the welfare gains of the population around the monitoring station by reducing the SPM and NO2 concentration to base level for various areas.

For computing the damage avoided or welfare gain from air quality improvement, we have taken the average pollution concentration of SPM for the period April 2005-March 2005. Then we have taken the deviation of concentration from the standard. Then if the concentration exceeds the standard we have multiplied the excess amount with the cost of reduction. Then summing all cost of reducing overall the months we get the yearly cost of reduction for a representative household. Taking the total number of household in that ward, we could make an approximate estimate of total cost of reduction in that area.

We therefore present the air account of Kolkata considering both quantity and quality accounts for the year 2005 (Table 8):

Based on this accounting practice, the last part of this paper concentrates on the most crucial aspect-framing of policies for sustainable development. The important policy recommendations for a sustainable future for Kolkata with respect to air resource are enumerated below.

IV. Policy recommendation

- While considering the air account, we have seen that a well developed air quality monitoring system exists in Kolkata with stations almost uniformly distributed. But this monitoring network must be extended to all district headquarters for better policy making.
- most of the countries have data reported for PM2.5 which is believed to be one of the principal

contributors of air pollution. But the West Bengal Pollution Control Board does not report data for this pollutant. Thus, inclusion of this pollutant in the daily monitoring data report must be looked into.

Monitoring Station	Air Quality Index 2005	2005-06 Household Cost of SPM Reduction to standard level (Rupees)	2005-06 Household Cost of NO2 Reduction to standard level (Rupees)
Dunlop	15	129057522	16781217.22
Ultadanga	10	116335225.3	11984379.23
Shyambazar	11	51456038.37	4500075.935
Salt Lake	2	NA	NA
Beliaghata	5	37786932.54	1496292.603
Moulali	13	50316022.78	9803148.555
Hyde Road	9	81635052.1	7450441.254
Topsia	14	127520295	11647801.49
Mominpore	7	92360548.43	7148317.428
Minto Park	4	36847657.08	5145276.113
Gariahat	12	43595618.39	7072449.832
Picnic Garden	6	115045503.2	6510707.378
Baisnab Ghata	1	24765319.76	0
Behala Chowrasta	8	48818567.62	7779512.28
Tollygaunge	3	24227212.34	3176210.324

Table 8 : Air Account of Kolkata based on monitoring stations
Source : Author's estimate

- Assessment of contribution of air pollution of all important sectors –industry, transport, household sector, energy sector, construction sector must be done. The accounting with all these sectors will provide insight as to the true percentage contribution of the different sectors. On basis of that, proper controlling mechanism with suitable enforcement will help the economy to a more sustainable state.

- Policy makers need to intervene more into this issue by proper analysis of the contribution of air pollution to the level of morbidity and mortality in the state. The hospitals may be advised to provide data on patients reported with air borne diseases on a daily basis to understand the severity of the situation.

The most important conclusion is that based on secondary data sources air quality account can be taken as a fairly good sustainable development indicator as it gives an idea of the level of air pollution, the cost of the society on account of air pollution. It can be used by policy maker for monitoring development pathway on sustainable development direction.

This can be updated from time to time and based on the findings, there needs to be a revision of policies addressing the priorities on a periodical basis. However, further improvement should also be in the agenda of the development planners to make this accounting practice more robust.

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Abating Environmental Change: The Fractured Climate Regime and India

Dr. Satabdi Das
South Calcutta Girls' College, E-mail: satabdi09das@gmail.com

Abstract Environmental problems have become a matter of global concerns today. But countries are mostly indifferent to the fact that emissions by any of them actually enhance the global stock of Green House Gases (GHGs) and affect all, though not equally. Therefore a different kind of politics has evolved where multiple stakeholders are negotiating and bargaining in the expectation to form an environmental regime where their respective interests are secured. Thus various fault-lines in the existing climate regime are visible which has reflected that countries' concerns for the threat are uneven which has been resulted in such fractured climate regime. But the climate postures of countries are not always confrontational. They are making strategic alliances too to strengthen their respective bargaining positions. So each response to environmental threats and individual country's relation with other actors both cooperative and confrontational are actually the reflections of each country's national interest.

As an emerging economy India is a crucial actor in this global environmental regime. But her economic interest and developmental aspirations have a clash with the process and outcomes of global environmental negotiations. It is not altogether possible for her to immediately reduce atmospheric release of GHG emissions drastically by making transition to a low carbon and climate resilient economy and society. The unavailability of technologies and financial cost of them as well as various conditions made by the donor countries have a role to play in delaying the switch over to cleaner energy here.

Against such a backdrop the present study will shed light on the following issues:

- The fractured environmental regime;
- India's significant stakes in this regime and how her interest clashes with the outcome and processes of global environmental parleys;
- India's effort to bridge the gap between her developmental aspirations and the need for environmental protection.

Keywords Green House Gases, Environmental Change, Climate Change Regime, India, National Interest.

I. Introduction

Environmental change is a significant challenge of our age. It is now an accepted fact that climate induced scarcity of resources is rising alarmingly and is intensifying scrambles for right to resources like energy, food, water and land. For changing climate, natural disasters are also becoming more frequent affecting the poorest and vulnerable sections the most across the world. Such global impacts and implications of climate change have given rise to the wide consensus among global community that measures should be taken in order to combat the crisis. Additionally, efforts that would help vulnerable people to cope with the changing environments in which they are living are urgently required.

Year	Carbon Dioxide (Parts per mill. by vol)	Emissions (Bill. Tons of Carbon)	Temperature (Degrees Celsius)
1950	n.a	1.61	13.85
1955	n.a	2.01	13.90
1960	316.91	2.53	13.99
1965	320.03	3.09	13.89
1970	325.68	4.00	14.03
1975	331.15	4.52	13.95
1980	338.68	5.21	14.18
1985	345.9	5.3	14.06
1986	347.15	5.46	14.13
1987	348.93	5.59	14.27
1988	351.48	5.81	14.31
1989	352.91	5.92	14.19
1990	354.19	5.99	14.38
1991	355.59	6.09	14.35
1992	356.37	5.95	14.13
1993	357.04	5.95	14.14
1994	358.89	6.08	14.24
1995	360.88	6.21	14.38
1996	362.64	6.36	14.30
1997	363.76	6.49	14.40
1998	366.63	6.45	14.57
1999	368.31	6.30	14.33
2000	369.48	6.45	14.33
2001	371.02	6.61	14.48
2002	373.10	6.72	14.56
2003	375.64	7.03	14.55
2004	377.38	7.36	14.49
2005	379.66	7.56	14.63
2006	381.84	n.a	14.54

Table 1 : Global Average Temperature and Carbon Emissions from Fossil Fuel Burning, 1950-2006 and Atmospheric Concentrations of Carbon Dioxide, 1960-2006
Source: Sawin, Janet. (2007). Carbon Emissions Continue Unrelenting Rise. In Starke, Linda,(ed.) Vital Signs 2007-2008: The Trends that are Shaping Our Future. Newyork, London : World Watch Institute. p.43.(Collated from the data organised by GISS, BP,IFA, CDIAC, DOE and Scripps Inst. Of Oceanography)

The governments, policy makers, scientists as well as civil society groups of different countries are now more concerned about this change in climate and its disastrous effects. Numerous scientific studies have also stressed the urgency of drastic reductions in Green House Gases (GHGs) emissions to stabilise global warming at a manageable level. The UN sponsored Intergovernmental Panel on Climate Change (IPCC) which was created in 1988, to assess the process of climate change, options for its prevention and how to adapt to its consequences, has fundamentally changed the views and dealings of global community towards the problem of global warming. Despite such awareness, the emission of heat trapping gases runs unabated which is evident in various records.

II. International Climate Regime

As the environmental consciousness has started evolving, the issue of climate change has moved from being only a scientific matter to being the most contentious and distinct issue in global environmental politics. Such efforts need and should be complemented by strong institutions, policy formulations as well as legal frameworks. The global response strategy to combat this problem is evident in various climate summits held under the aegis of the UN where meaningful attempts were made by the community of nations to curb GHG emissions. One of such significant effort is visible in the United Nations Conference on Environment and Development (UNCED) in Rio De Janeiro in 1992 or the Earth Summit, which gave birth to the United Nations

Framework Convention on Climate Change (UNFCCC) that came into being in 1994. The convention asked the countries to cooperate and participate effectively in accordance with their 'Common But Differentiated Responsibilities'(CBDR) to reduce GHGs at levels that would prevent dangerous anthropogenic interference with the global climate. This principle implies historical differences in the contribution of developed and developing nations to global environmental problems and divergences in their respective economic and technical capacity to tackle them. Particular responsibility was also laid on the developed states to provide 'new and additional' resources to developing countries to help them with their efforts to limit GHG emissions(Harris, 2011). The other achievements of the summit include the adoption of Agenda 21 which outlined the required actions for governments, international organizations, industries and the communities to achieve sustainability and the Convention on Biological Diversity.

There is no doubt that the summit introduced a forum to address both environment and development; however, by embracing the idea of CBDR, it actually reflected the differences in the perspective of ' ecological space' between the North and the South. Another bone of contention was the issue of Global Environmental Facility(GEF) that was intended to be the financing mechanism for Agenda 21. The developing nations pleaded that the developed world should provide at least 0.7 per cent of the GNP for the GEF, but the call was heeded by none of the Northern rich countries. Specifically the United States (US) had shown reservation on the funding mechanism and refused to transfer technology on the ground that the patent rights on new technology were owned by private industries and it fell within the domain of international property rights(IPRS). However the Southern clan led by India countered the argument (Qureshy, 1992). Despite its several weaknesses, the Rio summit is considered a turning point in the global environmental trajectory and it gave impetus to a series of landmark climate conferences that ultimately gave birth to the Kyoto protocol in 1997.

Kyoto Protocol shares framework convention's objectives, principles and institutions while strengthening it by setting targets to limit green house gases. It asks developed nations to cut their emission of Green House Gases(GHGs) to an average of 5.2 percent below the 1990 level and to reach the goal between the years 2008 to 2009 (United Nations Convention on Climate Change [UNFCCC], 1998). The protocol also envisages several mechanisms, for example Emissions Trading, the Clean Development Mechanism (CDM) and Joint Implementation to allow developed countries to meet their GHG emission limits by purchasing GHG emission reductions credits from elsewhere.

Although, the protocol was an important step in addressing climate change, but since its very inception there was a wide discontent over the protocol's various provisions and it was considered by some quarters as a grave disappointment and setback as it only set agreed upon national objectives while leaving each signatory country to pursue those goals in its own way (Cooper, 1998). The main weakness of it was incomplete participation as the US did not ratify the treaty due, at least in part, to the perception of inequitable sharing of burdens while emerging economies like India and China were exempted from emission caps. Amidst chaos finally in 2004 Russia ratified the Kyoto Protocol and it came into force on February,16, 2005.

Since the signing of Kyoto Protocol, there always exists a tension between Kyoto supporters and detractors. If one closely examines the protocol it becomes evident that the disagreement is inherent in Kyoto protocol and it sows the seeds of inequity culminating in growing conflict of interests and distrust between and among both the signatories and non signatories. The Kyoto mechanisms like CDM has been a contentious issue with diverse perceptions. It provides an opportunity for developing countries to access modern environmentally sustainable technologies and receive financial incentives to overcome

the barriers. However, in this process, these countries may lose the low cost mitigation options to industrialized countries, while leaving behind only more expensive ones to pursue. The central concept of its additionality implies that to earn emission reduction certificate, a project must demonstrate that its reductions are additional to those that other wise would not have taken place. This may stimulate all sorts of manipulation. Emission levels may be artificially raised to subsequently claim reductions(Pearson, 2011). The developing countries also emphasized that the CDM project should lead to technology transfer in reality giving the country not only the 'ability to operate the technology but also to replicate and innovate' in order to prevent the 'eco - imperialism' of the North. Along with such weaknesses, the absence and inadequacy of monitoring, compliance and enforcement provisions as well as the negligence in the issue of technology development, diffusion and adoption and the funding, Kyoto Protocol failed to reach its expected goal of creating an atmosphere of cooperation to combat climate change across the world. However, rigorous attempts were also made to chalk out more effective vehicles for renegotiating or extending the protocol or devising an all encompassing new deal.

Years	Landmark Post Kyoto Conferences of Parties
2005	At Montreal, Canada work on the post Kyoto process began to search for an improved and more inclusive version.
2007	In Bali countries agreed on a road map to launch negotiations towards a global equitable agreement for addressing climate change. In the Bali action plan (BAP) the North-South differentiation found its highest expression as it asked the developed countries that are not members to Kyoto Protocol to make 'comparable efforts' to those in the protocol. The plan also obligates the developing countries to take nationally appropriate mitigation actions enabled and supported by finance and technology from developed countries, which together are to be measurable, reportable and verifiable. Such different formulations for developed and developing country commitments and actions based on the equity and common but differentiated responsibility principles and differentiation between them had come to be known as the 'firewall' (UNFCCC, 2008).
2009	At the Copenhagen summit efforts were made from different quarters to replace Kyoto Protocol. But it failed to reach any all encompassing agreement and came to an end with an agreement that was officially named Copenhagen Accord drafted by the US and the BASIC (China, India, Brazil and South Africa). It calls on both the industrialized nations and developing countries to set their emission targets by February 2010. In the contentious area of monitoring, verification and reporting, it provides that unsupported action could be subject to assessment only by domestic institutions but adds a new provision for international consultations and analysis without impinging on national sovereignty. On the finance side, it provides US $ 100 billion for long term funding for developing countries and US $ 30 billion for short term, which would go to the poorest and vulnerable for mitigation and adaptation (Hurrell and Sengupta, 2012).
2010	In Cancun summit, efforts were also made to pass the burden of climate mitigation onto developing countries. It anchored the Copenhagen Accord's pledges made by the developed world, inside the UNFCCC and had largely managed to invert the top-down, differential Kyoto architecture while replacing it by a bottom up, 'undifferentiated' system based on pledge and

(Contd.....)

Years	Landmark Post Kyoto Conferences of Parties
	review. The new discipline required developing countries, especially the emerging powers to be treated in much the same way as the developed world with regard to their climate mitigation and reporting obligation (Hurrell et al., 2012). The conference reached a compromise to set up a 'Green Fund' which was expected to mobilize US $ 100 billion per year by 2020, for assisting developing countries in adaptation and mitigation purposes.
2011	At Durban, countries had tried to open a new avenue of environmental cooperation by announcing 'Durban Platform for Enhanced Action' which is going to be developed by 2015 and will come into force by 2020. It is expected that such a platform may develop a protocol with legal force applicable for 'all parties' that would blur the 'firewall'.
2012	At Doha, the Kyoto Protocol managed to survive as countries agreed on the second commitment period of the Kyoto Protocol (2013-2020) to follow immediately after the first period expires on 31st December 2012. After many years of wrangling, here the developing countries successfully made the developed world agree on framing 'institutional arrangements' for loss and damage.
2013	In the Warsaw summit, the North-South divide has again come into prominence. The developed world as usual has tried to blur the 'Bali firewall' between them and the developing block by not using the language of differentiation in the draft containing decisions of Warsaw conference. The G77 had asked for a separate new mechanism for Loss and Damage, while the US and Norway demanded it be relegated to just a body under the existing adaptation institutions (Sethi, 2013).
2014	In the Peruvian capital of Lima efforts were made for negotiating an outline text for the 2015 Paris agreement. It was also expected to provide final clarity regarding the contribution of countries to the 2015 climate pact in the form of Intended Nationally Determined Contributions (INDCs) by the first quarter of 2015(PTI, 2014). The main issues that are dividing countries were centred on the excessive focus on mitigation in the INDCs, which was opposed by the developing countries who wanted that INDCs should reflect mitigation, adaptation, finances, technology and capacity building and it should be a comprehensive contribution (Menon, 2014). The Lima agreement creates obligations on countries but makes no mention of the distinction between Annex 1 and non-Annex 1 groups. Rather, it uses a new phrase drawn from the recent agreement between the US and China, that countries' responsibilities will be based on "common but differentiated responsibilities and respective capabilities in light of different national circumstances."The Bali 'firewall' was thus breached (Jacobs, 2014).
2015	The 21st CoP took place in Paris where the text of the climate pact has established a commitment by 195 countries to take concrete measures to reel in planet-warming carbon emissions. It adopts a more ambitious target for limiting global warming than in the past by mentioning 1.5 degrees Celsius as part of the concrete goal to stay well below 2 degrees. It has been agreed upon that as part of a global effort, developed country Parties should continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels (Davenport et.al., 2015).

Table 2, ***Source: Prepared by the author herself with the help of data collected from various sources as mentioned in the in-text references.***

There is no doubt that the UNFCCC/Kyoto process plays a crucial role within the UN system to address the climate change issue. But it is also true that many times countries' vested interests have created a deadlock in the deliberations of various climate meets under this process. All these result in growing involvement of an array of other multilateral bodies and processes in the environmental issues. Various countries had opted for a new path, that is creating smaller clubs of key countries that could cooperate on climate change issues. The Asia Pacific Partnership (APP) of 2005 involving six countries on the Asian Rim and Canada that joined latter, and Major Economies Forum (MEF) are significant among them. Parallely, leaders at various G-8 summits starting from Gleneagles in 2005 to Heiligendamm in 2007 and at L'Aquila in 2009, reiterated their commitments to delivering bold actions to tackle climate change.

There also exist growing awareness that climate change has severe impact on peace and security.

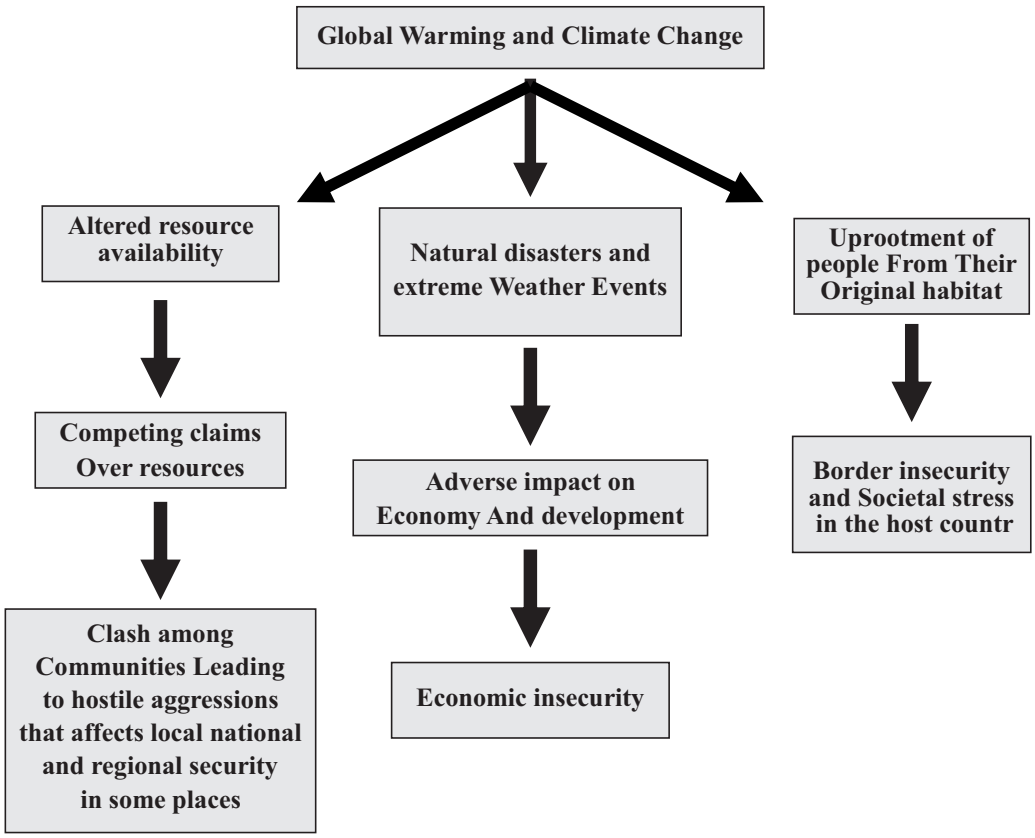

Figure - I

The securitization of the issue has thus become a bare necessity. In such a situation, Security Council has come into prominence that has opened another platform, parallel to the UNFCCC process, for solving the problem of environmental insecurities. Yet, from various quarters doubts were raised about the fact that whether the Council was the proper forum to discuss the issue. So again there were fragmentations in opinions over this issue.

Years	Security Council Involvement in the Climate Issues
1992	The Security Council for the first time acknowledged the potential threat emanating from environmental insecurity. In the statement of the President of the Security Council at the 3046th Meeting of the UN on 31 January, 1992, this concern was expressed clearly.
2007	A day long thematic debate on the topic of "Energy, Security and Climate" in the UNSC was held on 17th April, 2007 under the leadership of the UK government.
2011	The second UNSC debate on climate change and its security implications took place under the initiative of the German presidency. Although the states still remained divided over whether the Council was the right place to discuss climate change but almost all Council's members agreed that for some countries like the low lying ones who are vulnerable to rising sea-levels, changes in environment might carry severe security implications.
2013	The Arria formula meeting which was an informal UNSC session, was organized by Pakistan and the UK to review and address climate change-induced challenges for international peace and security.

TABLE-3
Source: The author herself.

III. The Faultlines within the Fractured Climate Regime

The various climate summits have made it amply clear that in various conferences efforts are made to reach meaningful actions to combat climate change but they have ended with empty proclamations and blame game. The battle lines within the climate regime could be drawn along the following divisions-

- The North- South divide on the question of assigning responsibility for cleaning up the polluted environment and over industrial countries' financial, technological or administrative support to the developing South;
- The transatlantic strain between the EU and the US as the former has politically been a strong supporter and fervent promoter of the protocol by pressing for deep cuts in emission levels, while the latter is a stern detractor demanding more generous levels of emissions. The US added further fuel to the flames by withdrawing from the Kyoto Protocol. Basically since the Copenhagen summit the US has started playing more influential part in climate negotiations and most of the developed countries had supported the US in their effort to establish a new agreement – 'the pledge and review' which was a climbdown from the existing global climate architecture. Therefore, a reconfiguration of international climate regime and leadership crisis, with the EU unable to lead any more, have come into prominence. Basically the projection of power by the emerging economies, more specifically the BASIC which in coalition with the US drafted the much criticized Copenhagen Accord and the US leadership aspirations had actually started sidelining the European powers.
- Division in the developing block on the question of responsibility and vulnerability. Viz-

1. BASIC group (Brazil, South Africa, India and China)- These fast growing economies who emit more than other G-77 countries have shared a common non negotiable stand against mandatory mitigation obligations except when they are not supported by developed countries.
2. Association of Small Island States (AOSIS) and the Least Developed Countries (LDCs) demanding mandatory emissions cut commitments from BASIC countries.

3. Organization of Petroleum Exporting Countries (OPEC) who consider themselves to be included in the list of most vulnerable countries. The 'response measure' to climate change may affect their economy as it requires diminishing dependence on fossil fuels like oil.

Various summits and conferences on environmental change have thus well revealed the fact that climate regime is fractured and countries' vested national interests precedes the concern for environment. In such a situation the major actors of climate politics have made strategic partnerships for strengthening their respective bargaining positions. Like during the Copenhagen summit the nexus between the US, India and China ; the hyphenated relation between India and China in the climate front despite their traditional animosity and territorial disputes; the US-China duopoly by which the concept of G-2 evolved as a 'global axis' in the climate arena as without the engagement of the planet's two top emitters of GHGs, China and the US, nothing decisive would come into play; Strategic negotiation between India and the US on a five-year MOU on energy security, clean energy and climate change in January 2015.

IV. India and the Fractured Climate Regime

As an emerging economy India has significant stakes in the global environmental regime. She has underscored the notion of equity in the environmental change debate by proclaiming the principle of CBDR which aims to establish an effective, cooperative and equitable global approach to environmental problems. She is confronting with double challenges. First, like other poor developing countries, India is impinged highly by environmental catastrophes and degradation. Her vulnerability to climate change has been increased by her low adaptive capacity and too much dependence on natural resources. Second, she is dealing with environmental change while facing with the challenge of sustaining rapid economic growth. Such growth is essential for enhancing the living quality of vast majority of her people and to reduce the vulnerability of poor multitude to environmental change.

So in various multilateral policy fora, India on behalf of the developing countries, is asserting socio economic development and poverty eradication as her primary policy objectives. She has considered the climate mitigation option as an impediment in achieving these goals. It is therefore in her national interest to seek for greater carbon space that is required for fulfilling the country's developmental aspirations. This is also the reason behind the per capita emission line of thinking which is inherent to her climate negotiation position. But every time specially in the post Kyoto Process, India and other emerging economies are expected to take the equal share of climate change burden at various international platforms at the expense of their economic development. Despite such international pressure, India walked its own path prioritizing economic development and asserting the deployment of clean energy measures by the adoption of improved energy efficient technology and through various adaptation measures. To achieve all its goals the CBDR principle has thus proved to be very fruitful in many ways. Considering this, even in the latest Paris summit of 2015, India and the developing nations managed to put back the principle of equity and CBDR in text. But the country had also taken pro active stance in curbing emissions intensity too. In her Intended nationally determined contributions it had commited to reducing its emissions intensity by 33-35 per cent by 2030, compared with 2005 levels. However along with China she put forward her reservations on periodic review of the INDCs as the Paris agreement commits all countries to a common system of review and monitoring, doing away with the differentiation between the developed and developing countries. The INDCs which is the testimony of a bottom up climate approach is not a new phenomenon. The non binding character of these nationally determined

pledges, with preference given to transparency rather than legal enforcement, to ensure accountability, has been in the making since the failed Copenhagen talks. But India has set ambitious yet realistic targets in its INDC which actually puts her on a much stronger moral ground to stake its position globally.

However, India has often been criticized for her "feet dragging" climate posture by the developed world and it has been argued that she is hiding behind the poor while is showing little eagerness to follow a clean growth and climate resilient trajectory that require relatively little ecological space. Additionally within India the unsustainable pattern of consumption by the urban rich which is taking place at the expense of the rural poor, also receives much criticism. In her natural constituency that is the G-77 collective, India is isolated today. Her emphasis on the CBDR principle is criticized by various fractions of G-77 group (the AOSIS and the LDCs) who are demanding mandatory, immediate and strong actions from India and other developing countries in order to bring them into 'mitigation net'. Even within the BASIC group countries differ in terms of their emission profiles. So there exists little solidarity in their approaches to climate mitigations.

In such a situation, India has also made strategic partnership with major actors of climate politics like with the US and China. During Copenhagen summit China, India and the US shared a common platform and devised the Copenhagen Accord which was the only outcome of this much debated summit. They have been cooperating with each other in the climate negotiation field in order to strengthen their bargaining position vis-a-vis the developed world. During the Indian Prime minister Narendra Modi's visit to China in May 2015, these two parties again have tried to strengthen their strategic alliance by issuing the joint statement which highlights their urge to "work together, and with other parties, to advance the multilateral negotiations to achieve a comprehensive, balanced, equitable and effective agreement under the UNFCCC in 2015, with a view to ensuring the full, effective and sustained implementation of the UNFCCC"(Roy, 2015). They again stressed the significance of equity in climate regime and asserted the differentiated responsibilities depending on the national circumstances of the stakeholders. The signing of a five-year MOU on energy security, clean energy and climate change between India and the US in January, 2015 is another instance of great cooperation between India and a major actor of climate politics. They planned to cooperate to achieve a successful and ambitious agreement in Paris Conference of Parties, 2015.In a way this is a shift in India's hard line environmental position that any agreement should apply only to the developed world. At the global level Indo-US energy cooperation have generated new expectations that India may take more bolder announcements considering the fact that it is one of the most vulnerable countries to the impacts of climate change in the near future with this finance and technology cooperation with the US. However, India dismissed such idea and asserted that such move should come from developed countries first and added that this Indo-US cooperation is different from Sino-US bilateral deal where both Washington and Beijing set their respective emission cut goals in November 2014.

Actually India's alliance with either China or with the US is to some extent counterproductive for her, as both in absolute terms and per capita basis India emits less than these major emitters. India's "current per capita emissions are 1.8 tonnes and by 2030, under the business-as-usual scenario, it will be 4 tonnes—nowhere close to that of the US and China. Between 2011 and 2030, China will take over 25 per cent of the remaining carbon space; US will occupy 11 per cent more and India only 7 per cent more"(Narain, 2014). She is losing diplomatic space in the environmental negotiations too as with the Sino-US climate agreement of 2014, India is facing added pressure to forego her right to development and to take more proactive role in Paris climate conference of 2015. Again during the US President's visit to India in January 2015, President Obama stressed that the world does not stand a chance against

environmental change unless developing nations like India reduce their dependence on fossil fuels. Though the US had extended hands to cooperate in India's transition to low carbon economy, but it is not justified to ask developing nations and emerging economies like India to decrease their dependence on the same fossil fuels that helped power the growth of developed world for decades.

Though India is facing such tremendous pressure for adopting mitigation actions in the post Kyoto period, adaptation to climate change and resilience building are the most fruitful options for her. So it has become a paramount priority for her to devise a comprehensive adaptation strategy. However, it requires investments and planning, technological advancement as well as institutional arrangements which many developing countries like India lack. Starting from the UNFCCC, in various climate summits the need for adaptation funding in the most vulnerable countries had been emphasized. However, adaptation measures have always received little attention than mitigation efforts. The reasons can be that the affluent Northern countries are capable enough to adapt to climate change while through mitigation they can have at their disposal less costly means to fulfill emissions reduction commitments by procuring Cerified Emission Reductions (CERs) from developing countries. Additionally, the recent environmental summits have witnessed the reluctance of developed countries in disbursing climate finance for aiding adaptation measures in the Southern countries. In India where adaptation to climate change is a bare necessity, the government is also not always working in favour of it while preparing the budget. In a study of union budget by the Oxfam India, it is noted that expenditure on adaptation pertaining to human capabilities constitutes more than 80 per cent of the total expenditure on adaptation as of 2009-10 budget estimates and constitutes around 2.22 per cent of GDP out of the total of 2.68 per cent of GDP as per 2009-10 budget estimates. The existing budgetary allocation for improvement in ecosystem services in the context of adaptation is meagre at 0.46 percent of GDP as per 2009-10 budget estimates. (Ganguly and Panda, 2010) Even there is a lack of governmental competitiveness in building a bridge between poverty eradication and climate adaptation measures. The National Action Plan on Climate Change (NAPCC) has enumerated several policy measures which are necessary for adaptation and it has identified climate sensitive sectors within the economy.

Figure 2 : National Action Plan on Climate Change

But it does not analyze the 'content and substance' of adaptation measures. Moreover financing for NAPCC is also not clear. In a preliminary estimate it is said that Rs. 2.3 lakh crore is needed to achieve the NAPCC (Jebaraj, 2013). With resource crunch being a major hurdle for achieving sustainable growth, the Economic Survey also favoured setting up of 'National Green Fund' to finance public private sectors aimed at protecting the environment(The

Hindustan Times, 2013). But there do not exist any domestic sources of funding for this yet.

Each and every stakeholder has its own priorities while devising climate strategies at the global level. India is not an exception. She has significant stakes in the global environmental parleys. But her goal is to have an equitable share in the available carbon space. This space is required for fulfilling her developmental aspirations. In such a situation sustainable development is a possible means to bridge the gulf between development and environmental protection in India. For this, 'equitable access to sustainable development' is required that depends on equitable share in the available carbon space. But sustainability criterion requires adequate and appropriate financial and technology transfer from the developed countries. Such transfer may help India and other developing countries to address their requirement for environmentally sound technologies.

However, in reality, India and other developing countries have to buy these technologies at exorbitant rate and these technologies are often incompatible with the local systems. The traditional knowledge base that is potential enough to foster sustainability is often ignored by the governments of developing countries. The indigenous communities who live mostly at the 'ecological margins' of human settlement are the finest observers of changes in environment. Their traditional ways of living, dependence on biodiversity and ecological services can provide rich insights for sustainable living and well being. But these communities and their knowledge and expertise regarding sustainable resource management and development are excluded from the processes of decision and policy making on environmental change at the global level. The community based mitigation and adaptation actions are not taken into considerations in global environmental deals.

Another mechanism facilitating sustainable developments in developing countries is the CDM. Though it is essential for promoting sustainable development in countries that host CDM projects but India's approach to this is not satisfactory. Unlike China she does not steer CDM investment in tandem with her policy priorities. Mostly CDM projects are concentrated in large industrialized states like Gujarat and Maharashtra whereas less developed states have few such projects in comparison to their populations like in Bihar and Uttar Pradesh. As a result they lack CDM created investment opportunities.

V. Concluding Remarks

Thus lopsided domestic policies regarding environment and sustainable development are responsible for human misery in India to a large extent. At the global level she is voicing her concern for equity in terms of per capita emissions in the hope that it would provide her with more carbon space to fulfill the developmental needs. But it is also true that within India there exists inequity in resource distribution, in the availability of socio political and economic safety nets at the time of environmental disasters and people of all strata do not find representations in the policy making. She has failed to maximize people's participation in the development process. Here the level of overall emissions is rising due to the luxurious emissions of the affluent which is further escalated by the survival emissions of the poor multitude. Her poverty stricken population though requires integration of environmental concerns in economic and social development but partial policy formulations failed to achieve this goal. So environmental security and protection should be established at the national level and at all levels first. Until those most vulnerable are capable of achieving a healthy and productive life which is environmentally sustainable too, any effort to raise voice for securing India's national interest that is balancing the goal of environmental protection with her developmental imperatives will be unsuccessful at the global platform.

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The Right to Pollution Free Environment: A Basic Human Right

Rinita Das
St. Xavier's College, Kolkata, E-mail: rdas1708@gmail.com

Abstract Scientific and technological advancement has given mankind a free hand to exploit the natural resources. At present, we realize the increasing trend of environmental pollution and ecological imbalance. The various representative samples of the Earth's environment try to maintain a balance to keep the existence of life undisturbed on earth. In India, a philosophy of peaceful coexistence with nature is noticeable since time immemorial as nature was worshipped as a part of one's religion. This philosophy finds place in The Constitution of India too. This is a doctrinal study analyzing the concern of the Indian judiciary for preservation and protection of environment by progressive construction of the laws and formulation of the various principles to be compulsorily followed in order to avoid major catastrophe or extinction of mankind.

Keywords life, pollution, right, Supreme Court

I. Introduction

Human beings are an indispensable part of nature. Since time immemorial man is not without the love of nature, which can be inferred from the writings of great men of the past as well as the practice of some religion. Man protects the environment and the environment in turn nourishes and protects him. The relationship of man to nature has been cordial but in recent years there has been a disruption in this harmonious relation, which is reflected by many environmental hazards due to the spectacular development of science and technology. Instead of maintaining a harmony with nature, man has attained mastery over it and exploited its representative samples, which are necessary for human existence.

In ancient times self-restriction was imposed by religion and ethics and not necessarily by law. Overuse, abuse, misuse led to the formulation of the legal regulatory framework for the preservation and protection of the environment. Advanced industrialization has given rise to the myriad forms of environmental pollution and health hazard which lead to the problem of insanitation, uncontrolled deforestation, waste disposal, including the discharge of untreated sewerage, industrial effluents, chemical, smoke and radio active waste housing problem, green house effect, ozone layer depletion and so on.

This is a doctrinal study reflecting the various legislative and judicial efforts for combating pollution. This study highlights the growth of the environmental jurisprudence in India based on the progressive decisions of the Indian Judiciary.

II. Legislative Efforts

The first United Nations Conference on Human Environment held in Stockholm 1972 proclaimed that it is the imperative goal of mankind to defend and improve the human environment for the present and the future generation. So the governments of the Nations were asked to formulate the legislations on the basis on these principles which came to be known as the Magna Carta on Human Environment. It was held that the protection of the environment is a major issue that effects the social and economic development of the nation.

The 42nd Amendment Act to the Constitution Of India incorporated Article 48A which provided "the State shall endeavor to protect and improve the environment and safeguard the forest and wildlife of the country." as a part of the Directive Principles which made it obligatory on the part of the State to follow this principle at the time of framing laws. The same Amendment Act by incorporated in Article 51A(g) a fundamental duty, which states that it would be the duty of all citizens "to protect and improve the natural environment including the trees forest, lakes, rivers and wildlife and to have compassion for living creatures". These Articles impose the correlated duty and right on all individuals and the State to protect and preserve the environment. Some items like "population control and family planning", "forest protection of wildlife and birds" has been shifted to the Concurrent List of Schedule VII of the Constitution empowering both the Central and the State government to frame laws in this regard. In 1980,

Article 21 guarantees "right to life and personal liberty" and 'right to pollution free environment" is a basic need for the survival of the mankind. Any attempt to defile, damage and destroy the ecology would be in violation of the human rights. Various judgments of the Supreme Court and the State High Courts give a newer and the finer perspective of the environmental protection. Some of the Acts that were passed for the environmental concerns are the Indian Forest Act 1927, The Factories Act 1948, Atomic Energy Act 1962, Insecticide Act 1968.Wild life Protection Act 1972, The Water Prevention and Control of Pollution Act 1974, The Water Prevention and Control Of pollution (Cess) Act 1977, Forest Conservation Act 1980, The Air Prevention and control of pollution Act 1981,the Environment Protection Act 1986. For the speedy disposal of the cases and to stop the immediate harm to the environment the National Environment Tribunal Act 1995, National Environment Appellate Authority Act 1997 has been passed.

III. Judicial Endeavor for Pollution Free Environment

Environmental crisis is disrupting the lives of the people and the most unfortunate part is that the poor, underprivileged and the non-humans have to bear the brunt of this crisis. In the light of the imbalance of the power, which leads to the abovementioned crisis, the Courts identified environmental issues as a concern common to all. It is not the conflict of interests between two or more private individuals. The Courts maintained a semblance between development and environment which will be reflected, in the following cases. Indian Courts have accepted Indian moral and social ethics relating to environment protection. Moral Code of Conduct specifies that killing of animals and birds is the sin of highest order. The High Court of Kerela in F.K.Hussain V Union of India (1990) opined that "Water and rivers have dominated the destiny and fortune of man. Plentiful River brought prosperity to those who lived in the banks. If Bhagirathi bought salvation, Ganga brought life…. ages have rolled by it and it has remained eternal.

The nonrenewable resources of the Earth may not be replenished by the same in the days to come having dire consequences for the future generations. The Hon'ble Supreme Court in T. Damodar Rao v S.O. Municipal Corporation, Hyderabad (1987) also gave a word of caution to the mankind by various judgments. Environmental law is based on the realization of mankind of the dire physical necessity to preserve these invaluable and none too easily replenish able gifts of Mother Nature to man and his progeny from the reckless wastage and rapacious appropriation that common law permits."

As we inherited the Earth with all richness and fullness in it's grandeur from our ancestors, we also owe a duty to preserve the same and give it to the future generations to come. We are merely the custodians of this magnificent World. The judgment in Sachidananda Pandey v State of West Bengal (1987) reflects that we should respect the Earth as we owe our lives to it and should also impart the necessity of respecting the Earth improving the ethics and be a strict guard of it."You must teach your children that the

ground below their feet is the ashes of our grandfathers so that they will respect the land. Tell your children that the Earth is rich with the lives of our kin. Whatever befalls on the Earth befalls on the sons of the Earth. The Earth is even precious to the creator. …contaminate your bed and you will one night suffocate in your own waste". In Shantistar Builders v Narayan Khimalal Totame (1960) the Supreme Court held "basic needs of man have been traditionally accepted as three: food, shelter and clothing. The right to life is guaranteed in any civilized society. This would take within its sweep the right to food, right to clothing, and the right to decent environment and reasonable accommodation to live in.

During the 1980s, India faced many hazards, which created havoc on mankind attributable to his own neglect having the potential to destroy the Earth affecting the future also. But the judgment of the Court does not reflect the concern to protect the environment. It is not out of place to mention the Silent Valley case (1987). Silent Valley is in the district of Kerela which has India's largest tropical evergreen forest which abounds by unique vegetation, animals, birds and mammals. This forest also prevents soil erosion, regulates the climate and maintains the ecosystem of the place. State government wanted to construct a hydro electric project in the valley. When an application was filed in the Court to prevent the Government from doing so, the Court refused to interfere and stated that it is the discretion of the State to use a national asset for the benefit of the nation by constructing the hydro power project or to maintain the glory of the forest protecting the soil and wildlife. This reflects that the court is not so eager to maintain and protect the environment.

A considerable change has been noticed in the judgments of the Court, which reflected their greater concern on degrading environment. Rural litigation Entitlement Kendra is a voluntary organization, which invoked the epistolary jurisdiction of the Supreme Court because a grave public interest was involved as illegal and unauthorized mining operations were carried on in the Mussoorie hills that adversely affected the ecology of the area and caused environmental disturbance. The Bhargawa Committee was appointed to assess the effects of the mine on the ecology of the area and on the basis of the Report; the Court ordered for non-renewal of lease and consequently all the operations to be stopped. The Court further warned that one "should not forget that the tapping of the resources should be done with requisite attention and care so that ecology and environment may not be effected in any serious way…….permanent assets of the mankind are intended to be exhausted in one generation"

The worst industrial hazard that mankind has witnessed is The Bhopal Gas Leak Disaster where forty tones of Methyle Isocyanide leaked from the chemical plant of Union Carbide Corporation, killing three thousand people and leaving another two lakhs injured. It was contended that a multinational corporation has an "indelegable and absolute duty" to the people and the country in which it functions. Any dangerous act that it performs should be conducted with the highest standard. M.C.Mehta V Union of India (1987) popularly known as the Oleum Gas Leak Disaster is also an example of the heath hazard of the took place only one year after the Bhopal Incident, oleum gas leaked from Shriram Food And Fertilizers Ltd killing one and leaving several injured. The Supreme Court decided that necessary steps should be taken to locate such industries in such a manner that would pose a least threat to the community by maximizing the safety requirements of such industries. This case is popularly known as Shriram Food and Fertilizer Case wherein the Supreme Court suggested for the setting up of Environmental Courts for the first time and also awarded Rs.10000 to the petitioner for having showed the courage to fight the case against such a multinational company for the benefit of the nation, as a token of appreciation. The liability is based on the social cost for carrying on such a dangerous activity. The measure of compensation would be corresponding to the magnitude and capacity of the enterprise because compensation should have a deterrent effect. The larger and more prosperous the enterprise is, greater would be the compensation. In various judgments it was found that the Supreme Court reiterated that the awareness in the protection of

the environment was created by the Stockholm Conference which considerably helped in the growth of the environmental jurisprudence in India.

Through ignorance and inadvertence we can do massive harm to the Earth where only life survives. So it has become imperative to protect earth for the present and future generation. In State of H.P. V Umed Ram (1986) the Supreme Court held that "right to life" under Article 21 includes some finer facets of human civilization including better standards of life, hygienic conditions in workplace and leisure. In recognition to the extended view of Article 21 the Supreme Court in Subhas Kumar V State of Bihar(1991) reiterates that, if anything impairs or endangers the quality of life the citizen has the right to recourse to Article 21.

In M.C.Mehta V Kamal Nath (2000), the motel was constructed by Kamal Nath, Former Union Minister, on the bank of the river Beas which discharged untreated effluents. The Supreme Court made it clear that if the hotel is discharging untreated effluents in the river Beas which cause a disturbance to the basic environment that is necessary for life, it will be treated as hazardous to life. 'Life' does not mean "mere animal existence". It includes right to livelihood, better standards of life, hygienic conditions in workplaces and leisure which would be congenial to the human existence and so exemplary fine may be imposed to be a deterrent on others.

In Hinch lal Tiwari v Kamla Devi (2001) the Supreme Court clarified the importance of natural resources by stating that the resources of the community like forest, tank, pond are the nature's bounty which maintain delicate ecological balance and so it needs to be protected for ensuring a quality of life which is enshrined under Article 21 of the Indian Constitution. M.C.Mehta V Union of India (1987) popularly known as the Ganga Pollution Case, a number of tanneries were discharging untreated effluents in the river Ganga which made the water of the river highly toxic. The Supreme Court held that closure of industries bring unemployment and loss of revenue to the State but life, health and ecology has a greater significance to man. The Court further observed that the tannery which cannot afford to set up a water treatment plant cannot be allowed to run.

In M.C.Mehta V Union of India (1992) the Supreme Court decided that it is the imperative duty of the government to keep the citizens informed about the environment free of cost. The Court further asked that environmental education to be made compulsory at all levels of education. Mass awareness should be created through radio, television and the like.

M.C.Mehta V Union of India (1997) which is popularly known as the Taj Trapezium Case is in regard to the emission of the substantial level of sulphur dioxide by various industries which caused acid rain which leads to the yellowing of the white marble of the Taj. Due to the hazard the Supreme Court ordered 292 industries to close down or to switch to compressed natural gas or shift from the Taj trapezium. The Supreme Court ordered closure of the industries for the protection of the environment. In Vellore Citizens Welfare Forum V Union of India (1996) 584 industries were discharging toxic effluents in the river Palar, which was spoiling the chemical properties of the soil and also the ground water. The Court issued directions to install pollution control device and get the permission order from the Pollution Control Board before they start their operation. No one may be permitted to pollute the environment for one's own interest harming the interest of the others in the community. The Court formulated "The Precautionary Principle" imposing the duty on the government to abate pollution, take assistance of science to identify measures against degradation. The Court ordered Rupees 10,000 each on all the tanneries for causing such pollution which would be utilized for compensating the affected person and restoration of the damaged ecology.

In Narmada Bachao Andalon v Union of India (2000) the Supreme Court opined that when there is a state

of uncertainty due to the lack of data or material about the extent of damage that pollution is likely to cause then, the burden of proof must necessarily be on the industry or the unit which is likely to cause such pollution.

In Andhra Pradesh Pollution Control Board V Prof. M. V. Nayudu (2001), the Supreme Court suggested to fortify the Appellate Authority established under the Water Act, National Environmental Tribunal Act by appointing technical members having special knowledge in environmental science and management and set up environmental courts.

In Indian Council For Environ Legal Action v Union Of India (1996) the "Polluter's Pay Principle" was formulated wherein the polluting industry is absolutely liable to compensate for the harm caused to the environment, and is also liable to pay the cost of restoring the environmental degradation and reverse the damaged ecology. This case was instituted when five factories were producing hydrochloric acid in the Bichari village in Udaipur, discharging highly toxic effluents polluting the underground water and soil.

In Sachidananda Pandey v State of West Bengal (1987) the Court opined whenever there is a problem in regard to ecology….the Court should bear in mind Article 48A and 51A(g) …….and should not shrug it's shoulders and say that priorities are a matter of policy and so it is the matter of the policy making authority." This is a contradictory observation of the Supreme Court in the light of the growing degradation of the environment. The Court overruled the judgment of Silent Valley.

In M.C.Mehta V Union of India (1996) the Supreme Court recognized the statutory duty of the Pollution Control Board (PCB) to prevent the pollution by declaring sensitive areas and enforcement of the standards. The Public Interest Litigation was filed against the Pollution Control Board of Haryana for failure in their statutory duty to prevent and abate air pollution and noise pollution caused by the mine operators in Ludhiana, which is close to Badkal Lake and Suraj Kund. The Supreme Court declared the standards of the sensitive area are stringent than the standards prescribed for industrial and residential area. In pursuant to the judgment, the CPB recommended 5 km from the tourism area as "sensitive area" to enforce the pollution control rules strictly. In Almitar H. Patel V Union of India (2000) the Government was ordered to appoint the officers to implement the orders regarding the solid waste disposal littering and cleaning of the metropolitan city. Thus it is found that the Hon'ble Court leaves no stones unturned to empower and enforce the pollution control. M.C.Mehta V Union of India (1997) was also a proof of the struggle of the Supreme Court to protect the environment in case of degradation. The concern of the Court for the employees is also reflected in the judgment. This case came up when the Calcutta tanneries were operating in violation of the Environment Protection Act and Water Act.The Court asked for the relocation of the tanneries and payment of compensation to the employees. The Green Bench of the Calcutta High Court was directed to monitor the same. Implementation of the laws relating to the environment is a major challenge which the country faces. The anxiety of the Court is reflected without any pinch of doubt when the Supreme Court observed in Tarun Bhart Sangh Alwar v Union Of India (1992) that "preservation of the fauna and flora, some species of which are getting extinct at an alarming rate, has become a great and urgent necessity for the survival of humanity and these laws reflect a last battle for the restoration…."

IV. Conclusion

The finite World has an infinite population and India alone has the population of 16% of the total population of the World which indicates an increasing demand for fuel, food, water, space to live. This may lead to the various social, physical and psychological problems which include increased

consumption of fossil fuel, insanitary conditions, shortage of food and loss of nutrition, use of harmful fertilizers and pesticides. The poverty also destroys the people's capacity to use resource in a sustainable manner intensifying further pressure on the environment.

Problems relating to the depredated earth, traumatic subversion of the ecosystem and poisoning of air, water and food are rampant. So, environmental hygiene is an urgent problem which needs to be immediately solved in all the developing and the developed Nations. Scientists, Economists, Policymakers should reflect a serious thought on the degrading environment. The laws relating to the environment protection should be strictly followed and implemented. Any dereliction should be considered very seriously. Public participation should be increased. Duty for the protection of the environment should be treated as a non-delegable duty. The liberalization of industrial policy made consumer goods and services of best quality freely available improving the economic conditions of the common man. The consequent drawback is the discharge of the solid, liquids and gaseous pollutants into the environment which deserves immediate attention otherwise irreparable harm is caused to the ecosystem which may have a catastrophic effect on mankind. The problem of air, water, noise, harmful radiation and depletion of the ozone layer is actually caused by unplanned development programme and unrestricted exploitation without analyzing its effect on the environment. We should not overlook the danger which has the potential to engulf the whole world.

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Space Pollution

Dr. Subarnarekha Bhattacharyya
Physics Department, The Bhawanipur Education Society College, Kolkata
E-mail: subarnarekha@yahoo.com

Abstract Space activities in Earth orbit are increasingly indispensable to our civilization. Through the last five decades (from 1957 after the launch of Sputnik), thousands of spacecraft have been launched into orbit for scientific and national security purposes. Orbiting spacecrafts serve vital roles as communications links, scientific investigation platforms and are providers of remote sensing data for weather, climate, land use and scientific purposes. These tasks are concentrated in a few orbital regions, including low Earth orbit (LEO), semi synchronous orbit, and geosynchronous Earth orbit (GEO). One consequence of this activity has developed the creation of a large population of debris — nonfunctional satellites, rockets, other debris created by collisions or explosions, all these artificial space objects that serve no useful function — orbit around the Earth creating space pollution.

In this paper the basics of space debris, its source, tracking and observation, its removal and mitigations are briefly discussed.

Keywords space debris, LEO, GEO, hypervelocity impact, mitigation

1. Introduction

In recent years the mass of man-made debris in Low-Earth Orbit (LEO) has reached a critical density. NASA[1] defines orbital debris as "all man-made objects in orbit about the Earth which no longer serve a useful purpose." The creation of debris in LEO and GEO and reentry of debris in earth's atmosphere change the debris population continuously. Larger debris can be tracked by ground based sensors but it is difficult to track numerous smaller pieces of debris. Spacecrafts are much more likely to collide with smaller debris than with larger objects. Modern Hypervelocity impact facilities are unable to simulate all relevant debris impact unless they are based on experimental data. As a result of these limitations, current spacecraft protection may not provide their desired level of protection. Although large uncertainties remain, an improved understanding of the debris environment, combined with the growing availability of analytic and experimental tools to quantify the threat to a spacecraft from debris has made it feasible for designers to assess the debris hazards and attempt to protect the spacecraft appropriately.

2. Debris in orbit

i) Type of debris : The catalogued debris can be roughly estimated from the data given in Table 1[2] which is categorized in fig. 1[5] whereas the statistics of the tracked debris is given in fig 2[3] followed by the satellite box score shown in Table 2[4].

To improve the efficiency of orbital debris research, a committee[5] of U.S. National Research Council

in 1995 recommends exploring the creation of an international system for collecting, storing and distributing data on orbital debris. Distribution of orbital debris by type and source is illustrated in Table 3[6]. NASA's Three-Dimensional Orbital Debris Evolutionary Model LEGEND[7] is used to cover the near-Earth space between 200 and 50,000 km altitude. The model provides debris characteristics (number, type, size distribution, spatial density distribution, velocity distribution, flux, etc.) as functions of time, altitude, longitude, and latitude.

ii) Major Debris contributions: Several space incidents had developed a large number of space debris surrounding the earth which is the results of the accidental collision or breakup of satellites and rockets or due to the illegal human space activities violating space law. For example, in June 1996,[8] the upper stage of a Peagasus rocket broke up creating 700 objects larger than 10 cm and 3,00,000 of 4 mm to 10 cm in size. Chinese anti-satellite weapon test (ASAT) destroyed the Feng Yun-1C weather satellite on 11 January 2007 (increased the trackable space object population by 25%)[9],accidental collision between two satellites, Iridium-33 and Kosmos-2251[10], on 10th February 2009 added 16% more to debris population. Near 800 km of altitude this debris gets accumulated and creates a threat to the spacecrafts performing Earth observation missions and communications links.

iii) Debris Impact and damage: The effects of orbital debris impacts depend on velocity, angle of impact, and mass of the debris. Satellites and debris could collide at speeds of upto 40,000 km/hr. Damage to shuttle windows, damage to HST high gain antenna, severing of the Small Expendable Deployer System are the examples of the affected portions of the surface of operational systems [11]. For example, a speck of paint of 1/5 th mm made a 4 mm crater in the window of a space shuttle in 1982.

A total of 38 impacts[12] were identified on the orbiter window thermal panes of Discovery (OV-103) in 2001 as well as on the windows of Endeavour (OV-105)

Even if a collision does not fragment a spacecraft, the impact may generate a variety of other damage modes (e.g., spallation, deformation, leakage, rupturing).

3. Debris detection

o prevent orbital debris problem [13], modeling [14] of the debris dynamics and corresponding detection is a challenge for the today's space technology. Orbital Debris Engineering Model, ORDEM 3.0 (released by NASA) or ESA's Debris Environment Long Term Analysis (DELTA) are effective tools to model orbital debris environment (i.e. debris spatial density, flux etc.). Telescopes are suited mainly to GEO and high altitude debris observations, whereas radars are advantageous in the LEO regime, below 2000 km. Data is acquired using ground-based radars and optical telescopes, space-based telescopes, and analysis of spacecraft surfaces returned from space. Current optical measurement research of orbital debris continues with the MODEST, MCAT and NASS projects[15]. Ground-based telescopes can detect debris in GEO down to 10 cm, ground-based radars can detect LEO debris down to a few millimetres. Some important data sources [16] are the U.S. Space Surveillance Network, the Haystack X-Band Radar, FGAN radar, the Hubble Space Telescope (HST) and the Space Shuttle spacecraft. Protection of spacecrafts from debris impact and to remove debris from space region of interest is two major challenges for controlling space pollution.

i) Protection from impact: Current space debris population alert spacecraft designers to introduce

protection concepts into their space vehicles. A hazard for space objects and orbital stations is posed by hypervelocity impact with meteoroids and space debris particles. Orbital debris protection involves conducting hypervelocity impact measurements to assess the risk presented by orbital debris to operating spacecraft and developing new materials and new designs to provide better protection from the environment with less weight penalty. Experimental hypervelocity impact testing generally provides the majority of information for damage assessments. Hypervelocity Impact Technology Facility (HIT-F) at NASA or ESA's space projects on hypervelocity impact tests in association with damage-assessment tools help in the analysis and interpretation of impact features. Covering sensitive parts with protective fabric layers are incorporated also. Collision avoidance is also applied sometimes. But avoidance manoeuvres cost fuel, shorten a spacecraft's lifetime and may disrupt data and service continuity.

ii) **Debris Removal:** Medium sized debris (5 mm to 10 cm) is the greatest threat to operational spacecraft but no such reasonable solutions are found yet. Proposals for active debris removal generally focus on large space debris objects. Various methods [17] of capturing large objects were proposed involving a net, inflatable longeron, tethered harpoon, articulated tether/lasso and an electrostatic/adhesive blanket. Active debris removal techniques are not always feasible and very much costly. A cost of more than $15 million is required for each piece of debris [18] in LEO to be removed. To minimize the impact on debris removal cost [19] is still under survey.

4. Mitigations

To design operational measures that can limit the generation of debris – is called mitigation. In order to have an active control on the space debris environment and to sustain safe space activities in the future, it is necessary to implement an identified control measures along with the effective and balanced debris mitigation practices based on an international consensus [20]. Since from 1993, IADC (Inter-Agency Space Debris Coordination Committee) has conducted annual meetings to discuss research results in debris measurements, modeling, protection and mitigation whereas quadrennial series of ESA-organised European Conferences on Space Debris or International Astronautical Congress and COSPAR (Committee on Space Research) Scientific Assemblies discuss the current results regularly.

5. Conclusion

The space activity has triggered global solutions to some of society's biggest challenges. The danger posed by orbital debris should be thought of fundamentally as a long-term environmental problem. In 2014, the International Space Station had to move three times to avoid lethal chunks of space debris. The problem also threatens crucial and costly satellites in orbit. Catastrophic collisions are likely to continue to increase the growth of space debris population particularly in LEO. The optimal debris mitigation strategy should be a compromise between the reliability and effectiveness of spacecraft end-of-life passivation, the re-orbit altitude and the acceptable debris background in the GEO ring. However, for as long as the re-orbit altitudes currently used are less than 500? km above GEO, new spacecraft explosions must be avoided in order to preserve the geostationary environment over the long term.

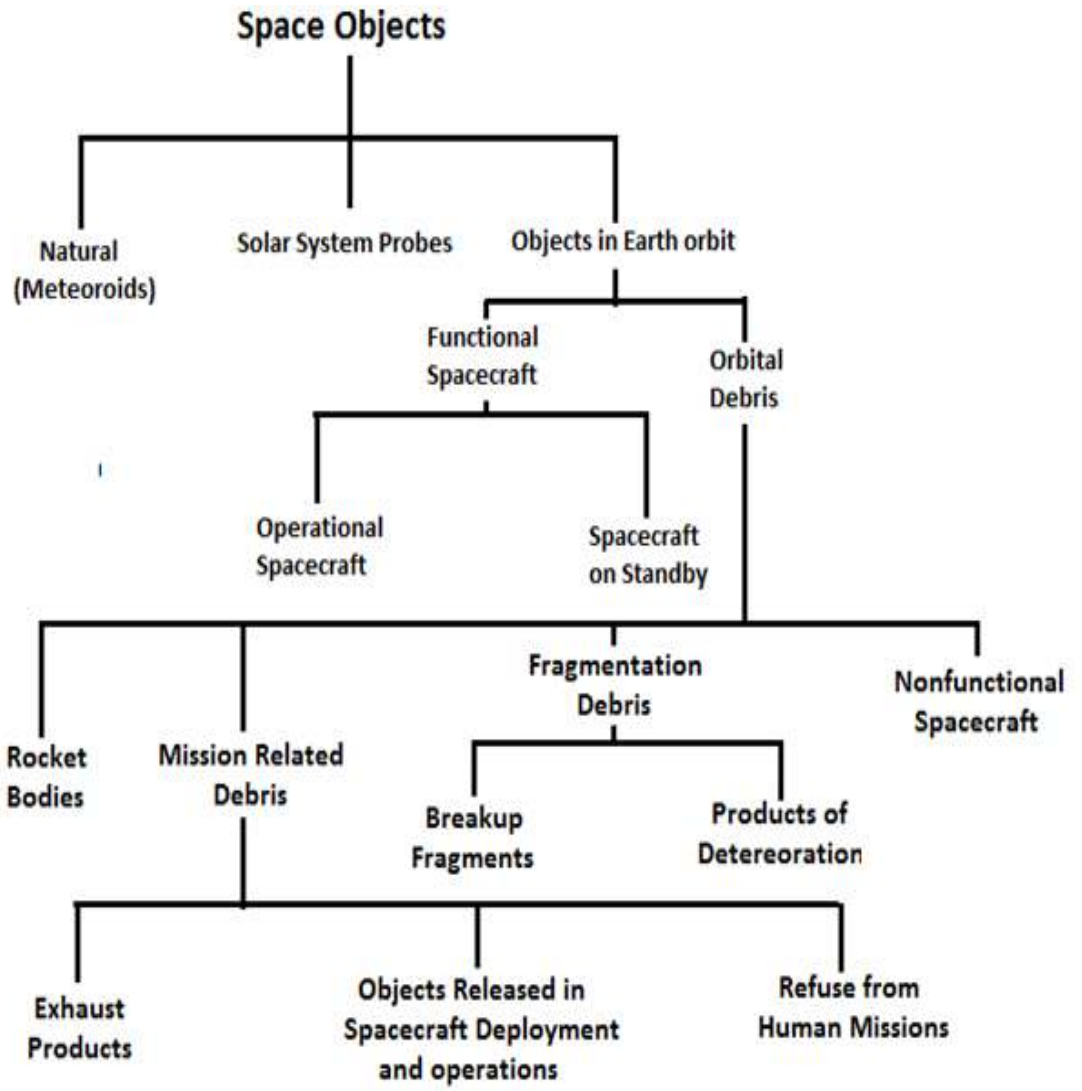

Figure 1: Classes of space objects
Ref: Orbital debris: technical assessment (NAS-NRC), National Academy Press 1995

Object size	Number	% of Total	% of Mass
Over 10 cm	8500	0.02	99.93
1-10 cm	110,000	0.31	0.035
0.1-1cm	35 million	99.67	0.035

Table 1: Catalogued debris in space as on 2003
Ref: H. Couper, N.Henbest. Encyclopedia of space, DK,2003, 58-59

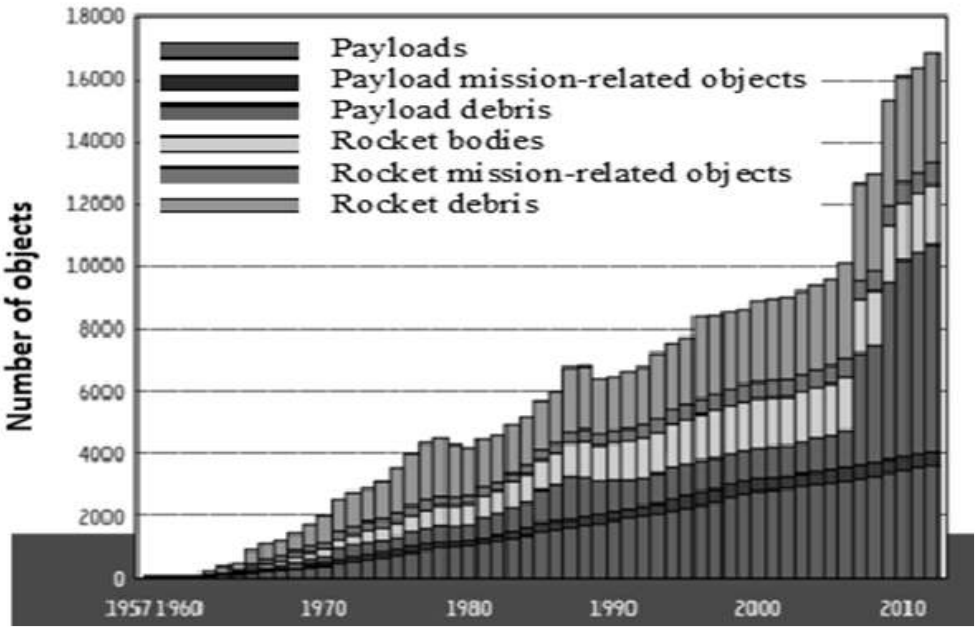

Figure 2 : Catalogued space debris as of October 2012
Ref: K. Fletcher. The space debris environment, European Space Agency, BR-309, 2013, 3

Country/ Organization	Payloads	Rocket bodies and debris	Total
CHINA	140	3638	3788
CIS	1425	4864	6289
ESA	42	45	87
FRANCE	56	437	493
INDIA	48	125	173
JAPAN	124	82	206
USA	1125	3811	4936
OTHERS	606	118	724
TOTAL	3566	13120	16686

Table 2 : Satellite box score as on 1st January 2013
Ref: J. C. Liou. Satellite box score, Orbital debris quarterly news, 17(4), October 2013, 10

on-orbit									
	U.S.	**CIS**	**France**	**PRC**	**India**	**Japan**	**ESRO/ ESA**	**Other**	***Totals***
Payloads	82	11	11	23	6	19	3	60	215
Rocket bodies	17	22	5	15	2	6	0	13	80
Debris dispensed	0	0	0	0	0	0	0	0	0
Mission related debris	160	78	5	51	0	17	1	3	315
Breakup debris	110	141	12	2065	-9	2	7	35	2363
Anomalous debris	38	69	2	0	0	0	0	0	109
Totals	407	321	35	2154	-1	44	11	111	**3082**
decayed or beyond Earth orbit									
	U.S.	**CIS**	**France**	**PRC**	**India**	**Japan**	**ESRO/ ESA**	**Other**	***Totals***
Payloads	22	48	0	7	1	2	3	1	84
Rocket bodies	40	67	9	14	1	3	0	3	137
Debris dispensed	0	0	0	0	0	0	0	0	0
Mission related debris	19	73	11	26	3	17	1	25	175
Breakup debris	71	214	5	29	29	21	0	4	373
Anomalous debris	15	1	1	0	0	0	0	0	17
Totals	167	403	26	76	34	43	4	33	**786**
							Grand Total ->		***3868***

Table 3 : Orbital debris source vs type accounting
Ref: N.L.Johnson. History of on-orbit satellite fragmentations, 14th edition, NASA/TM–2008–214779, 2008

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