

ISSN 2277-4831

bodhi bijnan

Volume:02 Number:01 2012

A Journal of Science



**Publication of
Vivekananda College, Kolkata**

bodhi bijnan
Journal of Science

Advisory Committee of Bodhi
(A bilingual Journal of Vivekananda College, Kolkata)

Chief Advisor
Tapan Kumar Poddar
Principal, Vivekananda College

Advisors

Debasish Sengupta
Manindranath Pandit
Siddhartha Guha Ray
Bidyut Kumar Roy
Nabakishore Chanda
Ratan Kumar Kar
Sutapa Kumar Rai

Department of Mathematics
Department of Commerce
Department of History
Department of Mathematics
Department of Bengali
Department of Chemistry
Department of Botany

Editorial Board of Bodhi Bijnan

Joint Editors

Arvind Pan
Department of Physics
Vivekananda College

Senjuti Roy Mukherjee
Department of Zoology
Vivekananda College

Associate Editors

Chapal Kumar Chatterjee
Department of Physics
Vivekananda College

Debasish Mukherjee
Department of Mathematics
Vivekananda College

Surasri Choudhuri
Department of Chemistry
Vivekananda College

Kuntal Narayan Chaudhuri
Department of Botany
Vivekananda College



Struggle for livelihood is a central issue of human society. As a result, a special section of society, particularly the students of science and technology are engaged in relentless effort to improve the condition of mankind. Their experiments and research not only enriches the society but also bless the mankind with new ray of hope. Despite occasional failure, their untiring effort in research has benefited the human society from time immemorial. Scientific researches and innovations are reflected in several journals and magazines. Bodhi Bijan, a bilingual journal , recognized by the Indian National Centre for the use of ISSN, is an example of reflection of scientific research and scientific query .This journal is published by Vivekananda College ,Thakurpukur, with the humble intention that oneday this small but sincere effort might open up new vintas of scientific research in future.



Green Roof: A Ray of Hope

Tapan Kumar Poddar*

Abstract: The slogan 'Go Green' is sweeping the world now. From a simple item to a large construction, everywhere we want a touch of green which is environment friendly, recyclable and made from natural resources. The place where we live, we work and spend most of our time also need some touch of green. The Green Roof Technology refers to a structure which is nature friendly in terms of design, construction, maintenance and renovation and of course beneficial to human health and aesthetics. New technologies are constantly being developed to complement current practices in creating greener structures with a view to reduce the overall impact of environment on human being by efficient use of energy, water and natural resources, by protecting the health of occupants and by reducing waste, pollution and environment degradation. The trends of setting green roofs in advanced countries are very fast but in our country it is not so promising, it has just initiated and people are become interested to accept this concept for their own betterment.

The basic need for human being is food and shelter. Food is essential for the survival while shelter complies with many of our needs. It gives us protection from the external enemies as well as environmental odds; provides space for rest.

With the development of science and technology and growing rate of population, all modern cities and urban areas are heavily filled with fast growing concrete buildings. An aerial view of most urban areas shows swaths of asphalt, black tar and gravel ballasted roof tops. Heat radiates off from this dark roof tops and water rushes over the hard impermeable roof surfaces. To encounter these hazards as well as growing awareness about the dangers of the greenhouse effects and global warming, 'Go Green' is becoming the catch phrase of the day. As a result, a new trend that breaks up the monotony of common roofs— green roof top (fit.-1) idea is getting popular day by day.

Long popular in Europe, green roof tops attract the attention of homeowners, businesses even, city planners as an alternative attractive way to promote environmentalism. Green roofs supplement traditional conventional vegetation. Without disrupting urban infrastructure— they just occupy a neglected space and make it useful.

Green roof is also referred as eco-roof, living roof, oikostegi, vegetated roof, horizontal vegetated complex walls etc.

HISTORY OF GREEN ROOF

Green roofs have a century long history. The origin of green roof dots back to around 500 B.C when the Hanging Garden of Babylon was constructed. This was famous as one of the Seven Wonders of the Ancient World. This Hanging Garden was constructed over arched stone beams and waterproofed with layers of reeds and thick tar; plants and trees were then planted.

Modern green roofs are made of a system of manufactured layers deliberately placed over roofs to support growing medium and vegetation. This is a relatively new concept which was first developed in Germany in 1960's and since then spread to many countries. Considering the plentiful benefits the popularity of green roof is growing across the globe. They become increasingly popular in United States of America, but of course not as common as in Europe.

GREEN ROOF AWARENESS

Recent information reveals that green roof research and technology and activities exist in about 40 countries around the globe. Some of them are:

* Principal, Vivekananda College, Thakurpukur, Kolkata-700063



Germany: Green roof traditions started in Germany more than 100 years ago. In 1970's, green roof technologies were elevated to the next level. Germany is the country with most green roofs in the world and with the most advanced knowledge in modern green roof technology. In Germany, two cities Berlin and Stuttgart are with the most green roofs. Nearly one-third of all German cities have regulations to support green roof technology.

Australia: Popularity of green roofs is increasing in Australia over the last 10 years. In 2010, the largest green roof project was announced in Australia. Since 2008, most of the city councils and big business houses in Australia are active in promoting the benefits of green roofs.

Canada: In May 2009, a by-law was passed in Toronto mandating green roofs on residential and industrial buildings which are a minimum six storeys high. The largest green roof of six acre in Canada was installed in 2008 on the top of the Vancouver Convention Centre.

France: In France, a 8000 square meters of green roof has been created on the top of the International School in Lyon. Another green roof of similar size has also been constructed on the new museum at Boulogne.

United States of America: Green roof movement in United States is gaining fast popularity. Many corporate houses and residential complexes are showing interest in setting green tops. Ford Motor Company's River Rouge Plant, Michigan covered 42000 square meters of roof top with sedum and other plants. California Academy of Sciences building in San Francisco provided 2.5 acres of green roof. 1300 square meters of roof top of Zeckendorf Towers, formerly an undistinguished roof top, is now covered with green plants, making the largest residential green roof in New York.

Switzerland: Switzerland has one of the Europe's oldest green roofs, created in 1914 at Zurich. Recent examples are found in the Cantonal Hospitals at Basel and in the Sihlpost platform at the main railway station in Zurich.

Iceland: Green roofs are frequently found on the traditional farmhouses and farm buildings in allover Iceland.

Sweden: The first green roof botanical garden of the world was set up in Augustenborg in 1999. In 2001, the Scandinavian Green Roof Institute was established in Sweden. In 2012, the roof top of a shopping mall, Emporia, was converted in green roof, the size of which is approximately equivalent to four soccer fields.

United Kingdom: At present, green roofs are common in UK, but in 2003, English Nature commented that green roofs are largely ignored by the UK policy makers. An early example of green roof in UK is on the top of Derry & Toms Departmental Store in Kensington, London in 1938. The recent examples can be found at the University of Nottingham Jubilee Campus, Harriman Museum at Canary Wharf and the Ethelred Estate in Central London. The University of Sheffield has established a Green Roof Centre of Excellence to enhance research.

China: Now a days China concerns itself more and more about how to make a life better and how to resolve the environmental problems in modern city. Beijing has 90 million square metres of potential green roof spaces. Beijing government has been using subsidies to create green roofs since 2008. Presently, on an average, 100000 square metres of green roof areas are added per year in Beijing since 2005.

Japan: The Japanese government has given green roofs a high priority at national as well as city level as a primary means to reduce energy budget of its citizens. Japan is one of the major global centres of green roof implementation. One of the famous example in Japan is the Prefectural International Hall in Fukuoka city. The roof of this building features a whopping 35000 plants representing 76 different plant species.

India: In our country, the awareness and installation of green roof is not very convincing though it is highly beneficial to this kind of warm climate like us. In India, an important example of green roof is Rajiv Gandhi International Airport at Hyderabad.



BENEFITS OF GREEN ROOF

Green roofs offer many public, private and design based benefits which are the causes for its growing popularity. It serves several purposes for a building such as absorbing rainwater, providing insulation, creating a habitat for wildlife, helping to lower urban air temperature and mitigate the heat island effect.

PUBLIC BENEFITS

Aesthetic Improvement: Beautification of urban areas by greening the roof tops in an easy and effective strategy. It has aesthetic value as well as it increases investment opportunities.

Waste Diversion: Recycled materials are used in the growing medium. It helps in prolonging the life of waterproofing membranes and the service life of heating, ventilation systems through decreased use.

Storm-water Management: Water is retained by green roof substrate which is returned to the atmosphere through transpiration and evaporation by the plants on it. In summer, depending upon the types of plants and depth of growing medium, green roofs retain 70%-90% of the precipitation that falls on them; in winter, the rate of retention is between 25%-40%. As a result of rainwater retention, green roof also moderate the temperature of water and act as natural filters for many of the water that happens to run-off. Green roofs help in the management of storm water drainage and reduce the total amount of run-off by as many as 75% and also delay the time at which run-off occurs, Thus reducing the stress on sewer system at peak flow periods. Studies have shown that the ability of green roof to retain water longer also aids in retaining many pollutants that would otherwise be released directly into the environment.

Reduce Heat: Plants on roof tops are able to cool cities during hot summer months and reduce urban heat effect through the daily dew and evaporation cycle.

Research group of Nottingham Trent University, England, released their observation as below:-

	Summer	Winter
Daily Mean Temperature	18.4°C	0°C
Normal Roof Temperature beneath membrane	32.0°C	0.2°C
Green roof Temperature beneath membrane	17.1°C	4.7°C

Improve Air Quality: Airborne pollutants and atmospheric depositions are captured or absorbed in green roofs. It also filters the noxious gases, thereby reduces disease rate, such as asthma. The temperature moderating effects of green roofs can reduce demand on power plants.

New Amenity Spaces: Green roofs create new spaces for a number of community uses.

- Increase agricultural space for food production by the local co-operatives.
- Create commercial space for display and set up of terrace restaurant.
- Increase recreational space for children's playground.

Local Job Creation: There is significant potential for creation of new jobs related to green roof market such as construction, installation, design, plant growth and maintenance.

PRIVATE BENEFITS

Energy Efficiency: Green roofs offer insulation which can reduce the amount of energy required for moderate the temperature of a building. The National Research Council of Canada calculated that an extensive green roof could reduce the daily energy demand for air conditioning in the summer by over 75%.

Increase Roof Membrane Durability: Green roof decreases the exposure of waterproofing membranes to large temperature fluctuations, causing increased durability of the roof membranes.



Fire Retardation: Green roofs offer fire protection since it has much lower heat load compare to conventional roofs.

Reduction of Electromagnetic Radiation: The risk of electromagnetic radiation from wireless devices and mobile communication to human health is still a big question for debate, however, green roofs are capable to reduce electromagnetic radiation by over 99%.

Noise Reduction: Green roofs have excellent noise attenuation capacity. An extensive green roof can reduce sound from outside by 40 decibels, while an intensive green roof can reduce sound by 45-50 decibels.

Increase Real Estate Value: Green roofs can increase the marketability of a building since it has various benefits and opportunities.

OTHER BENEFITS

Increase Biodiversity: Green roofs can sustain a natural habitat of a variety of plants and invertebrates and also attracts various bird species. This stabilized ecosystem certainly maintains high levels of productivity and ensure the delivery of many useful materials and services.

Improved Well-Being: Reduced pollution and better water quality can bring down the demand on the health care system. Green roof also serves as a community hub to increase social cohesion and thereby increase the sense of community and public safety.

Urban Agriculture: Green roofs can be utilized as a site for urban agriculture project which reduce the footprint of the community. It also serves as a source of community empowerment which provides increased feelings of self reliance and supplies improved levels of nutrition.

iv) Educational Opportunities: It is an easily accessible sight to the students and visitors to learn about biodiversity and also the technology and benefits of green roofs.

DISADVANTAGES OF GREEN ROOF:

Under present state, the main disadvantage of green roof is the initial investment costs in building materials, waterproofing system and roof barriers. The additional mass of soil and water retention on top demands more structural support. In earthquake prone areas more additional cost is required. Maintenance cost could be higher in some cases depending upon the type of green roof and the nature of plant species.

Green roof Varieties: Basically three types or varieties of green roof technologies are observed in all over the world.

	Intensive Green Roof	Semi-Intensive Green Roof	Extensive Green Roof
Depth of growing medium	Over 12 inches	6-12 inches	3-6 inches
Maximum weight	18-35 kg/sq. ft.	15-25 kg/sq. ft.	7-15 kg/sq. ft.
Plant types	Perennials, Lawn grass, Shrubs, Trees	Selected perennials, Sedum, Shrubs, Herbs, Ornamental grasses	Moss, sedum, Succulents, Herbs, Few grasses
Irrigation	Advanced system	Occasional	Not required
Maintenance cost	High	Medium	Low
Initial cost	High	Medium	Low



COST OF GREEN ROOF:

The initial investment cost of green roof depends on a number of factors, such as the depth of growing medium, arrangement of irrigation system, types of plant species and also accessibility. At present, in United States, in addition to the cost of waterproof layers, 15 to 20 dollars per square foot is the cost for installation. In Europe, the usual cost for installation of well designed green roof is between 100 to 200 euros per square meter.

CONCLUSION:

Green roof technology and its application in large scale would be the future solution to make the cities environment friendly and habitable. Green roofs not only help in temperature mitigation but also adjust the pollution level by absorbing pollutants in a big way. These benefits attract people all over the globe. In India, the green roof movement has kicked started and the awareness among the common people is increasing. Application of green roofs is also very easy on the budget. The initial higher payment is balanced by lowering of the future utility bills. The cost of green roof application varies with region, climate, building pattern and green roof type and design. In advanced countries researchers are still in search to lower the cost of application and maintenance charge and to increase its durability. Green roof concept applies to both existing and new constructions, from a small building space to a large development project. This only requires close co-operation among the designer team, the architects, the engineers and obviously the clients.

FURTHER READINGS:

- Herman, M.S., 2003. Green Roof in Germany: Yesterday, today and tomorrow. In 1st North America Green Roof conference, Chicago.
- Liu, K and Bhaskaran, B., 2003. Thermal Performance of Green Roof through Field Evaluation. National Research Council of Canada, Report No. NRCC-46412.
- Realties, vol. 9 (1), 2013

Websites:

- www.en.wikipedia.org
- www.greenroofs.org
- www.roofsystemsconsultants.com
- www.mosacres.com

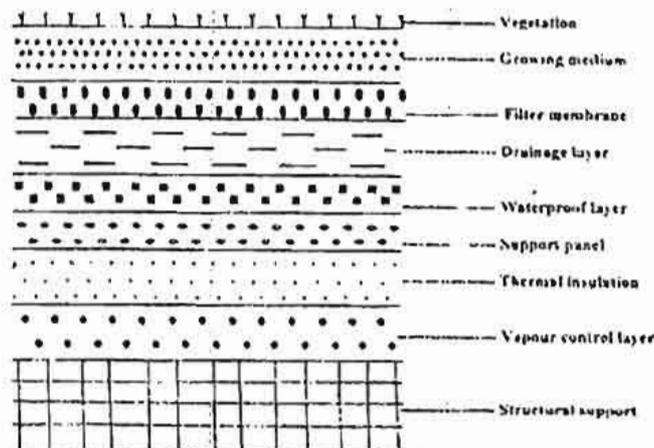


Fig. 1. Cross section of a Green Roof.



Dimensional Analysis in Physics

Debnarayan Jana*

Abstract: In modeling any physical phenomena, the first step is the identification of the relevant variables and the second step is to relate these variables through some physical laws. Dimensional analysis (DA) provides us a very simple heuristic method to solve the dependence on the variables without invoking much theoretical knowledge. In DA, one first predicts the physical parameters which will influence the problem and then by grouping these relevant parameters in appropriate dimensionless combinations; one can get a better understanding of the problem. Moreover, it is of great help to experiments because it eventually provides a guide to the parameters which influence the phenomenon.

Dimensional analysis (DA) is nothing but a mathematical technique used generously in physical science, chemical science and technology to study the dimensions of physical quantities and correctness of equations. This mathematical technique is most suitable in research work for design and conducting model tests. The word dimensional means a parameter which has dimensions. In contrast, the dimensionless constants such as $\pi, \frac{1}{4}$ etc. do not have dimensions.

Dimensional analysis (DA) is one of the powerful tools in theoretical physics, often invoked to solve the problems without much mathematics. Dimensional analysis in physics has been routinely used to discuss the dependence of various physical quantities with others and for conversions of units from one system to others. Here, we would like to discuss two physical problems which can be tackled so nicely by this method. These problems are not often discussed in the text books or in the classrooms for the young students. The bottom line of the DA is that one does not solve the exact functional form of the solution to a given problem.

Every natural or physical relation/equation must be dimensionally correct. This is nothing but the **principle of homogeneity** in DA. Dimensional analysis (DA) refers to the physical nature of the quantity and the type of units (dimension) used to specify it. The dimensions of any physical quantity can be expressed in terms of mass-length-time (MLT); or in other words, the left hand side (lhs) and the right hand side (rhs) of the equations must have same power of M, L and T. Thus, every term in a physical equation must have the same dimension. In fact, the correctness of an equation can be verified by this approach.

There are functions which are dimensionless. For example, trigonometric, logarithms, exponential are such functions. Angles are defined in terms of the ratio of lengths; hence they are dimensionless. One may also form dimensionless number from the physical parameters. For example, if P denotes the pressure, r radius,

mass m and time t, then it is easy to note that $\left[\frac{Pr t^2}{m}\right]$ is dimensionless. It is obvious that functions of dimension-

less variables are also dimensionless and dimensionless functions must have dimensionless arguments. For example, consider the radioactive decay equation $N(t) = N_0 \exp(-kt)$; it is easy to note that k must have the dimension of inverse of time, because exponential function must have dimensionless arguments. The principle of homogeneity also indicates that the form of an equation is independent of the size of the base units.

Can we ask the simple question that: Is there any simple way to identify the number of dimensionless constants in a physical problem? This can be answered by the famous Buckingham's Π theorem. This theorem is the central one in DA. And it relates the dimensionally governed quantities and several governing parameters

*Department of Physics, University of Calcutta, 92, A.P.C. Road, Kolkata-700009.



with identified dimensionless parameters. The statement of this theorem is as follows: If there are n variables (dependent and independent) in a physical phenomenon and if these variables contain m fundamental dimensions, then the variables are arranged into $(n-m)$ dimensionless terms which are known as Π terms. For example, let X_1, X_2, \dots, X_n be n variables in a physical problem. Out of them, we assume X_1 be the independent variable and rests of the others are dependent. Therefore, we can write mathematically as

$$\begin{aligned} X_1 &= f(X_2, X_3, \dots, X_n) \\ f(X_1, X_2, \dots, X_n) &= 0 \end{aligned} \quad (1)$$

This equation (1) is dimensionally homogeneous. It contains n variables and if there are m fundamental dimensions, then it can be written as groups of $(n-m)$. In other words,

$$f_1(\Pi_1, \Pi_2, \dots, \Pi_{n-m}) = 0 \quad (2)$$

Note that the function f_1 is not supplied by DA. We need a real theory to find that or experiment may help us to do that. Here are the some characteristic features of Π theorem.

- Each Π term by its very definition is dimensionless and is independent of the system of units.
- Division or multiplication by any constant naturally does not change the character of any term.
- Moreover, each term contains $(m+1)$ variables, where m is the number of fundamental dimensions

also called repeating variables. No two repeating variables have the same dimension. The repeating variables should form a dimensionless group. Besides, in fluid mechanics, the repeating variables are chosen in such a manner that one of them contains geometric property, another flow property and the third one fluid ones.

Suppose, we assume in the previous case that X_2, X_3, X_4 are repeating variables and if fundamental dimensions $m=3$ then each Π -term can be written as

$$\begin{aligned} \Pi_1 &= X_2^{a_1} \cdot X_3^{b_1} \cdot X_4^{c_1} \cdot X_1 \\ \Pi_2 &= X_2^{a_2} \cdot X_3^{b_2} \cdot X_4^{c_2} \cdot X_5 \\ \Pi_{n-m} &= X_2^{a(n-m)} \cdot X_3^{b(n-m)} \cdot X_4^{c(n-m)} \cdot X_n \end{aligned} \quad (3)$$

Now, each equation is solved by **principle of dimensionless homogeneity** and values of a_1, b_1 and c_1 etc are obtained. Finally, one can rewrite the result in the form of

$$\begin{aligned} \Pi_1 &= (\Pi_2, \Pi_3, \Pi_4, \dots, \Pi_{(n-m)}) \\ \Pi_2 &= (\Pi_1, \Pi_3, \Pi_4, \dots, \Pi_{(n-m)}) \end{aligned} \quad (4)$$

Below we discuss two problems which can be analyzed by DA.

Problem 1:

Let us warm up with a simple example of flow of a viscous liquid through a tube of length l and radius r obeying streamline motion. We are interested in the volume V of such a Newtonian liquid flowing per unit time through the tube due to the existence of a pressure difference P between the two ends of the tube. We know for a Newtonian liquid, the stress is proportional to the velocity gradient and the constant of proportionality known as the coefficient of viscosity. It is clear from the very definition of the coefficient of viscosity that $[\eta] = ML^{-1}T^{-1}$. If one assumes that



$$\frac{dV}{dt} = f(r, l, P, \eta) \quad (5)$$

then, by dimensional analysis, it is not possible to find out the dependences on the various parameters. The reason is that we have three variables MLT but we have four parameters. Moreover, r and l have the same dimension of length. Using Π theorem, we note down that there are two dimensionless quantities in the

problem which are $\Pi_1 = \frac{Pr^4}{\left(\frac{dV}{dt}\right)\eta l}$ and $\Pi_2 = \frac{l}{r}$. Then, it is easy to see that

$$\frac{dV}{dt} = \frac{Pr^4}{\eta l} \Phi\left(\frac{l}{r}\right) \quad (6)$$

This problem however can be avoided from the simple physical understanding of the problem that it is not the pressure difference but the pressure gradient which is the important parameter for the liquid flow. This immediately eliminates one of the four variables to write the above equation as

$$\frac{dV}{dt} = f\left(r, \frac{P}{l}, \eta\right) \quad (7)$$

Comparing the various powers of MLT on both sides, we obtain the following equations:

$$\begin{aligned} x - 2y - z &= 3 \\ y + z &= 0 \\ 2y + z &= 1 \end{aligned} \quad (8)$$

Therefore, the final rate of volume flow can be written as

$$\frac{dV}{dt} = C \frac{Pr^4}{\eta l} \quad (9)$$

Here, C is a dimensionless constant. The above equation should be compared with the exact relation known as Poiseuille's equation

$$\frac{dV}{dt} = \frac{\pi Pr^4}{8\eta l} \quad (10)$$

Problem 2: Pythagoras theorem

We will apply the dimensional analysis to Pythagoras theorem to right angled triangles. Any right angle triangle such as OXY can be uniquely specified by three parameters (a, b, c) or two dimensionless angles (θ, ϕ) and the hypotenuse (XY) c .

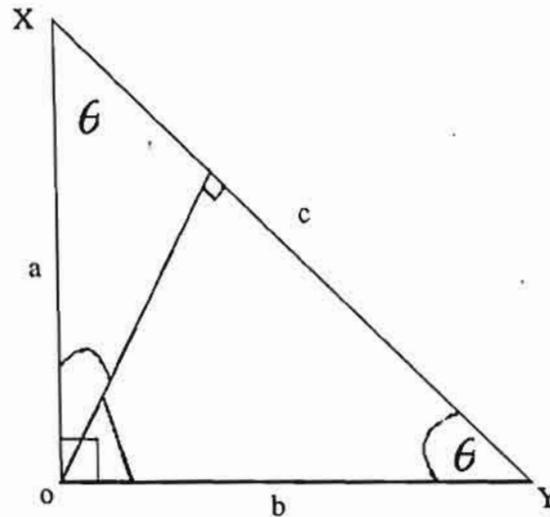


Figure 1: Example of a right angle triangle OXY

All these parameters (a, b, c) have the dimension of length. The area of the right angle triangle can thus be uniquely specified by the parameters (c, θ, ϕ) . Mathematically, $\Delta OXY \equiv f(c, \theta, \phi)$ where θ and ϕ are the angles shown in figure 1. The other two sides of the triangle are $OX=a$ and $OY=b$. As mentioned, c has the dimension of length, the area can be written from dimensional arguments $\Delta OXY \equiv f(c, \theta, \phi) = c^2 g(\theta, \phi)$ as . It is to be noted that the function $g(\theta, \phi)$ being a function of dimensionless parameters is dimensionless and is unknown. Moreover, it will not depend on the parameter c at all because of simple dimensional reason. Now, we notice that we can divide the triangle into two similar triangles having hypotenuse a and b. This geometric construction is shown in figure 2.

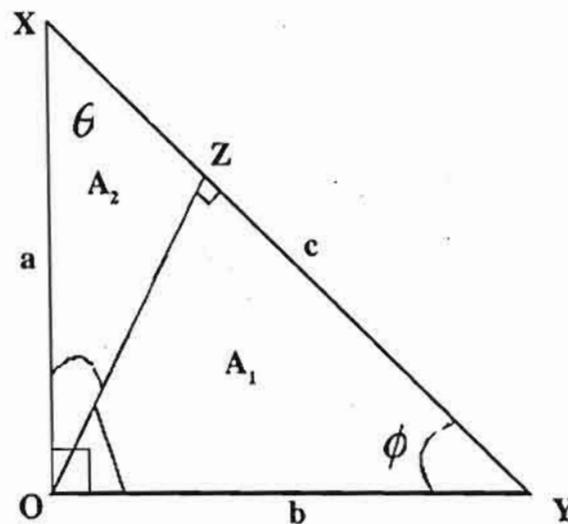


Figure 2: Geometric construction of two similar triangles



We can represent the area of OXZ and OZY by the parameters (a, θ, φ) and (b, θ, φ) respectively. Now, the total area of the OXY triangle is the sum of the area of two triangles OXZ and OZY. Therefore,

$$c^2 g(\theta, \varphi) = a^2 g(\theta, \varphi) + b^2 g(\theta, \varphi) \quad (11)$$

It is interesting to note that all the triangles are similar in nature and hence, naturally their areas should be described by the same function $g(\theta, \varphi)$. Thus, $g(\theta, \varphi)$ is universal, dimensionless and scale invariant function. Therefore, the above equation (9) reduces to

$$c^2 = a^2 + b^2 \quad (12)$$

There exist much simpler methods to prove this theorem. But this approach beautifully uses the power of dimensional analysis to indicate the relation with the area. However, one needs to remember a cautionary remark in this regard. This approach, however, can not be used for the triangles drawn in curved surface such as a riding saddle or football.

CONCLUSION

In this paper, we have indicated the power of dimensional analysis to two interesting problems in science. These problems are not normally discussed in the framework of dimensional analysis in the class. I hope the students will enjoy these problems and it will definitely help them to design various models in other branches of science.

ACKNOWLEDGEMENTS

I would like to acknowledge my students of post-graduate class for asking several questions related to this matter. I have been benefited from discussions with the dedicated teachers of physics community.

REFERENCES

- Jana, D. 2011. Dimensional Analysis: Modern Perspectives, Lambert Academic Publishing, Germany.
- Jana, D. 2008. Phys. Edu., 25, 35.
- Buckingham, E. 1944. Phys. Rev04, 375.
- Barenblatt, G.I. 1996. Scaling, Self-similarity, and Intermediate Asymptotics, Cambridge University Press, Cambridge, UK.
- Misic Tatjana, Najdanovic-Lukic Marina and Nescic Ljubisa, 2010. Eur. J. Phys, 31, 893.
- Jana, D. 2002. Phys. Edu., 19, 167.
- Tanimoto, S. Dimensional Analysis and Physical Laws, ArXiv:physics/0609117v1



রসায়ন আর অণুর জগৎ

দেবব্রত মন্ডল *

‘আপনার গবেষণার বিষয়টা ঠিক কী?’

প্রশ্নকর্তা যদি বিজ্ঞানচর্চার সাথে প্রত্যক্ষ বা পরোক্ষভাবে যুক্ত না হন, তবে এর সন্তোষজনক উত্তর দেওয়া কঠিন। এসবক্ষেত্রে রাসায়নিক বর্ণালীবিদ হিসেবে একটা হালকা চালের উত্তর আমি প্রায়শ দিয়ে থাকি: ‘আমি অণুদের ওপর আলো ফেলে দেখি ওরা কী করছে।’ উত্তরটা শুনে নানান লোকের প্রতিক্রিয়া হয়; যার মধ্যে বিশেষ করে মনে আছে এক রসিক ব্যক্তির মন্তব্য: ‘বাঃ! এ তো ভারী মজা: যেন অন্ধকারে একঝাঁক প্রজাপতির ওপর জোরালো টর্চের আলো ফেলে তাদের ওড়াউড়ি দেখা।’ উপমাটা মজার বটে, কিন্তু নিতান্ত অসার নয়। সত্যিই আমরা, রসায়নবিদরা, ‘অণু’ ব্যাপারটাকে নিয়ে এতো অবলীলায় নাড়াচাড়া করি যে এরা আমাদের কাছে জীবন্ত প্রজাপতির মতই বাস্তব! অথচ, আমরা কেউই এদের কোনদিন সরাসরি চোখেও দেখব না, কানেও শুনে পাব না এদের ডানার ঝটপটানির আওয়াজ!

সাধারণজনে রসায়ন বলতে এখনো হয়তো বোঝে টেবিল জুড়ে বিচিত্র আকার-আয়তনের নানান কাঁচের পাত্র ও বকযন্ত্র, যাদের মধ্যে লাল-নীল-হলদে-সবুজ নানান তরল- কোনটা ফুটছে, কোনটা ফোঁটা ফোঁটা করে পাতিত হচ্ছে, কোনটার ভিতর থেকে হুশ-হুশ করে বেরোচ্ছে বিদ্যুটে গন্ধের গ্যাস! এরপর উপরি পাওনা রয়েছে ছোট-বড় দুর্ঘটনার নিত্য সম্ভাবনা। সাধারণজনের মধ্যে রসায়নের অন্য একটা পরিচয় হল অফুরন্ত তথ্যের স্তূপ হিসেবে। এত অসংখ্য পদার্থ আমাদের চারপাশে, যেন তাদের নাড়ি-নক্ষত্রের সব খবর জমা থাকার কথা রসায়নবিদদের মগজে। মোটের উপর, গত একশো বছরেও রসায়নবিদ্যা সম্পর্কে সাধারণ ধারণার খুব বেশি পরিবর্তন হয়নি। অথচ ঘটনা হল, lab skill ও Chemical information-এর অপরিহার্য গুরুত্ব মেনেও আজকের দিনে আমাদের মধ্যে কেউই আর নিজেেকে একজন ‘modern alchemist’ বা চলমান ‘chemical encyclopedia’ হিসেবে দেখি না। বরং যেকোন practising chemist-এর চিন্তা-ভাবনা-ভাষ্যের অনেকটা জুড়েই থাকে অণু-পরমাণু, তাদের ‘চেহারা-চালচলন’ ও ক্রিয়াকলাপের ইতিবৃত্ত।

সাধারণত বিজ্ঞানের ছাত্রের কাছে অণু-পরমাণুর প্রথম পরিচয় হয় জড়বস্তুর building-block হিসাবে। বাড়ি তৈরি করতে যেমন ইট-কাঠ-পাথর লাগে, তেমনই যে কোনো জড়বস্তুর গঠনের মূল উপাদান হল পরমাণু, আর তারপরে অণু। প্রাচীনযুগ থেকেই নানান দার্শনিকের পর্যবেক্ষণ থেকে এই ধারণার সূত্রপাত, যা ঊনবিংশ শতাব্দীতে আভোগাড্রো, ডালটন প্রমুখ মণীষীদের হাত ধরে বিজ্ঞানের একটি মৌলিক সূত্র হিসেবে প্রতিষ্ঠিত হয়েছে। এখন, শুধুমাত্র স্থবির building-block দিয়ে বস্তুর গঠন হয়তো বোঝা গেল, কিন্তু তার ভৌত-রাসায়নিক ধর্মগুলোর ব্যাখ্যা হবে কী করে?

এই প্রশ্নের উত্তর খুঁজতে গিয়ে প্রায় সমসময়েই গড়ে উঠল আর একটা আশ্চর্য শক্তিশালী বিষয়: আণবিক গতিতত্ত্ব। আমরা অণুকে একটা জঙ্গম কণা হিসেবে দেখতে শিখলাম। আপাতদৃষ্টিতে স্থবির যে জড়বস্তু, তার অভ্যন্তরেও নিরন্তর চলছে অণুর গতিময় আলোড়ন! অণুরা পাগলের মত যদিকে খুশি যেমন ইচ্ছে ছোট্টাছুটি করছে, পরস্পরকে ধাক্কা না খাওয়া পর্যন্ত সোজা সরল রেখার সমগতিতে উর্দ্ধমুখে দৌড়োচ্ছে, প্রবলবেগে আছড়ে পড়ছে দেওয়ালে। ঠিক কতটা তাদের গতিবেগ?

যদি সাধারণ তাপাংকে ($T=300K$) N_2 অণু ধরি, তবে $M=28g/mole=0.028kg/mole$,

$$\text{এবং, rms velocity} = \sqrt{\frac{3RT}{M}} = 500ms^{-1} \text{ (প্রায়)}$$

অর্থাৎ আমাদের N_2 অণুগুলো ১ সেকেন্ড-এ গড়েপ্রায় ১/২ কিমি ছুটে যাচ্ছে! এরপর যদি মনে করিয়ে দিই যে এদের নিজেদের আয়তন মাত্র কয়েক Angstrom ($=10^{-10}m$), তাহলে বাস্তব পরিস্থিতিটা কী দাঁড়াল? এরা এক একজন ১ সেকেন্ড-এ নিজেদের আয়তনের তুলনায় 10^{12} গুণ দূরত্ব অতিক্রম করছে!

* সহকারী অধ্যাপক, রসায়ন বিভাগ, কলকাতা বিশ্ববিদ্যালয়, ৯২, এ পি সি রোড, কলকাতা-৭০০ ০০৯



কোথায় লাগে উসেইন বোস্ট?

এই বিপুল গতিশক্তি, আমাদের সাধারণ ইন্দ্রিয়ের যার কোন হদিশ ই পাওয়া যায়না, তাই থেকেই উৎপত্তিলাভ করেছে তাপাংকে ও চাপ-এর মত ইন্দ্রিয়গ্রাহ্য বস্তুধর্ম। ঊনবিংশ শতাব্দীর দ্বিতীয়ভাগে, যখন ম্যাক্সওয়েল-বোলৎজমান-কেলভিন-ব্লুসিউস ও আরো অনেক কৃতী বিজ্ঞানীর হাত ধরে আণবিক গতিতত্ত্ব বিকাশলাভ করেছে, তখন বিজ্ঞানী-মহলে কিরকম সাড়া পড়ে গিয়েছিল সেটা এখন থেকেই খানিকটা আঁচ করা যায়। কণার গতিবেগ এখন আমাদের চিন্তাভাবনার এতটাই অমোঘ যে রিচার্ড ফেইনম্যান এক জায়গায় বলেই গিয়েছেন যে পদার্থবিদ্যার অনেকটা, আর রসায়নবিদ্যার প্রায়-সবটাই অণু-পরমাণুর ছুটোছুটি-ছুটোপুটি (wiggling and jiggling) দিয়েই ব্যাখ্যা করা যাবে।

অবশ্য আণবিক গতিতত্ত্ব বেশিদিন তার অজ্ঞাত স্থান ধরে রাখতে পারেনি, নিউটনীয় গতিবিদ্যার উপর তার নির্ভরতাই শেষ পর্যন্ত তাকে পিছু হঠতে বাধ্য করল, যখন গত শতাব্দীর শুরুতে হুডমুড করে এসে পড়ল কোয়ান্টাম গতিবিদ্যা।

কিন্তু কণার গতিবেগের যে ধারণা, শুধু সেটা দিয়েই কি রসায়নবিদ-রা তাঁদের সব প্রশ্নের সমাধান পেয়েছিলেন?

একটা বিরাট সমস্যা থেকেই যায়: অণুর উপর শুধুমাত্র গতিময়তা আরোপ করলেই কি যথেষ্ট হল? অণু-পরমাণুকে না হয় চলমান বল বা মার্বেল হিসেবেই দেখলাম, কিন্তু তা দিয়ে কি সব জটিল বিক্রিয়া বা সবরকম রাসায়নিক ধর্মের ব্যাখ্যা করা যাবে?

'অণু' আর 'পরমাণু' —এই দুটো সংজ্ঞার মধ্যে বিভ্রান্তির অবসান প্রথম করেন আভোগাড্রো, যখন ১৮১১ সালে তিনি বলেন যে বস্তুর (গ্যাসের) ক্ষুদ্রতম কণার অণু, এবং অণু নিজে হল কয়েকটি পরমাণুর সমষ্টি। এখন, ধরে নেওয়া যাক পরমাণুরা নিটোল গোলকের মত। তাহলে প্রশ্ন হল: অণুরা কেমন দেখতে?

অণু কি শুধু একটা মণ্ড-এর মত, যেমন একতাল মাছের ডিম, যেটা অনেক ছোট ছোট গোলাকৃতি ডিমের সমষ্টি, কিন্তু যার নিজের কোন স্পষ্ট আকার নেই? নাকি, এক একটা অণুরও সুনির্দিষ্ট 'চেহারা' বলে যদি কিছু আছে? এই মৌলিক প্রশ্নটা রসায়নবিদদের কাছে একটা বিরাট চ্যালেঞ্জ হিসেবে দেখা দিয়েছিল। শর্ত বলতে ছিল একটাই: অণুর 'চেহারা' বলে যদি সত্যিই কিছু থাকে, তবে সেটা তার রাসায়নিক ধর্ম ব্যাখ্যা করতে পারতে হবে। অবশেষে এই সূত্র ধরে ঊনবিংশ শতাব্দীর মাঝামাঝি কেকুলে প্রথম রাসায়নিক বন্ধনীর একটা সুনির্দিষ্ট রূপ প্রস্তাব করলেন। জৈবযৌগের জন্য তিনি নির্মাণ করলেন Molecular Structure বা আণবিক অবয়ব। Carbon, hydrogen, oxygen প্রভৃতি পরমাণুরা বন্ধনীর শিকলে বাঁধা পড়ে এক একটা অণুর একান্ত নিজস্ব অবয়ব তৈরি হল, যা দিয়ে তার stoichiometry ও reactivity- উভয়ই মেলানো গেল। এই পদক্ষেপ অনুসরণ করে ক্রমশ বিকাশলাভ করল Theory of Molecular Structure ও Theory of Chemical Bond.

আমরা পেতে শুরু করলাম নানান ধরনের অণুর নানানরকম সুনির্দিষ্ট অঙ্গসংস্থান। কোনো কোনো অণু হল dumb-bell এর মত দেখতে, কেউবা লম্বা শিকল, কেউ চ্যাপ্টা disc-এর মত। কেকুলে নিজেই benzene যৌগের রূপ নিয়ে ভাবতে ভাবতে স্বপ্ন দেখে ফেললেন: কিভাবে hydrocarbon শিকলের দুই প্রান্ত জুড়ে গিয়ে চ্যাপ্টা চক্রাকার শিকলের মত তৈরি হচ্ছে aromatic molecules। অণুর রাসায়নিক চরিত্র নির্ধারণ করতে গিয়ে গুরুত্ব দিতে হল তার জ্যামিতিক ধর্মকে-তার bond length/bond angle-গুলো কী কী, তার ক'টা অক্ষ বা পৃষ্ঠতল আছে, কোথায় তারা অবস্থিত, ইত্যাদি। এর পরবর্তী পর্যায়ে অণুরা হয়ে উঠে 'বহুভুজ', তাদের 'শরীরে' যুক্ত হল substituents, side-chains, functional groups।

এইসব বিপুল কর্মকাণ্ড-এর বেশিটাই সম্পন্ন হয়েছিল ঊনবিংশ শতাব্দীর দ্বিতীয়ভাগে। যখন ভাবি যে সে সময়ে রসায়নবিদদের কাছে কোনোই sophisticated instrument বা computer ছিল না, ছিল কেবল রাসায়নিক বিক্রিয়ার বিবিধ তথ্য, আর সেগুলোই অবলম্বন করে, নিজেদের কল্পনাশক্তি আর কাণ্ডজ্ঞান খাটিয়ে তাঁরা অনেকেই অজ্ঞত যৌগের নিখুঁত আণবিক অবয়ব রচনা করে গেছেন, তখন বিশ্বয় আর শ্রদ্ধার অবধি থাকে না। বিজ্ঞানের ইতিহাসে এমন accurate imagination / intuition- এর দৃষ্টান্ত বড়ো একটা খুঁজে পাওয়া যাবে বলে মনে হয়না। এই বৈপ্রবিক কর্মকাণ্ডের পরিণতিতে রাসায়নিক বিক্রিয়া সম্পর্কেও ধারণাগুলো নতুনভাবে সমৃদ্ধ হয়ে উঠল: বিক্রিয়ার মানে হয়ে উঠল অণুতে-অণুতে দ্বৈরথ, তাতে কোনো অণুর অঙ্গচ্ছেদ হবে, অন্য কারো ঘটবে কলেবরবৃদ্ধি, কেউ জোড় বাঁধবে, কেউ বাঁধন ছিঁড়ে পালিয়ে যাবে।



অণুর অঙ্গবিন্যাস আরো সূক্ষ্মতা পেল নিউক্লিয়াস আর ইলেকট্রনের আবিষ্কারের ফলে, একে একে লিউইস, মুলিকেন, পলিঙ প্রমুখ মহাবিজ্ঞানীদের হাত ধরে। আরো সাম্প্রতিককালে, quantum mechanics-এর ব্যাপক প্রয়োগ রসায়নবিদ্যাকে দিয়েছে অভূতপূর্ব scientific accuracy। অনিবার্যভাবে এসেছে নানান abstract idea, যেমন অনিশ্চয়তাসূত্র বা ইলেকট্রনের তরঙ্গ-ধর্ম। আশ্চর্যের বিষয়, অণুর অব্যবের কল্পনায় কিন্তু এইসব দুরূহ প্রস্তাবনাকেও বেশ সহজেই ফিট করিয়ে দেওয়া গেছে। এখানকার কোন রাসায়নিক পেপার বা পাঠ্যবইয়ে অণুর 'ছবি' বলতে বোঝায় নির্দিষ্ট জায়গায় বসানো ছোট ছোট পিণ্ডের মত একাধিক নিউক্লিয়াসের একটা সমাহার, যার উপর সাদ্র তরলের মত প্রলিপ্ত রয়েছে 'ইলেকট্রন-মেঘ'। ছবিটা কৃত্রিম ও inaccurate, কিন্তু অসাধারণ কার্যকরী।

সব মিলিয়ে গত এক-দেড়শো বছরের রসায়নের অভাবনীর সাফল্যের পিছনে একটি শক্তিশালী visual & functional tool হিসেবে অণুর অসীম অবদান। মনে হয় এটা সম্ভব হয়েছে কারণ পুরো ব্যাপারটার মধ্যেই যেন zoomorphy-র মত একটা ধারণা প্রচ্ছন্ন হয়ে রয়েছে। এক একটি অণু যেন সত্যিই আমাদের কাছে পুরোদস্তুর 'হাত-পা-মাথা ওয়ালা' এক একটি ছোট ছোট পোকামাকড়, যাদের এক এক প্রজাতির এক এক ধরনের স্বভাব ও প্রবণতা, আর তার সাথেই তালে তাল মিলিয়ে এক এক ধরনের চেহারা ও অঙ্গসংস্থান। আমরা, রসায়নবিদরা চাই ওদের ইচ্ছেমতন কাটাছেঁড়া করতে, ওদের একে অপরের সঙ্গে লড়িয়ে দিতে।

যখন বর্ণালীবিদ্যার ল্যাভে ঢুকে কোন রাসায়নিক দ্রবণের উপর আলো ফেলি, তখন তড়িচ্চুম্বকীয় তরঙ্গের অভিঘাতে দ্রবণের অণুগুলোর অনেকেই শক্তিশক্তি করে, সেই শক্তি ক্রমশ ছড়িয়ে পড়ে তাদের গতিতে, কম্পনে, ঘূর্ণনের spectroscopic signal record করে আমরা সেই উদ্দীপনার হদিশ পাই। আমরা বুঝতে পারি কোন কোন অণুগুলো কীভাবে বেকেরে যাচ্ছে, কারা কাদের গিয়ে ধাক্কা মারছে, কার অঙ্গহানি হচ্ছে।

একঝাঁক পোকাকার উপর টর্চের আলো ফেললে তারা যে অস্থির হয়ে ডানা ঝটপটিয়ে ওঠে, তার সাথে এই উত্তেজনার তুলনা করলে খুব ভুল হয় কী?



A Tribute to Srinivasa Ramanujan

Debasish Sengupta*

Srinivasa Ramanujan, a world famous Indian mathematician, was born in a poor brahmin family on Dec. 22, 1887 at Erode, Madras Presidency in his maternal house. His father K. Srinivasa Ayyangar, worked as a clerk in a sari shop and mother Komalammal, was a housewife and sang spiritual songs at a local temple. They lived in Sarangapani street in the town of Kumbakonam, which is now a museum after Ramanujan.

On Oct. 1892, Ramanujan was admitted to a school near his maternal residence. In 1894, he was enrolled in the Kangayan Primary school at Kumbakonam. After the death of his parental grandfather he was admitted to a school in Madras, which he did not like to attend. That is why he was again sent back to Kumbakonam. Here Ramanujan learnt about tradition and Puranas from his mother and also learnt to sing religious songs to perform pujas at the temple.

In 1897, he passed his primary examination in English, Tamil, Geography and Arithmetic and stood first in the district. His formal mathematics learning started this year when he was admitted to the Town Higher Secondary School. Surprisingly by the age of 11, he had exhausted the mathematical knowledge of college mathematics and absolutely acquired the knowledge of advanced trigonometry written by S.L. Loney. Throughout his school career he received many certificates of merit.

In 1902, he showed a mastery over infinite series and was able to solve the cubic equations by applying his own method. In 1903, Ramanujan studied in detail the book, "A synopsis of elementary results in pure and applied mathematics" by G. S. Carr, which ignited his drooping spirit. Inspired Ramanujan independently developed and investigated the Bernoulli's numbers and was able to determine Euler's constant upto 15 decimal places. In 1904, he became graduate from town H.S. School and was awarded the K. Ranganathan Rao prize for mathematics. He received scholarship to study at government Arts College, at Kumbakonam which he subsequently lost as he was so focused on mathematics that he failed most of the other subjects. He was then admitted at Pachaiyappa's college in Madras but failed to perform better. In 1906, he failed his Fine Arts degree examination and same results were repeated in the next year. Thus without a degree, he left college and started to pursue independent researches in mathematics which he put in a notebook.

In July, 1909, he was married to a nine year old bride Janaki Ammal, though this time he lived in extreme poverty. He met deputy collector V. Ramaswamy Aiyer, who then founded Indian Mathematical Society, for a job at the revenue department, showing his mathematics notebooks to prove his ability to work in the accounts department. Ramaswamy sent Ramanujan to R. Ramachandra Rao, the district collector for Nellore and the secretary of the Indian Mathematical Society. Ramanujan impressed Rao by discussing the theories of elliptic integrals, hyper-geometric series and the theory of divergent series and showed his brilliance in mathematics. In 1911, he got a temporary job in A G's office, Madras and in 1912 appointed as a clerk in Madras Port Trust. At this time Ramanujan continued his mathematical researches with Rao's financial help and published some of his works in the *Journal of Indian Mathematical Society*. In 1913 he got a research scholarship from University of Madras for his proficiency in mathematics. During this period he became more powerful in his mathematical researches and after a lot of hurdles he sent his works some leading mathematicians at Cambridge University for publishing but could not satisfy many of them as he

*Associate Professor, Department of Mathematics, Vivekananda College, Thakurpukur, Kolkata-700063.



lacked proper educational qualification, though they felt that Ramanujan had a flair for mathematics and some ability. Prof. H.F. Baker, Prof. E.W. Hobson of Cambridge University returned his papers without any comment. On 1913, Ramanujan sent his papers to Prof. G.H. Hardy and that was the turning point in his life. Hardy consulted with Prof. Littlewood, one of his colleagues for its suitability and they were amazed at the works. Though some of his works had already been worked out by some of the mathematicians but many of them proved Ramanujan's potentiality and brilliance. Especially the works on hyper-geometric series, integrals, continued fractions amazed Prof. Hardy most and commented that Ramanujan was a mathematician of the highest quality, a man of altogether exceptional originality and power. On Feb, 1913, Prof Hardy invited Ramanujan expressing his interest in his works and wanted to see the proofs of some of his results. Ramanujan at first refused to leave his country and sent a letter containing many theorems. Prof. G Walker of Trinity college, Cambridge, viewed Ramanujan's works and urged him to spend time at Cambridge. Despite trepidations of his family, on March, 1914, he set sail for England.

In 1916, Ramanujan was awarded B.A. Degree by research of the Cambridge University and after 1920 this degree was recognized as Ph. D Degree, In 1918 he was elected Fellow of the Royal society for his investigations on elliptic functions and the theory of numbers. In Oct, 1918 he was elected fellow of the Trinity College, Cambridge (Fellow of Cambridge philosophical society). During this five years stay in Cambridge, he published 21 papers, five of which were in collaborations with Prof. G.H. Hardy.

During world war-I, when food was already scarce, it got harder for him to get special food and Ramanujan began to suffer from health problems. He did not keep well and was undergoing treatment at some hospital in London. After some days he returned to India and was ailing throughout one year after his return (13 March, 1919-April, 26, 1920). In Jan, 1920 in his last letter he wrote to Hardy about his last work, "I discovered a very interesting function which I call 'Mock' theta function; Unlike the 'False' theta Function they enter into mathematics as beautifully as ordinary theta function.....". Srinivasa died of illness, malnutrition and liver infection on April, 26, 1920 at the age of 32.

He is remembered for his great contribution to mathematical developments which are presently known as Landau-Ramanujan constant, Mock-theta function, Ramanujan conjectures, Ramanujan prime, Ramanujan-Soldner constant, Ramanujan theta function, Ramanujan's sum, Roger-Ramanujan identities, Ramanujan Master theorem, Ramanujan-Hardy numbers (Taxi-cab numbers) etc.

The formidable task of truly editing the 'Note Books' written by Ramanujan was taken up by Prof. Bruce C. Berndt of the University of Illinois, in May 1977 and his dedicated efforts resulted in the 'Ramanujan Note Books' published by Springer-Verlag in five parts, the first of which appeared in 1985. The three original 'Ramanujan Note Books' are with the library of the University of Madras, some of the correspondences, papers/letters on or about Ramanujan are with the National Archives at New Delhi and Tamil Nadu. A large number of his letters and related papers/correspondences and notes by Hardy, Watson, Wilson are with the Wren library of Trinity College, Cambridge. The Ramanujan Institute for Advanced study in Mathematics is situated near the administrative building of the University of Madras, where the bust of Ramanujan is housed. The 'Ramanujan Journal', an international publication was launched to publish works in all areas of Mathematics influenced by his works.

Even today, his fascinating results and mathematical theories and a number of unpublished works in the 'Note Books' filled with theorems, continue to baffle and enthrall mathematicians of the present day. Ramanujan's innovations have not been surpassed either before him or after him. His results continue to



have foreseen impact in fields of mathematics which were not born in his time. As years pass by, his fame increases and the influence of his work spreads into new areas. It is no surprise therefore that as long as there is mathematical science and Scientific activity in the world, so long we (Indians) will hear of Ramanujan and his genius.

REFERENCES

Dictionary of Scientific Biography.

Biography in Encyclopaedia Britannica.

Kanigel R. 1991 The Man who knew Infinity: A life of the genius Ramanujan, New York.

Srinivas Rao K. Srinivasa Ramanujan: A Mathematical Genius, East West Books Madras Pvt Ltd.

Ranganathan S.R. 1967 Ramanujan: the man and the mathematician, London.

Hardy G.H. 1940. Ramanujan, Cambridge.



Are you a Fitness Fanatic ?

Tapanjyoti Das*

Nowadays everybody is more or less a fitness fanatic, much worried about their bodyweight— some for their look, others for their health. This is a good upgrowing concern. We, the health consultants, are often questioned about the facts behind an overweight as well as the secrets of keeping up normal bodyweight & good health. Here are few words for those internees.

ARE YOU AN OVERWEIGHT ?

You may think you're overweight — but are you? Assess whether you're overweight or obese, using recognized international guidelines. You should first check your Body Mass Index (BMI). The Body Mass Index is a formula used by health professionals throughout the world to assess an adult's body weight in relation to their height. It's a useful measure, because in most people it correlates highly with their body-fat percentage. However body builders and some other sportspeople, pregnant or lactating women and very elderly, frail people shouldn't be used for children, who have their own calculations.

High BMI is linked to increased risk of death from all causes, including diabetes, cardiovascular diseases, high blood pressure and osteoarthritis.

WORKING OUT YOUR BMI

The calculation is simple : BMI = your weight in kilograms divided by your height in metres (squared) or

$$BMI = \frac{Weight(kg)}{Height(m)^2}$$

- ▶▶ To get your weight in kilograms, divide your weight in pounds by 2.2.
- ▶▶ To get your height in metres, multiply your height in inches by 0.025.
- ▶▶ Squared height is your height multiplied by itself (e.g. $1.65 \times 1.65 = 2.72$). It is probably best to use a calculator to work this out.

Below is a table of weight for heights expressed as BMIs, which will save most people the trouble of working out the formula. If your own height and/or current weight isn't there, then you can use the formula as above.

BODY MASS INDEX CHART

Find your height and read down the column until you find the weight nearest yours, then read across for your approximate BMI

* Consultant Physician & Gastroenterologist, Fellow Gastro Academy, USA; Visiting Consultant Woodlands Nursing Home, Peerless Hospital, Genesis Hospital & RSV.



Height [Inches (Metres)]								BMI
60(1.5)	62(1.55)	64(1.6)	66(1.65)	68(1.7)	70(1.75)	72(1.8)	74(1.85)	
Weight [(lb) (Kg)]								
89 (40)	95 (43)	101 (46)	108 (49)	115 (52)	121 (55)	128 (58)	135 (62)	18
94 (43)	100 (46)	107 (49)	114 (52)	121 (55)	128 (58)	135 (62)	143 (65)	19
99 (45)	105 (48)	113 (51)	120 (54)	127 (58)	135 (61)	143 (65)	150 (68)	20
104 (47)	111 (50)	118 (54)	126 (57)	134 (61)	141 (64)	150 (68)	158 (72)	21
109 (50)	116 (53)	124 (56)	132 (60)	140 (64)	148 (67)	157 (71)	166 (75)	22
114 (52)	121 (55)	130 (59)	138 (63)	146 (67)	155 (70)	164 (75)	173 (79)	23
119 (54)	127 (57)	135 (61)	144 (65)	153 (69)	162 (73)	171 (78)	181 (82)	24
124 (56)	132 (60)	141 (64)	150 (68)	159 (72)	168 (77)	178 (81)	188 (86)	25
139 (63)	148 (67)	158 (72)	167 (76)	178 (81)	188 (86)	200 (91)	210 (96)	28
148 (67)	158 (72)	169 (77)	180 (82)	191 (87)	202 (92)	214 (97)	226 (103)	30
173 (79)	185(84)	197 (90)	210 (95)	222 (101)	236 (107)	250 (113)	263 (120)	35
198 (90)	211 (96)	225 (102)	240 (109)	254 (116)	270 (122)	260 (130)	301 (137)	40

THE 10- SECOND TEST

By measuring your waist circumference you can get a strong indication of whether you are at health risk from your weight. Measure your waist in inches or centimetres without holding the tape too tightly or too loosely. As a guide, your waist measurement is the narrowest part of your trunk or a spot approximately 1 inch (2.5 cm) above your belly button. Write your measurement down and check here :

Men	Women
Waist circumference over 94cm (37 in)- indicates slight health risk; take care.	Waist circumference over 80 cm (31.5 in)- indicates slight health risk; take care.
Waist circumference over 102 cm (40 in) - indicates substantially increased risk.	Waist circumference over 88 cm (34.5 in) - indicates substantially increased risk.

NOTE: Abdominal fatness can also be gauged using the Ashwell Shape Chart (waist-to-height ratio) or the waist-to-hip ratio. However, these are a little more complicated to use and research has shown that the basic waist circumference test shown here is equally, or more, accurate in deciding your health risks.

BMI UNDER 18.5

Classification: *Underweight*

You do not need to lose any more weight and, although your risk of having health problems associated with obesity is very low, you may be at increased risk of other problems such as amenorrhoea in women (no menstrual periods), bone loss, nutrient deficiency and others— and the risks become greater the lower your BMI. Some experts say that this classification is too low and that underweight is a BMI under 20; but, when smokers are taken out of the equation, the classification seems sound.



BMI 18.5—24.99

Classification : *Normal range*

You do not need to lose weight or gain weight. You are within healthy weight guidelines and the risk of weight-related health problems is minimal. The 'ideal' BMI is between 22 and 23 for young adults. At the upper range of normal (around 24.99), if you feel you are overweight, do the waist circumference test above as an additional check. If you are at the upper end and have been gaining weight steadily at more than 5lb (2.25kg) per decade over age 25, it may be time to pay more attention to diet and exercise levels and aim to put no more on, or at least slow down the rate of increase.

BMI 25—29.99

Classification : *Overweight (pre-obese)*

From a BMI of 25 up to around 27, you have a slightly increased risk of health problems, and some experts feel that any weight between these BMIs should be called the 'caution zone' for overweight. By using the BMI with the waist circumference test above, you can get a clearer picture of whether or not you have cause for concern. Efforts should be made to ensure that your weight doesn't increase any more. From over 27 to 29.99, the risk of health problems becomes higher. In one study, a measureable increased incidence of high blood pressure, heart disease and diabetes was noted at 27.3 for women and 27.8 for men. Again, the waist circumference test gives you added information on your risk level. For many people within this category it would be advisable to lose weight to get your BMI down to at least 25-27.

BMI 30—34.99

Classification : *Obese Class 1*

You are officially 'obese' (very overweight) and at this level your risk of weight-related diseases increases considerably, especially if you have a large waist circumference (see the test above). Reducing your weight by even 5% or 10% would result in considerable health benefits.

BMI 35—40

Classification : *Obese Class 2*

Your risk of death and weight-related diseases and health problems increases considerably between these BMI, with a risk defined as 'severe'. It is important to reduce your weight to lower BMI.

BMI OVER 40

Classification : *Obese Class 3 (extreme obesity, morbid obesity)*

You have an extremely high risk of early death and weight-related diseases and health problems. At a BMI over 40, it is unusual not to have a medical condition associated with the obese condition. It is very important to reduce your weight to a lower BMI, and your doctor can refer you for specialist help and advice.

NOTE: Overweight and obesity can also be gauged using your percentage of body fat— but to determine this you need a body fat monitor for definitions of obesity by body-fat percentage.

FAQ (FREQUENTLY ASKED QUESTIONS)

Q. Does dieting make us fat ?

No— this is a very simplistic statement with a tiny grain of truth in it. If long-term calorie reduction made people fat, then people in famines throughout the world would be fat, not bone-thin. When you look at the evidence, it is obvious that if you don't get enough to eat, you will lose weight, not gain it.



If you create for your body a long-term energy deficit, expending more energy than you ingest in the form of calories, then you will definitely lose weight. It's always best if conscious 'dieting' is combined with regular exercise of various types and if the dieting is done in a steady manner on a suitable balanced diet.

There is some evidence that seems to show that repeated bouts of 'yo-yo' dieting may make it progressively harder to lose weight, but this is probably to do with the fact that repeated dieting tends to deplete lean tissue (muscle) and each time weight is regained the lost lean tissue isn't replaced unless muscle-building exercise is done. Over time this would mean that the metabolic rate would be reduced, as lean tissue is more metabolically active than fat. Severe crash-dieting may also deplete more lean tissue than slow dieting.

The answer is to avoid yo-yo-and crash-dieting— which are depressing anyway and to get plenty of muscle-enhancing exercise, whether slimming or attempting to maintain your weight.

Q. Can I lose weight without dieting?

You can create a small long-term calorie deficit or negative energy balance by increasing the amount of exercise you do to 'burn up' calories, and this will be enough alone to help you lose weight slowly over time, all other factors being equal (e.g. as long as you don't begin to eat more). One group in a study who didn't diet but increased exercise levels lost about 6 lb (2.7kg) over a year.

The amount you could lose like this would be about 1 lb (0.5kg) for every 3,500 calories you burn up over and above your current rate. To burn an extra 3,500 calories over a week, i.e., 500 a day, would be possible but not easy. However, even an extra 200 calories burnt every day would produce weight loss over time.

The only other ways to lose body fat without 'dieting' (i.e., reducing your calorie intake to create a negative energy balance) are to have surgery such as liposuction or to take pills to speed up the metabolic rate. Some prescription slimming pills will do this, but others still require you to eat less and help by reducing appetite. You can lose weight that is body fluid by taking diuretics, but these should only be taken under medical advice, and is pointless if you are trying to lose fat.

However, if by 'dieting' you mean 'following a set or crash diet', then it is perfectly possible to lose weight by altering your eating patterns, rather than 'going on a diet'. Several studies have shown that a healthy low-fat, high-carbohydrate diet of around 1,500 calories a day (much higher than in many diets) produces the best long-term weight loss, and that crash-dieting is, indeed, a waste of time. So if you don't like the word diet, don't use it.

Q. What is the best way to lose weight?

By both reducing your calorie intake a little (for most people around 500 calories fewer a day is a good average to aim for) and increasing your energy output (activity) on a regular basis.

There is probably no such thing as an absolute best for the way either to reduce calories or to exercise— both will vary according to your tastes, weight, means, health and many other factors.

In general terms, however, it seems that the most successful long-term weight-loss programmes involve reduction in total fat and simple carbohydrate intake, thus reducing total calorie intake, and eating regular meals containing plenty of fruit and vegetable at a slow speed. The most popular and easy way to increase energy output is regular walking.

Q. Is it a good idea to take slimming pills?

The World Health Organization (WHO) describes approved prescription of slimming pills as 'an adjunct to other weight-loss therapies and a way of helping to maintain body weight over time'. However, WHO also



points out that these drugs are best used in conjunction with diet and lifestyle management, and that when weight-management drugs are discontinued weight is regained.

It should go without saying that prescribing slimming pills should be used under medical supervision. Current criteria in the UK are that intervention with drugs should only be applied after a minimum of 3 months of 'lifestyle intervention' and if a weight loss of 10% has already been achieved. However, these guidelines are not always followed. Normally you shouldn't be given a prescription for slimming drugs unless you have a BMI of at least 30 or have health problems associated with your weight.

Two drugs are most likely to be prescribed. One is *Orlistat*, which works by blocking the absorption of about one-third of the fat in your food. Patients are required to follow a low-fat diet anyway (otherwise complications such as 'leak bowel' may occur). The guideline for prescribing *Orlistat* in the UK is that you should have lost 2.5 kg (5½ lb) in the previous month by diet and exercise, be between 18 and 75, and have a BMI of at least 28. There are other criteria for longer use.

The other drug is *Sibutramine*, which acts by both inhibiting appetite and stimulating metabolic rate. Possible side effects include unwanted increase in blood pressure, and, as it is fairly new, the long-term effects are uncertain. Restrictions have been imposed upon its prescription.

Phentermine is another drug which stimulates the central nervous system and is used as an appetite suppressant. This is less often used.

Do I think slimming drugs are good idea? I wouldn't presume to judge, but certainly the message seems to be that they are only to be considered for a small proportion of overweight people. The decision on whether you are a suitable patient is best left to a doctor or specialist who knows you. For that reason, I wouldn't recommend you visit a private doctor who has never met you before.

However, scientists in many countries are working hard to find a slimming pill that is safe and effective. Recently there have been reports on injection that kills fat cells; a gene which stops mice making fat cells; and the uncoupling protein 'UPC-3', which can turn surplus calories directly into heat rather than body fat. A variety of varying degrees of usefulness are sold.

Q. Can I loose weight by operation?

Perhaps the best-known operation is now liposuction — a process that 'sucks' the fat from your body through a tube. It is the only operation, that actually removes your body fat but it is usually not such a 'minor' operation as some people would have believed.

Other operations rely upon reducing the amount that you can eat, or by preventing the absorption of foods, or a combination of the two. All of these operations are available privately, but may also be available in the UK via the NHS if you are a suitable case. However, they are not to be undertaken as anything except a last resort for the obese, as they have life-changing consequences.

One other type of operation is an abdominoplasty, which is really for the post-obese person who has a lot of loose 'spare' skin hanging around. The operation cuts away the loose flesh. See your general physician for a discussion about your options regarding surgery.

FAT FACT: An average man has about 26 billion fat cells, called adipocytes, in his body while a woman has around 35 billion. When people put on weight, the fat cells first actually increase in size, then later multiply in obesity.

Q. Why do so many people put weight back on after they have dieted?

All the research agrees with you that the majority of slimmers do regain their lost weight. About 10% of slimmers will have retained their new slim weight after 9 months; only about 5% after several years. Some



research (but not all) says that after 5 years almost everyone returns to, or goes higher than, their starting weight.

The main reason is usually that calorie intake gradually creeps up and, because, as we've seen, a slim person has a slower metabolic rate than a fat person, calorie intake needs to be restricted permanently if the new weight is to remain. This should not mean that a newly-slim person should have to remain on a 'slimming-level' diet for life, but certainly a calorie intake lower than pre-diet levels is needed. Many people find it hard to continue with this more restrained way of eating.

The best way to keep weight off permanently is to take more exercise, but again many slimmers are reluctant to do this. In other words, ex-slimmers find that their lifestyle just isn't conducive to the permanent changes necessary for permanent weight loss. However, there is some brighter news. A very recent American study of ex-Weight Watcher slimmers found that 5 years later over 70% were still below their original weight and nearly 20% were within 5lb (2kg) of their original goal weight. Again in America, the National Weight Control Registry recruited 784 people who had maintained at least a 30lb (13.5kg) weight loss for an average of 5½ years. Most had a genetic background (e.g. fat parents) which might be assumed to predispose them to overweight, and, indeed, many had been overweight since childhood, but still managed to keep the weight off.

Q. How can I avoid regaining all the weight I've lost?

First of all, let's hope that you have settled on a reasonable 'target' weight, which is always easier to maintain than one that is too low. For young adults, a target BMI of around 22 to 23 is as low as you want to go – but 25 would be fine if your starting level was higher than 28, especially if you are over 40. For older adults, a target BMI of around 24-25 is often reasonable. Use your common sense. If you go too low, you will need to reduce your regular calorie intake down low as well, and this may be too hard to do.

Secondly, let's hope that you dieted slowly so that you didn't lose too much lean tissue (muscle). The more muscle you have on your body, the more calories you will burn up every day rather than storing them as fat. Research shows that very fast (crash) dieting does lose more lean tissue than slow dieting.

Thirdly, you need to eat a healthy balanced diet and keep the total fat content fairly low, while filling your plate with more of the complex carbohydrates, vegetables, fruits and low-fat proteins. You need to eat regular smallish meals and snacks- portion control is a simple method of watching total calorie intake. If you look at the standard diet plan, you will see how to use it as a blueprint for a weight maintenance plan. Fourthly, look at your lifestyle and try to adjust it so that you are less inclined to overeat.

Last, but definitely not least, you need to take regular exercise – preferably both aerobic (e.g. walking, cycling) and weight training (e.g. with free weights or at a gym).

A DAY IN THE LIFE OF YOUR METABOLISM & YOUR BMI

By altering your behavior, in small way throughout the day, and paying attention to your natural body rhythms, you can increase your metabolic rate and calorie burn-up considerably, as well as lowering the total amount of calories eaten— which directly or indirectly will definitely influence your BMI, hence bodyweight.

7 am

Get up ! Getting up an hour earlier than usual every day can burn off many extra calories, depending upon how you spend the time. Light household chores use up 2.2 times your basal metabolic rate (average extra 75 calories burnt on top of BMR per hour)



7.05 am

Stand at an open window and breathe in deeply for a minute or two. This helps to waken your body and kick-start your metabolism.

8.00 am

Have breakfast — a light meal including some protein, carbohydrate and fat (e.g. wholegrain cereal, semi-skimmed milk and some seeds)- the ideal combination to avoid hunger pangs later in the morning. A cup of coffee with your breakfast will increase alertness and boost metabolism. Eat your food slowly.

8.30 am

Take 20-30 minutes light aerobic (cardiovascular) exercise (e.g. exercise bike, step video, or walk to work or the shops). This will help convert the carbohydrate in your breakfast to glycogen for your muscle stores and will give your metabolic rate, adrenaline (epinephrine) levels and mental alertness a boost as well as using about 3.5 times the calories of your normal BMR (average extra calories burnt up in 30 minutes = 55).

10 am

Stand up as much as possible throughout the day if you have a sedentary job — e.g. when talking on the phone or to people. For every hour of standing rather than sitting, you can use up an extra 50 or so calories, depending on your BMR. Fidgeting, rather than sitting completely still, will also help to burn up calories so stretch, move your legs, wave your arms about!

11 am

Take a 10-minute break and walk around or up and down the stairs. Get some fresh air and eat a small healthy food (e.g. an apple). The snack will help stave off hunger before lunch and increase your metabolic rate slightly.

12.45 pm

Relax a little to prepare your digestive system for lunch— it will absorb food better if you are not tensed. If at work, make easy phone calls or read mail.

1.00 pm

Have a fairly high-protein lunch (chicken, meat, fish, pulses) between 1 and 2 pm. Protein raises the metabolic rate and there is some evidence that a high protein, low-carb lunch will avoid the post-lunch tiredness slump that many people experience. Don't skip lunch— research shows if you eat now you tend to eat a healthier lunch than if you eat later, say at 3 pm. A lunch will also help you avoid bingeing on sweet foods later. Take time over eating your lunch — fast eating is linked with fat bellies!

1.30 pm

Take 20-30 minutes of light aerobic exercise (e.g. a walk at a good pace). Research shows that the metabolism boosting effect of eating is increased with exercise.

4 pm

Have a small healthy snack, e.g. a pot of natural yoghurt or some dried apricots (see 11 am).

4 or 6 pm

Visit the gym, Research shows that for most people, this is the best time to work out, when muscle and core body temperature is at its highest and endurance levels are at their peak. Incorporate plenty of weight



training, as 3-5 weight sessions a week, including up to 30 reps exercising all the major muscle groups, can increase metabolic rate by up to 15% over time.

7—8 pm

Have your evening meal, including carbohydrates, protein and fat. Leaving it much later than this will make you inclined to eat more or binge on fatty, salty or sweet foods before your meal is ready. Begin to relax and wind down.

9 pm

A session of easy yoga or stretching will help the body to de-stress and relax in preparation for bed, as your levels of adrenaline go lower.

10—11 pm

The best time to go to bed, as the body increases its output of melatonin, body temperature begins to drop and metabolic rate slows. As you sleep, lung function and breathing become slow. Exercising when your body clock says it's time for sleep is counterproductive.

SLIMMING DIET

A basic seven-day diet plan contains approximately 25% fat (of which about 5% are saturates), 20% protein and 55% carbohydrate, and at least 18g fibre a day. The amounts give approximately 1,500 calories a day, which is a suitable slimming level for many people. The plan is intended as an example of how a healthy slimming diet looks—in subsequent weeks you can vary the menus to suit yourself, with the help of the Food Value Charts and the meal suggestions or simply follow the low-fat, high-carbohydrate route.

TIPS:

Drink plenty of fluid every day—about 2 litres (3 ½ pints). Water, black and green tea, herbal tea, redbush tea are unlimited. Limit coffee to 3-4 medium-strength cups a day, which you shouldn't count towards your fluid intake.

You have a 300ml/ (1 ½ pint) skimmed milk allowance for use in tea and coffee or as a drink by itself.

You can also have unlimited green salad items, leafy green vegetables, fresh or dried herbs and spices, vinegar, balsamic vinegar, lemon juice.

WEIGHT MAINTENANCE AND DIFFERING DIETING NEEDS

The basic blueprint contains about 1,500 calories. If your own ideal slimming level is different, simply decrease or increase portion sizes to suit. (For example, if you are slimming on 1,750 calories, you would need to increase portion sizes by about 15%). For weight maintenance simply do the same (e.g. if your weight maintenance level is 2,000 calories a day, simply increase portion sizes by about 30%). Alternatively you could select 500 extra calories' a day worth of foods from the Food Value Charts, trying to keep the fat in the extra items to no more than 25%. Alternatively, seek for further advice on menus for weight maintenance.

Q. What is a crash diet?

A diet very low in calories (usually anything less than 1,000 calories a day) is described as a 'crash diet', often with a 'faddy' eating element to it—for example, nothing but eggs and milk, or cheese and tomatoes—which will result in rapid weight loss. Usually over 3 lb (1.5 kg.) a week is promised.



Q. Are crash diets really such a bad idea?

Amongst health experts, crash diets are seen as a bad idea for most people as:

1. They encourage loss of more lean tissue (muscle) than diets which produce a slower weight loss on higher calorie level.
2. They may be lacking in nutrients – both macronutrients such as fat, protein or carbohydrate, and micronutrients such as vitamins and minerals.
3. They don't encourage sensible eating habits and this means that after the crash diet is over weight is easily regained. In time, this can turn into a 'yo-yo' dieting habit, which is very demoralizing.

Q. Is fasting a good idea for weight loss and how long can I fast?

We have a detailed explanation of what happens to your body when you drink water but don't eat, right down to death after 60 or so days. After reading it, you will probably agree that fasting as a means of long-term weight loss isn't such a good idea, even though it is bound to produce good results while it lasts.

There are many advocates of fasting, and it is a well-recognized way of life in India. There are, however, inherent dangers in fasting and, no doubt, once the fast is over, there is almost inevitable regaining of weight, so it does seem rather pointless.

Having said all that, some people enjoy short regular periods of fasting say, one day a week, or a two-day fast once a month, or a week's fast four times a year – and are none the worse for it. Used in such a way, it is possible that fasting might help keep weight stable. However, for most people, I am sure that a good detox diet is a better idea.

Q. What is the lowest number of calories I can eat to slim and stay healthy long-term?

The World Health Organization says the lowest recommended dieting level (except under medical supervision) is 1,200 calories a day, but prefers 1,400-1,500. One very good rule-of-thumb is that you shouldn't diet below your own basal metabolic rate – the rate at which your body uses up (expends) calories just lying still, doing nothing. This is your basic energy output. An average BMR for many women is around 1,500 calories a day & for men it is a minimum of 1,800 calories.

You would then lose weight on such a diet according to how many calories you burn up in all your daily activity over and above your BMR. For very sedentary people this is as low as a few hundred; for an active people it can be double the BMR — and for these people I would say dieting on the BMR would actually be too low. However, very active people rarely need to diet as they very rarely seem to get fat in the first place.

Another good rule is to increase your calorie intake if your weight loss speeds up over the sensible 1-2 lb a week that dieticians recommend. You don't actually need to worry about counting your calorie intake as long as sensible weight loss is proceeding. This also holds true of weight maintenance — you don't need to count calories for life; just weight yourself occasionally (or check your waistband for tightness!) and if nothing's changed, you're doing a good job.

Q. What are the benefits and disadvantages of very low calorie, liquid only diets ?

VLCDs, as they are called, are most often used to get weight off severely overweight people under medical supervision, when their life is in danger or before operations. They are also sold as slimming aids to the general public.



Each meal is usually around 250 calories and, on such a regime (3 such meals a day total diet), weight loss is rapid. If only replacing one or two meals a day the results are slower. The meals are fortified with a range of vitamins, minerals and so on, and should be nutritionally balanced.

Some people find it easier to replace a meal with a formula, as all the worrying about what to eat is removed and so it is the element of choice – and room for temptation and/or cheating, its an 'eat to live' philosophy. I suppose those are the benefits if you're that sort of a person.

The disadvantages could be that you have little choice, and if you enjoy real food the regime can be very despiriting. If you want fast food to lose weight, there are plenty of quick and easy meals. Again, these formulas do nothing to re-educate you to better eating habits, lean tissue loss may be greater than on a higher-calorie regimen and once off the system, the weight may readily return. WHO says the use of VLCDs by individuals without medical supervision is unwise and should not be recommended. However, used to replace one meal a day, they can be useful.

Q. What are the best (quick and /or easy) cooking methods for slimmers?

Well, there's plenty of scope. The only method that is probably unwise for slimmers is deep-frying. An easy cooking method is tray-baking, perhaps with a little olive oil. This can be used for almost all vegetables, meat and fish. Stir-frying is simple and, if you eat meat, fish and poultry, marinating lean cuts and then grilling or barbecuing takes a lot of beating for flavor and ease.

CONCLUSION

Beyond this discussion, I leave a lot of information for you but I think I could place a basic idea about bodyweight maintenance, Diet plan, Activity & Exercises for a healthy look & life. Indeed, lifestyle & diet plan will vary from place to place, person to person and for this you have to look for a medical expert for your appropriate guidance.

Acknowledgement: Judith Wills / Anita Bean / Jane Alexander / Udo Erasmus & others



Death on The Track

Sreejata Biswas*

Abstract: Free movement of elephants is impeded in India by various man made constructions. Railway track passing through the forests have become death trap to wild elephants. Most incidences of deaths occur at night when speeding trains accidentally hit elephants that pass the rail tracks. The problem can be solved by joint efforts of railways and forest authorities by adopting safety measures. It is the duty of the nation to offer our national heritage animal a better place to live.

The Ministry of Environment and Forests India in the year 2010 declared elephant as a National Heritage Animal. Elephants are our national pride and wild life asset. They are closely associated with our culture and heritage. On the occasion of 150th year of the Indian Railways a mascot in the form of a cartoon elephant, 'Bhola' was adopted. A real elephant was used in some of the celebrations. Yet elephant deaths in railway accidents have been reported from all elephant range states in India, with more than 110 train-hit deaths recorded since 1987. Nearly 90% of these deaths in the past two decades were recorded in Assam, West Bengal, Uttarakhand and Jharkhand. At least 19 elephants were killed on India's railways in 2010, making it one of the worst on record.

DISTRIBUTION OF ELEPHANTS IN INDIA

India is home to about 25000 Asian elephants, the largest population in the world. In India elephant populations are restricted to four general areas (Sukumar, 1993):

- a) In the Northwest — at the foot of the Himalayas in Uttaranchal and Uttar Pradesh, ranging from Katarniaghat Wildlife Sanctuary to the Yamuna River
- b) In the Northeast — from the eastern border of Nepal in northern West Bengal through western Assam along the Himalaya foothills as far as the Mishmi Hills, extending into eastern Arunachal Pradesh, the plains of upper Assam, and the foothills of Nagaland, to the Garo Hills of Meghalaya through the Khasi Hills, to parts of the lower Brahmaputra plains and Karbi Plateau; isolated herds occur in Tripura, Mizoram, Manipur, and in the Barak Valley districts of Assam
- c) In the central part — in Jharkhand and in the southern part of West Bengal, with some animals wandering into Chhattisgarh
- d) In the South — eight populations are fragmented from each other in northern Karnataka, in the crestline of Karnataka–Western Ghats, in Bhadra–Malnad, in Brahmagiri–Nilgiris–Eastern Ghats, in Nilambur–Silent Valley–Coimbatore, in Anamalai–Parambikulam, in Periyar–Srivilliputhur, and one in Agasthyamalai

HOME RANGE AND CORRIDOR

The average home range of an elephant herd in India is 267 km² in Rajaji National Park (Sukumar, 2003), 651 km² in south India (Baskaran *et al.*, 1995), 588 km² in Buxa Tiger Reserve (Sukumar *et al.*, 2003) and an amazingly vast 3,708 km² in southwestern West Bengal (Chowdhury *et al.*, 1998). Resources that govern the home range size are availability of water or rainfall and the quality of forage or habitat type (Fernando, 1995). Elephants are believed to have one of the most advanced mammalian social organizations (Sukumar, 2003).

*Assistant Professor, Department of Zoology, Bangabasi Morning College, Kolkata.



Elephants maintain fidelity to their home range in the short term (Baskaran *et al.*, 1995) even in severely fragmented ranges (Datye & Bhagwat, 1995a, Datye & Bhagwat, 1995b, Sukumar *et al.*, 2003); they even have fixed crossing points between forest patches (Weerakoon *et al.*, 2004). Elephant herds move across three different scales:

- (1) daily movement between feeding and water sources,
- (2) seasonal movement between dry and wet season forage areas within home ranges and
- (3) medium-term movements between sectors of the seasonal home range (Seidensticker, 1984).

Elephant corridors are narrow strips of land that allow elephants to move from one habitat patch to another. There are 88 identified elephant corridors in India.

ELEPHANTS AND ECOSYSTEM

Since 1986, *Elephas maximus* has been listed as endangered by IUCN as the population has declined by at least 50% over the last three generations. The role that elephants play in nature is immense. Elephants are classified as 'megaherbivores' and consume up to 150 kg (330 lb) of plant matter per day (Samansiri and Weerakoon, 2007). As much as 80 percent of what elephants consume is returned to the soil as barely digested highly fertile manure. Elephants can provide water for other species by digging water holes in dry riverbeds. Elephants act as seed dispersers by their fecal matter. It is often carried below ground by dung beetles and termites causing the soil to become more aerated and further distributing the nutrients.

DEATH OF ELEPHANTS ON RAILWAY TRACK

WEST BENGAL SCENARIO

According to a report of PTI, June 21, 2012, altogether 63 elephants died in West Bengal either naturally or by accident in a span of two years (Anon., 2012). Out of the 63 elephant deaths between January 2010-2012, 49 were in North Bengal and 14 in South Bengal. Of the 49 elephant deaths in North Bengal, 27 were natural and the rest accidental, but in South Bengal, of 14 deaths, seven were natural and as many accidental. In the track between Siliguri and Alipurduar, a total of 39 dead elephants were reported during the period of 1958 to 2008, of which ten were reported killed between 2004 to 2008 (Roy *et al.*, 2009). On the night of Sep 22, 2010, under a harvest moon, seven elephants from a wild herd were killed by a speeding goods train in North Bengal. The herd of elephants was crossing from one part of the forest to another when two young elephants got trapped on the tracks. When other elephants came to their rescue, the goods train hit them, killing five elephants on the spot and the rest succumbed to injuries (Dutt and Chaudhary, 2010). The massacre site in Jalpaiguri is a designated jumbo corridor where railway drivers are required to provide safe crossing to the elephants. At least 34 elephants have been killed on this track by trains in last 11 years. Two elephants were knocked down by the Asansol Express while they were crossing the rail track in the Dooars forest area of Banerhat in Jalpaiguri district on June 26, 2011 (Anon, 2011). Both the elephants died after few days, following multi-organ failure. A five year old female elephant was mowed down by a speeding train between Savoke and Gulma railway stations under Mahananda Wildlife Sanctuary in Darjeeling district on the night of October 03, 2011 (Bannerjee, 2011). The sub-adult female was struck just after 7:00pm and her body was dragged almost 250m along the tracks before being pushed to the side by the engine. Once the train had eventually come to a stop, the rest of her herd returned to the tracks and surrounded her body, blocking the tracks for more than an hour until the Forest Department could drive them back into the forest.



OTHER STATES

Assam has seen the most number of elephants killed in train accidents among all Indian states, with about 47 individuals killed since 1987. Very recently a pregnant elephant was killed near the 'Deepor Beel' bridge after it was hit on February 27, 2010 (Anon, 2010). Herds of elephants from the reserve forest area come to Deepor Beel Lake to quench thirst and also bathe, and often these pachyderms have to cross the railway tracks. Speeding trains in the Deepor Beel region have reportedly killed 31 elephants since 1998. A report of Times of India, 3 Aug 2012, reveal that an elephant was killed by a speeding train on the outskirts of Guwahati on 1 August, 2012 night as the railway tracks continue to be a deathtrap for the pachyderms in the state. Another vulnerable site is the railways in Kerala. In 2010, on August 15, Indian Independence Day, a female juvenile elephant, estimated to have been about 3-4 years old, was struck by a train and killed between Walayar and Kanjikode, in the state of Kerala, on the railway line between Coimbatore and Palakkad (Bucknell, 2010). Earlier in 2008, four elephants were killed in the track in the same area.

REASON BEHIND THE KILLER TRACK

The Terai and Dooars regions of North Bengal were once strongholds of the Asian elephant. The area includes about 2,200 sq km of forest. Wild elephants are found from the Mechi River on the India-Nepal border in the west, to the Sankosh River in the east on the Bengal-Assam State border. Recent and sudden changes in land-use patterns have severely threatened the elephant population of the area.

In 2001, The Indian Railways planned to convert the existing metre-gauge railway track between Siliguri and Guwahati via Alipurduar and Coochbehar in North Bengal into broad-gauge. It was likely to adversely affect many protected areas and reserve forests in North Bengal. Previously only four passenger trains and a few goods trains used to run on this track daily. Wildlife experts and organisations strongly opposed the gauge conversion. Lt. Col (Retd.) S.R. Banerjee, the then Director of the West Bengal Chapter of the World Wildlife Fund for Nature (WWF), India filed a Public Interest Litigation (PIL) in the Calcutta High Court to stop the implementation of the proposed project. Despite concerns raised by conservationists, the 168km stretch of track was upgraded to broad gauge in 2002, and since then five elephants have been killed on average every year, and many other animals besides.

Rail routes slicing through wild habitats not only cause direct mortality and injury to wild animals through train accidents but also create habitat fragmentation, degradation, wildlife population fragmentation and reduction of wildlife access to vital habitats. Railways now cut through most prime elephant habitat in India. Goods trains regularly pass through elephant habitat during the night, and this is when most collisions occur. With India's rapid development, railways are increasingly extending into rural areas, and tracks are being upgraded to a broader gauge, for running faster trains. As such they are becoming an increasing menace to crossing elephants, and the death toll keeps rising. It has been reported that the wildlife and forest officials blame the railway authorities for not enforcing a 25km/h speed limit through the region. But there are solutions to this problem. National Train Hits Project aims to mitigate loss of wild animals in railway accidents, specifically targetting endangered Asian elephants as a flagship. Wildlife Trust of India - International Fund for Animal Welfare (WTI-IFAW) began the project and found that as well as enforcing speed limits, night patrols to alert train drivers to elephants crossing the tracks can be particularly effective at reducing casualties. Speed limits in accident hotspots, tracking of elephants along tracks, and research into warning systems for when large animals are crossing are also among the recommendations set out in Elephant Task Force Report from the Indian Ministry of Environment and Forests. Where tracks pass through elephant corridors it is also recom-



mended that over- or underpasses are constructed in critical bottleneck areas. However, the problem is that recommendations are not always enforced, and as well as insisting on speed limits, experts also call for a ban on the movement of goods trains at night in particularly sensitive areas.

REVENGE ON THE TRACK

Bucknell (2010) narrates an extraordinary report from the Gulma Forest near Jalpaiguri, West Bengal of a lone bull elephant charging a train and head-butting it during mid August, 2010. At first, the bull was blocking the track and the train came to a stop 50m away. It then charged, kicked the engine, waited a moment and then rammed it before heading off. The forest department was called in and drove the elephant 2km into the forest, but it came back and again, blocked the tracks and charged and rammed another train before heading off into the forest. It is suspected that the bull was part of a herd that was crossing the track a month back when a train hit and killed one of the members of the herd. It is also in roughly the same area that two other elephants have been killed, and so it is thought that the bull was somehow seeking revenge.

A similar report is stated by Shaji in 2012. A tusker that witnessed a massive elephant killing on railway track did not overcome the impact of the tragedy that befell its friends. Since the massacre, this tusker is reported to have destroyed crops in farms adjoining its territory and has attacked people on several occasions. The tusker attacked a CRPF personnel on 28 August, 2012 and was part of a herd that had met with a tragic accident on February 4, 2008, according to wildlife activists who frequent the area. Four elephants were killed when a train travelling at a speed in the excess of 135 Km/h, rammed the six-member herd near Walayar in Kerala at around 1.30am. Three elephants including a pregnant female and a calf were killed on the spot.

TRACKING THE SOLUTIONS

Assam once had one of the worst records for elephant mortality on the railways, and while there is still a long way to go before deaths are completely eradicated, more than 100 accidents have already been averted by the Elephant Family and WTI team in the past three years. Senior officials of the Assam Forest Department, Northeast Frontier Railway and Wildlife Trust of India (WTI), met on December 4, 2008, at the Assam State Zoo to discuss the recommendations of the WTI study. Several action plans were formulated, including joint patrolling in crucial sections, installation of signage, and training and awareness generation for train drivers, among others. Strategies on improving visibility in blind turns and problems created by steep embankments along the track were also discussed.

A true success story is in Rajaji National Park. The issue of elephant deaths in railway accidents in Uttarakhand is localised in a 18km stretch of railway track passing through Rajaji National Park. Yet, between 1987 and 2002, Uttarakhand lost about 20 of its 400 plus elephants to train accidents. The effort initiated by WTI-IFAW in collaboration with the Uttarakhand Forest Department and Northern Frontier Railways has succeeded in ensuring zero elephant deaths in train accidents along these tracks since 2002. WTI-IFAW acted as a facilitator between the Uttarakhand Forest Department and Northern Frontier Railways. In search of effective control to prevent train-elephant accidents, a combination of various mitigation measures was employed. Joint patrolling was carried out to monitor movement of elephant herds near the track. The patrol team was equipped with communication tools to convey the information on elephant movement to railway staff. The interventions also included installation of signage and hoardings in relevant areas, levelling of steep embankments abutting the track to prevent trapping of elephants between them, awareness generation among train drivers and other railway staff, clearing vegetation in blind turns to improve visibility for train drivers etc. The study had identified high temperature and uneven water source distribution within the park as one of the major factors necessitating movement of animals across the track. Habitat management activities such as maintenance of water bodies



(through de-silting) were carried out. All these concerted efforts could completely save the lives of elephants on the killer tracks. It is now the post-monsoon season in India and elephants are at their most mobile as they move between feeding areas ahead of winter. So it is the concern of all elephant lovers: let project elephant be successful to initiate similar exercise along the railway tracks of entire nation.

CONCLUSION

Elephant migration is central to their survival. Seasonal habitat preferences are related to the availability of water and the palatability of food plants. Migration between populations is critical to gene flows that bring variation. It is the duty and responsibility of mankind to conserve elephants to sustain biodiversity. Formulating action plans, patrolling in accident prone areas, installation of signaling system are on one hand of reducing the death of elephants along the railway lines, whereas on the other are more crucial actions like training and awareness generation for train drivers. It is a good sign that recently both the concerned departments of railways and forests have come forward with proactive support to control death of large animals on railway tracks. With proper initiative and persistent action the nation will restore safety of elephants and walk in the right track to save elephants.

REFERENCES

- Baskaran N, Balasubramanian M, Swaminathan S, Desai, A.A. 1995. *Home range of elephants in the Nilgiri Biosphere Reserve, South India*. In: A Week with Elephants (J.C. Daniel and H.S. Datye, eds.), pp. 296-313. Bombay Natural History Society/Oxford University Press, Bombay
- Chowdhury, S., Khalid, M.A., Roy, M., Singh, A.K. and Singh, R.R., 1998, *Management of elephant populations in West Bengal for mitigating man-elephant conflicts*, Wildlife Institute of India, Dehradun, India
- Datye, H.S and Bhagwat, A.M., 1995a, *Estimation of crop damage and the economic loss caused by elephants and its implications in the management of elephants*. In: A Week with Elephants (J.C. Daniel and H.S. Datye, eds.), pp. 375-388. Bombay Natural History Society/Oxford University Press, Bombay.
- Datye, H.S. and Bhagwat, A.M., 1995b, *Home range of elephants in fragmented habitats of central India*, Journal of the Bombay Natural History Society 92(1): 1-10.
- Fernando, P., 1995, *Implications of socio-ecology and genetics on the conservation and management of the Sri Lankan elephant*. In: A Week with Elephants (J.C. Daniel & H.S. Datye, eds.), pp. 225-235. Bombay Natural History Society/Oxford University Press, Bombay.
- Roy, M. Baskaran, N., Sukumar, R., 2009, *The Death of Jumbos on Railway Tracks in Northern West Bengal*. Gajah: Journal of the IUCN/SSC Asian Elephant Specialist Group, 31: 36-39
- Samansiri, K. A. P., Weerakoon, D. K., 2007, *Feeding Behaviour of Asian Elephants in the Northwestern Region of Sri Lanka*. Gajah: Journal of the IUCN/SSC Asian Elephant Specialist Group, 2: 27-34
- Seidensticker, J., 1984, *Managing elephant depredation in agricultural and forestry projects*. A World Bank Technical Paper, The World Bank, Washington DC, USA.
- Sukumar, R., 1993, *The Asian Elephant: Ecology and Management*, Cambridge University Press.
- Sukumar, R. 2003. *The Living Elephants: evolutionary ecology, behavior and conservation*, Oxford University Press, New York



Sukumar, R., Venkataraman, A., Cheeran, J.V. and Mujumdar, P.P. 2003: *Study of elephants in Buxa Tiger Reserve and adjoining areas in northern West Bengal and preparation of conservation action plan*, Centre for Ecological Sciences, Indian Institute of Science, Bangalore

Weerakoon, D.K., Gunawardene, M.D., Janaka, H.K., Jayasinghe, L.K.A., Perera, R.A.R., Fernando, P. and Wickramanayake, E., 2004, *Ranging behaviour and habitat use of elephants in Sri Lanka. In: Endangered Elephants, past present & future*. Proceedings of the Symposium on Human Elephant Relationships and Conflicts, Sri Lanka, September 2003 (J. Jayewardene, ed.), pp. 68-70. Biodiversity & Elephant Conservation Trust, Colombo

NEWS REPORTS

Anon., ANI, Mar 04, 2010, *PFA activists protest against elephants killing*

Anon., Indo-Asian News Service, July 01, 2011, *Elephant hit by train dies, another very critical*

Anon., PTI Jun 21, 2012, *63 elephants die in 2 years in Bengal*

Bannerjee, M.R., Statesman News Service, October 06, 2011, *Minister seeks explanation for elephant's death*

Bucknell, D., August 23, 2010, *Train kills a young elephant in Kerala*, www.elphantfamily.org

Dutt, B., and Chaudhary, J., CNN-IBN, Sep 24, 2010, *Elephants die on killer railway tracks*

Shaji, K. A., Tamil News Network, Aug 29, 2012, *Tusker was part of herd run over by train.*



Polycystic Ovary Syndrome – An Enigma

Soma Aditya (Bandyopadhyay)*

Abstract: Polycystic ovary syndrome (PCOS) is the most frequent endocrine disorder in reproductive-age women. It has significant and diverse clinical implications including reproductive (infertility, hyperandrogenism, hirsutism), metabolic (insulin resistance, impaired glucose tolerance, type 2 diabetes mellitus, adverse cardiovascular risk profiles) and psychological (increased anxiety, depression, poor self-esteem and reduced quality of life) features. It is a heterogeneous condition and the phenotype varies widely depending on life stage, genotype, ethnicity and environmental factors including lifestyle and bodyweight. Both hyperandrogenism and insulin resistance contribute to the pathophysiology of PCOS. Considering the aetiological role of insulin resistance and the impact of obesity on both hyperinsulinaemia and hyperandrogenism, multidisciplinary lifestyle improvement aimed at normalising insulin resistance, improving androgen status and aiding weight management is recognised as a crucial initial treatment strategy.

Polycystic ovary syndrome (PCOS) is a very common reproductive health problem of women. It is considered as one of the leading causes of female subfertility (Boomsma, 2008) and affects approximately 5% to 10% of women. The condition was first described in 1935 by American gynaecologists Irving F. Stein, Sr. and Michael L. Leventhal, from whom its original name of *Stein-Leventhal syndrome* is taken. Stein and Leventhal were the first to recognize an association between the presence of polycystic ovaries and signs of hirsutism and amenorrhea (Speroff et al., 1999). After successful wedge resection of the ovaries of women diagnosed with PCOS, their menstrual cycles became regular, and they were able to conceive. As a consequence, a primary ovarian defect was thought to be the main culprit, and the disorder came to be known as polycystic ovarian disease. The name of the condition comes from the appearance of the ovaries which are usually enlarged bilaterally and may reach several times their normal size (Balen *et al.*, 2003). One ovary may be significantly larger than the other. The ovaries typically appear glistening white because of a smooth, thickened capsule and show many follicles in various stages of development and atresia often arranged like a string of pearls along the surface. The most striking ovarian feature of PCOS is hyperplasia of the theca stromal cells surrounding arrested follicles (Goldfien and Monroe, 1994).

PCOS appears to be a heterogeneous condition bearing a wide variety of clinical manifestations with a mild presentation in some but a severe disturbance of reproductive, endocrine and metabolic functions in others. The signs and symptoms of the disease often begin soon after menarche. In some cases, PCOS develops later during the reproductive years in response to substantial weight gain. In adolescents, infrequent or absence of menstruation may signal the condition. In women past puberty, difficulty becoming pregnant or unexplained weight gain may be the first sign. The major features of PCOS are anovulation, resulting in irregular menstruation or amenorrhea (Teede *et al.*, 2010), ovulation-related infertility, and polycystic ovaries; excessive amounts of androgenic hormones, resulting in acne and hirsutism; and insulin resistance (Teede *et al.*, 2010), often associated with obesity, Type 2 diabetes, and high cholesterol levels. The symptoms and severity of the syndrome vary greatly among affected women and the disorder often goes undiagnosed because of its many baffling and seemingly unrelated features.

The menstrual irregularities in PCOS usually manifest around the time of menarche. Some women have oligomenorrhea (i.e. menstrual bleeding that occurs at intervals of 35 days to 6 months, with < 9 menstrual periods per year) or secondary amenorrhea (an absence of menstruation for 6 months). Hyperandrogenism

*Assistant Professor, Department of Zoology, Sarojini Naidu College for Women, Dum Dum, Kolkata.



clinically manifests as excess terminal body hair in a male distribution pattern (hirsutism), commonly seen on the upper lip, chin, around the nipples, and along the linea alba of the lower abdomen (Lobo, 2007; Huang *et al.*, 2010). There is also increased activity of the sebaceous glands often associated with acne. Signs of more severe virilization such as male pattern balding (androgenic alopecia), clitoromegaly, increased muscle mass, voice deepening are rare and characteristic of an extreme form of PCOS termed hyperthecosis. PCOS is the most common cause of anovulatory infertility. Obesity is present in nearly half of all women with PCOS. Approximately 10% of women with PCOS have type 2 diabetes mellitus, and 30-40% of women with PCOS have impaired glucose tolerance by 40 years of age (Moran *et al.*, 2010). Many women with PCOS have obstructive sleep apnea syndrome. PCOS women may have dark, velvety hyperpigmented skin on the nape of their neck, skin folds, knuckles, and/or elbows called Acanthosis nigricans. It is most often the result of insulin resistance. Women with PCOS show a prevalence of metabolic syndrome characterized by abdominal obesity (waist circumference >35 inch), dyslipidemia (triglyceride level >150 mg/dL, high-density lipoprotein cholesterol [HDL-C] level < 50 mg/dL) (Rocha *et al.*, 2010; Apridonidze *et al.*, 2005), elevated blood pressure, a proinflammatory state characterized by an elevated C-reactive protein level, and a prothrombotic state characterized by elevated plasminogen activator inhibitor-1 (PAI-1) and fibrinogen levels. PCOS women have increased prevalence of coronary artery calcification and a thickened carotid intima media, which may be responsible for subclinical atherosclerosis (Meyet *et al.*, 2005). The challenges to feminine identity and body image due to obesity, acne and excess hair, as well as infertility and long-term health-related concerns compromise quality of life and adversely impact on mood and psychological well-being. There are reports that women with PCOS are more prone to depression, anxiety, low self-esteem, negative body image, and psychosexual dysfunction (Barry *et al.*, 2005).

Despite the heterogeneity in symptoms associated with PCOS, the essential feature is arrested follicular development at the stage when selection of the dominant follicle takes place. In a normal menstrual cycle, a cohort of follicles start developing, from which a dominant follicle (a fluid-filled cyst) is selected that bursts to release the egg. After ovulation, the follicle remnant is transformed into a progesterone-producing corpus luteum, which shrinks and disappears after approximately 12–14 days. In PCOS, there is a so-called “follicular arrest” (Speroff *et al.*, 1999; Bulun and Adashi, 2011), i.e., several follicles develop to a size of 5–7 mm, but not further. No single follicle reaches the preovulatory size (16 mm or more). The loss of recycling results in a hormonal steady state causing persistent anovulation that is associated with increased production of androgens.

Women with PCOS have abnormalities in the metabolism of androgens and estrogen and in the control of androgen production. High serum concentrations of androgenic hormones, such as testosterone, androstenedione, dehydroepiandrosterone (DHEA) and dehydroepiandrosterone sulfate (DHEA-S), may be encountered in these patients (Chang, 1984). However, individual variation is considerable, and a particular patient might have normal androgen levels. PCOS is also associated with peripheral insulin resistance and hyperinsulinaemia (Nagamani *et al.*, 1986), and obesity amplifies the degree of both abnormalities. Insulin resistance in PCOS can be secondary to a postbinding defect in insulin receptor signaling pathways, and elevated insulin levels may have gonadotropin-augmenting effects on ovarian function.

PCOS is a complex, heterogeneous disorder of uncertain aetiology. The cause of this syndrome is unknown and it is possible that there are several causes. It has been suggested that in some patients this disorder may be initiated by excessive adrenal androgen production at the time of puberty or by a stress-induced increase in adrenal androgen secretion (Goldfien and Monroe, 1994). The peripheral conversion of androgen to estrogen could facilitate the secretion of increased amounts of LH, leading to increased ovarian androgen production and impaired follicular maturation. In some patients, there is a strong family history, which suggests that it is



a genetic disease. Such evidence includes the familial clustering of cases, greater concordance in monozygotic compared to dizygotic twins and heritability of endocrine and metabolic features of PCOS. The genetic component appears to be inherited in an autosomal dominant fashion with high genetic penetrance but variable expressivity in females; this means that each child has a 50% chance of inheriting the predisposing genetic variant(s) from a parent, and if a daughter receives the variant(s), then the daughter will have the disease to some extent (Crosignani and Nicolosi, 2001).

The genetic variant(s) can be inherited from either the father or the mother, and can be passed along to both sons (who may be asymptomatic carriers or may have symptoms such as early baldness and/or excessive hair) and daughters, who will show signs of PCOS. The allele appears to manifest itself at least partially via heightened androgen levels secreted by ovarian follicle theca cells from women with the allele. The exact gene affected has not yet been identified (Legro and Strauss, 2002).

This syndrome could also result from central nervous system abnormalities, leading to inappropriate secretion of hypothalamic GnRH. This, in turn, could increase the secretion of LH. Under the increased stimulatory effect of LH secreted by the anterior pituitary, stimulation of the ovarian theca cells is increased which in turn, increases the production of androgens. Because of a decreased level of follicle-stimulating hormone (FSH) relative to LH, the ovarian granulosa cells cannot aromatize the androgens to estrogens, which leads to decreased estrogen levels and consequent anovulation (Goldfien and Monroe, 1994). High local levels of androstenedione and testosterone in the polycystic ovary may impede normal follicular growth and increase the rate of atresia, resulting in the formation of numerous small cystic follicles.* Serum levels of estrone and free estradiol are elevated secondarily to increased peripheral aromatization of the ovarian androgens and reduced SHBG. The elevated levels of estrogen, in turn, may further sensitize the pituitary gland to hypothalamic GnRH, sustaining the abnormality.

PCOS is a disease with many long-term complications. Patients need regular follow-up with their physicians for early detection and management of any untoward sequelae associated with the syndrome. Women with PCOS are at risk for endometrial hyperplasia, high blood pressure, depression, dyslipidemia, cardiovascular disease, strokes, weight gain, miscarriage, sleep apnea, non-alcoholic fatty liver disease, Acanthosis nigricans and Autoimmune thyroiditis.** Women with PCOS who conceive are at increased risk for gestational diabetes, preeclampsia, cesarean delivery, and preterm and postterm delivery (Boomsma *et al.*, 2008). Their newborns are at increased risk of being large for gestational age but are not at increased risk of stillbirth or neonatal death. Women with PCOS who develop gestational diabetes should continue to monitor their blood sugar after giving birth (Boomsma *et al.*, 2008). They may have persistent problems with high blood sugar (diabetes) after delivery.

Where PCOS is associated with overweight or obesity, successful weight loss is the most effective method of restoring normal ovulation/menstruation, but many women find it very difficult to achieve and sustain significant weight loss. Low-carbohydrate diets and sustained regular exercise may help (Poehlman *et al.*, 2000). Some experts recommend a low GI diet in which a significant part of total carbohydrates are obtained from fruit, vegetables and whole grain sources (Marsh and Brand-Miller, 2005). Vitamin D deficiency may play some role in the development of the metabolic syndrome, so treatment of any such deficiency is indicated. Losing weight can also help treat the health conditions such as diabetes, high blood pressure, or high cholesterol.

Induction of ovulation is required for anovulatory women who wish to conceive. Most women ovulate in response to clomiphene citrate and FSH. In women whose ovaries fail to respond, combined therapy consisting of adrenal suppression and clomiphene may be more successful. Previously, the anti-diabetes medication

* (Speroff *et al.*, 1999; Goldfien and Monroe, 1994)

** (Apridonidze, 2005; Meyer *et al.*, 2005; Hardiman *et al.*, 2003; De Groot *et al.*, 2011)



metformin was recommended for treatment of anovulation, but it appears less effective than clomiphene (Legro *et al.*, 2007). The use of pulsatile GnRH to induce ovulation has generally not been effective. Wedge resection of the ovaries is rarely employed today.

For patients who do not respond to clomiphene, diet and lifestyle modification, there are options available including assisted reproductive technology procedures such as controlled ovarian hyperstimulation with FSH injections followed by in vitro fertilisation (IVF).

In patients producing moderate to large amounts of estrogen continuously, endometrial hyperplasia with consequent bleeding and even endometrial carcinoma may develop. In such patients, the cyclic administration of a progestational agent may be required (Goldfien and Monroe, 1994; Hardiman *et al.*, 2003)).

Though surgery is not commonly performed, the polycystic ovaries can be treated with a laparoscopic procedure called "ovarian drilling" (puncture of 4–10 small follicles with electrocautery, laser, or biopsy needles), which often results in either resumption of spontaneous ovulations or ovulations after adjuvant treatment with clomiphene or FSH.

Women who do not wish to become pregnant can be effectively treated for hirsutism by suppression of androgen production or by anti-androgen therapy such as flutamide, and spironolactone (Radosh, 2009).

Finally, PCOS is a chronic condition with reproductive and psychological manifestations usually beginning in adolescence then transitioning to include infertility and increasing metabolic complications over time. Both hyperandrogenism and insulin resistance contribute to the pathophysiology of PCOS. Management should focus on support, education, addressing psychological factors and strongly emphasizing healthy lifestyle with targeted medical therapy as required. Comprehensive evidence-based guidelines are needed to aid early diagnosis, appropriate investigation, regular screening and treatment of this common condition.

REFERENCES

- Boomsma CM, Fauser BC, Macklon NS 2008. Pregnancy complications in women with polycystic ovary syndrome *Semin. Reprod. Med* 26 (1): 72
- Speroff L, Glass RH, Kase NG 1999. Anovulation and the Polycystic Ovary. In: *Clinic / Gynecologic Endocrinology and Infertility*. 6th ed. Lippincott Williams & Wilkins.
- Balen AH, Laven JSE, Tan SL, Dewailly D 2003. Ultrasound assessment of the polycystic ovary: international consensus definitions *Hum Reprod Update* 9 (6): 505
- Goldfien A, Monroe SE 1994. Ovaries. In: Greenspan FS, Baxter JD, eds. *Basic and Clinical Endocrinology*. 4th ed. Prentice-Hall International Inc.
- Teede H, Deeks A, Moran L 2010. Polycystic ovary syndrome: a complex condition with psychological, reproductive and metabolic manifestations that impacts on health across the lifespan *BMC Medicine* 8: 41
- Lobo RA 2007. Hyperandrogenism: Physiology, etiology, differential diagnosis, management. In: Katz VL, Lentz GM, Lobo RA, Gershenson DM, eds. *Comprehensive Gynecology*. 5th ed. Philadelphia, Pa: Mosby Elsevier
- Huang A, Brennan K, Azziz R 2010. Prevalence of hyperandrogenemia in the polycystic ovary syndrome diagnosed by the National Institutes of Health 1990 criteria *Fertil. Steril* 93 (6): 1938
- Moran LJ, Misso ML, Wild RA, Norman RJ 2010. Impaired glucose tolerance, type 2 diabetes and metabolic syndrome in polycystic ovary syndrome: a systematic review and meta-analysis *Hum Reprod Update* 16 (4): 347



- Rocha MP, Maranhão RC, Seydell TM et al. 2010. Metabolism of triglyceride-rich lipoproteins and lipid transfer to high-density lipoprotein in young obese and normal-weight patients with polycystic ovary syndrome *Fertil Steril* 93 (6): 1948
- Apridonidze T, Essah PA, Iuorno MJ, Nestler JE 2005. Prevalence and characteristics of the metabolic syndrome in women with polycystic ovary syndrome *J Clin Endocrinol Metab* 90:1929
- Meyer C, McGrath BP, Teede HJ 2005. Overweight women with polycystic ovary syndrome have evidence of subclinical cardiovascular disease *J Clin Endocrinol Metab* 90:5711
- Barry JA, Kuczmierzyck AR, Hardiman, PJ 2011. Anxiety and depression in polycystic ovary syndrome: a systematic review and meta-analysis *Hum Reprod* 93 (6): 1948
- Bulun SE, Adashi EY 2011. The physiology and pathology of the female reproductive axis. In: Kronenberg HM, Melmed S, Polonsky KS, Larsen PR, eds. *Williams Textbook of Endocrinology*. 12th ed. Philadelphia, Pa: Saunders Elsevier
- Chang RJ 1984. Ovarian steroid secretion in polycystic ovarian disease *Seminars Reprod Endocrinol* 2: 244
- Nagamani M, Dinh TV, Kelder ME 1986. Hyperinsulinemia in hyperthecosis of the ovaries *Am J Obstet Gynecol* 154: 384
- Crosignani PG, Nicolosi AE 2001. Polycystic ovarian disease: heritability and heterogeneity *Hum Reprod Update* 7 (1): 3
- Legro RS, Strauss JF 2002. Molecular progress in infertility: polycystic ovary syndrome *Fertil Steril* 78 (3): 569
- Hardiman P, Pillay OC, Atiomo W 2003. Polycystic ovary syndrome and endometrial carcinoma *Lancet* 361 (9371): 1810
- De Groot, PCM, Dekkers OM, Romijn JA, Dieben SWM, Helmerhorst FM 2011. PCOS, coronary heart disease, stroke and the influence of obesity: A systematic review and meta-analysis *Hum Reprod Update* 17 (4): 495
- Poehlman ET, Dvorak RV, DeNino WF, Brochu M, Ades PA 2000. Effects of resistance training and endurance training on insulin sensitivity in nonobese, young women: a controlled randomized trial *J Clin Endocrinol Metab* 85:2463
- Marsh K, Brand-Miller J 2005. The optimal diet for women with polycystic ovary syndrome? *Br. J. Nutr.* 94 (2): 154
- Legro RS, Barnhart HX, Schlaff WD 2007. Clomiphene, Metformin, or Both for Infertility in the Polycystic Ovary Syndrome *N Engl J Med* 356 (6): 551
- Radosh L 2009. Drug treatments for polycystic ovary syndrome *Am Fam Physician* 79: 671



Pheromones and Chemical Communication

Mohua Guha* and Anjan Guha**

Abstract: Pheromones (also sometimes called as ecto-hormones) are 5 to 20 carbon molecules that act as chemical signal between the members of the same species and elicit a particular behavioural or physiological change. Pheromones help in maintaining the fitness, mate choice, mate selection to avoid genetic relatedness, sexual maturation, successful fertilization, kin recognition, maternal infant bonding, dominance hierarchy, aggression, aggregation and many other aspects of the social organization in the living world. They can be of various types such as aggregation, alarm, epideictic, releaser, primer, territorial, trail, sex pheromones and so on. In insects, pheromones are being reported to be produced from Nasonov's gland, Venom gland, Richard's gland, Tergal gland, Dufour's gland and glands on the midgut, hindgut, pygidium, rectum, sternum, and hind tibia etc. Salivary glands, glands associated with the eye, lungs, trachea, liver, gall bladder, bile duct, portion of the small intestine, kidney, ureter, bladder, urethra, male and female accessory gland, rectum and anal sac could be the possible odour sources in mammals. The pheromone after being released into the environment diffuses through air or water. Amongst the invertebrates, insects mainly sense the pheromones with the help of the receptors present in their antennae while in mammals Vomero Nasal Organ (VNO) is present for sensing the presence of pheromones. In moths and other insects the message is finally being transferred to lateral horn of protocerebrum while in mammals the message after being transferred through the amygdala, is finally being interpreted by the hippocampus. Pheromones have also been reported in plants. Human pheromones, anthropines have been identified which are lipophilic compounds that remain associated with the skin and follicles that determine the individual signature of human odours. Pheromones in future have the potency to be better utilized by man for pest and wildlife management.

The word pheromone has been derived from two Greek words pherein meaning "to transport" and hormone "to stimulate". It is a secreted or excreted chemical factor that causes a defined chemical signal between members of the same species, eliciting a particular behavioral or physiological change. They are also sometimes called as ecto-hormones. These chemical messengers are transported outside the body and result in communication between the individuals of the same species and thus cause behavioural changes. The German Biochemist Adolf Butenandt first characterized such a chemical released by the female silkworm to attract mates and called it bombykol. The general size of the pheromone molecules can be limited to about 5 to 20 carbons and a molecular weight between 80 and 300 since the molecular diversity is high within this range along with the olfactory efficiency. Pheromones of various types are known to be present in almost all the phyla of the living world starting from plants to human beings.

PEROMONES IN ANIMALS

STRUCTURE OF PHEROMONES

Pheromones are based on a chain of carbon and attached hydrogen atoms. The carbon backbone forms a zigzag because of the tetrahedral arrangement of the four carbon bonds. The chemical nature of the molecule changes when other atoms such as oxygen, nitrogen or other functional groups are added to the chain or substituted for hydrogens or carbons. The functional group may consist of alcohol, aldehyde, amine, carboxylic acid, ester, ketone etc.

*Assistant Professor, Department of Zoology, Narasinha Dutt College, Howrah.

**West Bengal Forest Service, Divisional Forest Officer, Kharagpur Division.



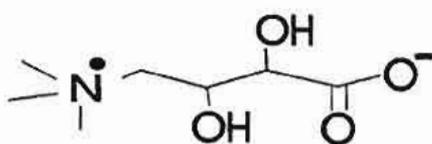
FUNCTIONS

Pheromones, being the chemical signal between the individuals of the same species, help in maintenance of health and fitness, mate choice, mate selection to avoid genetic relatedness, sexual maturation, successful fertilization, kin recognition, maternal infant bonding, dominance hierarchy, aggression, aggregation and many other aspects of the social organization in the living world.

TYPES

There are various kinds of pheromones based on their functions, some of which are being discussed here in brief. Aggregation pheromones function in defense against predators, mate selection and for overcoming host resistance by mass attack. The most striking example of the aggregation pheromone can be seen in the desert locust *Schistocerca gregaria* where two reversibly transformable morphologically, physiologically and behaviourally distinct phases: solitaria and gregaria can be seen in the life cycle.

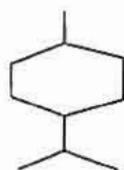
Alarm pheromones are being released when attacked by a predator and it can trigger flight or aggression in members of the same species.



Anthopleurine

Sea anemone

Alarm call pheromones



Limonene

Termite

Epideictic pheromones in insects are very interesting to note. The females who lay their eggs in fruits deposit these substances in the vicinity of their clutch to signal to the other females of the same species that they should clutch elsewhere. This is seen in the apple maggot fly *Rhagoletis pomonella*.

Releaser pheromones cause an alternation in the behavior of the recipient while Primer pheromones trigger a change in the developmental events. The territorial pheromones mark the boundaries of an organism's territory. This is seen in many mammals including tigers and leopards. The signal pheromones cause short-term changes, such as the neurotransmitter release that activates a response. Information pheromones are indicative of an animal's identity or territory and the trail pheromones are very common in social insects like ants.



Sex pheromones indicate the availability of the female for breeding and the male animals may also emit pheromones that convey information about their species and genotype. An interesting point to note is that the Asian elephant *Elephas maximus* shares its female sex pheromone (Z)-dodecen-1-yl acetate with some 140 species of moth.

Pheromones have evolved in all animal phyla to signal sex and dominance status and are responsible for stereotypical social and sexual behavior among members of the same species.

PHEROMONE PRODUCTION

In insects, pheromones are being reported to be produced from Nasonov's, Venom, Richard's, Tergal, Dufour's glands, glands on the midgut, hindgut, pygidium, rectum, sternum, and hind tibia etc. Salivary glands, gland's associated with the eye, lungs, trachea, liver, gall bladder, bile duct, portion of the small intestine, kidney, ureter, bladder, urethra, male and female accessory gland, rectum and anal sac could be the possible odour sources in mammals.

PASSAGE OF PHEROMONE THROUGH AIR AND WATER

Pheromones diffuse through the air following the formula mentioned below.

THE RADIUS (R) OF ACTIVE SPACE AT TIME 't' IS GIVEN BY :

$$R(t) = \sqrt{4Dt \log \left(\frac{2Q}{K(4\pi Dt)^{3/2}} \right)}$$

$$\text{for } 0 \leq t \leq \frac{1}{4\pi D} \left(\frac{2Q}{K} \right)^{2/3}$$

= 0 otherwise

Where Q - QUANTITY OF PHEROMONE

K - THRESHOLD OF SENSITIVITY OF RECEIVER

D - DIFFUSION COEFFICIENT (CORRELATE WITH MW)

$$R_{max} = \sqrt{\left(\frac{2Q}{K} \right)^{2/3} \times \frac{3}{2\pi e}} = 0.527 \left(\frac{Q}{K} \right)^{1/3}$$

$$t_{\text{fade-out}} = \frac{1}{4\pi D} \left(\frac{2Q}{K} \right)^{2/3} = e \cdot t_{R_{max}} = \frac{0.126}{D} \left(\frac{Q}{K} \right)^{2/3}$$

The maximum range of a diffusing chemical signal is independent of 'D', the range of signals is approximately same in air and water, but in water the signal takes far longer to travel and then fades as the time scale is inversely proportional to 'D', The kinetics affecting rise-time and fade out will be slowed many times in water.

PHEROMONE RECEPTION AND SIGNAL TRANSMISSION

Pheromones are being detected by receptors belonging to the superfamily of heterotrimeric GTP-binding protein (G protein)-coupled receptors. Insects mainly perceive these molecules with their long, thin, and mobile antennae. The paired antennae provide information about the direction and intensity of scents. The receptors for the pheromones are found to be more concentrated in this part of their body.

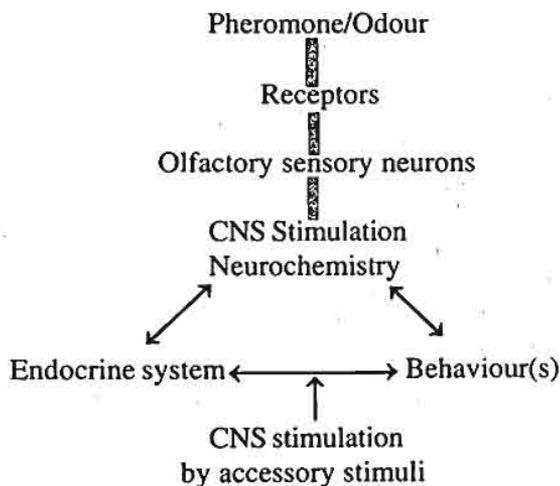
In mammals, the chemical signals are detected primarily by the vomeronasal organ (VNO), a chemosen-



sory organ located at the base of the nasal septum. VNO is present in most amphibian, reptiles and non-primate mammals but is absent in birds, adult catarrhine monkeys and apes. Three different G-protein-coupled receptors have been identified in the VNO, each found in distinct regions: the V1Rs, V2Rs, and FPRs. V1Rs, V2Rs and FPRs are seven transmembrane receptors which are not closely related to odorant receptors expressed in the main olfactory neuroepithelium.

When the pheromones bind the G-protein coupled receptors, the cAMP gated ion-channels open which creates a potential difference, the signal of which is being transmitted by the Olfactory Sensory Neurons (OSN). In moths and other insects, the message is finally being transferred to lateral horn of protocerebrum while in mammals the message after being transferred through the amygdala, is finally being interpreted by the hippocampus.

SUMMARY OF THE MODE OF ACTION



A DISCUSSION ON PHEROMONES IN SOME VERTEBRATES

SEA LAMPREY (*Petromyzon marinus*)

Sea lamprey is a quasiparasitic, marine animal which breeds in coastal freshwater streams where its males build simple nests, which females locate using pheromones. 3-Ketopetromyzonol sulfate (3K-PS) is a male sex pheromone component that has been identified. The tasks of finding suitable spawning streams and then mates are very essential for their survival and both of these activities are mediated by potent pheromones.

FISH

The role of the pheromones in the communication between the individuals of the same species of fishes have well been reported. An example of the pheromonal communication system in the goldfish *Carassius auratus* has been described here. Pre-ovulatory primer and Post-ovulatory releaser pheromones coordinate reproduction in the goldfish *Carassius auratus*. In the evening while female matures her eggs before release, rising levels of the steroid 17, 20 β -P in her blood leak into the water. The male's olfactory system detects the pheromone and stimulates his brain to release male GtH which in turn stimulates testicular 17,20 β -P synthesis and promotes increased milt (sperm and seminal fluid production). The next morning at ovulation eggs within the reproductive tract stimulate the production of PGFs which act as hormones to stimulate female sexual behavior. Metabolites of PGFs leak out and function as a releaser pheromone stimulating male sexual behavior.



AMPHIBIA

The skin glands of anurans secrete various biologically active compounds, the pheromones, which are peptides consisting of various numbers of amino acid residues. They have an important role in sexual relationships like female attraction and/or territorial announcement, mate choice and female receptivity etc. Female attracting pheromones like sodefrin and silefrin have been identified in Japanese fire bellied newt (*Cynops pyrrhogaster*) and Japanese sword-tail newt (*Cynops ensicauda*) respectively. In amphibians, pheromone detection is mediated through neurons of the vomeronasal organ. Possible pheromone receptors include two groups of the G-protein coupled with seven transmembrane proteins.

Antipredator pheromones have also been reported in the amphibians. Tadpoles of *Rana aurora* release a chemical that provides conspecifics with an early warning of predator presence. *Bufo boreas* tadpoles living in the presence of conspecific alarm cues and chemosignals of specific predators reduce the time of metamorphosis in order to reduce the time in the presence of its predators. The attraction to conspecific chemical cues in nonlarval anurans was first demonstrated in the toad *Bufo cognatus*. Postmetamorphic toads of this species formed aggregations and were attracted to areas that had been previously occupied by postmetamorphic conspecifics. This suggests that orientation to chemical cues is involved in the aggregation response.

REPTILE

Although all reptile orders have been examined, the vast majority of the literature has dealt only with squamates, primarily snakes and lizards. Behaviours governed by pheromones include conspecific trailing, male-male agonistic interactions, sex recognition and reptilian predator recognition. Reptiles provide excellent candidates for further studies in this field not only in squamates, but also in the orders where little experimental work has been conducted to date.

BIRD

Communication studies in birds related to pheromones remained neglected as compared to acoustic and visual channels. The existence of pheromones has never been formally demonstrated in this vertebrate class but different groups of birds such as petrels, auklets and ducks have been shown to produce specific scents that could play a significant role in within-species social interactions.

MAMMAL

Tigers communicate with one another with the help of Marking fluid which is a lipid-rich fluid sprayed upwards and backwards through the urinary channel of both the sexes. The volatile molecules present in this fluid are made to last longer with the help of lipid fixatives. The lipid comprises cholesterol ester, wax ester, triglyceride, free fatty acids, diglyceride, monoglyceride, free sterol and phospholipid.

Musth is an important male phenomenon affecting different aspects of elephant society including reproduction. It is an annual period of heightened sexual activity and aggression in male elephants that is linked to physical, sexual and social maturation. During musth, the temporal gland secretions (as well as the urine and breath) of adult male Asian elephants (*Elephas maximus*) discharge a variety of malodorous compounds together with the bicyclic ketal, frontalinal. The pheromone frontalinal exists in two chiral forms. The enantiomers (molecular mirror images) of frontalinal are released by Asian elephants in a specific ratio that depends on the animal's age and stage of musth and different responses are elicited in male and female conspecifics when the ratio alters.

PHEROMONES IN PLANTS

One possible example of a hormone as a pheromone is the plant hormone ethylene, which is produced by an individual plant to stimulate ripening of fruit, loss of leaves, and other physiological changes. Ethylene also



passes through the atmosphere to surrounding plants and stimulates their production of defensive chemicals, thus acting as a pheromone. Not everyone is convinced by the evidence that has been presented for this phenomenon, but the possibility is intriguing.

Jasmonate and its derivatives are lipid-based hormone signals that regulate a wide range of processes in plants, ranging from growth and photosynthesis to reproductive development. In particular, Jasmonates are critical for plant defense against herbivory and plant responses to poor environmental conditions and other kinds of abiotic and biotic challenges. Reminiscent of talking trees in fiction, some Jasmonates can also be released as volatile organic compounds (VOCs) to permit communication between plants in anticipation of mutual dangers.

PHEROMONES IN MAN

German physician Gustav Jager was the first to propose the concept of human pheromones, anthropines (from the Greek *Anthropos*, meaning man) which he identified as lipophilic compounds that are associated with the skin and follicles that determine the individual signature of human odours. A possible role of pheromones in human kin recognition, menstrual synchrony and sexual orientation has been suggested by various researchers. A few pheromones like androstenol (in males), copulin (in females) have been reported till date.

The synchronization of menstrual cycles among women was studied by Martha McClintock, based on the unconscious odour cues. This is also known as McClintock effect after the primary investigator. This study showed that when a group of women were exposed to whiff of perspiration from other women, it caused their menstrual cycles to speed up or slow down depending on the time in the month when the sweat was collected: before, during or after ovulation.

Three axillary steroids have been described as human pheromones: androstenone, androstenol, and androstadienone. The axillary steroids are produced by the testes, ovaries, apocrine glands and adrenal glands. These chemicals are not biologically active until puberty when the sex steroids influence their activity. This change in activity associated with puberty is some of the best evidence that our species do communicate through odors.

The smell of androstadienone, a chemical component of male sweat, maintains higher level of cortisol in females. This compound is being detected via the olfactory mucosa. The scientists believe that the ability of this compound to influence the endocrine balance of the opposite sex makes it a human pheromonal signal.

CONCLUSION

Pheromones play a very important role in the animal world as has already been discussed. They can further be used by man to induce many behaviours in animals that can help in proper pest management and wildlife management in future. In case of pest management, pheromone trap can be used to trap pests for monitoring purposes, to control the population by creating confusion, to disrupt mating, as well as to prevent further egg laying. Pheromones may be used in wildlife management to induce breeding in endangered populations, to mark the territory to restrict the animals within a particular area of the forest so as to reduce the man-animal conflict and in several other ways.

FURTHER READINGS

- Baldwin IT *et al*, 2006. *Science*, 311: 812-815,
- Brennan & Keverne, 2004. *Curr. Biol.* 14: R81-R89,
- Caro SP, Balthazart J, 2010. *J Comp Physiol A Neuroethol Sens Neural Behav Physiol*, 196(10): 751-766,
- Greenwood DR *et al*, *Nature*, 2005, 438: 1097-1098,
- Ha and Smith, 2008. *Cell* 133:761-763,



- Mason RT, Parker MR, 2010. *J Comp Physiol A Neuroethol Sens Neural Behav Physiol*, 196(10): 729-743,
McClintock MK, *Nature*, 1971. 229 (5282): 244-5,
Poddar-Sarkar M, *J Lipid Mediat Cell Signal*, 1996. 15(1): 89-101,
Rajchard J, 2005. *Vet. Med.-Czech*, 50: 385-389,
Rajchard J, *Veterinari Medicina*, 2006. 51: 409-413,
Rasmussen LE, Greenwood DR, 2003. *Chem Senses*, 23(5): 433-446,
Stern K, McClintock MK, *Nature*, 1998. 392 (6672): 177-9,
Taymour M, 2012. *Journal of Advanced Research*, 3 (1): 1-9,
Tristram D. Wyatt, 2003. *Pheromones and Animal Behaviour*,
Warren S. T. Hays, 2003. *Behavioral Ecological Sociobiology*, 54 (2): 97-98,
Yamagishi K *et al*, 2002. *Zoological Science*, 19: 1467,



Detection of beta thalassemia trait and identification of the mutant locus among the school/college students in Barrackpore region by HPLC and ARMS PCR

Paromita Sarbadhikary, Anwesha Nandi, Swati Roy Gangopadhyay*

Abstract: Thalassemia is an inherited autosomal recessive genetic disorder, characterized by decreased and defective production of haemoglobin, leading to anaemia. Thalassemia is classified as α -Thalassemia and β -Thalassemia depending on which chain of the hemoglobin molecule is affected. Prevalence of β -Thalassemia is about 3-15% in India, highest in northern, western and eastern parts, while it is much less in south India. β Thalassemia is caused by mutations on chromosome 11 that affect the transcription, translation, and stability of the β -globin products. While prevalence of Hemoglobin E is mostly present in the North Eastern states it ranges from 0.4-64.5% in different populations of Eastern India. Hemoglobin E – a Hemoglobinopathy is an inherited variant of normal adult HbA, resulting from a substitution of lysine for glutamic acid in the 26th codon of β globin chain (codon 26th GAG \rightarrow AAG). Every year 10,000 children with thalassemia major are born in India, which constitutes 10% of total number in the world, and presently there are 8 % reported carriers in India. Thus, for a cause of community awareness, screening of carriers and for the generation of awareness before marriage, determination of both normal and abnormal hemoglobin (variant Hb) is absolutely needed. Blood samples of more than 3000 students residing in/near the area of Barrackpore, were screened for the thalassemia trait or other hemoglobinopathies by the VARIANT Hemoglobin Testing System (Bio-Rad). Among them 176 blood samples were detected as thalassemia carrier, among which 66 and 97 samples were found to be β -Thalassemia trait and heterozygous Hemoglobin E respectively. By ARMS PCR analysis, codon 8/9 (+G), codon 41/42(-CTTT), and Codon 25(G-A) mutations in heterozygous condition have been detected. To identify the specific point mutation a pair of allele-specific primers one of which has its 3'-terminal nucleotide complementary to the point mutation (Mt ARMS primer) and other to the normal DNA sequence (ARMS primer) was used in PCR.

Thalassemia, also known as "Cooley's anemia", is an inherited disease of the red blood cells. In thalassemia, the genetic defect results in reduced rate of synthesis of normal globin chains of hemoglobin leading to instability or abnormal oxygen transport. To survive, many people with thalassemia need blood transfusions at regular intervals.

Thalassemias are classified according to which chain of the globin molecule is affected: in α thalassemia, the production of α globin is deficient, while in β thalassemia the production of β globin is defective. Thalassemia produces a deficiency of α or β globin, Beta thalassemia is due to mutations in the Hb beta gene on chromosome 11 (Mendelian Inheritance in Man (OMIM) 141900), also inherited in a Mendelian recessive fashion. In β thalassemia, excess α chain is produced, but these do not form tetramers: rather, they bind to the red blood cell membranes producing membrane damage, and at high concentrations have the tendency to form toxic aggregates. The severity of the damage depends on the nature of the mutation. Some mutations (β^0) prevent any formation of β chains; others (β^+) allow some β chain formation to occur.

In India, β -thalassaemia is the most common monogenic disorder. The disease is characterized by its genetic heterogeneity at the molecular level, and more than 300 mutations of the β -globin gene have been characterized all over the world, though each population seems to harbor only a few of these mutations. As the ethnic composition of the Indian population is varied and complex (Sengupta, 2008), each region of the country

*Barrackpore Rastraguru Surendranath College, North 24 Parganas, Kolkata-700120



has its own distinct set of mutations (Varawalla *et al.*, 1991, Gupta *et al.*, 2008). The eastern region of the country is very poorly characterized in this regard. Among the Bengali population as far studied it appears that the hemoglobin variant HbE is very common along with β -thalassemia (Das *et al.*, 1991). HbE in conjunction with β -thalassaemia produces HbE- β -thalassaemia, a more common form of the disease in eastern India. As thalassaemia is an incurable disease, screening of the population for carrier detection, awareness generation and pre/post marital genetic counseling is the only way to eradicate thalassaemia from the society. We have screened the high- school and college students for carrier detection and identification of mutant locus for β -thalassaemia through both HPLC and ARMS-PCR based method. We also made an elaborate effort to counsel the detected carriers so that they restrain themselves from engaging in marital relationship with the carrier partners.

MATERIALS AND METHODS

Collection of blood: 2 ml of blood from the students and other pre marital population was drawn in EDTA coated vials. Blood was analyzed in cell counter for Hb%, amount of RBC, MCV, MHC, and RDW. For the detection of carriers for thalassaemia HPLC based Variant Hemoglobin Testing System (Bio-Rad) was used. Haemoglobin A2/F calibrator was reconstituted by adding 10ml Haemoglobin A2/F calibrator diluent. A set of normal and abnormal controls was run at the beginning and end of each group of blood samples. The whole blood primer was prepared by adding 1ml of deionized water and is used at the beginning of each run in condition the cartridge for analysis. For sample analysis, 5 μ l whole blood samples is pipetted into 1.5 ml vials and mixed with 1ml of hemolysis reagent (provided with the kit) and placed into specific wells of the VARI-ANT machine. Samples can be analyzed at a time and each sample analysis requires 6.5 min.

SAMPLE PREPARATION FOR THE PCR

Whole blood was digested with proteinase K to release the DNA in presence of non ionic detergent Tween 20 and centrifuged at 13,000g for 10 sec. The crude pellet dissolved in K- Buffer (50mM KCl, 15mM Tris HCl (pH 8.3), 2.5mM MgCl₂, 0.5% Tween 20, 100mg/ml fresh Proteinase K) and was used in PCR. [E.S. Kawasaki PCR Protocols; A guide to methods and applications].

PRIMERS FOR PCR

The following set of ARMS primers which are specific for normal and individual mutant locus of beta globin gene were used at a concentration of 3 pico moles for each set of PCR. Amplification was carried out for 25 cycles with the denaturation at 94° C for 1min, annealing at 68° C for 1min and extension at 72° C for 1min 30 sec. PCR products were detected on 1% agarose gel.



Following sets of primers were used for PCR

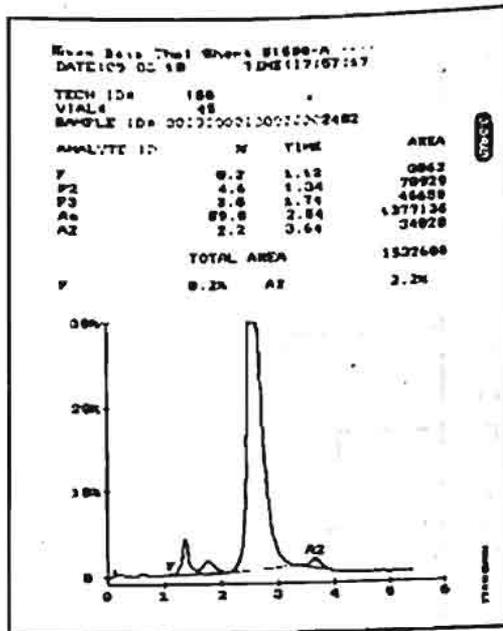
Primer	Types of mutation
CCT TGC CCC ACA GGG CAG TAA CGG CAC ACT CCT TGC CCC ACA GGG CAG TAA CGG CAC ACC	Cd. 8/9 (+G)
GAG TGG ACA GAT CCC CAA AGG ACT CAA AGA GAG TGG ACA GAT CCC CAA AGG ACT CAA CCT	Cd. 41/42 (-TCTT)
TAA CCT TGA TAC CAA CCT GCC CAG GGC GTC TAA CCT TGA TAC CAA CCT GCC CAG GGC GTT	Cd. 26 (G to A)
*GAT GAA GTT GGT GGT GAG GCC CTG GGT AGG TTA AAC CTG TCT TGT AAC CTT GAT ACG AAA	IVS 1-1Int. (G to T)
CTC CTT AAA CCT GTC TTG TAA CCT TGT TAC CTC CTT AAA CCT GTC TTG TAA CCT TGT TAG	IVS 1-5nt (G to C)
CAA TGT ATC ATG CCT CTT TGC ACC GAG TCA AGG CTG AGA GAT GCA GGA	Internal control primer
ACC TCA CCC TGT GGA GCC AC *CCC CTT CCT ATG ACA TGA ACT TAA	Common Reverse primer A Common Reverse primer B

RESULTS AND DISCUSSION

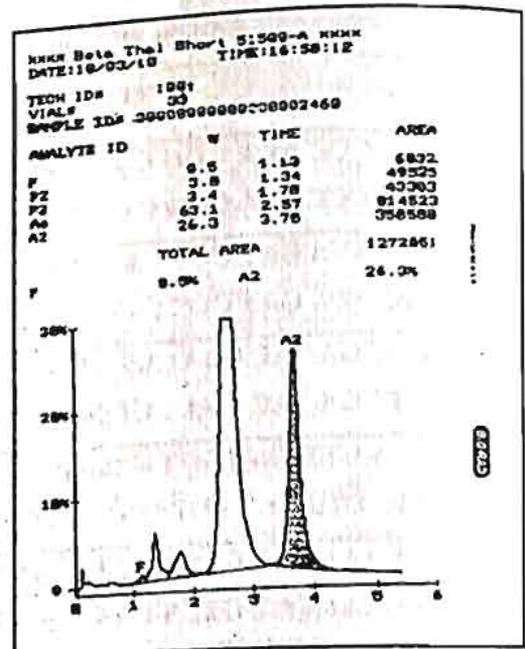
Detection of beta thalassemia traits by variant: We have screened 3175 samples for the detection of beta thalassemia carriers. Among them 176 (5%) students were found to be carriers for beta thalassemia. Table 1 represents the types of beta thalassemia traits that are prevalent within the college students in Barrackpore region. The frequency of Hb E trait (0.031) is quite higher than beta thal trait (0.021). Hb D and Hb S mutation was also detected at low frequency in Barrackpore region.

No. of samples screened	Total Carriers	Types of Thalassemia carrier	Number of carriers	Frequency
3175	176	β - thal Trait	66	0.021
		HbE Trait	97	0.031
		HbD Trait	9	0.003
		HbS Trait	4	0.001

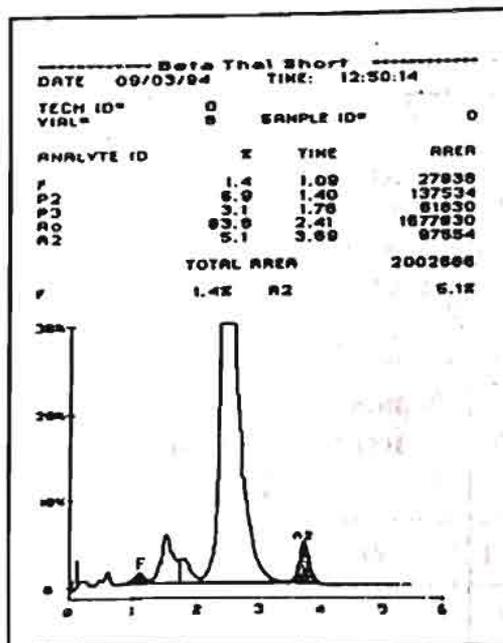
Table 1. The types of beta thalassemia traits that are prevalent within the college students in Barrackpore region



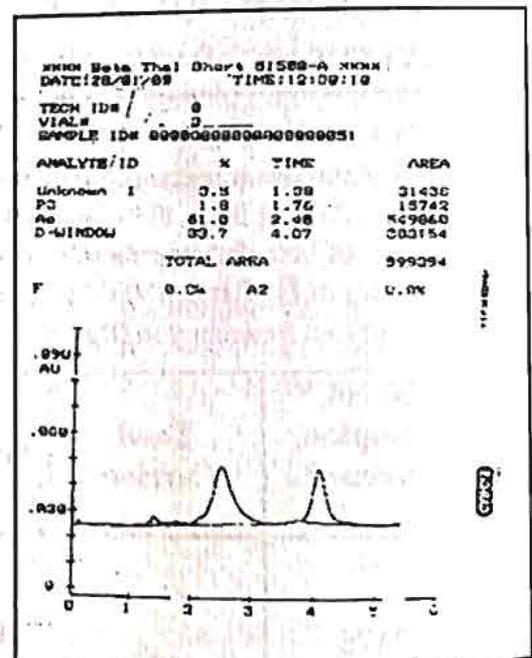
A-Normal



B- HbE trait



C- Beta-Thal Trait



D- Hb D trait

Chromatogram shows the distribution of peaks of different forms of Haemoglobin (mainly HbA, HbF and HbA2) of normal (A) and Hb E trait (B) Beta-Thal Trait (C), and Hb D trait (D)

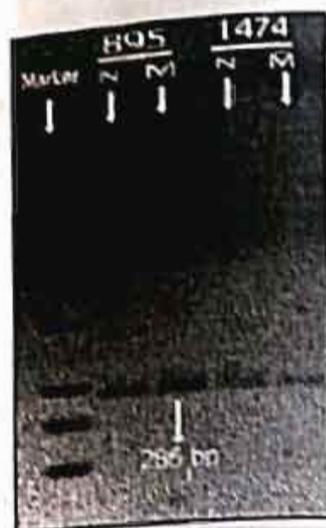


Beta thalassemia in heterozygous condition was detected by Hb Virant HB testing system that basically acts on the principle of ion exchange chromatography. Normal individual contains 94-96% HbA and 0-1% fetal haemoglobin HbF (Haemoglobin that contains two alpha and two gamma chains). Beside that they also contain 2-3.5% HbA₂ (Haemoglobin that contains 2 alpha chain and two delta chains). With the accumulation of mutation either in homozygous or in heterozygous condition the percentage of different forms of haemoglobin varies and this variant forms of hemoglobin could be detected from the chromatogram. For accurate detection, along with the % haemoglobin, the retention time and the overall area of the peaks will have to be considered. Other group of mutations like HbD, HbS can be detected from the specific windows appearing on the chromatogram. Detection of variant forms of haemoglobin by HPLC is sometimes limited because minor components of HbS and other Hb variants eluting after HbA₂ may co elute with HbA₂. This may result in a falsely elevated area percent value of HbA₂. Also hemoglobin D and E co elute with HbA₂. Specimens determined to have HbA₂ levels greater than 10% should be tested further. To overcome this limitation and to detect the particular mutant locus within beta globin gene PCR based Amplification Refractory Mutation System (ARMS) was performed (Newton *et.al.*, 1989). We have used 5 sets of ARMS primers that are specific for amplifying mutant and normal allele for a particular mutant locus. 176 carriers as identified by HPLC were tested for allele specific amplification by ARMS PCR. Among the carrier samples screened for the detection of mutant locus 15 individuals were found to have Cd. 8/9 (+G), 25 have Cd. 41/42 (-TCTT), 70 have Cd. 26 (G to A) mutation in heterozygous condition. With this set of primers we were unable to detect any mutation for IVS 1-1nt. (G to T) and IVS 1-5nt (G to C) locus.

ARMS PCR result shows that point mutation in codon 26 (G - A) is responsible for HbE trait and individuals are the carrier of HbE. While in parallel studies, it has been observed that deletion mutation in Cd. 41/42 (-TCTT) is responsible for one of the mutation leading to thalassemia minor. The incidence of HbE amongst the population studied is quite high and goes well within the data of previous workers who also reported the high prevalence of HbE amongst the population of other regions of Eastern India (Das *et.al.*, 1991).



Normal- 286 bp DNA band with BG 9 HbE N primer but not with BG 10 HbE M primer



Hb E carrier - 286 bp DNA band primer with both BG 9 HbE N primer and BG 10 HbE M primer; showing heterozygous state.

Primer	Types of mutation	No of detected sample	PCR product size
CCT TGC CCC ACA GGG CAG TAA CGG CAC ACT CCT TGC CCC ACA GGG CAG TAA CGG CAC ACC	Cd. 8/9 (+G)	15	225bp
GAG TGG ACA GAT CCC CAA AGG ACT CAA AGA GAG TGG ACA GAT CCC CAA AGG ACT CAA CCT	Cd. 41/42 (-TCTT)	25	439bp
TAA CCT TGA TAC CAA CCT GCC CAG GGC GTC TAA CCT TGA TAC CAA CCT GCC CAG GGC GTT	Cd. 26 (G to A)	70	286 bp
*GAT GAA GTT CGT GGT GAG GCC CTG GGT AGG TTA AAC CTG TCT TGT AAC CTT GAT ACG AAA	IVS 1-11nt. (G to T)	Not detected	281 bp
CTC CTT AAA CCT GTC TIG TAA CCT TGT TAC CTC CTT AAA CCT GTC TIG TAA CCT TGT TAG	IVS 1-5nt (G to C)	Not detected	285 bp
CAA TGT ATC ATG CCT CTT TGC ACC GAG TCA AGG CTG AGA GAT GCA GGA	Internal control primer		861 bp
ACC TCA CCC TGT GGA GCC AC *CCC CTT CCT ATG ACA TGA ACT TAA	Common Reverse primer A Common Reverse primer B		

Table 2. The number of heterozygous individual having allele specific mutation in their beta globin gene. Allele specific primer sequences and the size of the PCR product are shown here.



Identification and counseling of thalassemia carriers is essentially required because if both parents are thalassemia carriers, there is 25% probability with each pregnancy that their child will be thalassemic and 50% probability that their child will be carrier. Moreover once a child is diagnosed to have thalassemia major disorder, he/she has to take lifelong treatment which includes regular 3 weekly filtered packed red cell transfusions, chelation therapy for iron overload, management of complication of iron overload and transfusion (Thacker, 2008).

The high prevalence of HbE trait in the region of Barrackpore has become a matter of great concern and hence we have emphasized on counseling of the carrier students. Carrier Screening Programs are being conducted in several countries using various approaches with a perspective to eradicate thalassemia. They include screening of the general population, screening of high risk communities and cascade screening. In India, only those individuals having thalassemia major undergo blood transfusion and their families have some knowledge about this genetic disease, while the general population is ignorant of this disorder (Thacker, 2008).

In many places in India, the affected children could not get themselves tested due to non availability of facilities for screening in nearby town and also due to non- affordability. Such a situation must be avoided by establishment of more centers and cost effective technology for screening.

Identification of unmarried carriers especially at school and college level is very important as it gives them the option of selecting a partner who is non- carrier. Individuals whom we have counseled showed very much positive approach and attitude towards the knowledge about thalassemia, its genetic inheritance and the consequence of their offspring if the child is thalassemia major. India has one of the largest private health care sectors in the world. Using public- private partnership, a good network must be developed for the screening and identification of carriers in a cost- effective way with an objective to eradicate thalassemia from the country.

REFERENCES

- The Distribution of the Thalassemia Gene: A Historical Review By AMOZ I. CHERNOFF
M. Sengupta, 2008. Thalassemia among the tribal communities of India. *The Internet Journal of Biological Anthropology*. 1, 2
- Varawalla NY, Old JM, Sarkar R, Venkatesaon R, Weatherall DJ, 1991. The spectrum of β -thalassemia mutations on the Indian subcontinent: the basis for prenatal diagnosis. *Br J Haematol*, 78:242-247.
- M.K. Das, B. Dey, M. Roy, B.N. Mukherjee, 1991. High Prevalence of Haemoglobin E in three Populations of the Malda District, West Bengal. *Hum. Hered*; 41:84-88
- Newton, C. R., Graham, A, and Heptinstall, L. E, 1989. Analysis of any point mutation in DNA. The amplification refractory mutation system (ARMS). *Nucl. Acids Res.* 17,2503-2516.
- Anju Gupta, Swati Sarwai, Neelam Pathak and Sarita Agarwa, 2008. Beta-Globin Gene mutations in India and their Linkage to haplotypes 1, *Int J Hum Genet*, 8(1-2): 237-241
- Naveen Thacker, 2007. Prevention of Thalassemia in India; Prevention of thalassemia, President, IAP, Deep Children Hospital, 208, Sector 1-A, Gandhidham, Kutch 370 201, Gujarat, India.
- R.B. Colah, R. Surve, P. Sawant, E. D'Souza, K. Italia, S. Phanasgaonkar, A.H. Nadkarni and A.C. Gorakshakar. HPLC Studies in Hemoglobinopathies Institute of Immunohaematology (ICMR), 13th Floor, New Multistoreyed Building, KEM Hospital Campus, Parel, Mumbai, India



Brownian Motion - An Eclectic Potpourri

Saugata Bhattacharyya*

In 1827, Robert Brown, the Scottish botanist, observed rapid, inherent, incessant and zigzag (extremely irregular) motion of pollen grains of *Clarkia pulchella* in aqueous suspension. Brown, used dead pollens and finely ground inorganic dust to show that the motion still persisted and proved through a series of experiments that the motion was not due to i) vital force, a mysterious force attributed to all living matter at that time, ii) currents, iii) convection rolls or iv) evaporation. Though he was unable to pinpoint the exact cause of the motion, Brown gave birth to a problem whose successful resolution would require almost a century.

The problem was picked up again by Jules Regnault in 1858 who described the motion as a result of the absorption of incident light ending up in local heating of the solvent and creating a microscopic convection current. Interestingly, Christian Wiener, in 1863 argued that the motion is due to the internal molecular motion in the fluid but unfortunately he assumed that there were two kinds of molecules involved in the process, the material molecules and the aether molecules. Subsequent experiments showed that the motion was independent of i) the chemical composition or the shape of the container and ii) External effects (e.g. incident light, wind etc.)

During 1874-1880 three Belgian Jesuits, J. Delsaux, J. Thirion and X. Carbonelle attributed the motion to molecular fluctuations. They argued that the distribution of molecular velocities will give rise to fluctuations in density and hence in pressure in the microscopic scale which average out in the macroscopic scale. The idea of fluctuations was once again introduced by Leon Guoy in 1888 and found a supporter in none other than Henri Poincare. Scientists studied the effects of solvent viscosity and ambient temperature to find that for finer particles and less viscous and hotter solvents the motion was very pronounced.

Another very interesting, important and far-reaching implication came from the velocity measurements of the Brownian particles. The velocity did not seem to have a proper limit for small time intervals. The clue to the problem was in the fact that the Brownian trajectory was continuous but nonsmooth at every length scale. Smoluchowski actually understood that and held that the force acting on the Brownian particles was also nonsmooth. Assuming this, he arrived at results that could explain the behaviour of diffusing particles e.g. sugar cubes diffusing in tea, perfume permeating from one corner of the room to another or the diffusion of a drop of ink in water. The crux of the problem lays in the understanding that the time scale of observation is much larger compared to the time scale at which the actual collisions are taking place. So that the observed displacement is in reality an average over a multitude of zigzag displacements. Thus making the curve non-differentiable and rendering the concept of velocity or average velocity meaningless. This observation and understanding led to the modelling of Brownian motion by a random process and eventually gave birth to the theory of probability calculus and the theory of stochastic process. Mathematicians knew about curves statistically self-similar at every scale, called fractals which are full of kinks and are differentiable nowhere. And Weierstrass had discovered such pathological functions like

$$g(x) = \sum_{n=1}^{\infty} b^n \cos(a^n \pi x)$$

where a is odd, $b \in (0, 1)$, and $ab > 1 + 3\pi/2$ is nowhere differentiable. With Norbert Wiener showing in 1923

* Vidyasagar College, Department of Physics, Kolkata-700006,



the mathematical existence of Brownian motion, existence of a random (stochastic) process with the given properties was truly established.

Together Einstein and Smoluchowski showed that viscosity and other forms of dissipation, are on a molecular level, caused by thermal motion of particles i.e. found a relation between viscous or any kind of dissipative force and the random or fluctuating part of the force - the so called fluctuation-dissipation formula. Later Smoluchowski established that for a large but finite system in thermal equilibrium variables must vary in time in a manner akin to the Gaussian White Noise - the cause of Brownian motion. That is, he proved that Brownian motion is ubiquitous in all macroscopic physical systems in equilibrium!!

In fact, with the French physicist J. Perrin receiving the Nobel Prize in 1926, marking the beginning of the centenary of Brownian motion, for showing that the colliding particles obey gas laws and calculating the Avogadro's number, the phenomenon had come a full cycle and had a solid footing.

Barring Kepler's laws, Newton's laws of dynamics and the laws of thermodynamics one rarely finds a phenomenon that is as relevant even today as Brownian motion, in spite of being almost two hundred years old.

THE MATHEMATICAL STRUCTURE

Different theoretical approaches were developed by Einstein-Smoluchowski, Langevin, Lorentz and Fokker-Planck. We shall leave aside the Fokker-Planck approach for the sake of brevity. We restrict ourselves to the linearized picture for the sake of simplicity and also for the reason that motions along different directions are independent of each other. We notice that the only observable quantity is the displacement of the Brownian particle $s(t) = x(t) - x(0)$. We show that the mean squared displacement is proportional to time i.e. $\langle s(t)^2 \rangle = 2Dt$. And it turns out that the distribution of s is Gaussian or

$$W(s, t) = \frac{1}{\sqrt{4\pi Dt}} \exp\left(-\frac{s^2}{4Dt}\right) \quad (2.0.1)$$

where D is the diffusion constant. In the same way rotations about an axis can be considered with an analogous result which is left as an exercise to the readers.

The Einstein Approach: Comparison With Diffusion Phenomenology

Suppose that

- the suspended particles, visible under microscope, are irregularly dispersed in a liquid.
- Movement of one particle is independent of the motion of others.
- Movement of one particle during two distinct and non-overlapping intervals of time are considered independent as long as the time interval is not too small.

We, therefore, introduce a characteristic time scale τ in the problem, by hand, which is microscopically large but macroscopically small, such that the motions during non-overlapping intervals of length τ can be considered statistically independent. Assuming (well substantiated by experiments) suspended particles exert a pressure

$$p = nk_B T \quad (2.1.1)$$

where n is the number density of the particles, T is temperature in degree Kelvin and k_B is the Boltzmann's constant, we can write phenomenologically

$$\vec{j} = -D \nabla n \quad (2.1.2)$$



where \vec{j} is the current density. Along x direction, the equation looks like

$$j = -D \frac{\partial n}{\partial x} \quad (2.1.3)$$

If, now an external force fe and a velocity dependent resistive force $-\zeta v$ act on the particle, then in the stationary case the two forces balance each other giving rise to a terminal velocity

$$v = \frac{fe}{\zeta} \quad \text{leading to} \quad (2.1.4)$$

$$j = nv = n \frac{fe}{\zeta} \quad (2.1.5)$$

In a stationary state, where the pressure gradient causes current flow, the force density turns out to be

$$nfe = -\frac{\partial p}{\partial x} = -k_B T \frac{\partial n}{\partial x} \quad \text{leading to} \quad (2.1.6)$$

$$j = -\frac{k_B T}{\zeta} \frac{\partial n}{\partial x} \quad \text{with the identification} \quad (2.1.7)$$

$$D = \frac{k_B T}{\zeta} \quad (2.1.8)$$

The Model

If in a time interval τ the x coordinate of a particle changes by s and the number density of particles being in the interval s to $s + ds$ is

$$dn = n\phi(s)ds \quad (2.1.9)$$

where $\phi(s)$ is the probability that the x coordinate of the particle suffers a change s with the properties

$$\int_{-\infty}^{\infty} \phi(s)ds = 1 \quad (\text{normalization}) \quad (2.1.10)$$

$$\phi(s) = \phi(-s) \quad (\text{isotropy}) \quad (2.1.11)$$

Therefore, we can write,

$$n(x, t + \tau) = \int_{-\infty}^{\infty} n(x - s, t) \phi(s) ds \quad (2.1.12)$$

It is extremely interesting to note that the above equation is, in essence, the Chapman-Kolmogorov equation! This is a very general equation that was formally established by Chapman and Kolmogorov much later and is considered a cornerstone of statistical processes. Einstein used it in his work even before its proponents established it!! Now, assuming $n(x, t)$ to be a smooth function of its arguments (otherwise density could not be defined) and Taylor expanding both sides, we obtain

$$n(x, t) + \tau \frac{\partial n}{\partial t} + \dots = n(x, t) \int_{-\infty}^{\infty} \phi(s)ds - \frac{\partial n}{\partial x} \int_{-\infty}^{\infty} s\phi(s)ds + \frac{1}{2} \frac{\partial^2 n}{\partial x^2} \int_{-\infty}^{\infty} s^2\phi(s)ds + \dots \quad (2.1.13)$$

The first terms on both sides cancel out, the second term on the right vanishes due to eqn.(2.1.11), ultimately, giving rise to upto the quadratic level,



$$\frac{\partial n}{\partial t} + \vec{\nabla} \cdot \vec{j} = 0 \quad \text{or in one dimension}$$

$$\frac{\partial n}{\partial t} + \frac{\partial j}{\partial x} = 0 \quad \text{leading to the equation}$$

$$\frac{\partial n}{\partial t} = D \frac{\partial^2 n}{\partial x^2} \quad (2.1.15)$$

Comparison yields

$$D = \frac{\langle s^2 \rangle}{2\tau} \quad \text{and} \quad (2.1.16)$$

$$\langle s^2 \rangle = \frac{2k_B T}{\zeta} \tau \quad (2.1.17)$$

We understand that eqns.(2.1.12) and (2.1.15) represent the same physics, one in integral form and the other in the differential form. It must be kept in mind though, that in obtaining eqn.(2.1.15) we had to truncate eqn.(2.1.12) after Taylor expansion.

Calculation Of The Distribution Function

Next, we take up the initial value problem of how $n(x, t)$ spreads in space and time as promised. We take the initial condition that at $t = 0$ all particles were placed at the origin rendering $n(x, t)$ to be infinite and zero otherwise. If we denote by N the total number of particles then

$$t = 0 \quad n(x, 0) = N \delta(x) \quad (2.1.18)$$

using the Fourier representation we can write

$$n(x, t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \tilde{n}(k, t) e^{ikx} dk. \quad (2.1.19)$$

Using eqn.(2.1.19) in eqn.(2.1.15) we obtain

$$\frac{\partial \tilde{n}(k, t)}{\partial t} = -k^2 D \tilde{n}(k, t) \quad (2.1.20)$$

yielding a solution

$$\tilde{n}(x, t) = \tilde{n}(k, 0) e^{-Dk^2 t} \quad (2.1.21)$$

Identifying $\tilde{n}(k, 0) = N$ we write

$$\tilde{n}(k, t) = N e^{-Dk^2 t} \quad (2.1.22)$$

and then using eqn.(14) in eqn.(11) we obtain

$$\begin{aligned} n(x, t) &= \frac{1}{2\pi} \int_{-\infty}^{\infty} N e^{-Dk^2 t} e^{ikx} dk = \frac{N}{2\pi} e^{-x^2/4Dt} \int_{-\infty}^{\infty} e^{-Dt(k - \frac{x}{2Dt})^2} dk \\ &= \frac{N}{2\pi} e^{-x^2/4Dt} \sqrt{\frac{\pi}{Dt}} = \frac{N}{\sqrt{4\pi Dt}} e^{-x^2/4Dt} \end{aligned} \quad (2.1.23)$$

We are now in a position to calculate the mean squared displacement with the above distribution formula



$$\begin{aligned}
 \langle x^2 \rangle &= \frac{1}{N} \int_{-\infty}^{\infty} n(x, t) x^2 dx = \frac{1}{\sqrt{4\pi Dt}} \int_{-\infty}^{\infty} x^2 e^{-x^2/4Dt} dx \\
 &= \frac{4Dt}{\sqrt{\pi}} \int_{-\infty}^{\infty} x^2 e^{-x^2} dx = \frac{4Dt}{\sqrt{\pi}} \int_0^{\infty} x^{1/2} e^{-x} dx \\
 &= \frac{4Dt}{\sqrt{\pi}} \Gamma(3/2) = 2Dt \tag{2.1.24}
 \end{aligned}$$

Defining the mean displacement as $l_x = \sqrt{\langle x^2 \rangle} = \sqrt{2Dt}$ we see that it is proportional to the square root of time which is the hallmark of diffusion.

Some Idea About the Length and Time Scales Involved in the Process

For spherical particles having mass m , radius r , suspended in a fluid of viscosity η and moving under an external force f_e the resistive force is known to be $6\pi\eta r v_c$ (Stokes' Law) where v_c is the terminal velocity of the

particle. This yields $v_c = \frac{f_e}{6\pi\eta r}$ and $\zeta = 6\pi\eta r$. Starting with

$$D = \frac{k_B T}{\zeta} = \frac{RT}{A_0} \frac{1}{6\pi\eta r} \equiv \frac{RT}{A_0} B \tag{2.1.25}$$

where A_0 is the Avogadro's number and B is the mobility and R is the universal gas constant we see that this relation can be used to determine either D or A_0 and also that D depends only on η when temperature and radius of the suspended particles are known. Recalling the definition of l_x , the mean displacement, we see that rewriting things properly we can express

$$l_x = \sqrt{\frac{RT}{A_0} \frac{1}{3\pi\eta r}} \quad \text{or} \tag{2.1.26}$$

$$A_0 = \frac{1}{l_x^2} \frac{RT}{3\pi\eta r} \tag{2.1.27}$$

Thus, if A_0 is known one can determine l_x and vice-versa. Using the known values of $A_0 = 6.023 \times 10^{23}$, $\eta = 1.35 \times 10^{-2} \text{ gm. cm}^{-1} \cdot \text{sec}^{-1}$ for water at 17°C , radius $r = 10^{-4} \text{ cm}$ and $R = 8.31 \times 10^7 \text{ erg. mole}^{-1} \cdot \text{deg. K}^{-1}$ one finds

$$l_x = 8 \times 10^{-5} \text{ cm.}$$

Justifying The Existence Of Random Force From Theoretical Considerations

From the kinetic theory results one can write for the suspended particles having a mass ' m '

$$\frac{1}{2} m \langle v^2 \rangle = \frac{3}{2} k_B T \tag{2.1.28}$$



independent of their size and environment. For particles having $m = 2.5 \times 10^{-15}$ gm in colloidal platinum solution one calculates for $T = 292K$

$$\sqrt{\langle v^2 \rangle} = \sqrt{\frac{3RT}{mA_0}} = 8.6 \text{ cm/sec} \quad (2.1.39)$$

which gives us a rough idea about the order of magnitude of the velocity for thermal motion. In a solution of solvent viscosity η these particles will experience a resistive force according to the Stokes' Law and we have

$$m \frac{dv}{dt} = -6\pi\eta r \quad (2.1.30)$$

with a solution

$$v = v_0 \exp\left(-\frac{6\pi\eta r}{m} t\right) \quad (2.1.31)$$

If we denote by $t_{0.1}$ the time for v to become $0.1v_0$ then

$$t_{0.1} = \frac{m \ln 10}{6\pi\eta r} \quad (2.1.32)$$

For platinum particles in water we obtain $t_{0.1} = 3.3 \times 10^{-7}$ sec which implies that under the action of viscous forces only, the particles would almost completely lose their initial velocities within a time span of $t_{0.1}$. Therefore, the particles must get impulses from the water molecules at random during that time interval to sustain their average velocity. So, only by assuming the existence of a random force can one reconcile kinetic theory results with hydrodynamic predictions.

THE LANGEVIN APPROACH

We pick up the thread from where we left in the last section by writing down the equation of motion of the suspended particle in the form

$$m \frac{dv}{dt} = -\zeta v + F(t) \quad (2.2.1)$$

where $F(t)$ is a random force or additive noise. Rewriting the equation in terms of position we obtain

$$\begin{aligned} m\ddot{x} &= -m\Gamma \dot{\delta}\dot{U} + F(t) \\ \ddot{x} &= -\Gamma \dot{\delta}\dot{U} + f(t) \text{ or} \\ \dot{\delta}\dot{\delta} &= f(t) \end{aligned} \quad (2.2.2)$$

where $\Gamma = \zeta/m$ and $f(t) = F(t)/m$. We assume

$\langle F(t) \rangle = 0$ and $F(t)$ is independent of x and v .

$F(t)$ varies extremely rapidly compared to variation of v .

$\langle F(t)^2 \rangle \neq 0$ and $\langle F(t) F(t') \rangle = 2D\delta(t-t')$ where D is some constant.

It is interesting to note that the average or the correlation function $\langle F(t) F(t') \rangle$ is not only peaked about $t-t'$ but also a function of the time interval $|t-t'|$ only i.e. stationary in time, meaning that while performing a Brownian motion experiment any instant of time can be chosen to be the origin of time.



Taking an average of the last step of eqn.(2.2.2) we obtain

$$\frac{d}{dt}\langle v \rangle = -\Gamma\langle v \rangle \quad \text{leading to a solution} \quad (2.2.3)$$

$$\langle v(t) \rangle = \langle v(0) \rangle e^{-\Gamma t}$$

while using $\delta\delta\dot{U} = v$ we rewrite the equation as

$$\dot{x} = -\Gamma\delta\delta\dot{U} + f(t). \quad (2.2.4)$$

Multiplying the above equation by x , rearranging terms and taking an average we obtain

$$\frac{d}{dt}\langle x\dot{x} \rangle - \langle \dot{x}^2 \rangle = \frac{\Gamma}{2} \frac{d}{dt}\langle x^2 \rangle + \langle xf(t) \rangle \quad (2.2.5)$$

and then using the equipartition theorem in one dimension

$$\frac{1}{2}m\langle \dot{x}^2 \rangle = \frac{1}{2}k_B T \quad (2.2.6)$$

alongwith

$$\langle xf(t) \rangle = 0 \quad (2.2.7)$$

yield

$$\left(\frac{d^2}{dt^2} + \Gamma \frac{d}{dt} \right) \langle x^2 \rangle = 2 \frac{k_B T}{m} \quad (2.2.8)$$

Equation (2.2.7) needs a bit of justification. The timescale at which the random force changes is extremely fast compared to the timescale over which an observable displacement is produced. So if we average out the fast degrees of freedom (an idea which is essentially used in the *Dynamic Renormalization Group*) in that process x can be thought of as essentially constant and the average

is performed over only $f(t)$ yielding zero. It is in this light that the eqn.(2.2.7) has to be understood.

Solving the differential eqn.(2.2.8) we obtain,

$$\langle x^2(t) \rangle = \left(\frac{2k_B T}{m\Gamma} \right) t - \frac{2k_B T}{m\Gamma^2} (1 - e^{-\Gamma t}) \quad (2.2.9)$$

We immediately notice that for large time scales (the *diffusive regime*)

$$\langle x^2(t) \rangle \approx \left(\frac{2k_B T}{m\Gamma} \right) t \quad (2.2.10)$$

ignoring the constant term while for small enough times (the *ballistic regime*)

$$\langle x^2(t) \rangle \approx \left(\frac{2k_B T}{m\Gamma} \right) t^2 \quad (2.2.11)$$

The timescale for which the behaviour of the system crosses over from the ballistic to the diffusive regime is extremely interesting. It is also important to note that while in the diffusive regime the dissipative force (represented by Γ) plays an important part in the ballistic regime the dynamics is governed entirely by the inertial motion. Comparing with eqn.(2.1.25) one immediately identifies

$D = \frac{k_B T}{m\Gamma}$ as predicted by the Einstein's theory.



The Relation Between Random and Fluctuating Force: The Fluctuation-Dissipation Theorem

In this section we would like to establish a relation between the dissipative force and the randomly fluctuating force. To that end we start by multiplying the last step of eqn.(2.2.2) by v to obtain

$$v \dot{v} = -\Gamma v^2 + v f(t)$$

or

$$\frac{d}{dt} v^2 = -2\Gamma v^2 + 2v(t)f(t) \quad (2.2.12)$$

Now taking an ensemble average of eqn.(2.2.12) we obtain

$$\frac{d}{dt} \langle v^2 \rangle = -2\Gamma \langle v^2 \rangle + 2 \langle v(t)f(t) \rangle \quad (2.2.13)$$

The last term in the above equation is entirely nontrivial. To deal with this term we start with the identity

$$\int_{t_1}^{t_2} v(t') dt' = v(t_2) - v(t_1) \quad (2.2.14)$$

Setting $t_2 = t$ and $t_1 = t - \Delta t$ we get

$$v(t) = v(t - \Delta t) + \int_{t-\Delta t}^t \dot{v}(t') dt' \quad (2.2.15)$$

Substituting for \dot{v} from eqn.(2.2.2) we get

$$v(t) = v(t - \Delta t) + \int_{t-\Delta t}^t [-\Gamma v(t') + f(t')] dt' \quad (2.2.16)$$

This implies

$$\begin{aligned} \langle v(t)f(t) \rangle &= \langle v(t - \Delta t)f(t) \rangle + \int_{t-\Delta t}^t \langle [-\Gamma v(t') + f(t')] f(t) \rangle dt' \\ &= -\Gamma \int_{t-\Delta t}^t \langle v(t')f(t) \rangle dt' + \int_{t-\Delta t}^t \langle f(t')f(t) \rangle dt' \end{aligned} \quad (2.2.17)$$

It is important to understand that

$$\langle v(t - \Delta t)f(t) \rangle = 0$$

and also

$$\int_{t-\Delta t}^t \langle v(t')f(t) \rangle dt' = 0$$

because the random force at a time instant t can in no way be depend on the velocity at a previous instant. Therefore, we have from eqn.(2.2.17)

$$\langle v(t)f(t) \rangle = \int_{t-\Delta t}^t \langle f(t')f(t) \rangle dt' \quad (2.2.18)$$

We now use the stationary property of the correlation function which implies

$$\langle f(t' + s)f(t + s) \rangle = \langle f(t')f(t) \rangle$$



to obtain

$$\begin{aligned}
 \langle f(t')f(t) \rangle &= \int_{t-\Delta t}^{t'} \langle f(t')f(t) \rangle dt' = \frac{1}{2} \int_{t-\Delta t}^{t+\Delta t} \langle f(t')f(t) \rangle dt' \quad (\text{and using } t' \equiv t+s) \\
 &= \frac{1}{2} \int_{t-\Delta t}^{t+\Delta t} \langle f(t)f(t+s) \rangle ds = \frac{1}{2} \int_{-\Delta t}^{\Delta t} \langle f(0)f(s) \rangle ds \\
 &= \frac{1}{2} \int_{-\infty}^{\infty} \langle f(0)f(s) \rangle ds \quad (2.2.19)
 \end{aligned}$$

where we have made use of the stationary property of the correlation in the 3rd step of the above equation. As s denotes a very small time scale and Δt is actually very large compared to it we have used ∞ in the limits of the integration in the last step of eqn.(2.2.19). Therefore, we return to eqn.(2.2.13)

$$\begin{aligned}
 \frac{d}{dt} \langle v^2 \rangle &= -2\Gamma \langle v^2 \rangle + 2 \langle v(t)f(t) \rangle \\
 &= -2\Gamma \langle v^2 \rangle + \int_{-\infty}^{\infty} \langle f(0)f(s) \rangle ds \quad (2.2.20)
 \end{aligned}$$

In thermal equilibrium,

$$\langle v^2 \rangle = \frac{k_B T}{m}$$

and hence

$$\frac{d}{dt} \langle v^2 \rangle = 0$$

leading to

$$\begin{aligned}
 \Gamma &= \frac{m}{2k_B T} \int_{-\infty}^{\infty} \langle f(0)f(s) \rangle ds \\
 &= \frac{1}{2mk_B T} \int_{-\infty}^{\infty} \langle F(0)F(s) \rangle ds
 \end{aligned}$$

The above equation is extremely important as it shows a critical balance in the system in equilibrium. On one hand energy is fed into the system through fluctuations and on the other it gets dissipated through the dissipative mechanisms operative in the system. Only in equilibrium they strike a balance. This is the famous *Fluctuation-Dissipation Relation*. On the left hand side of eqn.(2.2.21) we have $\Gamma = \zeta/m$, the scaled coefficient of the velocity dependent dissipative force and on the other we have a two point correlation function of the fluctuating force. The special case where the fluctuating forces are δ -correlated we have a very simplified picture where

$$\begin{aligned}
 \Gamma &= \frac{1}{2mk_B T} \int_{-\infty}^{\infty} 2D\delta(s)f(s) ds \\
 &= \frac{D}{2mk_B T} \quad (2.2.22)
 \end{aligned}$$



Here we have made use of the 3rd property of the fluctuating force $F(t)$ as stated in the beginning of the section (2.2). Recalling that $\zeta = 6\pi\eta r$ for the Stokes' Law we readily see the connection

$$D = 6\pi\eta r k_B T$$

which is a simplified form of Fluctuation-Dissipation Relation in a special situation.

THE LORENTZ APPROACH

This is an innovative iterative procedure devised by H.A. Lorentz to depict the same results obtained by Einstein's theory but starting with the Langevin equation in velocity space i.e. the last step of eqn.(2.2.2). Assuming the initial condition that at $t = 0$ the velocity is v_0 and that at t is v_t we write

$$\dot{v} = -\Gamma v + f(t)$$

and integrating w.r.t time from 0 to t obtain

$$v_t - v_0 = -\Gamma v_0 t + h(t) + o(t^2) \quad (2.3.1)$$

where we have integrated over a sufficiently small time interval so that the terms quadratic in time can be neglected and

$$h(t) = \int_0^t f(t') dt' \quad (2.3.2)$$

Rearranging and rewriting eqn.(2.3.1) we get

$$v_t = v_0(1 - \Gamma t) + h(t) \quad (2.3.3)$$

Squaring eqn.(2.3.3) and keeping terms linear in time yields

$$v_t^2 = v_0^2(1 - 2\Gamma t) + 2v_0(1 - \Gamma t) h(t) + h(t)^2 + o(t^2) \quad (2.3.4)$$

Taking the ensemble average of eqn.(2.3.4) with the knowledge that

$$\langle v_0^2 \rangle = \langle v_t^2 \rangle \quad (2.3.5)$$

because of thermal equilibrium and

$$\langle v_0 h(t) \rangle = 0 \quad (2.3.6)$$

we obtain

$$\langle h(t)^2 \rangle = \left(\frac{2\Gamma k_B T}{m} \right) t \quad (2.3.7)$$

Now consider a total time interval $\tau = nt$ split into n equal intervals of duration t such that in the second step the variables are v_1 and h_1 , in the third they are v_2 and h_2 , in the fourth v_3 and h_3 and so on. Defining

$$\beta = (1 - \Gamma t)$$

we rewrite eqn.(2.3.3) and use it to write a system of equations as

$$\begin{aligned} v_1 &= \beta v_0 + h_1(t) \\ v_2 &= \beta v_1 + h_2(t) = \beta^2 v_0 + \beta h_1(t) + h_2(t) \\ v_3 &= \beta v_2 + h_3(t) = \beta^3 v_0 + \beta^2 h_1(t) + \beta h_2(t) + h_3(t) \\ v_n &= \beta v_{n-1} + h_n(t) = \beta^n v_0 + \beta^{n-1} h_1 + \beta^{n-2} h_2 + \dots + h_n(t) \end{aligned} \quad (2.3.8)$$



Denoting $v_0 = h_0$ for the sake of notational convenience we can in general write

$$v_n = \sum_{k=0}^n \beta^{n-k} h_k \quad (2.3.9)$$

The displacement Δx produced in time τ therefore, can be expressed as

$$\begin{aligned} \Delta x &= \tau (v_0 + v_1 + v_2 + \dots + v_{n-1}) \\ &= \tau [v_0 + (\beta v_0 + h_1(t) + (\beta^2 v_0 + \beta h_1(t) + h_2(t)) + \\ &\quad (\beta^3 v_0 + \beta^2 h_1(t) + \beta h_2(t) + h_3(t)) + \dots] \\ &= \tau [v_0(1 + \beta + \beta^2 + \dots + \beta^{n-1}) + h_1(1 + \beta + \beta^2 + \dots + \beta^{n-2}) \\ &\quad + h_2(1 + \beta + \beta^2 + \dots + \beta^{n-3}) + \dots + h_{n-1}] \\ &= \tau [h_0 \frac{1-\beta^n}{1-\beta} + h_1 \frac{1-\beta^{n-1}}{1-\beta} + h_2 \frac{1-\beta^{n-2}}{1-\beta} + \dots + h_{n-1}] \\ &= \frac{\tau}{1-\beta} [h_0(1-\beta^n) + h_1(1-\beta^{n-1}) + h_2(1-\beta^{n-2}) \\ &\quad + \dots + h_{n-1}(1-\beta)] \\ &= \tau \sum_{v=0}^{n-1} h_v \frac{(1-\beta^{n-v})}{(1-\beta)} \end{aligned} \quad (2.3.10)$$

We now try to calculate $\langle (\Delta x)^2 \rangle$ and accordingly write

$$\begin{aligned} \langle (\Delta x)^2 \rangle &= \frac{\tau^2}{(1-\beta)^2} \left\langle \left(h_0(1-\beta^n) + \sum_{v=1}^{n-1} h_v(1-\beta^{n-v}) \right) \left(h_0(1-\beta^n) + \sum_{\mu=1}^{n-1} h_\mu(1-\beta^{n-\mu}) \right) \right\rangle \\ &= \frac{\tau^2}{(1-\beta)^2} \left(\sum_{v,\mu=1}^{n-1} h_v(1-\beta^{n-v}) (1-\beta^{n-\mu}) \langle h_v h_\mu \rangle + 2 \sum_{v=1}^{n-1} (1-\beta^{n-v}) \langle h_v h_0 \rangle + (1-\beta^n)^2 \langle h_0^2 \rangle \right) \end{aligned} \quad (2.3.11)$$

We now make use of the relations

$$\langle h_v h_0 \rangle = 0 \text{ for } v \neq 0 \quad (2.3.12)$$

$$\langle h_\mu h_\nu \rangle = \delta_{\mu\nu} \langle h^2 \rangle \text{ for } \mu\nu \neq 0 \quad (2.3.13)$$

$$\langle h^2 \rangle = \left(\frac{2\Gamma k_B T}{m} \right) \tau \quad (2.3.14)$$

$$\langle v_0^2 \rangle = \langle h_0^2 \rangle = \frac{k_B T}{m} \quad (2.3.15)$$

Plugging in the above relations in eqn.(2.3.11) we get

$$\langle (\Delta x)^2 \rangle = \frac{\tau^2}{(1-\beta)^2} \left(\sum_{v=1}^{n-1} (1-\beta^{n-v})^2 \langle h^2 \rangle + (1-\beta^n)^2 \langle h_0^2 \rangle \right)$$



$$\begin{aligned}
 &= \frac{r^2}{(1-\beta)^2} \left(\sum_{v=1}^{n-1} (1-\beta^v)^2 \langle h^2 \rangle + (1-\beta^n)^2 \langle v_0^2 \rangle \right) \\
 \langle (\Delta x)^2 \rangle &= \frac{r^2}{(1-\beta)^2} \left(\sum_{v=1}^{n-1} (1-\beta^{n-v})^2 \langle h^2 \rangle + (1-\beta^n)^2 \langle h_0^2 \rangle \right) \\
 \langle (\Delta x)^2 \rangle &= r^2 \frac{(1-\beta^n)^2}{(1-\beta)^2} \langle v_0^2 \rangle + \frac{r^2 \langle h^2 \rangle}{(1-\beta)^2} \sum_{v=1}^{n-1} (1-\beta^v)^2 \\
 &= \frac{1}{\Gamma^2} \left[\langle v_0^2 \rangle (1-\beta^n)^2 + \langle h^2 \rangle \sum_{v=1}^{n-1} (1-\beta^v + \beta^{2v}) \right] \\
 &= \frac{1}{\Gamma^2} \left[\langle v_0^2 \rangle (1-\beta^n)^2 + \langle h^2 \rangle \left(n-1 - 2\beta \frac{1-\beta^{n-1}}{1-\beta} + \beta^2 \frac{1-\beta^{2n-2}}{1-\beta^2} \right) \right] \quad (2.3.16)
 \end{aligned}$$

Now in the limit of very large n only the term proportional to n matters and hence in that limit using eqn.(2.3.14)

$\langle (\Delta x)^2 \rangle$ we get

$$\begin{aligned}
 \langle (\Delta x)^2 \rangle &= \frac{n}{\Gamma^2} \langle h^2 \rangle = \frac{n}{\Gamma^2} \left(\frac{2\Gamma k_B T}{m} \right) r \\
 &= \left(\frac{2k_B T}{m\Gamma} \right) (nr) \\
 &= \left(\frac{2k_B T}{\zeta} \right) \tau,
 \end{aligned}$$

the same result, obtained from both the Einstein and Langevin picture. It would be interesting if one could recover the result for the ballistic regime from this picture in the limit of very small n . One could even try to derive the Fluctuation-Dissipation relation from this picture.

RANDOM WALK AND THE BROWNIAN MOTION

Consider an infinite one dimensional lattice with lattice spacing a with a drunkard situated at one of the lattice points trying to walk to his home. He is so drunk that he does not know his way and takes a step to the right or left with equal probability of $\frac{1}{2}$. His movement has two features though:

- he always takes a step of size unity
- the duration of a single step is Δt

We are interested to find the mean and variance of the displacement of the walker as a function of time. This is the standard random walk problem. If the drunkard takes steps in two different directions with two different probabilities then that would be the biased random walk problem. We are going to present a discrete time formalism of the problem and indicate how the passage to continuum time description may be effected.

Formulation Of The Problem

Suppose after j -steps the walker lands up at the n th site. We define $P(n, j)$ as the probability for the walker to



be at the n th site after the elapse of j th time step. Then, we understand that at the previous instant of time, i.e. at the $(j - 1)$ th instant, the walker was either at the $(n - 1)$ th or the $(n + 1)$ th site. therefore one writes

$$P(n, j) = \frac{1}{2} [P(n+1, j-1) + P(n-1, j-1)] \text{ or}$$

$$P(n, j+1) = \frac{1}{2} [P(n+1, j) + P(n-1, j)]$$

where we have obtained the second step by replacing j by $j + 1$ in the first step. The symmetry of the unbiased random walk is reflected in the fact that the equations are invariant under the transformation $(n - 1) \leftrightarrow (n + 1)$. The passage to the continuum description follows automatically by subtracting the the first step from the second of eqn.(2.4.1) to obtain

$$P(n, j+1) - P(n, j) = \frac{1}{2} [P(n+1, j) + P(n-1, j) - 2P(n, j)]$$

$$\frac{P(n, j+1) - P(n, j)}{(j+1)\Delta t - j\Delta t} = \frac{1}{2} \frac{P(n+1, j) + P(n-1, j) - 2P(n, j)}{(j+1)\Delta t - j\Delta t}$$

$$\frac{P(n, j+1) - P(n, j)}{\Delta t} = \frac{1}{2\Delta t} [P(n+1, j) + P(n-1, j) - 2P(n, j)] \quad (2.4.2)$$

$$\frac{\partial P(n, t)}{\partial t} = \omega [P(n+1, t) + P(n-1, t) - 2P(n, t)] \quad (2.4.3)$$

where to obtain eqn.(2.4.3) from eqn.(2.4.2) we have taken the limit $\Delta t \rightarrow 0$ The product $j\Delta t \rightarrow t$ when along with $j \rightarrow \infty$ we also impose $\Delta t \rightarrow 0$. $P(n, t)$ represents the probability that the drunken walker occupies the n th site when time t has elapsed. $\omega = (2\Delta t)^{-1}$ is the transition probability between a site and one of its nearest neighbours. One might wonder about what happens to ω in the limit $\Delta t \rightarrow 0$ but that is the price that we pay for using 'continuous time - discrete space' description of the problem. The problem does not occur when both space and time are either continuous or discrete. One look at the r.h.s of the third step of eqn.(2.4.2) would tell anybody that the expression is nothing but the second partial derivative of $P(n, t)$ w.r.t space should we care to divide and multiply the expression by the lattice spacing and then take the limit of lattice spacing $\rightarrow 0$. The eqn.(2.4.3) is then, in disguise, the diffusion equation that we know so well by now. Mathematically speaking, the displacement of the drunken walker is a Markov proces, where the probabilities are governed by the Master Equation (2.4.3).

Solution of the problem

First, we tackle the problem using the idea of distribution. Assume the lattice to be lying along the x -direction. The total number of steps taken by the walker is j , out of which j_+ steps are taken in the forward direction while j_- are taken in the backward direction. This immediately yields

$$j_+ + j_- = j \text{ and } j_+ - j_- = n \text{ or}$$

$$j_+ = \frac{1}{2}(j + n) \text{ and } j_- = \frac{1}{2}(j - n) \quad (2.4.4)$$



As the walker takes the forward and backward steps with equal probability we write

$$P(n, j) = \left(\frac{1}{2}\right)^j \frac{j!}{j_+! j_-!} = \left(\frac{1}{2}\right)^j \frac{j!}{\left(\frac{j+n}{2}\right)! \left(\frac{j-n}{2}\right)!} \quad (2.4.5)$$

i.e. the probability distribution of the particles after j steps follows a binomial distribution. Taking the general case of the biased random walk as an example we can write

$$P(n, j) = [pP(n-1, j-1) + qP(n+1, j-1)] \text{ and} \\ p+q = 1 \quad (2.4.6)$$

where p is the probability of the forward step while q is that of the backward step. In the same manner as before one can write down

$$P(n, j) = {}^j C_{j_+} p^{j_+} q^{j_-} = \frac{j!}{\left(\frac{j+n}{2}\right)! \left(\frac{j-n}{2}\right)!} p^{\frac{j+n}{2}} q^{\frac{j-n}{2}} \quad (2.4.7)$$

In the limit of large j and large pj the distribution reduces to a Gaussian distribution after one makes use of the *Stirling's approximation*. Writing j_+ as x for convenience, we determine the mean and variance as

$$\langle x \rangle = jp \quad (2.4.8)$$

$$\langle x \rangle = j(j-1)p^2 + jp \quad (2.4.9)$$

$$\langle x^2 \rangle - \langle x \rangle^2 = jp(1-p). \quad (2.4.10)$$

With these basic formalities completed we define the Fourier transform on the discrete lattice by

$$\tilde{P}(k, t) = \sum_x P(x, t) e^{ikx} \quad (2.4.11)$$

with j replaced by t , n by x and $P(n, j)$ by $P(x, t)$. Applying this to the master eqn.(2.4.3) we obtain

$$\frac{\partial}{\partial t} \tilde{P}(k, t) = \omega [e^{ik} + e^{-ik} - 2] \tilde{P}(k, t) = -2\omega(1 - \cos k) \tilde{P}(k, t) \quad (2.4.12)$$

with a solution

$$\tilde{P}(k, t) = e^{-2\omega t(1 - \cos k)} \tilde{P}(k, 0) \quad (2.4.13)$$

The initial condition $\tilde{P}(k, 0) = -1$ corresponds to $P(x, 0) = \delta_{x,0}$ (ref. eqn. (2.1.18)). Now nothing that

$$\langle x^2 \rangle = \sum_x x^2 P(x, t) \\ = \left. \frac{\partial^2 \tilde{P}(k, t)}{\partial k^2} \right|_{k=0} \\ = 2 \omega t \quad (2.4.14)$$



where we have used eqn.(2.4.11) in the second step and eqn.(2.4.13) in the third step of the above equation with the initial condition $\tilde{P}(k, 0) = 1$. Once again, we obtain diffusion from the standard random walk. Using the inverse Fourier transform of eqn.(2.4.13) we obtain,

$$\begin{aligned}
 P(x, t) &= \sum_k \tilde{P}(k, t) e^{ikx} = \sum_k e^{-2\omega t(1-\cos k)} e^{-ikx} \\
 &= e^{-2\omega t} \sum_k e^{(2\omega t \cos k - ikx)} = e^{-2\omega t} I_x(2\omega t)
 \end{aligned}
 \tag{2.4.15}$$

where $I_x(2\omega t)$ is the modified Bessel function of first kind and order x . Using the asymptotic behaviour of this function ($x \rightarrow \infty, t \rightarrow \infty$ with $\frac{x^2}{t}$ fixed) we obtain

$$P(x, t) \approx \frac{1}{\sqrt{4\pi\omega t}} \exp\left(-\frac{x^2}{4\omega t}\right)
 \tag{2.4.16}$$

Comparing with eqn.(2.1.33) we immediately identify w as D in the Einstein's formulation. To take care of the dimension of D and w we recall that to begin with we took the lattice spacing to be unity for simplifying our calculations. If instead we worked with a as the lattice spacing then we would get wa^2 in place of w and that would take care of the problem of dimensional incongruence.

EPILOGUE

The rich mathematical framework generated by this phenomenon is being extensively used in mathematics, biology, ecology, social sciences, stock market fluctuations, nonlinear dynamics, dynamic critical phenomena and in many other contemporary topics. The advent of quantum Brownian motion has expanded the horizon even further giving rise to topics like quantum noise and its applications in the field of quantum optics and by establishing a link between dissipative systems and quantum field theory; quantum decoherence needs a special mention here as this year's Nobel Prize in physics was awarded in this topic where noise plays a vital role. Thanks to Brownian motion we understand the role played by noise in our life - from Johnson's noise in the electrical circuits to the design of nanorobots to molecular motors (e.g. kinesins or proteins that move on intramolecular membranes)- it is everywhere. We now realize that noise is not always detrimental as it can act constructively not only by sustaining the signal but also by amplifying it (e.g. stochastic resonance); finally noise is a crucial element in all biochemical reactions without which life in its present form would not exist. So, for a complete understanding of life as a scientific process one must understand Brownian motion which, despite being almost two hundred years old, still remains relevant in the twenty first century.

FURTHER READING

- Banerjee D., 2004. Solution Of Quantum Langevin Equation: Approximations, Theoretical And Numerical Aspects, Journal Of Chemical Physics, 120, 19, pp 8960,
- Bhattacharjee J. K., 2000. Statistical Physics - Equilibrium and Non-Equilibrium Aspects, Allied Publishers,
- Chandrasekhar S., 1943. Stochastic Problems in Physics And Astronomy, Reviews of Modern Physics, 15, 1, pp.1.



- Cowan B., 2005. Topics In Statistical Mechanics, Imperial College Press,
- Cross M., California Institute of Technology, Lectures on Statistical Physics,
<http://www.pma.caltech.edu/mcc/Ph127/index.html>
- Doob J.L., 1953. Stochastic Processes, Wiley, N.Y.,
- Einstein A., 1956. Investigations On The Theory Of The Brownian Movement, Dover Publications,
- Erdélyi A., 1956. Asymptotic Expansions, Dover Publications, N.Y.,
- Honerkamp J., 2002. Statistical Physics, Springer Verlag, Berlin,
- Kadanoff L., 1999. Statistical Physics - Statics Dynamics And Renormalization, World Scientific,
- Kardar M., 2007. Statistical Physics of Fields, C.U.P.,
- Kubo R., Toda M. and Hashitsume N., 1985. Statistical Physics II, Springer-Verlag, Berlin,
- Le Bellac M., Mortessagne F. and Batrouni G.G., 2004. Equilibrium and Non-Equilibrium Statistical Thermodynamics, C.U.P.,
- Lemons D.S., 2002. An Introduction To Stochastic Processes in Physics, The Johns Hopkins University Press,
- Mazo R.M., 2002. Brownian Motion, Fluctuations, Dynamics and Applications, O.U.P.,
- Mazenko G.F., 2006. Non-equilibrium Statistical Mechanics, Wiley-VCH,
- Metzler R. and Klafter J., 2006. The Random Walk's Guide To Anomalous Diffusion: A Fractional Dynamics Approach, Physics Reports, 336, 1-77.
- Miguel M.S. and Toral R., 1997. Stochastic Effects In Physical Systems, arXiv:cond-mat/9707147-v1, 14 July,
- Montroll E.W. and Lebowitz J.L., 1984. Studies in Statistical Mechanics, Vol.XI, North Holland Physics Publishing,
- Pauli W., 1973. Statistical Mechanics, Dover Publications, N.Y.,
- Peliti L., 2011. Statistical Mechanics In A Nutshell, Princeton University Press,
- Plischke M. and Bergersen B., 2006. Equilibrium Statistical Physics, 3rd ed., World Scientific,
- Pottier N., 2010. Nonequilibrium Statistical Physics: Linear Irreversible Processes, O.U.P.,
- Ray, D.S., 1999. Notes On Brownian Motion And Related Phenomena, arXiv:physics/9903033 v2 [physics.ed-ph], 7 May,
- Reichl L.E., 1998. A Modern Course in Statistical Physics, John Wiley and Sons,
- Risken H., 1989. The Fokker-Planck Equation, Springer-Verlag, Berlin,
- Salinas S.R.A., 2001. Introduction To Statistical Physics, Springer-Verlag, N.Y.,
- Schwabl F., 2006. Statistical Mechanics, 2nd ed., Springer-Verlag, Berlin,
- Sethna J.P., 2006. Statistical Mechanics: Entropy, Order Parameter And Complexity, O.U.P.,
- Uhlenbeck G.E. and Ornstein L.S., 1930. On The Theory of Brownian Motion, Physical Review, 36, 823,
- Van Kampen N.G., 2007. Stochastic Processes In Physics And Chemistry, 3rd ed., Elsevier,
- Weiss U., 2008. Quantum Dissipative Systems, 3rd ed., World Scientific,
- Zwanzig R., 2001. Non-equilibrium Statistical Mechanics, O.U.P.,



The Blinding Tree *Excoecaria agallocha* L. (Euphorbiaceae): a Review

Asis Kumar Pal* and Kuntal Narayan Chaudhuri*

Abstract: *Excoecaria agallocha* L. (Euphorbiaceae) is a small tree occurring in the mangrove forests of the Indo-Pacific region. The plant exudes acrid latex that is injurious to the human eye, and, therefore, called the "blinding tree." Traditionally, the plant has economic, medicinal and cultural importance. The species has lately gained interest as the source of a wide array of novel, bioactive natural products with potential application in agriculture and medicine. Although the species is still common and widespread, a number of threats have resulted in an overall population decline throughout its range.

Mangroves are intertidal forested wetlands that are confined to the tropics and subtropics (Tomlinson, 1986). Their total global area is estimated at 18.1 million hectares (Spalding *et al.*, 1997). More than 40% of the world's mangroves occur in South and South-East Asia. The Sundarbans, the contiguous mangrove vegetation of the Ganges-Brahmaputra delta in India and Bangladesh, cover about one million hectares and represent the largest coastal wetland system in the world (Gopal and Chauhan, 2006). The genus *Excoecaria* L. of the family Euphorbiaceae consists of about 40 species, which are native to the palaeotropics. The most widely reported among these is the mangrove tree species *E. agallocha* L., which occurs throughout the tropical coastlines of Asia and Oceania. The tree is referred to as *agallocon* in Greek (from the Sanskrit tradename *agaru*) in Dioscorides' (*ca.* 40-90 CE) *Materia Medica* (Vannucci, 1989). In several parts of its range, *viz.* India, Bangladesh, the Philippines, etc., the local populations of the plant are used in commercial forestry. Various parts of the plant have been traditionally used by the autochthonous communities of the mangroves, including in indigenous herbal medicine. In southern India, the tree assumed cultural importance since the ancient times. The plant is well-protected by a wide range of toxic chemical defences. Its milky sap or latex is poisonous; hence it is called the blinding tree, river poison tree, blind-your-eye mangrove or milky mangrove in English (Table 1). With the discovery of a plethora of secondary metabolites and the subsequent elucidation of their pharmaceutical and other biological activities, the species is becoming increasingly important as a potential source of agrochemicals and therapeutic agents.

GEOGRAPHICAL DISTRIBUTION

Excoecaria agallocha occurs along the tropical coastlines of the Old World (Fig. 1), from South Asia, across Indo-China and the Malay Archipelago, to East Asia, Australia and the South-West Pacific (Willis, 1973). In Asia, it is found in India, Sri Lanka, the Maldives, Bangladesh, Myanmar, Thailand, Malaysia, Singapore, Cambodia, Vietnam, China, Taiwan, Japan, the Philippines and Indonesia. In Oceania, it is present along Australia's northern and south-eastern coasts and in the Pacific islands of Micronesia and Melanesia (Kathiresan and Bingham, 2001). In India, it occurs in coastal Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Pondicherry, Andhra Pradesh, Orissa, West Bengal, and the Andaman and Nicobar Islands (Balakrishnan and Chakrabarty, 2007).

* Assistant Professor, Department of Botany, Vivekananda College, 269 D.H. Road, Kolkata-700063



Table 1. Local names of *Excoecaria agallocha* L. in the Indo-Pacific region.

Name	Language (Area)	Name	Language (Area)
<i>Sinu-gaga</i>	Fijian (Fiji)	<i>Geva</i>	Marathi (Maharashtra)
<i>Hai-qi</i>	Chinese (China, Hong Kong)	<i>Uso</i>	Konkani (Goa)
<i>Gian</i>	Vietnamese (Vietnam)	<i>Hara</i>	Kannada (Karnataka)
<i>Tatom</i>	Cambodian (Cambodia)	<i>Komatti</i>	Malayalam (Kerala)
<i>Alipata</i>	Filipino (Philippines)	<i>Thillai</i>	Tamil (Tamil Nadu, Pondicherry (Sri Lanka)
<i>Buta-buta</i>	Malay (Malaysia)	<i>Tilla</i>	Telegu (Andhra Pradesh)
<i>Kayu buta-buta</i>	Indonesian (Indonesia)	<i>Guan</i>	Oriya (Orissa)
<i>Tatum-thale</i>	Thai (Thailand)	<i>Gewa</i>	Bengali (West Bengal, (Bangladesh)
<i>Kayaw-taway</i>	Burmese (Myanmar)		
<i>Thelakiriya</i>	Singhalese (Sri Lanka)		

MORPHOLOGY AND GENETIC DIVERSITY

Excoecaria agallocha is a dioecious, deciduous tree, 15-20 m high (Fig. 2a). The stem is glabrous, solid, cylindrical, green, and densely branched. The bark is fissured, grey to brown (Fig. 2b). The wood is light (32 N.mm⁻²), soft and pale. The leaves are simple, exstipulate, petiolate, ovate to elliptical, yellow to green, alternate, coriaceous to fleshy, 4-9 cm long and 3-6 cm wide, with bluntly acuminate apex, rounded base, crenulate to serrate margin, and unicostate reticulate venation (Fig. 2c). Small (about 1.0 cm), circular salt glands (2-4) are present on each side of the leaf base. Latex exudes from the stem and leaves, which contain laticiferous cells. The roots are often superficial, cable-like and horizontally spreading (Fig. 2d). The dense, axillary inflorescences are unisexual, with minute (2 mm) flowers, appearing during June-July. The male inflorescences are erect or pendulous catkins (Fig. 2e). The female inflorescences are mixed cymes. Small (about 1.5-2.0 cm), trilobed, green fruits (Fig. 2g) are schizocarpic, and each lobe (coccus) contains a small (0.3 cm), single seed (Naskar, 1993; Naskar and Mandal, 1999).

This sexually reproducing dioecious species exhibits considerable morphological uniformity. However, like *Acanthus ilicifolius* (Lakshmi *et al.*, 1997), *Rhizophora* spp. (Lakshmi *et al.*, 2002) and *Avicennia* spp. (Parani *et al.*, 1997), it exhibits genetic variability, which is independent of the morphological and sexual differences. Somatic chromosome numbers (2n) in India vary from 108 (Das *et al.*, 1999), 130 (Das *et al.*, 2011) to 140 (Dutta, 1967). In China, the intertidal populations have higher genetic diversity than the inland populations, which suggests greater gene flow via seed among the former (Zhang *et al.*, 2005). In India, Lakshmi *et al.* (2000) showed high intra-population and inter-population genetic variability. A study of the male populations in India suggests that ocean currents, land barriers and limited dispersal ability of its seeds play important role in this phenomenon (Das *et al.*, 2011).

ECOLOGICAL LOCATION AND ADAPTATIONS

Excoecaria agallocha has wide ecological amplitude ranging from terrestrial, freshwater, brackish and saline environments. This major canopy species of the inter-tidal communities near the high tide mark grows up to 100 m along river slopes, tidal creeks, or on the margins of swamps, mud flats and tidal meadows (Naskar, 1993). The tree dominates only occasionally inundated forests (Saha and Choudhury, 1995). Often invading open, disturbed areas with freshly silted soil, it grows away from the inter-tidal zone in fresh waters, paddy



fields, or on dykes, roadsides and reclaimed lands (Naskar and Mandal, 1999). In the Sunderbans, it is mainly associated with *Heritiera fomes* (Sterculiaceae) to form 60% of these forests (Iftexhar and Islam, 2004), and with *Ceriops decandra* (Rhizophoraceae) and *Sonneratia apetala* (Sonneratiaceae) as well (Rashid *et al.*, 2008). It is associated with *Hibiscus tiliaceus* (Malvaceae) in China (Peng and Xin-Men, 1983) and *Avicennia* spp. in South-East Asia (Naskar and Mandal, 1999).

The plant is a moderately salinity-tolerating halophyte. It is described in the literature both as a true mangrove (De Silva and De Silva, 1998; Balachandran *et al.*, 2009; Saritha and Tessy, 2011) as well as a mangrove associate or back mangrove (Naskar and Mandal, 1999; Lakshmi *et al.*, 2000; Mukherjee *et al.*, 2006). It lacks several key adaptations of the true mangroves such as the pneumatophores and vivipary. Naskar and Mandal (1999) described salt glands on the deciduous leaves, whose lifespan is about 4 months. Salt accumulates in the vacuoles of senescent leaves and their seasonal fall is an effective mechanism to remove the excess salt from the plant body. The species is windpollinated (Ng and Sivasothi, 1999), but the sticky tricolporate pollen grains (Fig. 2f) are also transferred by frequently visiting bees, *Apis dorsata* in South Asia, and *A. cerana* in East Asia (Naskar and Mandal, 1999). The toxicity of the sap discouraged most animals from eating the fruits. Seeds are dispersed by explosion of the fruits. Buoyant seeds are further transported by the tidal streams and currents (Naskar and Mandal, 1999).

ECOLOGICAL IMPORTANCE AND FUNCTIONS

Mangroves are living shields against the devastating impacts of cyclonic storms and tidal waves along the tropical coastlines (Danielsen *et al.*, 2005). They promote land accretion and embankment stabilization, and prevent sea encroachment (Mazda *l.*, 2002). The cable-like, spreading roots of *Excoecaria agallocha* bind together the loose sandy soil on which it often grows in gregarious monospecific stands to check soil erosion (Naskar and Mandal, 1999). In Bangladesh, *E. agallocha* saplings are transplanted on the *chars* (mudflats) of the Ganges-Brahmaputra delta to trap sediments and stabilize them.

Mangrove forests are also rich in biodiversity and function as the habitat for the wildlife (Gopal and Chauhan, 2006). *E. agallocha* supports many epiphytic angiosperms such as the creeper *Hoya parasitica* (Apocynaceae) and the insectivorous *Dischidia rafflesiana* (Asclepiadaceae), both in Thailand (Aksornkoae, 1993), the parasitic members of Loranthaceae, for example *Amyema mackayense* in Australia (Barlow, 1981), *Dendrophthoe pentandra* in Vietnam (Hong and San, 1993), *D. falcate* in India (Naskar and Mandal, 1999), *Viscum ovalifolium* in Indonesia (Danser, 1931) and Thailand (Aksornkoae, 1993), and *V. orientale* in India (Naskar and Mandal, 1999). Allelopathic influence of this tree on seed germination and seedling growth was reported in rice (Rajangam and Argumam, 1999), pulses and millets (Kavitha *et al.*, 2012). Phytoplankton productivity is inhibited by the latex of *E. agallocha* as studied in the Pichavaram, Vellar and Agniar wetlands in Tamil Nadu (Kathiresan *et al.*, 1987; 1990).

Diverse microbes, predominantly fungi, are found to live inside, in the rhizosphere and on the phylloplane of the mangrove plants. Most of the mangrove fungi are harmful to their host plants. Pal (2012) described eleven pathogenic fungi (Table 2) isolated from the infected leaves of *E. agallocha* in the Indian Sundarbans (Fig. 3). This includes the uredinial stage of the mangrove rust fungus *Skierka agallocha* (Purkayastha and Pal, 1998) and the new species of leaf spots fungus *Pestalotiopsis agallochae* (Pal and Purkayastha, 1992). In the Krishna-Godavari delta, Sarma and Vittal (2001) studied the decaying mangrove materials. Thirteen species of saprophytic fungi were identified in from *E. agallocha*, viz. *Epicoccum purpurascens*, *Halocyphina villosa*, *Halorosellina oceanicum*, *Hypoxylon* sp., *Hysterium* sp., *Lulworthia* sp., *Massarina thalassiae*, *M. velatospora*, *Passeriniella obiones*, *Phomopsis* sp., *Verruculina enalia*, *Zopfiella* sp. and *Zalerion varium*. These predominantly ascomycetous species were not exclusive to *E. agallocha*, the dominant tree species of



the area which did not support a rich diversity of fungi in comparison with the other mangrove trees. Chinnaraj and Untawale (1992) reported *Hypoxylon oceanicum*, a marine ascomycetous fungus, from this plant. Chinnaraj (1994) reported ascomycetous (14), basidiomycetous (1), and deuteromycetous (4) fungi from this mangrove tree. Endophytic fungi reported from *E. agallocha* are *Glomerella* sp., *Sporormiella minima*, *Aspergillus niger* and *A. flavus* from the leaf (Kumaresan and Suryanarayanan, 2001; Sridhar, 2009; Ravindran *et al.*, 2012) and *A. flavus* and *Penicillium expansum* from the root (Lu *et al.*, 2010; Ravindran *et al.*, 2012). Xu *et al.* (2011) reported a novel actinomycetes species *Microbispora hainanensis* from the rhizosphere of *E. agallocha* in China. At the Bhitarkanika mangroves, Gupta *et al.* (2009a) reported the highest number of *Streptomyces* species (*viz.* *S. exfoliates*, *S. griseoluteus*, *S. nogalator*, *S. pactum*, *S. purpureus*, *S. tubercidicus*, *S. varsoviensis*, *S. viridochromogenes* and *S. xanthochromogenes*) from *E. agallocha*. Here, Gupta *et al.* (2009b) also studied the microbial population in the mangrove phyllosphere and fungal population was poor in moderate salinity and richer in low salinity zones, and bacterial population was moderate in both the zones. Wang *et al.* (2003) investigated the colonization of the arbuscular mycorrhizal (AM) fungi in the root systems of mangrove species in the wetlands of Qinzhou Bay, China, and found that *E. agallocha* possessed the highest spore density, infection intensity, and species richness. However, Kumar *et al.* (2007) reported the inhibitory effect of the root exudates on the growth of the AM fungus *Glomus mosseae*. The toxic latex is degraded by the soil bacteria soil, but not fungi, which helps in the detoxification of the latex in the environment (Reddy *et al.*, 1991).

Table 2. Fungi isolated from infected leaves of *Excoecaria agallocha* L. in the Indian Sundarbans.
Source: Pal (2012).

Fungus	Class
<i>Asteromella</i> sp.	Dothideomycetes
<i>Colletotrichum gloeosporioides</i> (Penzing) Penzing and Sacc.	Coelomycetes
<i>Coniella musaiaensis</i> var. <i>hibisci</i> B. Sutton	Coelomycetes
<i>Cytospora</i> sp.	Coelomycetes
<i>Drechslera</i> sp.	Hyphomycetes
<i>Glomerella cingulata</i> (Stoneman) Spauld. And H.Schrenk	Pyrenomycetes
<i>Myrothecium roridum</i> Tode ex Fr.	Hyphomycetes
<i>Pestalopsis agalloche</i> Pal and Purkayastha	Coelomycetes
<i>Phomopsis mangrovei</i> , KD. Hyde	Coelomycetes
<i>Phyllosticta</i> sp.	Coelomycetes
<i>Skierka agallocha</i> Raciborski	Teliomycetes

Mangroves also support diverse animal life. Shield bug (*Calliphara nobilis*) larvae feed upon the seeds of *E. agallocha* (Ng and Sivasothi, 1999). Three fruit flies, *Elleipsa quadrifasdata*, *Adrama magister* and the new species *Hardyadrama excoecaria* were reported to be associated with this tree with the larvae growing inside the seeds (Lee, 1991). Bees regularly visit *E. agallocha* flowers and its pollen grains were reported to be one of the secondary pollens in the honey of the Sunderbans and the Andamans (Singh and Kar, 2011), and a minor pollens in the honey of Qinglan wetlands, China (Yao *et al.*, 2006). In India, the bee *Apis dorsata* travels long distances to forage in the mangrove forests, where it prefers to build honeycombs on *E. agallocha* (Krishnamurthy, 1990). In the Bhitarkanika mangroves (Orissa), water birds such as the Asian openbill, little



cormorant, white ibis, little egret, cattle egret and intermediate egret, frequently use this tree species, mostly located in the centre of the heronry, for their nesting (Gopi and Pandav, 2011). However, all the products are not beneficial. The latex is toxic to the larvae of *Macrobrachium lamarrei*, a fresh water prawn (Krishnamoorthy *et al.*, 1995), and the penaeid prawns (Kathiresan and Thangam, 1987a). It also causes metabolic depression of *Oxiotelphusa senex*, a rice field crab (Ramamurthi *et al.*, 1991).

SOCIO-CULTURAL VALUES

Mangroves have a long historical link with human culture. The Sundarbans are dotted with the shrines dedicated to *banbibi* or *bandevi*, worshiped by the local Muslims and Hindus, respectively (Eaton, 1990). The sacred grove of Dubla Island in Bangladesh is a sanctuary for *Excoecaria agallocha* L. trees where local Hindus gather annually during a religious fair (Islam *et al.*, 1998). Lipata, a fishing village in the Antique province of Philippines, is named after the dominant *E. agallocha* tree species called *alipata* in Filipino.

The ancient temple town of Thillai (popularly called Chidambaram), located in the Cauvery delta of Tamil Nadu, is famous for its third-century temple of Thillai Nataraja. The names of the town, its temple complex and the presiding deity Nataraja (Shiva, the cosmic dancer) are associated with the sacred groves of *thillai* (*E. agallocha*) trees, which were once abundant in this area. These mangrove trees can now be found in the neighbouring Pichavaram wetlands, the second largest mangrove forest in the world. The temple complex was originally surrounded by a forest, whose dominant species *E. agallocha* is called *thillai* in Tamil. Legend has it that Shiva strolled in this sacred *thillai vanam* (forest) before his cosmic dance as Nataraja. King Shveta Varman, who is said to have been healed of leprosy by bathing in the sacred pond of the *thillai* forest, built a votive shrine dedicated to Nataraja near this pond, which later formed the central tank of the now magnificent temple complex. It is still a belief that a dip in this tank, under the influence of the *thillai*, cures leprosy and other "incurable" diseases. The bronze statues and stone sculptures of the temple depict the sacred *thillai* trees, along with the various deities of the Hindu pantheon, forming the highpoints of early Pallava and Chola art. A stone carving of *E. agallocha* in the temple complex, believed to have magical healing powers, is worshipped as the sacred *sthala vriksha* (temple tree) (Gunasekaran and Balasubramanian, 2012).

TRADITIONAL USE

Ethno-botanical exploitation of *Excoecaria agallocha* L. by the indigenous communities of the mangroves is mostly limited to its utilisation as a traditional source of poison and medicine. The latex of the tree is extremely poisonous. It has a "knock-down" effect on animals (Kathiresan and Thangam, 1987a). In New Guinea and Thailand, the aboriginal population use the latex to prepare poison arrow and darts for hunting (Karalai *et al.*, 1994). The latex is also used to as piscicide for the traditional poison fishing in South-East Asia and the South Pacific (Ng and Sivasothi, 1999). In the Solomon Islands, this latex is mixed with oil of *Cerbera manghas* (Apocynaceae) for fishing (Pillai and Sirikolo, 2001). In the Maldives, the branches are used for fencing, roofing and as firewood. The soft, light timber (which can be easily transported by the interconnected waterways) is not durable, but in India, Bangladesh and the Philippines, it is economically important as the commercial source of cheap timber and fuel. In Bangladesh, where no other softwood is available, *E. agallocha* is commercially felled as raw material for manufacturing packing boxes, matchsticks, matchboxes and paper. The timber is used to make planks for construction, used as firewood and to used make charcoal (Haq and Wodeyar, 2002). The wood is used to make matchboxes in the Philippines, knees of boats in Fiji (Vannucci, 1989) and the resinous wood is traditionally burned as incense in parts of South-East Asia (Uphof, 1968, Usher, 1974). The nectar of its flowers produces low-quality honey and wax (Naskar and Mandal, 1999).



Table 3. Use of *Excoecaria agallocha* L. in traditional herbal remedies.

Source	Disease Treated
Bark	Dermatitis, flatulence, leprosy, spasms and tumours
Wood	Epilepsy, flatulence, itching, leprosy, ulcer and animal stings
Leaves	Body aches, conjunctivitis, dermatitis, epilepsy, haematuria, leprosy, paralysis, rheumatism, sores, spasms and ulcers
Roots	Swellings of the extremities and toothaches
Seed	Arthritis

The plant is also important in ethno-medicinal practices throughout its distributional range (Table 3). Leprosy is treated with the smoke of the burning bark and wood in Sri Lanka (Jayaweera, 1980) and India (Bandaranayake, 1998), and with the wood decoction in Polynesia (Zepernick, 1972). Sores and ulcers are treated with the smoke in Fiji, with the leaf latex in New Guinea and Australia (Cribb and Cribb, 1981) and with the leaf juice boiled in oil in India (Kirtikar and Basu, 1999). In Myanmar, the leaf decoction is used for the treatment of epilepsy (Sahoo, 2001). Leaf juice boiled in oil is used as a strong irritant to treat rheumatism and paralysis (Pattanaik *et al.*, 2008). In the Solomon Islands, the latex from the leaf is taken with coconut milk as a purgative and emetic. Here, the leaves are also used as an analgesic for body aches (Pillai and Sirikolo, 2001). In Thailand, the bark and wood are used to treat flatulence (Karalai *et al.*, 1994). The bark is also used as purgative, emetic and abortifacient (Bloomfeild, 2002). In Sri Lanka, the roots, less poisonous than aerial parts, are used to treat swellings of the hands and feet (Jayaweera, 1980). In India, seed poultice is used for arthritis. Resinous exudates (*tejbul*) from the lower part of the trunk and roots are used as an aphrodisiac (Bandaranayake, 1998; Kirtikar and Basu, 1999). Oil distilled from the wood is used in Malaysia to treat itching, skin infections and stings from marine creatures. In India, the plant is used to treat snake-bite (Das, 2009). The Irulas of Tamil Nadu apply the latex on wounds as antiseptic (Ragupathy *et al.*, 2009). The plant is also used to treat tumours, dermatitis, conjunctivitis, haematuria, spasms and toothaches (Bandaranayake, 1998; Prabhakaran and Kavitha, 2012).

CHEMICAL CONSTITUENTS

Mangroves are biochemically unique. Their numerous novel natural products are well documented in the scientific literature. *Excoecaria agallocha* L. produces myriad secondary metabolites as part of its chemical defence. Phytochemical studies show the presence of diterpenoids (Konishi *et al.*, 1999; 2003a; 2003b; Wang *et al.*, 2006; 2007; Li *et al.*, 2007; Gowri *et al.*, 2009), triterpenoids (Zou *et al.*, 2006; Tian *et al.*, 2008), alkaloids (Prakash *et al.*, 1983), flavonoids (Konishi *et al.*, 2003a), phorbol esters (Ericson *et al.*, 1995), alcohols (Ghani, 2003), polyphenols (Li *et al.*, 2012; Ahmed and Kumar, 2012), steroids (Tian *et al.*, 2008), fatty acids (Agoramoorthy *et al.*, 2007) and saponins (Patra *et al.*, 2009b) and many more. Diterpenes esterified with aliphatic saturated carboxylic acids are the most common, and they include diverse agallochins, agallochaols, agallochaexcoerins, excoagallochaols, excoecarins and excoecariatoxins found in the different organs (Table 4, Fig. 4). Diterpenoids are synthesized in the roots and then translocated to the other parts of the plant (Anjaneyulu and Rao, 2002; 2003).



Table 4. Diterpenoids of *Excoecaria agallocha* L.

Source	Diterpenoid (Parent Compound)
Wood	Agallochaexcoerins A-C (labdane) Excoecarins A-C (labdane), D, E (beyerene), F-H (labdane), K, M (kaurane), N (atisane), and R-T (labdane)
Roots	Agallochins A-E (labdane), F (kaurane), G-I (beyerane), J-L (isopimarane) and M-O (labdane)
Stem	Excoecarins V1 (beyerane), V2 (kaurane) and V3 (atisane)
Stem and leaves	Agallochaols A, B (isopimarane), C (atisane) and D-F (isopimarane), and G-J (atisane), K-P (kaurane), Q (atisane) Excoagallochaols A-D (unique)
Bark and latex	Excoecariatoxin (daphnane)

Several other classes of natural products are also known. Taraxerane triterpenoid are present in the wood and leaves. Pentacyclic triterpenoids are known from the leaves. Triterpenoids such as taraxerone, taraxerol and β -amyrin are found in the stem. Piperidine alkaloids, common in Euphorbiaceae, were reported from wood and leaves. Phorbol esters have been identified from the leaves and bark. Latex contains alcohols such as exocarol, agalocol, isoagalocol, mannitol and cycloartenol. Leaves and stem contain the alcohol epitaraxerol. Polyphenols such as excoecariophenols A-D are present in the bark and leaves, and benzenetriol and ambelline are found in the leaves. The roots and stem contain ellagitannins. Gallotannins are present in the epidermis of the leaves. The leaves contain high percentage of fatty acids such as lauric, palmitic, linolenic, linoleic, oleic, stearic and myristic acids. Steroids such as β -sitostenone and β -sitosterol were also identified from the stem of *E. agallocha*.

BIOLOGICAL ACTIVITIES

Mangroves harbour many biologically active compounds, toxic to the pathogens, parasites and pests of humans, as well as domesticated plants and animals. These can be used to develop novel agrochemicals or therapeutics (Bandaranayake, 1998; 2002). The acrid latex of *Excoecaria agallocha*, on contact, causes skin irritation and temporary blindness. The plant's vapour causes throat and eye sores, and headache (Cribb and Cribb, 1981). Its daphnane- and tiglane-type diterpenoids are skin irritants (Karatil et al., 1994). However, the tree has potential use in pathogen and pest control (Table 5). Leaf extracts inhibit tobacco mosaic virus (Padmakumar and Ayyakkannu, 1997), *Aeromonas hydrophila*, a bacterial pathogen of the ornamental fish *Amphiprion sebae* (Dhayanithi et al., 2012) and fungal crop pathogens such as *Aspergillus flavus*, *A. niger*, *Fusarium oxysporum*, *Macrophomina phaseolina*, *Penicillium expansum*, *Rhizoctonia solani*, *Ustilago maydis* and *Xanthomonas compestris* (Vadlapudi et al., 2009). Latex excoecariatoxins kill insect pests due to their toxic their aliphatic side chains (Ohigashi et al., 1974). Bark extracts are highly toxic to the brine shrimp *Artemia salina* ($LD_{50} = 20 \text{ mg.ml}^{-1}$), but this is low for the rodents (Subhan et al., 2008c). Wood smoke repels and kills the mosquitoes *Culex sitiens* (Kathiresan and Thangam, 1987b), *C. quinquefasciatus* (Thangam and Kathiresan, 1992a) and *Aedes aegypti* (Thangam and Kathiresan, 1992b). Larvicidal bark extracts kill A.



aegypti, *C. quinquefasciatus* and *Anopheles stephensi* (Thirunavukkarasu *et al.*, 2011) and root extracts kill *C. quinquefasciatus* (Satyan *et al.*, 2012).

Table 5. Biological activities of *Excoecaria agallocha* L.

Source	Biological Activity
Wood	Insecticidal and antitumor-promoting activities
Leaves	Antiviral, antibacterial, antifungal, antiplasmodial, antifilarial, analgesic, antiinflammatory, antioxidant, cytotoxic, hypoglycaemic and antihyperglycemic activities
Stem	Antiviral, anti-inflammatory and cytotoxic activities
Root	Larvicidal activity
Bark	Antiviral, antibacterial, larvicidal, antiulcerogenic and gastroprotective, antioxidant, antiallergic and sedative activities.
Seed	Analgesic and antiinflammatory activities
Latex	Insecticidal, piscicidal, analgesic and antiinflammatory activities

Crude extracts of *E. agallocha* have been popular through the centuries in the local health care systems. The diverse pharmacological activities of these extracts and their constituents have been recorded in the last few decades, revealing their great potential in modern medicine (Table 5). The most important biological effect of these preparations is their toxicity against pathogenic viruses, bacteria, fungi, and parasitic protozoa and nematodes. A phorbol ester from the leaves and stem of the tree is active against the human immunodeficiency virus (Erickson *et al.*, 1995) by inhibiting the reverse transcriptase activity (Patil *et al.*, 2011). Polyphenols from the bark and leaves show inhibitory effect against the hepatitis C virus, with excoecariphenol D inhibiting the RNA polymerase and a protease (Li *et al.*, 2012). Leaf extracts strongly inhibit the activity of the pathogenic bacteria *Staphylococcus aureus* and *Proteus* sp. and bark extracts show significant activity against the *Staphylococcus aureus*, *S. dysenteriae*, *S. sonnei*, *Proteus* sp. and *Enterococci* (Subhan *et al.*, 2008c; Abeysinghe, 2010). Leaf extracts are also effective against the bacteria *Lactobacillus fermentum* and *Staphylococcus aureus*, and the fungi *Acremonium strictum*, *Curvularia lunata* and *Candida albicans* (Vadlapudi *et al.*, 2009). Leaf fatty acids are known to inhibit the bacteria *Bacillus subtilis*, *B. pumilus*, *Micrococcus luteus*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Escherichia coli*, the fungi *Candida albicans*, *C. krusei*, *C. tropicalis* and *C. parapsilosis* (Agoramoorthy *et al.*, 2007). Leaf extracts demonstrated activity against the protozoan parasite, *Plasmodium falciparum* (Ravikumar *et al.*, 2010). Patra *et al.*, (2009a) showed the leaf extracts was also toxic to the developmental stages of a filarial parasite, *Setaria digitata*. These extracts and metabolites also show significant cytotoxic properties. Diterpenes from the resinous wood exhibited antitumour-promoting activities in mouse skin carcinoma (Konishi *et al.*, 1998; Konoshima *et al.*, 2010). Flavonoid glycosides of the leaves are cytotoxic against human pancreatic and prostate cancer cells by inhibiting the hedgehog signalling pathway (Rifai *et al.*, 2011). Stem extract showed potent cytotoxicity against human lung and pancreatic cancer cell lines by inducing cell cycle arrest (at G1 phase) or apoptosis (Patil *et al.*, 2011; 2012). Cytotoxic polyphenols were reported from the fungus *Penicillium expansum*, which is endogenous to *E. agallocha* (Wang *et al.*, 2012). Several other biological effects are also known. Bark extracts show sedative effect due to the depressant action on the central nervous system (Subhan *et al.*, 2008c). Analgesic activity, mediated via peripheral and central nervous systems, was reported



with significant reduction in acetic acid-induced writhing and heat-induced tail withdrawal in mice using extracts of the latex, leaves, seeds (Babuseviam *et al.*, 2012) and bark (Subhan *et al.*, 2008b). The polyphenol-rich bark extracts also showed significant antioxidant activity which was indicated by DPPH, NO- and H₂O₂-scavenging assays (Subhan *et al.*, 2008a; Hossain *et al.*, 2009). Antioxidant property has also been reported for leaf extracts (Masuda *et al.*, 1999). Bark extracts exhibit antiulcerogenic effect by decrease the acidity and increase the mucosal defence in gastric areas (Thirunavukkarasu *et al.*, 2009). Gastroprotective effect of this extract inhibited ulceration induced by acetylsalicylic acid in mice (Subhan *et al.*, 2008b). Extracts of the latex, leaves and seeds of *E. agallocha* show antiinflammatory activity by significantly inhibiting the carrageenan-induced paw oedema in mice (Babuseviam *et al.*, 2012). The kaurane-type diterpenoids, agallochaol K, O and P, and atisane-type diterpenoid, agallochaol Q, of the stem, exhibit antiinflammatory properties by suppressing the activation of transcription factors and the expression of genes targeted by them in mouse macrophage cells (Li *et al.*, 2010). Extracts of the bark are also reported to exhibit antiallergic properties which inhibit the release of histamine in rodents (Hossain *et al.*, 2009). Leaf extracts of *E. agallocha* showed significant hypoglycemic and antihyperglycemic activities in mice (Rahman *et al.*, 2010).

THREATS AND CONSERVATION

Global mangrove vegetations have shrunk by 20% in the last three decades (FAO, 2007). The main threat is the fragmentation and degradation of their habitats, especially along their margins. Habitats are fragmented by commercial forestry, development of tourist, urban and industrial areas, construction of roads and ports, and land reclamation for agriculture, fishery, plantation and salt pans. Habitats are degraded due to siltation, pollution from oil spills, agricultural and urban runoff, and sea-level rise due to the global warming (Kathiresan and Bingham, 2001). *Excoecaria agallocha* is still a common, widespread mangrove capable of rapidly colonise disturbed areas. However, its overall population has significantly declined in many areas due to anthropogenic factors such as habitat destruction and over-exploitation. Natural threats include subsidence, cyclones and tsunamis. Commercially available volume of the species in Bangladesh has depleted by 45% in the last 60 years due to over-harvesting for timber and firewood (Hussain and Karim, 1994). Large scale seedling mortality occurred after a major oil spill in August 1994 near Dangmari, Bangladesh (Hussain and Acharya, 1994). Periodic outbreak of the moth *Achaea serva* defoliates large stands of these trees (McKillup and McKillup, 1997). Feeding by *Paralebeda* and *Selepa* caterpillars causes the total loss of shoots (Murphy, 1990). The tree is threatened by several pathogenic fungi (Table 2) and this wild species may function as an alternate host for crop pathogenic fungi. Increase in salinity due to rising sea levels threatens this moderately salt-resistant species whose inland expansion is limited by coastal development. Other problems are short flowering season, low seed production, limited seed dispersal and poor germination (Kathiresan, 2002). Although these threats and the population decline are serious, the species has not yet reached any of the threatened category thresholds and is presently listed as "least concern."

For conservation efforts, the conventional propagation techniques of *E. agallocha* include both sexual and asexual methods. Seeds germinate in 2 weeks at a low rate (24%), and cannot be stored beyond for a month (Upadhyay and Mishra, 2010). Vegetative propagation is done through stem cuttings. Rao *et al.* (1998) first reported *in vitro* multiplication with high (85%) survival rate during field transfer. Phenolic exudation, a problem during tissue culture, can be managed by adding activated charcoal (Arumugam and Panneerselvam, 2012). Presence of NaCl (300 mM) and KCl (200 mM) results in optimal growth of the saplings (Jenci and Natarajan, 2009). In Andhra Pradesh, local selfhelp groups have been trained to raise these saplings (Ravishankar and Ramasubramanian, 2004). In Bangladesh, as part of the coastal afforestation programme since 1966,



several species of mangroves including *E. agallocha* have been planted to restore degraded and fragmented vegetations (Serajuddoula *et al.*, 1995; Revilla *et al.*, 1998).

CONCLUSIONS

From the above discussion, it is apparent that humankind holds a love-hate relationship with *Excoecaria agallocha*, a major mangrove tree of the Indo-Pacific region. Despite its arsenal of noxious substances, the "blinding tree" has not only important ecological and ethno-botanical aspects, but is also endowed with potential in modern agriculture and medicine. Despite a lot of research with laboratory *in vivo* and *in vitro* models, more effort is needed in developing synthetic and more potent semi-synthetic products and their field and clinical trials. At the same time, both *in situ* and *ex situ* conservation approaches must be employed with the involvement of the local communities to prevent further endangering of the remaining natural populations of this important mangrove species.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. P.K. Roy, DFO, 24 Parganas (South) Division, West Bengal, for providing all the facilities for the collection of materials from the mangrove forests of the Sundarbans. AKP is also grateful to B.C. Sutton, Head, Biosystematic Services, International Mycological Institute (IMI), Egham, Surrey, UK for his help in the identification of fungi and to Dr. J.F. Hennen, Purdue University, USA for confirming the identity of the mangrove rust.

REFERENCES

- Abeysinghe PD (2010) Antibacterial activity of some medicinal mangroves against antibiotic resistant pathogenic bacteria. *Indian Journal of Pharmaceutical Sciences* 72:167-172.
- Agoramoorthy G, Chandrasekaran M, Venkatesalu V, Hsu MJ (2007) Antibacterial and antifungal activities of fatty acid methyl esters of the blind-your-eye mangrove from India. *Brazilian Journal of Microbiology* 38:739-742.
- Ahmed S, Kumar JP (2012) GC-MS Study of the *Excoecaria agallocha* leaf extract from Pitchavaram, Tamil Nadu, India. *Researcher* 4:10-14.
- Aksornkoae S (1993) Ecology and management of mangroves. IUCN, Bangkok.
- Anjaneyulu ASR, Rao VL (2002) *Ent*-kaurane and beyerane diterpenoids from *Excoecaria agallocha*. *Journal of Natural Products* 65:382-385.
- Arumugam M, Panneerselvam R (2012) Micropropagation and phenolic exudation protocol for *Excoecaria agallocha* an important mangrove. *Asian Pacific Journal of Tropical Biomedicine* 2:1096-1101.
- Babuselvam M, Ravikumar S, Farook KAM, Abideen S, Mohamed MP, Uthiraselvam M (2012) Evaluation of anti-inflammatory and analgesic effects on the extracts of different parts of *Excoecaria agallocha* L. *Journal of Applied Pharmaceutical Science* 2:108-112.
- Balachandran N, Kichenamourthy S, Muthukumaran J, Jayakanthan M, Chandrasekar S, Punetha A, Sundar D (2009) Diversity of true mangroves and their associates in the Pondicherry region of South India and development of a mangrove knowledgebase. *Journal of Ecology and the Natural Environment* 1:99-105.
- Balakrishnan NP, Chakrabarty T (2007) The family Euphorbiaceae in India: a synopsis of its profile, taxonomy and bibliography. Bishen Singh Mahendra Pal Singh, Dehradun.
- Bandaranayake WM (1998) Traditional and medicinal uses of mangroves. *Mangroves and Salt Marshes* 2:133-148.



- Bandaranayake WM (2002) Bioactivities, bioactive compounds and chemical constituents of mangrove plants. *Wetlands Ecology and Management* 10:421-452.
- Barlow BA (1981) The Australian flora: its origin and evolution. In: George AS (ed.) *Flora of Australia: Introduction* (Vol. 1). Australian Government Publishing Service, Canberra, pp. 25-75.
- Bloomfield SF (2002) Illness and cure in Tonga: traditional and modern practice. Vavau Press Ltd., Tonga.
- Chinnaraj S (1994) Higher marine fungi from mangroves (manglicolous fungi). In: Deshmukh SV (ed.) *Conservation of Mangrove Forest Genetic Resources: A Training Manual*. MS Swaminathan Research Foundation, Madras, pp. 271-277.
- Chinnaraj S, Untawale AG (1992) Manglicolous fungi from India. *Mahasagar* 25:25-29.
- Cribb AB, Cribb JW (1981) *Wild Medicine in Australia*. Fontana, Sydney, Australia.
- Danielsen F, Sørensen MK, Olwig MF, Selvam V, Parish F, Burgess N, Hiraishi T, Karunakaran VM, Quarto A, Suryadiputra N (2005) The Asian tsunami: a protective role for coastal vegetation. *Science* 310:643.
- Danser BH (1931) The Loranthaceae of the Netherlands Indies. *Bulletin du Jardin Botanique de Buitenzorg* 11:233-519.
- Das AB, Basak UC, Das P (1999) Genetic erosion of wetland biodiversity in Bhitarkanika forest of Orissa, India. *Biologia* 54:415-22.
- Das AB, Jena S, Pradhan C, Chand PK (2011) Genetic variability among male populations of a minor mangrove *Excoecaria agallocha* L. as evident by chromosome morphology and DNA markers. *The Nucleus* 54:39-47.
- Das K (2009) Medicinal plants for snake-bite treatment: future focus. *Ethnobotanical Leaflets* 13:508-521.
- Datta N (1967) *Excoecaria agallocha*. In: Love A (ed.) *IOPB Chromosome Number Reports XII*. *Taxon* 16:341-350.
- De Silva M, De Silva PK (1998) Status, diversity and conservation of the mangrove forests of Sri Lanka. *Journal of South Asian Natural History* 3:79-102.
- Dhayanithi NB, Kumar TTA, Balasubramanian T (2012) Effect of *Excoecaria agallocha* leaves against *Aeromonas hydrophila* in marine ornamental fish, *Amphiprion sebae*. *Indian Journal of Geo-Marine Sciences* 41:76-82.
- Eaton RM (1990) Human settlement and colonization in the Sundarbans, 1200-1750. *Agriculture and Human Values* 7:6-16.
- Ericson KL, Beutler JA, Cardellina JH, McMahon JB, Newman DJ, Boyd MR (1995) A novel phorbol ester from *Excoecaria agallocha*. *Journal of Natural Products* 58:769-72.
- FAO (2007) *The World's Mangroves: 1980-2005*. Food and Agriculture Organization of the United Nations, Rome.
- Ghani A (2003) *Medicinal Plants of Bangladesh*. The Asiatic Society of Bangladesh, Dhaka.
- Gopal B, Chauhan M (2006) Biodiversity and its conservation in the Sundarban mangrove ecosystem. *Aquatic Sciences* 68:338-354.
- Gopi GV, Pandav B (2011) Nest space partitioning among colonial nesting water birds at Bhitarkanika mangroves, India. *World Journal of Zoology* 6:61-72.
- Gowri P, Bhattar S, Reddy P, Rakesh Y, Basha S, Sarma A, Rao J (2009) Three new entlabdane diterpenoids from the wood of *Excoecaria agallocha* Linn. *Helvetica Chimica Acta* 92:1419-1427.
- Gunasekaran M, Balasubramanian P (2012) Ethnomedicinal uses of Sthalavrikshas (temple trees) in Tamil Nadu, southern India. *Ethnobotany Research and Applications* 10:253-267.



- Gupta N, Mishra S, Basak UC (2009a) Diversity of *Streptomyces* in mangrove ecosystem of Bhitarkanika. Iranian Journal of Microbiology 1:37-42.
- Gupta N, Mishra S, Basak UC (2009b) Microbial population in phyllosphere of mangroves growing in different salinity zones of Bhitarkanika (India). Acta Botanica Malacitana 34:33-37. 2:50-54. 514-515.
- Haq KMF, Wodeyar AK (2002) An ecological study of habitat of mangrove forest of Bangladesh. Journal of Human Ecology 13:225-230.
- Hong PN, San HT (1993) Mangroves of Vietnam. IUCN, Bangkok.
- Hossain SJ, Aoshima H, El-Sayed M, Ahmed F (2009) Antioxidative and antihistaminerelease activities of *Excoecaria agallocha* L. Pharmacology 2:927-936.
- Hussain Z, Acharya G (1994) Mangroves of the Sundarbans (Vol. 2): Bangladesh. IUCN, Bangkok.
- Hussain Z, Karim A (1994) Introduction. In: Hussain, Z, Acharya G (eds.) Mangroves of the Sundarbans. IUCN, Bangkok.
- Iftekhar MS, Islam MR (2004) Managing mangroves in Bangladesh: a strategy analysis. Journal of Coastal Conservation 10:139-146.
- Islam AKMN, Islam MA, Hoque AE (1998) Species composition of sacred groves, their diversity and conservation in Bangladesh. In: Ramakrishnan PS, Saxena KG, Chandrashekara UM (eds.) Conserving the Sacred for Biodiversity Management. Oxford-IBH Publishing, New Delhi, pp. 163-165.
- Jayaweera DMA (1980) Medicinal plants used in Ceylon. Journal of National Science Council of Sri Lanka 2:214-215.
- Jenci M, Natarajan S (2009) Growth and organic constituent variations with salinity in *Excoecaria agallocha* L., an important halophyte. Botany Research International 2:50-54.
- Karalai C, Wiriyaichitra P, Opferkuch HJ, Hecker E (1994) Cryptic and free skin irritants of the daphnane and tiglane types in latex of *Excoecaria agallocha*. Planta Medica 60:351-355.
- Kathiresan K (2002) A review of studies on Pichavaram mangrove, southeast India. Hydrobiologica 430:185-241.
- Kathiresan K, Bingham BL (2001) Biology of mangrove and mangrove ecosystems. Advances in Marine Biology 40:81-251.
- Kathiresan K, Bose KS, Thangam TS (1987) Light induced effect of *Excoecaria agallocha* L. on phytoplankton productivity in Pichavaram. In: Nair NB (ed.) Proceedings of the National Seminar on Estuarine Management, Trivandrum, pp.514-515.
- Kathiresan K, Bose KS, Thangam TS (1990) Effect of latex of *Excoecaria agallocha* L. on marine productivity. In: Rajarao VN (ed.) Perspectives in Phycology. Today & Tomorrow Publishers, New Delhi, pp. 319-321.
- Kathiresan K, Thangam TS (1987a) Biototoxicity of *Excoecaria agallocha* L. latex on marine organisms. Current Science 56:314-315.
- Kathiresan K, Thangam TS (1987b) Light induced effects of latex of *Excoecaria agallocha* L., on salt marsh mosquito *Culex sitiens* L. Journal of Marine Biological Association of India 29:378-380.
- Kavitha D, Prabhakaran J, Arumugam K (2012) Allelopathic influence of *Excoecaria agallocha* L. on seed germination and seedling growth of some pulses and millets. International Journal of Pharma and Bio Sciences 3:757-766.
- Kirtikar KR, Basu BD (1999) Indian medicinal plants. Lalit Mohan Basu, Allahabad.



- Konishi T, Konoshima T, Fujiwara Y, Kiyosawa S, Miyahara K, Nishi M (1999) Stereostructures of new labdane-type diterpenes, excoecarins F, G1, and G2 from the wood of *Excoecaria agallocha*. Chemical and Pharmaceutical Bulletin 47:456-458.
- Konishi T, Takasaki M, Tokuda H, Kiyosawa S, Konoshima T (1998) Anti-tumorpromoting activity of diterpenes from *Excoecaria agallocha*. Biological and Pharmaceutical Bulletin 21: 933-996.
- Konishi T, Yamazoe K, Kanzato M, Konoshima T, Fujiwara Y (2003a) Three diterpenoids (Excoecarins V1-V3) and a flavanone glycoside from the fresh stem of *Excoecaria agallocha*. Chemical and Pharmaceutical Bulletin 51:1142-1146.
- Konishi T, Yamazoe K, Konoshima T, Maoka T, Fujiwara Y, Kanzato M, Miyahara K (2003b) New bis-secolabdane diterpenoids from *Excoecaria agallocha*. Journal of Natural Products 66:108-111.
- Konoshima T, Konishi T, Takasaki M, Yamazoe K, Tokuda H (2001) Anti-tumorpromoting activity of the diterpene from *Excoecaria agallocha*. II. Biological and Pharmaceutical Bulletin 24:1440-1442.
- Krishnamoorthy P, Maruthanayagam C, Subramanian P (1995) Toxic effect of mangrove plant (*Excoecaria agallocha* L.) latex on the larvae of fresh water prawn *Macrobrachium lamarrei*. Environment and Ecology 13:708-710.
- Krishnamurthy K (1990) The apiary of the mangroves. In: Whigham DF, Dykyjova D, Hejny S (eds.) Wetland Ecology and Management: Case Studies, pp. 135-140. Kluwer Academic Press, Dordrecht.
- Kumar T, Ghose M, Brahmachary RL (2007) Effects of root exudates of two mangrove species on *in vitro* spore germination and hyphal growth of *Glomus mosseae*. Research Journal of Botany 2:48-53.
- Kumaresan V, Suryanarayanan TS (2001) Occurrence and distribution of endophytic fungi in a mangrove community. Mycological Research 105:1388-1391.
- Lakshmi M, Parani M, Nivedita R, Parida AK (2000) Molecular phylogeny of mangroves VI: intra-specific genetic variation in mangrove species *Excoecaria agallocha* L. (Euphorbiaceae). Genome 43:110-115.
- Lakshmi M, Parani M, Parida AK (2002) Molecular phylogeny of mangroves IX: molecular marker assisted intra-specific variation and species relationships in the Indian mangrove tribe Rhizophoreae. Aquatic Botany 74:201-217.
- Lakshmi M, Rajalakshmi S, Parani M, Anuratha CS, Parida AK (1997) Molecular phylogeny of mangroves I: use of molecular markers in assessing the intra-specific genetic variability in the mangrove species *Acanthus ilicifolius* Linn. (Acanthaceae). Theoretical and Applied Genetics 94:1121-1127.
- Lee CSC (1991) Fruit flies (Diptera: Tephritidae) reared from fruits of *Excoecaria agallocha* (Euphorbiaceae) in Singapore mangroves. Raffles Bulletin of Zoology 39:105-118.
- Li X, Lei J, Zheng YN, Isabel S, Lin WH (2007) New ent-isopimarane diterpene from mangrove *Excoecaria agallocha* L. Chemical Research in Chinese Universities 23:541-543.
- Li Y, Liu J, Yu S, Proksch P, Gu J, Lin W (2010) TNF- α inhibitory diterpenoids from the Chinese mangrove plant *Excoecaria agallocha* L. Phytochemistry 71: 2124-2131.
- Li Y, Yu S, Liu D, Proksch P, Lin W (2012) Inhibitory effects of polyphenols toward HCV from the mangrove plant *Excoecaria agallocha* L. Bioorganic and Medical Chemistry Letters 22:1099-1013.
- Lu Z, Zhu H, Fu P, Wang Y, Zhang Z, Lin H, Liu P, Zhuang Y, Hong K, Zhu W (2010) Cytotoxic polyphenols from the marine-derived fungus *Penicillium expansum*. Journal of Natural Products 73:911-914.



- Masuda T, Yonemori S, Oyama Y, Takeda Y, Tanaka T, Andoh T, Shinohara, A, Nakata M (1999) Evaluation of the antioxidant activity of environmental plants: activity of the leaf extracts from seashore plants. *Journal of Agricultural and Food Chemistry*, 47:1749-1754.
- Mazda Y, Magi M, Nanao H, Kogo M, Miyagi T, Kanazawa N, Kobashi D (2002) Coastal erosion due to long term human impact on mangrove forests. *Wetlands Ecology and Management* 10:1-9.
- McKillup SC, McKillup RV (1997) An outbreak of the moth *Achaea serva* (Fabr.) on the mangrove *Excoecaria agallocha* (L.). *Pan-Pacific Entomology* 73:184-185.
- Mukherjee AK, Acharya L, Panda PC, Mohapatra T (2006) Assessment of genetic diversity in 31 species of mangroves and their associates through RAPD and AFLP markers. *Zeitschrift für Naturforschung* 61:413-420.
- Murphy DH (1990). The natural history of insect herbivory on mangrove trees in and near Singapore. *The Raffles Bulletin of Zoology* 38:119-203.
- Naskar K (1993) *Plant Wealth of the Lower Ganga Delta: an Eco-Taxonomical Approach*. Daya Publishing House, Delhi.
- Naskar K, Mandal R (1999) *Ecology and biodiversity of Indian mangroves*. Daya Publishing House, Delhi.
- Ng PKL, Sivasothi N (1999) *A Guide to the Mangroves of Singapore I: The Ecosystem and Plant Diversity*. Singapore Science Centre, Singapore.
- Ohigashi H, Katsumata H, Kawazu K, Koshimizu K, Mitsui T (1974) A piscicidal constituent of *Excoecaria agallocha*. *Agricultural and Biological Chemistry* 38:1093-1095.
- Padmakumar K, Ayyakannu K (1997) Antiviral activity of marine plants. *Indian Journal of Virology* 13:33-36.
- Pal AK (2012) Fungi in the mangrove forests of Indian Sunderbans: biodiversity and parasitism. In: *Proceedings of the UGC Sponsored National Seminar on Coastal Vegetation, Ramnagar, Purba Medinipur* (In Press).
- Pal AK, Purkayastha RP (1992) New parasitic fungi from Indian mangrove. *Journal of Mycopathological Research* 30:173-176.
- Parani M, Lakshmi M, Elango S, Nivedita R, Anuratha CS, Parida AK (1997) Molecular phylogeny of mangroves II: intra- and inter-specific variation in *Avicennia* revealed by RAPD and RFLP markers. *Genome* 40:487-495.
- Patil RC, Manohar SM, Katchi VI, Rao AJ, Moghe A (2012) Ethanolic stem extract of *Excoecaria agallocha* induces G1 arrest or apoptosis in human lung cancer cells depending on their P53 status. *Taiwania*, 57: 89-98.
- Patil RC, Manohar SM, Upadhye MV, Katchi VI, Rao AJ, Mulel A, Moghe AS (2011) Anti reverse transcriptase and anticancer activity of stem ethanol extracts of *Excoecaria agallocha* (Euphorbiaceae). *Ceylon Journal of Science (Biological Science)* 40:147-155.
- Patra JK, Mohapatra AD, Rath SK, Dhal NK, Thatoi HN (2009a) Screening of antioxidant and antifilarial activity of leaf extracts of *Excoecaria agallocha* L. *International Journal of Integrative Biology* 7:9-15.
- Patra JK, Panigrahi TK, Rath SK, Dhal NK, Thatoi HN (2009b) Phytochemical screening and antimicrobial assessment of leaf extracts of *Excoecaria agallocha* L.: a mangal species of Bhitarkanika, Orissa, India. *Advances in Natural and Applied Sciences* 3:241-246.



- Pattanaik C, Reddy CS, Dhal NK, Das R (2008) Utilisation of mangrove forests in Bhitarkanika wildlife sanctuary, Orissa. *Indian Journal of Traditional Knowledge* 7:598-603.
- Peng L, Xin-Men W (1983) Ecological notes on the mangroves of Fujian, China. In: Teas HJ (ed.) *Biology and Ecology of Mangroves*. W Junk Publishers, The Hague, pp. 31-36.
- Pillai G, Sirikolo QM (2001) *Mangroves of the Solomon Islands*. University of the South Pacific, Fiji.
- Prabhakaran J, Kavitha D (2012) Ethnomedicinal importance of mangrove species of Pitchavaram. *International Journal of Research in Pharmaceutical and Biomedical Sciences* 3:611-614.
- Prakash S, Khan MA, Khan H, Zamann A (1983) A piperidine alkaloid from *Excoecaria agallocha*. *Phytochemistry* 22:1836-1837.
- Purkayastha RP, Pal AK (1998) SEM studies on a mangrove rust of Sundarbans, Eastern India. *Mycological Research* 102:692-694.
- Ragupathy S, Newmaster SG (2009) Valorizing the Irula's traditional knowledge of medicinal plants in the Kodiakkarai Reserve Forest, India. *Journal of Ethnobiology and Ethnomedicine* 5:1-13.
- Rahman M, Siddika A, Bhadra B, Rahman S, Agarwala B, Chowdhury MH, Rahmatullah M (2010) Antihyperglycemic activity studies on methanol extract of *Petrea volubilis* L. (Verbenaceae) leaves and *Excoecaria agallocha* L. (Euphorbiaceae) stems. *Advances in Natural and Applied Sciences* 4:361-364.
- Rajangam M, Argumam K (1999) Allelopathic effects of *Excoecaria agallocha* L. on germination and seedling growth of rice. *Journal of Ecotoxicology and Environmental Monitoring* 9:63-66.
- Ramamurthi R, Jayasundaramma B, Lakshmi Rajyam C, Prasad DVLN, Varalakshmi C (1991) Bioactive substances from the latex of the mangrove plant *Excoecaria agallocha* L.: effects on the oxidative metabolism of crabs. In: Thompson MF, Sarojini R, and Nagabhushanam R (eds.) *Bioactive Compounds from Marine Organisms with emphasis on the Indian Ocean*. Oxford-IBH Publishing, New Delhi, pp. 105 - 109.
- Rao CS, Eganathan P, Anand A, Balakrishna P, Reddy TP (1998) Protocol for *in vitro* propagation of *Excoecaria agallocha* L. a medicinally important mangrove species. *Plant Cell Reports* 17:861-865.
- Rashid SH, Bocker R, Hossain ABME, Khan AA (2008) Undergrowth species diversity of Sundarban mangrove forest (Bangladesh) in relation to salinity. *Berichte des Institutes für Landschafts und Pflanzenökologie der Universität Hohenheim* 17:41-56.
- Ravikumar S, Inbaneson SJ, Suganthi P, Venkatesan M, Ramu A (2010) Mangrove plants as a source of lead compounds for the development of new antiplasmodial drugs from South East coast of India. *Parasitology Research* 108:1405-1410.
- Ravindran C, Naveenan T, Varatharajan GR, Rajasabapathy R, Meena RM (2012) Antioxidants in mangrove plants and endophytic fungal associations. *Botanica Marina* 55:269-279.
- Ravishankar T, Ramasubramanian R (2004) *Manual on mangrove nursery raising techniques*. MS Swaminathan Research Foundation, Chennai.
- Reddy TKK, Rajasekhar A, Jayasundaramma B, Ramamurthy R (1991) Bioactive substances from the latex of the mangrove plant *Excoecaria agallocha* L.: Antimicrobial activity and degradation. In: Thompson MF, Sarojini R, and Nagabhushanam R (eds.) *Bioactive Compounds from Marine Organisms with emphasis on the Indian Ocean*. Oxford-IBH Publishing, New Delhi, pp. 75-78.



- Revilla JAV, Ahmad I, Hossain A (1998) Forest inventory of the coastal afforestation divisions. Forest Department, Ministry of Environment and Forests (Government of Bangladesh), Dhaka.
- Rifai Y, Arai MA, Sadhu SK, Ahmed F, Ishibashi M (2011) New hedgehog/GLI signalling inhibitors from *Excoecaria agallocha*. *Bioorganic and Medicinal Chemistry Letters* 21:718-722.
- Saha S, Choudhury A (1995) Vegetation analysis of restored and natural mangrove forest in Sagar Island, Sunderbans, east coast of India. *Indian Journal of Marine Sciences* 24:133-136.
- Sahoo S (2001) Conservation and utilization of medicinal and aromatic plants. Allied Publishers Ltd., New Delhi.
- Saritha MK, Tessa PP (2011) Mangroves of Poyya backwaters of Thrissur district, Kerala, India. *Journal of Marine Biology Association of India* 53:8-13.
- Sarma VV, Vittal BPR (2001) Biodiversity of manglicolous fungi on selected plants in the Godavari and Krishna deltas, east coast of India. *Fungal Diversity* 6:115-130.
- Satyan RS, Sakthivadivel M, Shankar S, Dinesh MG (2012) Mosquito larvicidal activity of linear alkane hydrocarbons from *Excoecaria agallocha* L. against *Culex quinquefasciatus* Say. *Natural Product Research* 26:2232-2264.
- Serajuddoula MD, Khan MAS, Islam MR, Shahjalal MAH (1995) Introduction of nonmangroves in raised land: a way to maintain sustainable forest in coastal belt of Bangladesh. *Pakistan Journal of Forestry* 45:163-169.
- Singh S, Kar R (2011) Melissopalynological studies on mangrove honeys from Sunderbans (Bangladesh) and Little Andaman (India). *Current Science* 100:9-10.
- Spalding M, Blasco F, Field C (1997) World mangrove atlas. The International Society for Mangrove Ecosystems, Okinawa.
- Sridhar KR (2009) Fungal diversity of Pichavaram mangroves, southeast coast of India. *Nature and Science* 7:67-75.
- Subhan N, Alam MA, Ahmed F, Awal MA, Nahar L, Dey Sarker S (2008b) *In vitro* antioxidant property of the extract of *Excoecaria agallocha* (Euphorbiaceae). *DARU Journal of Pharmaceutical Sciences* 16:149-154.
- Subhan N, Alam MA, Ahmed F, Shahid IJ (2008a) Antinociceptive and gastroprotective effect of the crude ethanolic extracts of *Excoecaria agallocha* Linn. *Turkish Journal of Pharmaceutical Sciences* 5:143-154.
- Subhan N, Alam MA, Ahmed F, Shahid IJ, Nahar L, Dey Sarker S (2008c) Bioactivity of *Excoecaria agallocha*. *Brazilian Journal of Pharmacognosy* 18:521-526.
- Thangam TS, Kathiresan K (1992a) Smoke repellency and killing effect of marine plants against *Culex quinquefasciatus*. *Tropical Biomedicine* 9:35-38.
- Thangam TS, Kathiresan K (1992b) Mosquito larvicidal activity of mangrove plant extract against *Aedes aegypti*. *International Pest Control* 34: 116-119.
- Thirunavukkarasu P, Ramanathan T, Renugadevi G, Jayalakshmi S (2011) Studies on larvicidal potential of *Excoecaria agallocha* L. bark extract. *Journal of Pharmacy Research* 4:3480-3482.
- Thirunavukkarasu P, Ramkumar L, Ramanathan T (2009) Anti-ulcer activity of *Excoecaria agallocha* bark on NSAID-induced gastric ulcer in albino rats. *Global Journal of Pharmacology* 3:123-126.
- Tian MQ, Bao GM, Ji NY, Li XM, Wang BG (2008) Triterpenoids and steroids from *Excoecaria agallocha*. *Zhongguo Zhongyao Zazhi* 33:405-408.



- Tomlinson PB (1986) The botany of mangroves. Cambridge University Press, Cambridge.
- Upadhyay VP, Mishra PK (2010) Phenology of mangroves tree species on Orissa coast, India. *Tropical Ecology* 51:289-295.
- Uphof JCT (1968) Dictionary of Economic Plants. Verlag Cramer Publication, New York.
- Usher G (1974) Dictionary of Plants used by Man. Prescott, London.
- Vadlapudi V, Bobbarala V, Penumajji S, Naidu CK (2009) *Excoecaria agallocha* L.: antimicrobial properties against important pathogenic microorganisms. *International Journal of Chem-Tech Research* 1:865-867.
- Vannucci M (1989) The Mangroves and Us: A Synthesis of Insights. Indian Association of the Advancement of Science, New Delhi.
- Wang GW, Li HY, Sun WB (2003) Primary study on arbuscular mycorrhizas of mangrove in Qinzhou Bay. *Guihaia* 23:445-449.
- Wang J, Lu Z, Liu P, Wang Y, Li J, Hong K, Zhu W (2012) Cytotoxic polyphenols from the fungus *Penicillium expansum* 091 006 endogenous with the mangrove plant *Excoecaria agallocha*. *Planta Medica* (In Press).
- Wang JD, Li ZY, Xiang WS, Guo YW (2006) Further new *seco*-atisane diterpenoids from the Chinese Mangrove *Excoecaria agallocha* L. *Helvetica Chimica Acta* 89:1367-1372.
- Wang JD, Zhang W, Li ZY, Xiang WS, Guo YW, Krohn K (2007) Elucidation of excogallochaols A-D, four unusual diterpenoids from the Chinese mangrove *Excoecaria agallocha*. *Phytochemistry* 68:2426-2431.
- Willis JC (1973) A dictionary of the flowering plants and ferns. Cambridge University Press, Cambridge.
- Xu XX, Wang HL, Lin HP, Wang C, Qu Z, Xie QY, Ruan JS, Hong K (2011) *Microbispora hainanensis* sp. nov., isolated from rhizosphere soil of *Excoecaria agallocha* in a mangrove. *International Journal of Systematic and Evolutionary Microbiology* (In Press).
- Yao YF, Bera S, Wang YF, Li CS (2006) Nectar and pollen sources for honeybee (*Apis cerana cerana* Fabr.) in Qinglan mangrove area, Hainan Island, China. *Journal of Integrative Plant Biology* 48:1266-1273.
- Zepernick B (1972) Medicinal Plants of Polynesia. Verlag von Reimer, Berlin.
- Zhang ZH, Tang T, Zhou RC, Wang YG, Jian SG, Zhong CR, Shi SH (2005) Effects of divergent habitat on genetic structure of population of *Excoecaria agallocha*, a mangrove associate. *Acta Genetica Sinica* 32:1286-1292.
- Zou JH, Dai J, Chen X, Yuan JQ (2006) Pentacyclic triterpenoids from leaves of *Excoecaria agallocha*. *Chemical and Pharmaceutical Bulletin* 54:920-921.



Fig. 1. Global distribution of *Excoecaria agallocha* L. (indicated by yellow lines).



Fig. 2. Morphology of *Excoecaria agallocha* L. from the Indian Sunderbans. a Habit (mal) tree, b Bark, c Leaves (0.5x) with salt glands indicated by the arrows, d Roots, e Male inflorescences (0.25x), f Pollen grain (1000x), g Fruits and seeds (0.5x). Figures in parenthesis indicate magnification.

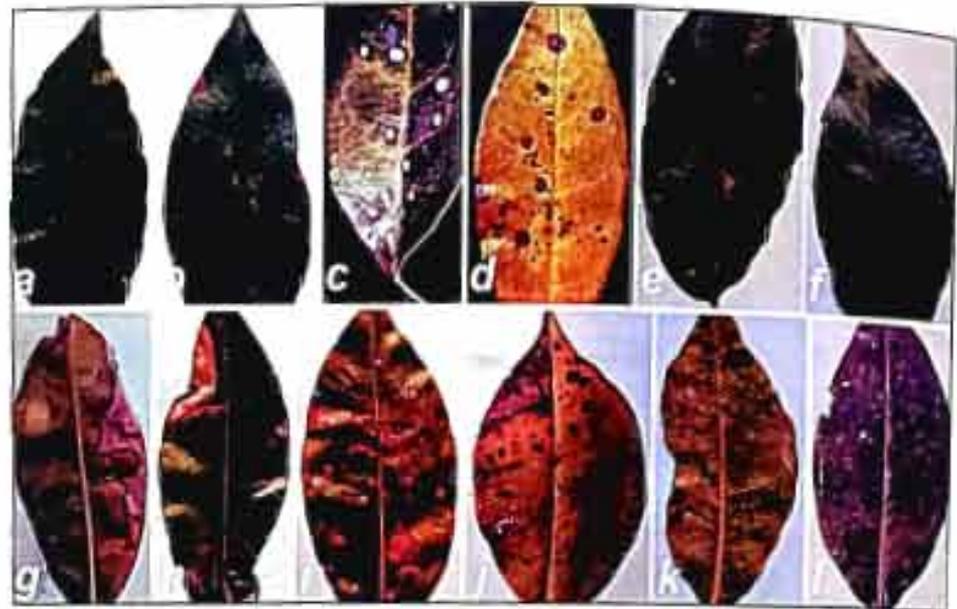


Fig. 3. Fungus-infected leaves of *Excoecaria agallocha* L. from the Indian Sundarbans. a Healthy leaf, b-l Leaves infected with the fungus: b *Asteromella* sp., c, d *Colletotrichum gloeosporioides*, e *Coniella musaiaensis* var. *hibisci*, f *Cytospora* sp., g *Drechslera* sp., h *Myrothecium roridum*, i *Pestalotia agallocha*, j *Phomopsis mangrovei*, k *Phyllosticta* sp., l *Skierka agallocha*. Bar = 2 cm. Source: Pal (2012).

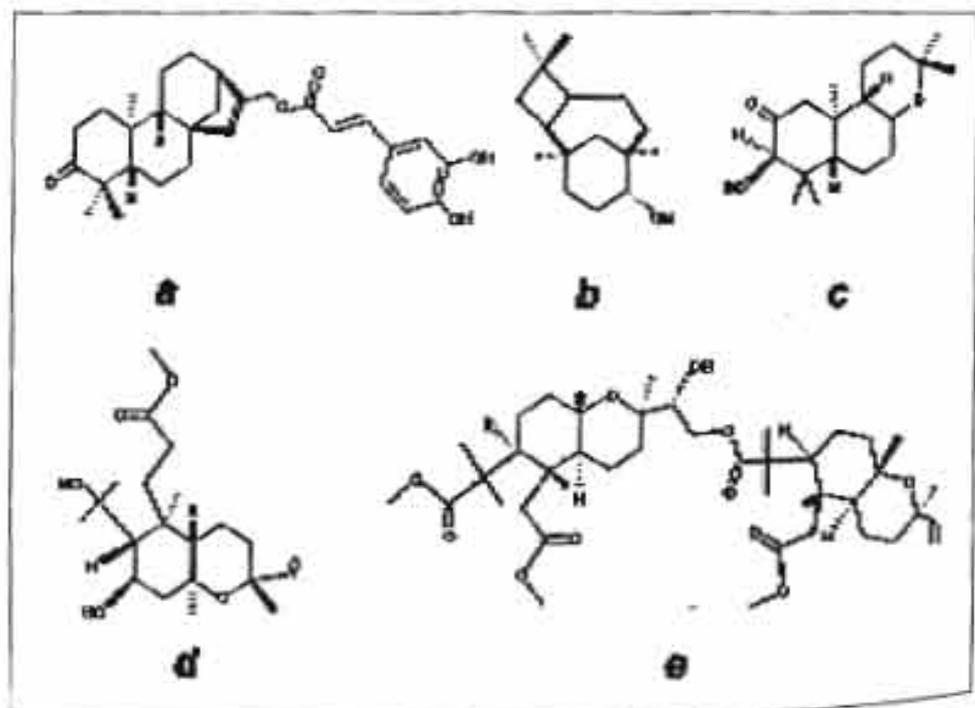


Fig. 4. Structures of some of the diterpenoids of *Excoecaria agallocha* L. a Agallochaol O, b Excoagallochaol D, c Agallochaexcoerin B, d Agallochin M, e Excoecarin R.

ভিক্টর হেস ও মহাজাগতিক আবিষ্কারের ১০০ বছর

জয়দীপ মিত্র*

কবিগুরু রবীন্দ্রনাথ ঠাকুর লিখেছিলেন: “আলোকের এই ঝরনা ধারায় ধুইয়ে দাও”-আলোকের ঝরনা ধারাই বটে, কিন্তু সে ঝরনা শুধু সূর্যালোকমাত্র তা নয়, সে ঝরনা-রশ্মির আগমন অনন্ত, অসীম মহাজগৎ থেকে-নাম তাই মহাজাগতিক রশ্মি (cosmic ray)। অবিরাম ধারাস্রোতের মতো তা ঝরে পড়ছে পৃথিবীপৃষ্ঠে-প্রতিমুহূর্তে কোটি কোটি কণা ভেদ করে যাচ্ছে আমাদের শরীর-প্রায় সম্পূর্ণটাই আমাদের অগোচরে। এই রশ্মির সঙ্গে বাতাসের কণাগুলির আন্তঃক্রিয়ায় কণাগুলির ঘটে ionization। তৈরি হয় আয়নিত কণার স্রোত। প্রথম থেকেই কি জানা ছিল এই কথা? নিশ্চয়ই নয়। বাতাসের কণার ionization এর সাথে বিজ্ঞানীরা পরিচিত থাকলেও ১৯১১-১২ সাল পর্যন্ত তার মূল কারণ ছিল অধরা। ১৯১২ সালে বিজ্ঞানী ভিক্টর ফ্রানজ হেস (Victor Franz Hess) পরীক্ষামূলক ভাবে প্রমাণ করলেন-এই ionization এর মূল কারণ মহাজগৎ থেকে আসা অজানা রশ্মিস্রোত - ২০১২ তাই মহাজাগতিক রশ্মি আবিষ্কারের শতবার্ষিকী।

Victor Hess জন্মেছিলেন অস্ট্রিয়ায়-২৪শে জুন, ১৮৮৩ সালে। বাবা Vinzens Hess ছিলেন রাজ্য Oettingen-Wallerstein এর এস্টেটের মুখ্য বনপাল। মা Sarafine Hess. প্রাথমিক শিক্ষা শেষ করে ভিক্টর যোগ দিলেন University of Graz-এ। সালটা ১৯০১। ১৯০৬ সালে Ph.D. সমাপ্ত করার পর ভিক্টর বার্লিন বিশ্ববিদ্যালয়ে post doctorate করার জন্য তখনকার বিখ্যাত পদার্থবিদ Paul Drude- এর কাছে আবেদন করলেন। Drude সে সময় কঠিন পদার্থের ভিতর দিয়ে তাপ ও তড়িত-পরিবাহিতা নিয়ে বিখ্যাত সব কাজ করছেন।

(বলে রাখা ভালো, আলোর গতিবেগের চিহ্ন হিসেবে আমরা যে সংকেত c ব্যবহার করি, তা Drude- এরই দেওয়া)। সঙ্গে আলোকের বিভিন্ন ধর্ম নিয়েও গবেষণা করছেন। ভিক্টর চেয়েছিলেন Drude- এর কাছে আলো নিয়ে গবেষণা করতে। কিন্তু অদৃষ্টের কি পরিহাস! ভিক্টর বার্লিন পৌঁছানোর কিছু সপ্তাহ আগেই Drude আত্মহত্যা করলেন।

এরপর Franz Exner, ভিয়েনা বিশ্ববিদ্যালয় থেকে তাকে গবেষণার জন্য আমন্ত্রণ জানালেন। সে সময় ভিয়েনা বিশ্ববিদ্যালয়ের জগৎজোড়া নাম-পদার্থবিদ্যা বিভাগে রয়েছেন Exner- বিকিরণ সংক্রান্ত গবেষণায় তাঁর খ্যাতি তখন সর্বত্র। ১৯০৭ সালে Boltzmann-এর স্থানে যোগ দিয়েছেন Friedrich Hasenohri

(1874-1915)। Hasenohri গবেষণা করছেন “electromagnetic mass” নিয়ে। প্রসঙ্গত বলে রাখি, Hasenohri- এর কাছে সে সময় Ph.D করলেন Erwin Schrodinger (পরবর্তীকালে কোয়ান্টাম বলবিদ্যার অন্যতম আবিষ্কারক হিসেবে তাঁর নাম চিহ্নিত হয়ে থাকবে)। ১৯১৫ সালে প্রথম বিশ্বযুদ্ধে গ্রেনেডের আঘাতে Hasenohri মারা যান। যা হোক, Hasenohri বা Exner এর সাথে কাজ করতে এসে বিকিরণের গতি-প্রকৃতি সংক্রান্ত গবেষণায় Hess ও উৎসাহিত হয়ে ওঠেন। পরে Victor অধ্যাপক Meyer এর তত্ত্বাবধানে Institute of Radium research-এ কাজ করতে আসেন। এখানে থাকাকালীন Victor মহাজাগতিক রশ্মি সংক্রান্ত বিখ্যাত গবেষণাগুলি করেন।

অনেকটা সময় পিছনে চলে যাওয়া যাক। অষ্টাদশ শতাব্দীর শেষভাগে আবিষ্কৃত হয়েছিল তড়িৎবীক্ষণ যন্ত্র। ১৭৮৫ সালে পরীক্ষা করতে গিয়ে Charles-Augustin de Coulomb (বিজ্ঞানের ছাত্ররা সবাই কুলম্ব সূত্রের সাথে পরিচিত) লক্ষ্য করেছিলেন কোন তড়িতাহিত ধাতব গোলককে বাতাসে রেখে দিলে স্বতঃস্ফূর্ত ভাবে তড়িৎক্ষরণ হয় এবং গোলকটি নিস্তাড়িৎ হয়ে পড়ে। তার আগে অনেকের ধারণা ছিল



* সহকারী অধ্যাপক, পদার্থবিদ্যা বিভাগ, স্কটিশচার্চ কলেজ, কলকাতা-৭০০০০৬



বাতাস তড়িতের অপরিবাহী। কুলম্ব দেখালেন তা ঠিক নয়। তড়িৎবীক্ষণের ক্ষেত্রের দেখা গেল একই ঘটনা। পরবর্তীকালে Michael Faraday আরো ভালোভাবে কুলম্বের ধারণার যথার্থতা প্রমাণ করলেন। যতদিন যাচ্ছিল, তড়িৎবীক্ষণ যন্ত্রের প্রভূত উন্নতিসাধন হচ্ছিল। প্রথিতযশা বিজ্ঞানী Lord Kelvin, Crookes -এরা পরীক্ষা নিরীক্ষার সুবিধার্থে তড়িৎবীক্ষণের সংস্কার করেছিলেন। ১৮৭৯ সালে Crookes লক্ষ্য করলেন তড়িৎবীক্ষণের ভিতরে বাতাসের চাপ কমালে তড়িৎক্ষরণ ঘটে ধীর গতিতে। মোটামুটি ভাবে বোঝা গিয়েছিল এইসব তড়িৎক্ষরণের মূলে রয়েছে তড়িৎবীক্ষণের ভিতরের বাতাসের কণাগুলির ionization। (যদিও পরে দেখা গেল এই ধারণাও ঠিক নয়)। কিন্তু বাতাসের কণাগুলির আয়নিত হওয়ার কারণ সম্পর্কে কোন ধারণা সে সময় ছিল না।

উনবিংশ শতাব্দীর শেষের দিক থেকে জোরকদমে কানাডা, ইটালি, আমেরিকা এবং বিশেষতঃ অস্ট্রিয়ায় বাতাসের তড়িৎ পরিবাহিতা নিয়ে বিভিন্ন গবেষণা আরম্ভ হয়। আগে বলেছি Exner-এর কথা। তিনিও এ বিষয়ে গবেষণা করছিলেন Ph.D ছাত্র Schrodinger এর সাথে। পরবর্তী জীবনে তাত্ত্বিক পদার্থবিদ্যায় গবেষণা করলেও Schrodinger-এর Ph.D. thesis ছিল “On the conduction of electricity on the surface of insulators in moist air”। ১৮৯৫ সালে বিজ্ঞানী Roentgen আবিষ্কার করলেন X-ray। ১৮৯৬ সালে বিজ্ঞানী Becquerel আবিষ্কার করলেন ইউরেনিয়াম মৌলের স্বতঃস্ফূর্ত তেজস্ক্রিয়তা ধর্ম। কিছুদিন পরেই Pierre ও Marie Curie পোলোনিয়াম মৌলেও তেজস্ক্রিয়তা সন্ধান পেলেন। তেজস্ক্রিয়তার কারণে মৌলগুলি স্বতঃস্ফূর্ত ভাবে রশ্মি বিকিরণ করে। দেখা গেল তেজস্ক্রিয় মৌলের উপস্থিতিতে তড়িৎবীক্ষণের পাতদুটি দ্রুত তড়িৎক্ষরণ করে। সুতরাং একদল বিজ্ঞানী ধারণা করেন, পৃথিবীর অভ্যন্তরে যে বিপুল তেজস্ক্রিয় মৌলের ভান্ডার রয়েছে, তা থেকে নির্গত তেজস্ক্রিয় বিকিরণের সাথে বাতাসের কণাগুলির আন্তঃক্রিয়ার ফলে ঘটছে ionization। কিন্তু Elser, Geitel, Wilson প্রমুখ বিজ্ঞানীরা তাদের পরীক্ষায় যে ফল পেলেন, তার ব্যাখ্যা তেজস্ক্রিয়তা দিয়ে সম্পূর্ণ ভাবে করা গেল না। প্রশ্ন উঠল, হয়তো এই ionization এর কারণ তেজস্ক্রিয়তা নয়, মহাজগৎ থেকে আসা কোন রশ্মি। ১৯০১ সালে Wilson লিখলেনঃ “We must conduct experiments to determine if the production of ions in the air free of impurities can be explained as arising from external sources, probably Rontgen radiation rays or cathode rays, but largely more penetrating”. এমন কি, তৎকালীন বিখ্যাত engineer ও পদার্থবিদ Nikola Tesla ১৯০১ সালে আমেরিকায় একটি power generator-এর পেটেন্ট নিয়েছিলেন। কারণ হিসেবে তার বক্তব্য ছিলঃ “the Sun, as well as other sources of radiant energy, throws off minute particles of matter [which] communicate an electrical discharge”। ১৯০৯ সাল পর্যন্ত যে সব পরীক্ষা হয়েছিল, তা থেকে বোঝা গিয়েছিল এই অজানা রশ্মির ভেদন ক্ষমতা (penetrating power) অত্যন্ত বেশী এবং পরীক্ষা ব্যবস্থায় যত অন্তরণ (insulation) ই থাকুক না কেন, এ রশ্মির প্রভাব সর্বত্র। বিজ্ঞানীরা বুঝতে পারছিলেন এই অজানা রশ্মির স্বরূপ নির্ধারণ করতে গেলে পরীক্ষা-নিরীক্ষা চালাতে হবে পৃথিবীপৃষ্ঠ থেকে উঁচুতে। কারণ উঁচুতে ওঠার সাথে পৃথিবীর তেজস্ক্রিয়তার প্রভাব কমে আসবে। পরীক্ষাগারের পরীক্ষায় এই রশ্মির স্বরূপ নির্ধারণ সম্ভবপর নয়।

এরপর আসা যাক জার্মান পাদরী Theodor Wulf-এর কথায়। Wulf ছিলেন পদার্থবিজ্ঞানী। ২০ বছর বয়সে তিনি পাদরী হয়ে যান। অবশ্য এতে Wulf-এর পড়াশোনা থেমে থাকেনি। গটিংগেন বিশ্ববিদ্যালয়ে Walther Nernst-এর কাছে পদার্থবিদ্যা পড়েছিলেন তিনি। অজানা রশ্মির স্বরূপ উদ্ঘাটনের জন্য আরো সূক্ষ্মভাবে পরীক্ষা করার জন্য Wulf তড়িৎবীক্ষণ যন্ত্রের বেশ কিছু পরিবর্তন করলেন। সোনার পাত দুটোর স্থানে লাগালেন “two strips of metalised glass in tension”। ১৯০৯ সালে জার্মানি, হল্যান্ড ও বেলজিয়ামের বিভিন্ন স্থানে তিনি পরীক্ষা চালালেন তার যন্ত্র নিয়ে। Wulf-এর ধারণা ছিল অজানা রশ্মির কারণ মৌলের তেজস্ক্রিয়তা। এরপর ১৯০৯ ও ১৯১০ সালে Wulf গেলেন প্যারিসে-আইফেল টাওয়ারের (উচ্চতা ৩০০ মিটার) মাথায় উঠে পরীক্ষা করলেন। কিন্তু ৩০০ মিটার উঁচুতে তেজস্ক্রিয়তা পরিমাণ যতটা কমার কথা ছিল পরীক্ষা থেকে তা পাওয়া গেল না। Wulf লিখলেন: বিকিরণের তীব্রতা “decreases at nearly 300m[altitude] not even to half of its ground value”। যদিও Wulf-এর নেওয়া data বহুদিন ধরে অন্যতম প্রমাণ্য data হিসেবে চালানোর জন্য বিজ্ঞানীরা আশ্রয় নিলেন বেলুন-পরীক্ষার। অজানা রশ্মির উৎস সন্ধান ১৯০৯সালে প্রথম বেলুনে চড়ে আকাশে গেলেন Karl Bergwitz। এর আগে অবশ্য Franz Linke -এর কথা জানা যায় যিনি ১৯০০ থেকে ১৯০৩ বার্লিন বিশ্ববিদ্যালয়ে গবেষণা করার সময় ১২ বার বেলুনে চড়ে আকাশে উড়েছিলেন। সঙ্গে ছিল Elster এবং Geitel এর তৈরি তড়িৎবীক্ষণ যন্ত্র। কিন্তু আশানুরূপ কোনো ফল Linke বা Bergwitz কারুর অভিযানেই পাওয়া যায়নি। বেলুনে চড়ে আকাশে গিয়ে এসব পরীক্ষা-নিরীক্ষার ক্ষেত্রে

প্রথম গুরুত্বপূর্ণ ভূমিকা গ্রহণ করেছিলেন Albert Gockel. Gockel ছিলেন University of Fribouring এর প্রফেসর। Bergwitz-এর অভিব্যানের কয়েকমাসের মধ্যেই Gockel বেলুনে চড়েছিলেন। সমুদ্রপৃষ্ঠ থেকে প্রায় ৪৫০০ মিটার পর্যন্ত উপরে উঠতে তিনি সক্ষম হয়েছিলেন তিনি। তিন-তিনবার বেলুনে চড়ে তিনি আকাশে যান এবং ৩০০০ মিটার উচ্চতা পর্যন্ত তিনি তড়িৎবীক্ষণ যন্ত্রের সাহায্যে অজানা রশ্মির খোঁজ চালান তিনি। Gockel লক্ষ্য করেছিলেন উচ্চতা বাড়ার সাথে ionization এর মাত্রার কোন হ্রাস ঘটে না। ১৯১০ সালে Gockel লিখেছিলেন: "a non-legible part of the penetrating radiation is independent of the direct action of the radioactive substances in the uppermost layers of the earth". সত্যি কথা বলতে কি, Gockel এর কপাল ছিল মন্দ। Schrodinger তাঁর Ph.D. গবেষণায় দেখিয়েছিলেন যদি তেজস্ক্রিয়তার কিছু অংশ পৃথিবী থেকে আর কিছু অংশ মহাজগৎ থেকে আসে, তবে ৩০০০ মিটার পর্যন্ত পৃথিবী থেকে প্রাপ্ত তেজস্ক্রিয় বিকিরণ মহাজগৎ থেকে আসা তেজস্ক্রিয় বিকিরণকে প্রশমিত করে দেয়। Gockel সাহেব যদি আরো কিছুটা উপরে চড়তেন, তাহলে তিনিই হয়তো মহাজাগতিক রশ্মি আবিষ্কারের পুরোধা হতে পারতেন।

যা হোক, কফিনে শেষ পেরেকটি পুতলেন Hess, অনেকে মনে করেন, Hess যেহেতু Schrodinger এর সাথে একই বিশ্ববিদ্যালয়ে গবেষণার কাজ করতেন, Hess, Schrodinger এর calculation এর সাথে পরিচিত ছিলেন। Hess জানতেন যে Gockel এর পরীক্ষায় কিছু গণ্ডগোলের কারণ ছিল Gockel এর যন্ত্রে উচ্চতার সাথে চাপের ভারতম্য হতো বেশ। ফলে গণনার ভুল হওয়ার সম্ভাবনা ছিল। Hess চাপ নিরোধক ionization chamber তৈরি করলেন।

Gockel এর মতো Hess ও ছিলেন পাকা বেলুন-উড়িয়ে। ১৯১১ থেকে ১৯১২-এই এক বছরে Hess বেলুনে উড়েছিলেন মোট দশবার। ১৯১১ সালে তিনবার আর ১৯১২ সালে সাতবার। ১৯১১ সালে প্রথমবার তিনি ১০৭০ মিটার পর্যন্ত উঠেছিলেন তিনি। পরীক্ষায় দেখলেন উচ্চতার সাথে ionization এর যে খুব একটা ভারতম্য হচ্ছে তা নয়। ১৯১১ সালে প্রকাশিত প্রবন্ধে Hess লিখলেনঃ "since the radiation of that height was not remarkably different from that at sea level, there must be another source of the penetrating radiation in addition to the gamma-radiation from the radioactive substances in the earth's crust." ১৯১২ সালের যে সাতবার বেলুনে চড়েছিলেন Hess তার মধ্যে দুটো উড়ান ছিল খুব উল্লেখযোগ্য। অনেকে



প্রশ্ন তুলেছিলেন এই রশ্মির উৎস হয়তো সূর্য। পরীক্ষার জন্য Hess ২৭৫০ মিটার উচ্চতায় উঠলেন। সূর্যগ্রহণ সত্ত্বেও Hess দেখলেন ২০০০ মিটার উচ্চতায় ও ionization এর তীব্রতা পৃথিবীপৃষ্ঠ থেকে বেশী। এর থেকে Hess সিদ্ধান্তে এলেন এই রশ্মির কারণ সূর্য নয়। এই বছরই সাত নম্বর বেলুন যাত্রায় হাইড্রোজেন ভর্তি বেলুনে চেপে ৭ই আগস্ট ৫৩৫০ মিটার উচ্চতায় উঠলেন তিনি। অষ্ট্রিয়ার এক শহর Aussig থেকে সকাল ৬টা ১২ মিনিটে উড়েছিল সেই বেলুন। প্রায় ৫ ঘণ্টা পর সে বেলুন দুপুরে এসে নেমেছিল জার্মানীর শহর Pieskow (বার্লিন থেকে ৫০ কিমি পূর্বে)। এ সমস্ত পরীক্ষার ফলাফল পুথানুপুথ্য রূপে পর্যালোচনার পর Hess তার বিখ্যাত সিদ্ধান্তে এলেনঃ বাতাসের কণাগুলির ionization এর মূলে রয়েছে মহাজগৎ থেকে আসা রশ্মিহোত। এই রশ্মির আগমন সূর্য থেকে আরো বহুদূরে থাকে অনন্ত, অসীম মহাবিশ্ব থেকে। ১৯১২ সালে Physikalische Zeitschrift পত্রিকায় Hess-এর বিখ্যাত প্রবন্ধ প্রকাশিত হয়ঃ "Observations in low level radiation during seven free balloon flights". পরীক্ষালব্ধ ফলাফল ব্যাখ্যা করে Hess তাঁর প্রবন্ধে যে মূল সিদ্ধান্তগুলিতে উপনীত হলেন সেগুলি ছিল এরকমঃ

"(i) Immediately above the ground the total radiation decreases a little (ii) At altitudes of 100m to 200m



there occurs again a noticeable growth of penetrating radiation. (iii) The increase reaches, at altitudes of 3000m to 4000m, already 50% of the total radiation observed on the ground. (iv) At 4000m to 5200m the radiation is stronger [more than 100%] than on the ground". নিশ্চিত ভাবে প্রমাণিত হল মহাজাগতিক রশ্মির অস্তিত্ব।

Hess লিখলেনঃ "The results of the present observations seem to be most readily explained by the assumption that a very high penetrating power enters our atmosphere from above, and still produces in the lowest layers a part of the ionization observed in closed vessels. since I found a reduction in the radiation at the balloon neither by night nor at a eclipse, one can hardly consider the Sun as the origin of this hypothetical radiation..."

এরপর অবশ্য বিভিন্ন পরীক্ষায় মহাজাগতিক রশ্মির অস্তিত্ব সন্দেহহীন ভাবে প্রমাণিত হয়েছে। ১৯২০ সালে Hess Graz বিশ্ববিদ্যালয়ে অধ্যাপক হিসেবে যোগ দেন। ১৯২১ সালে Hess যখন নিজের শহর Graz ফিরলেন, তখন জার্মানিতে একচ্ছত্র অধিপতি হিটলার। ইহুদী নিধন যজ্ঞে মেতে উঠেছিল তিনি। Hess এর স্ত্রী ছিলেন জাতে ইহুদী। সুতরাং কোপ পড়লো তাদের উপরেও। Hess এর চাকরি গেল। ভাগ্য ভালো, একজন সহানুভূতিশীল গেস্টাপো অফিসারের থেকে Hess জানতে পারলেন তারা অস্থিমায় থাকলে কিছুদিনের মধ্যে গ্রেপ্তার হবেন। তাদের চালান করে দেওয়া হবে concentration camp-এ। সুতরাং গ্রেপ্তারের প্রায় এক মাস আগেই Hess ও তার পরিবার পালালেন Switzerland-এ। ১৯৩৮ সালে USA-এর Fordham বিশ্ববিদ্যালয় থেকে আমন্ত্রণ আসে Hess এর কাছে। Hess আমেরিকা পাড়ি দিলেন। পরবর্তী জীবনটা Hess কাটিয়েছেন আমেরিকায়। ১৯৪৪ সালে তিনি আমেরিকার নাগরিক হন। চল্লিশের ও পঞ্চাশের দশকে মানব শরীরে রেডিয়ামের প্রভাব নিয়ে বহু মূল্যবান গবেষণা করেছিলেন তিনি। ১৯৬৪ সালের ৭ই ডিসেম্বর Hess মারা যান।

১৯৩৬ সালে মহাজাগতিক রশ্মি আবিষ্কারের জন্য নোবেল পুরস্কারে ভূষিত হয়েছিলেন তিনি। তাঁর সাথে সে বছর পদার্থবিদ্যার পুরস্কার পেয়েছিলেন পজিট্রন কণার আবিষ্কারক Anderson. Hess কে যে সমস্ত বিজ্ঞানী nominate করেছিলেন তাদের মধ্যে অন্যতম ছিলেন বিখ্যাত পদার্থবিদ Arthur Compton। নোবেল কমিটি কে পাঠানো রিপোর্টে Compton লিখেছিলেনঃ "The time now has arrived, it seems to me, when we say that the so-called cosmic rays definitely have their origin a such remote distances from the Earth that they may properly be called cosmic, and that the use of the rays has by now led to results of such importance that they may be considered a discovery of the first magnitude.... It is, I believe, correct to say that Hess was the first to establish the increase of the ionization observed in electroscopes with increasing altitude; and he was certainly the first to describe with confidence this increased ionization coming from outside the Earth."

Hess এর প্রতি সম্মানার্থে ২০০৪ সালে নামিবিয়ায় মহাজাগতিক রশ্মি নিয়ে গবেষণার জন্য তৈরি হয়েছে এক মানমন্দির (observatory). নাম দেওয়া হয়েছে HESS: High Energy Stereoscopic System.

তথ্যসূত্র

Atmospheric ionization and cosmoc rays: studies and measurements before 1912 Alessandro De Angelisa
arxiv: 1208.6527v1

Victor Franz Hess: A Short Biography Biman Nath, Resonance October 2007

Qiaozhen Xu and Laurie M. Brown The early history of cosmic ray research Am. J. Phys. 55. 23(1987);

Per Carlson, Alessandro De Angelis Nationalism and internationalism in science: the case of the discovery
of cosmic rays Eur. Phys. J. H 35, 309-329(2010).

চিত্রসূচী

http://www.mbpo.org/blog_details.asp?id=194

<http://www.nytimes.com/2012/08/07/science/space/>



Science Communication and Science Institutions : An Overview of Contemporary Kolkata

Arnab Kumar Banerjee*

Abstract: Science is mingled with decisions that are made at every level of our lives. From international environmental agreements, responses to occurrence of disease by community agencies, to many of the personal life style choices we make ourselves, understanding the science of the situation is essential for good decisions. Science communicating organizations basically transform scientific information into accessible understandable knowledge for the public. For the past two decades or so, science communication activities have gained momentum in India. Efforts have been made from both governmental and non-governmental platforms to enhance the public understanding of science. The idea is to help science and scientific culture penetrate India's socio-culturally diverse society, and to transform it into a nation with scientific orientation and of scientifically aware people. Before dealing with science communication in India terms like 'science' and 'communication' must be dealt separately. According to Raymond Williams, 'science' refers to "a whole body of regular or methodical observations or propositions...concerning any subject of speculation." Thus science becomes a kind of knowledge or argument rather than a subject. According to Merriam Webster Dictionary 'communication' means "an act or instance of transmitting" or "a process by which information is exchanged between individuals through a common system of symbols, signs, or behaviour". Science communication in Bengal has an age old history. Bangiya Bijnan Parishad, a pioneer science organization for cultivation and popularisation of science and scientific knowledge was founded in the year of 1948 by the collective efforts of all the eminent scientists and educationists of Bengal under the leadership of the great Savant Acharya Satyendra Nath Bose. Organizations like Central Glass and Ceramic Research Institute, Birla Industrial & Technological Museum, Indian Association for the Cultivation of Science, Saha Institute of Nuclear Physics, Indian Institute of Chemical Biology are also working hard to popularize science and also make the common mass aware of scientific knowledge. Their contribution is too much to be put to words. Although much has been achieved not only Bengal but also in India, there is still an urgent need to make science communication activities more effective, both in terms of quality and quantity. We have yet to take more positive measures to wipe out superstitions that have prevailed throughout the ages, particularly in the under developed tribal areas where literacy levels are low and superstition is a way of life. But we must not forget the contribution of the above mentioned institutes which will work as a push up for our future goals.

Science Communication and Science Institutions : An Overview of Contemporary Kolkata

Science is mingled with decisions that are made at every level of our lives. From international environmental agreements, responses to occurrence of disease by community agencies, to many of the personal life style choices we make ourselves, understanding the science of the situation is essential for good decisions.

Science communicating organizations basically transform scientific information into accessible understandable knowledge for the public. For the past two decades or so, science communication activities have gained momentum in India. Efforts have been made from both governmental and non-governmental platforms to enhance the public understanding of science. The idea is to help science and scientific culture penetrate India's socio-culturally diverse society, and to transform it into a nation with scientific orientation and of scientifically aware people.

Before dealing with science communication in India terms like 'science' and 'communication' must be dealt separately. According to Raymond Williams, science refers to "a whole body of regular or methodical observa-

*Dept. of Journalism & Mass Communication, Vivekananda College, Thakurpukur, Kolkata-700 063.
email: arnab_jour@yahoo.co.in M-09433304519



tions or propositions...concerning any subject of speculation." Thus science becomes a kind of knowledge or argument rather than a subject. According to Merriam Webster Dictionary 'communication' means "an act or instance of transmitting" or "a process by which information is exchanged between individuals through a common system of symbols, signs, or behaviour".

Kolkata enjoyed obvious advantages as the capital of British India till 1911. As in any other colonial city of the world, Kolkata witnessed the centralization of the organs of administration within its boundaries. To run their administration smoothly, the British introduced English education in the city. They set up colleges and universities which awarded degrees. In fact, the first college for Western style education in the country was set up in this city in 1817. It was named the 'Hindu College', later to be renamed as 'Presidency College'. The colleges and universities in Kolkata were basically designed to produce qualified clerks for the British administrative setup. But stalwarts like Raja Rammohan Roy and Iswar Chandra Vidyasagar felt the need for true scientific education instead of the useless stuff that the British East India Company (hereinafter referred to as 'Company') had included in the syllabus. Raja Rammohan Roy was the first to take up this issue with the directors of the Company. In a letter to Lord Amherst in 1823 he had expressed his deep anguish over the decision of setting up a Sanskrit school where there would be no scope for modern scientific learning for the students. He mourned that the Company had reneged on its earlier stated intention of imparting education in "useful sciences", the study of which had contributed to the advancement of several countries. He particularly stressed on the fact that the scientific philosophy of Roger Bacon should be introduced in the curriculum of Indian educational institutions. Iswar Chandra Vidyasagar took the struggle further. As a member of the faculty of the Sanskrit College he pressed on for the inclusion of Western sciences in the curriculum of the college. A mature scholar and visionary that he was, Vidyasagar did not hesitate to criticize the futility of learning from Hindu scriptures that was full of metaphysical ideas. He wrote that scientific philosophy should be introduced in the syllabus without delay in order to fight the pernicious effects of those metaphysical ideas on the society. The efforts of Iswar Chandra Vidyasagar did not meet with much success in the 1850s. In fact, when the University of Calcutta was established in 1857, there was a clear stress on humanities in the curriculum. This structure of the curriculum was said to be the brainchild of the dominant faculty of the humanities branch in the Oxford and Cambridge Universities. Though the University of Calcutta was designed on the model of the London University, science education was neatly ignored in the new-born University unlike in its London counterpart. In 1868, Asiatic Society stated emphatically that no student should be considered to be a matriculate unless he or she had a primary idea about natural history and physics. The Government of Bengal simply chose to ignore the suggestion. They maintained that teaching English language was the need of the hour. In fact, in 1872, the Government of Bengal paid little attention to the suggestion of its own Director of Education who had favored new science-centered education replacing old-fashioned courses. However, things started to change from the year 1872. The Bachelor of Arts course was divided into two sections- part A was devoted to humanities and part B to sciences. The course in sciences quickly gained popularity. In 1879, 191 out of a total of 373 students who passed out of the University of Calcutta belonged to the course for sciences. Thus, though belated, the struggle of Raja Rammohan Roy and Iswar Chandra Vidyasagar bore fruit. These two were, of course, not the only visionaries who had fought for the introduction of modern scientific education in Kolkata. Mahendra Lal Sircar, thirteen years younger to Vidyasagar, had proceeded to build up an infrastructure for active science research in Kolkata in the 1870s. This was an extremely difficult proposition at that time considering the fact that it was not even easy to get people interested to learn primary level science. Mahendar Lal Sircar, like Vidyasagar, believed that what passed as Hindu religious concepts were nothing but a mass of some baseless opinions on almost all subjects on earth. He believed that only scientific



education could free Hindu Bengalis from the shackles of those useless concepts. Standing firm on his belief, he went on to establish 'The Indian Association for the Cultivation of Science' in 1876. More about this institute has been included later in this chapter. Now, the British Government, on the surface, showed some interest in this institute. Sir Richard Temple, the then Lieutenant Governor was present in the inaugural programme of the institute. However, it later became clear that he was actually interested in producing some technicians from this institute who could serve the interests of the British Government. Mahendra Lal thought otherwise. He wanted his institute to impart scientific education in the true spirit of science. Utility based education was not his agenda. As his ideas differed from that of the British Raj, he ran into trouble in trying to collect funds for his institute. Rich zamindars or landlords who invariably sang the tune of the British Government chose to stay away from the Indian Association for the Cultivation of Science. The institute, the first of its kind in Kolkata and Bengal, could not blossom into the type of an organization its founder had dreamt of. It merely held on to its existence till the twenties of the next century when an exceptional scientist, C. V. Raman, brought glory to it through his Nobel-prize winning work.

It is apparent from historical accounts of the late nineteenth century and early twentieth century that the British rulers were not favorable to the idea of the Indians learning science in the way it was done back in their homeland, Great Britain. They were not ready to listen even to the suggestions of their compatriots if that differed with the official view. In 1897, world famous British scientists like Lord Kelvin, Joseph Lister, and William Ramsey etc. had proposed the setting up of an advanced laboratory to facilitate scientific research in India. By all possibilities Kolkata would have been the location for this laboratory had the proposal been approved. But the British Government in India paid no heed to the proposal of the scientists. In fact, the Government was not even ready to set up a good library to help Indian scientists returning from Europe. This apathy of the British Government frustrated many Indian scientists who had planned to do something big for science education and research in India. Most notable among them was Jagadish Chandra Bose. His effort to set up advanced research facilities in the city of Kolkata was stifled by the Government on a number of occasions. Finally, in 1917, he set up his own institute, named Bose Research Institute, in the city. The patriotic fervour that surrounded the establishment of this institute could be gauged from the great reception given to Jagadish Chandra Bose by the citizens of Bombay when he arrived there on a lecture cum fund-raising tour. The citizens contributed fifty thousand rupees to his fund in a single evening. The periodical 'Hindi Punch' wrote in its columns: "Such wild enthusiasm has never been recorded. Bravo Sir Jagadish, bravo the Bombay worshippers of knowledge, bravo the Bose Research Institute!"

It has to be noted here that a few positive changes other than the establishment of the Bose Research Institute took place in the early decades of the twentieth century which widened the scope of science learning in the city. Ashutosh Mukhopadhyay, a man with a towering personality became the Vice-Chancellor of the University of Calcutta in 1906. Owing to his untiring efforts, science education at the post-graduate level was introduced in the university. Infrastructure for scientific research was also set up. A decade onwards, Kolkata saw the establishment of a Science College under the auspices of the University of Calcutta. It was made possible with financial help from Rasbehari Ghose and Tarak Nath Palit. Prafulla Chandra Roy, the chemist with a great patriotic heart left Presidency College to join this Science College. Even Jagadish Chandra Bose joined this institution after retiring from Presidency College. He worked here until his own institute started operation. Nothing of these changes would have been possible without proper funding which came from wealthy landlords like Rashbehari Ghose and Tarak Nath Palit. In fact, their generosity towards science learning marked the end of a phase in which the moneyed landlords did not fund scientific research in the country in fear of offending the British rulers. The Science College set up and developed with the financial help from



these landlords quickly rose to fame riding on the shoulders of outstanding teachers and scientists like Meghnad Saha, Satyendra Nath Bose etc. Thus unfolded a saga, that of learning of science in the city of Kolkata. The success in this field is attributable not in the least to the British rulers but to Indians like Iswar Chandra Vidyasagar and Raja Rammohan Roy. These men succeeded because of their strong belief which in the words of Bertrand Russell is: 'Almost everything that distinguishes the modern world from earlier centuries is attributable to science'.

Science communication in Bengal has an age old history. Bangiya Bijnan Parishad, a pioneer science organization for cultivation and popularisation of science and scientific knowledge was founded in the year of 1948 by the collective efforts of all the eminent scientist and educationists of Bengal under the leadership of the great Savant Acharya Satyendra Nath Bose. Organizations like Central Glass and Ceramic Research Institute, Birla Industrial & Technological Museum, Indian Association for the Cultivation of Science, Saha Institute of Nuclear Physics, Indian Institute of Chemical Biology are also working hard to popularize science and also make the common mass aware of scientific knowledge. Their contribution is too much to be put to words. Although much has been achieved in not only Bengal but also India, there is still an urgent need to make science communication activities more effective, both in terms of quality and quantity. We have yet to take more positive measures to wipe out superstitions that have prevailed throughout the ages, particularly in under developed tribal areas where literacy levels are low and superstition is a way of life. But we must not forget the contribution of the above mentioned institutes which will work as a push up for our future goals.

BANGIYA BIJNAN PARISHAD

Bangiya Bijnan Parishad, a pioneer science organization for cultivation and popularisation of science and scientific knowledge was founded in the year of 1948 by the collective efforts of all the eminent scientists and educationists of Bengal under the leadership of the great Savant Acharya Satyendra Nath Bose, the National Professor. The chequered history of Parishad for the last sixty years illustrates how a powerful social movement, namely Science-Movement generated out of the ideas and values of such organisation. Now a days, Peoples' Science Movement spearheaded by so many groups across the country received inspiration directly or indirectly from Bangiya Bijnan Parishad.

Satyendra Nath Bose was always in favour of popularizing science. He strongly felt that it was duty to present science to the common man in his own language. For popularizing science Bose wrote in Bengali. This is the reason why his contribution in popularizing science is not known outside Bengal. It was largely Bose's efforts which led to the establishment of the Bangiya Bijnan Parishad (Science Association of Bengal), a registered society with the sole objective of promoting and popularizing science through the vernacular. The Parishad was formally inaugurated on January 25, 1948. The circular announcing the formation of the Parishad stated: "We need science at every step, but our system of education does not prepare us for it, so that we are not able to utilize science in our everyday life. The main obstacle so far was a foreign language through which education was being imparted. Today the ties have changed. New hopes and aspiration are emerging. Now it is the duty and the responsibility of our scientists to popularize science through the medium of our scientists to popularize science through the medium of vernacular and thus help to create a healthy scientific attitude among the people. As a first step to this effort it has been resolved to form a 'Bangiya Bijnan Parishad'. It was mainly through the inspired leadership of Professor Satyendranath Bose." The Parishad started a monthly magazine on popular science in Bengali, Jnan O Bijnan (Knowledge and Science). As part of his attempt in popularizing science through the vernacular Bose even started teaching Relativity to post-graduate students in colloquial Bengali.

It is note worthy to mention that to raise interest about science among the students Bangiya Bijnan Parishad



ushered in two different programmes namely, 'Gyan O Bijnaner Asor' and 'Prokriti Poruar Pathsala'. In order to encourage the younger scientists it also arranged awards like Gyan O Bijnan Puroshkar in 1995 and Ramendrasundoor Smriti Puroshkar in 1997. Not only this, it also celebrates occasions like 'World Environment Day', 'Hiroshima Day' and so on.

Bangiya Bijnan Parishad is such an organization which always tries to create awareness among mass following Bose's footsteps and it must be remembered that in communicating science through vernacular it was the first institute not just in Bengal but also in India.

Bangiya Bijnan Parishad, a pioneer science organization for cultivation and popularisation of science and scientific knowledge was founded in the year of 1948 by the collective efforts of all the eminent scientist and educationists of Bengal under the leadership of the great Savant Acharya Satyendra Nath Bose, the National Professor. The chequered history of Parishad for the last fifty years illustrates how a powerful social movement, namely Science-Movement generated out of the ideas and values of such organisation. Now a days, Peoples' Science Movement spearheaded by so many groups across the country received inspiration directly or indirectly from Bangiya Bijnan Parishad.

CENTRAL GLASS AND CERAMIC RESEARCH INSTITUTE (CGCRI)

Central Glass and Ceramic Research Institute (CGCRI), one of the foremost laboratories in the family of the Council of Scientific and Industrial Research was formally inaugurated on August 26, 1950 by Dr. B.C. Ray, the then Chief Minister of West Bengal in presence of eminent personalities : Dr. Shyama Prasad Mukherjee, Prof. C.V. Raman, Dr. Meghnad Saha and others. Dr. S.S. Bhatnagar was then Director-General of CSIR while Dr. Atma Ram was Director of the Institute. CGCRI, initially conceived as Central Glass and Silicate Research Institute along with NPL-New Delhi, NCL-Pune and CFRI-Dhanbad (now CIMFR) is among the first four CSIR laboratories planned in the pre-independence era.

In the early phases, the R&D activities of Institute concentrated mainly on the benefaction and characterization of raw materials of interest to glass and ceramics. An early R&D breakthrough was the indigenous development and production of optical glass. As times changed, the Institute expanded its scope and embraced newer areas of materials science. Today, CGCRI is the only research laboratory in India engaged in the development of glass, ceramics and ceramics based composite materials. A wide expertise pool generated through years of devoted efforts spans from basic research to technology development at bench and prototype scales.

A major achievement of the institute has been the turnaround in its image in the last one decade. The Institute rose to progress in all fronts namely the network and mission projects, large number of international collaborations, peer recognitions, service to the strategic, industrial and societal sectors, world class facility and infrastructures created and the tie ups with the Institution and universities both at home and the overseas. Currently the Institute is engaged in six sectors namely Materials, Minerals & Manufacturing, Communication & Instrumentation, Health Care, Energy & Environment, Water Technology and Rural Development out of the sixteen technology sectors that are of national priority in the eleventh five year plan. In tune with the global R&D scenario, the Institute has augmented a couple of frontier areas - Solid Oxide Fuel Cells and Nanostructured Materials besides its involvement in the high-tech areas: Specialty Glasses, Fibre Optics & Photonics, Bio-ceramics & Coating, Engineering Ceramics inclusive of Refractory, Composites and Non-Oxide Materials, Advanced Clay & Traditional Ceramics, Ceramic Membranes and Ceramic based Sensor and Actuators. The dimension of materials spans wide: tiny nano-particles to the big slab and blocks; a chain of state-of-the-art material characterization facilities provides the essential back up support to R&D in various areas. Fresh



initiatives are now under way to identify mega projects and areas where Institute can fortify itself in future.

SOCIETAL PROJECT / MISSION

Sl.No.	Title of Projects	Duration	Source of Funding	Principal Investigator	Co- Investigator (s)
1.	Nanomaterials and nanodevices in health and disease	2007-2012	Govt. Agency	Dr. D. Basu	Dr.Jui Chakraborty
2.	New insights in cancer biology P.S. Sen identification of novel targets and development of target based molecular medicine	2007-2012	Govt.	Dr. M.K. Sinha	D. Basu, B.Kundu,
3.	Development of selected medical implants	2005-2011	Govt. Agency	Dr. D.Basu	M.K.Sinha, S.Datta, S. Gangadharan, D. Bhattacharya, L.K. Naskar, J Chakraborty, A. Das Gupta
4.	Development of bio-ceramic based implants for rehabilitation	2008-12	Govt. Agency (partly funded by SIOR and PHS, Pune)	Dr. D. Basu	Dr. S.Datta,
5.	Development of bioactive ceramic coating on orthopedic implants (metallic) for sustained, localized delivery of biophosphonates to improve fixation	2009-2011	Govt. Agency	Dr. Jui Chakraborty	Dr. D.Basu, Dr. S.Datta



6.	Development of functionally graded patient specific orthopedic implants by rapid prototyping technique and their evaluation in-vitro & in-vivo	2009-2012	Govt. Agency	Dr. D. Basu	Mr. B. Kundu, Dr. A. Bandyopadhyay, WSU, USA
7.	Upgradation of clay pottery cluster at Matigara, Siliguri.	November, 2009 to July, 2010. Likely to continue	Govt. of W. Bengal	T.K. Mukhopadhyay	
8.	Technological upgradation of Murlu roofing tiles cluster, Bankura.	March, 2010 to September, 2010. Likely to continue	Govt. of W. Bengal	T.K. Mukhopadhyay	S. Ghatak
9.	Implementation of Bone China technology at CCRD, Panchmura, Bankura and assess the techno-economic viability of the same.	Ongoing since May, 2005	TIFAC and W. Bengal Govt.	T.K. Mukhopadhyay	
10.	Development of glazed terracotta products at Ranibandh, Bankura	1997-2000	DST, New Delhi	S. Chakraborti	T.K. Mukhopadhyay



11.	Pilot Scale Demonstration of 15 Ceramic Membrane Based Iron Removal Plants	2008-2011	Govt.	Dr. Sibdas Bandyopadhyay	Mr. T.K. Ghoshal(Co-PI) Mr. S Sensarma
12.	Development of Technology System for River Water Purification using MF/RO Membrane for Drinking Water Supply, Hasnabad Block (Jointly with CSMCRI, Bhavnagar)	2005-2011	Govt.	Dr. Sibdas Bandyopadhyay	Mr. Swachchha Majumdar(Co-PI) Mr. Subhendu Sarkar
13.	Design & Fabrication of high capacity ceramic membrane module and arsenic removal plants for attachment to contaminated deep tube wells	2004-2008	Govt.	Dr. Sibdas Bandyopadhyay	Mr. Swachchha Majumdar Mr. Subhendu Sarkar
14.	Pilot Scale Demonstration of Ceramic Membrane Based Iron Removal Plants in the North Eastern States	2004-2009	Govt.	Dr. Sibdas Bandyopadhyay	Mr. T.K. Ghoshal Mr. S Sensarma
15.	Up Scaling and Pilot Scale Demonstration of Ceramic Membrane Based Iron Removal Plants in West Bengal	2004-2009	Govt.	Dr. Sibdas Bandyopadhyay	Mr. Swachchha Majumdar Mr. T.K. Ghoshal Mr. Subhendu Sarkar



16.	Installation of Arsenic Treatment Unit using Ceramic Membrane Module Developed by CGCRI	2002 - 2004	Govt.	Dr. Sibdas Bandyopadhyay	Mr. Mainak Majumdar
17.	Upscaling of ceramic filter and system design for potabilisation of sub-surface water and arsenic contaminated groundwater for community supply	2001 - 2003	Govt.	Dr. Sibdas Bandyopadhyay	Dr. S.N. Roy

BIRLA INDUSTRIAL & TECHNOLOGICAL MUSEUM

The premise of Birla Industrial & Technological Museum, now 19A, Gurusaday Road, was known as 18, Ballygunge Store Road before 1919. Record shows that the Tagores purchased it from Mirza Abdul Karim in 1898. Meera Devi, the fourth of Rabindranath Tagore's five children, spent a large part of her childhood in this house. From Surendranath Tagore, G.D. Birla bought the property in 1919 and from henceforth came to be known as Birla Park.

After the Birlas took over the property, there were major changes. The house used by the Tagores was pulled down and architects N. Guin & Co. were called upon to design the main building structure as we see today. It is a colonial adaptation of a mixture of various styles of European Art.

With the Birlas as the new owner, 19A, Gurusaday Road (Birla Park) continued to be a special address. Luminaries like C.R. Das, Arobindo Ghosh, Sister Nivedita, Rashbehari Ghosh, Anandamohan Sen, and other important foreign visitors like Kakuzo Okakura, Yokoyama, Tikan, Hishida and Katusta, all famous Japanese artists, frequented it at the time of Tagores. Again close association of G.D. Birla with nationalist leaders brought Mahatma Gandhi, Motilal Nehru, Lala Lajpat Rai, Pundit Madan Mohan Malaviya to Birla Park. It may be of some interest to know that it was here that Chiang Kai-Shek met Mahatma Gandhi.

Now from Birla Park to Birla Museum is an interesting story. In 1956, Dr. B.C. Roy, the then Chief Minister of West Bengal, foresaw a big role of such Museums of Science, Technology & Industry in a developing country. This idea also matched with that of Shri G.D. Birla and the magnanimous Birla Park with its imposing building and five bigas surrounding space was handed over by him to Pundit Jawaharlal Nehru, the then Prime Minister of India for setting up a science museum in Kolkata.

After that, the transformation from a luxurious residence of historical importance to a public museum took exactly three years and the Museum was thrown open to the public on 2nd May 1959 by Union Minister Prof. Humayun Kabir, in presence of Dr. B. C. Roy, Sri B. M. Birla and Prof. M. S. Thacker, the then Director General of CSIR.



Backtracking down the memory lane, we find that during the first few years of its inception, BITM opened galleries on a) Iron & Steel b) Copper c) Petroleum d) Electricity e) Nuclear Physics and f) Motive Power. Then, one by one, Communication (1963), Mining (1964), Popular Science (1965), Electronics & T.V (1966), Transport (1973) galleries were added subsequently. Mock-up Coal Mine was inaugurated in 1983.

From the very beginning Popular Lectures and Film Shows got underway. Science Demonstration Lectures for students became a feature of BITM from 1965. The same year also saw the pioneering effort of BITM - the Mobile Science Exhibition (MSE). The first exhibition on wheels through MSE was 'Our Familiar Electricity'. The concept of Model Making Competition, popularly known as Science Fair can be traced back to 1967 and the very next year, the first Teachers' Training Programme was launched. Gaining a strong foothold in the city, BITM thought of going to the rural Bengal to spread the message of Science. In 1982, the first satellite unit of BITM, the District Science Centre at Purulia was opened.

From then on till date, Birla Industrial & Technological Museum, the first Scientific and Industrial Museum in this country have come a long way. With its various galleries, multifarious activities and ever increasing chains of satellite centres, it has become a place where Science happens in front of one's eyes through animated and interactive models. Side by side, the history of Technology and Industry rejuvenates itself to the visitors through real or scale down replicas.

DEVELOPMENT: In its mission to modernize and upgrade its activities and facilities from time to time, BITM is constantly developing new galleries and giving a facelift to the existing ones. In the new millennium BITM has added to its kitty the galleries on Mathematics, Life Science, Biotechnology, Metals, Fascinating Physics, Television. The ones, that got a face-lift, were the Motive Power, Transport, underground Mock up Coal Mine with 'light & sound show' and Popular Science. In the queue are the galleries for Children's and on Communication. A large exhibit -Dynamic Globe was added in recent past. 3D Show was added in 2006. In the area of Mobile Science Exhibition, units on Fun Science, Emerging Technologies, Mathematics, Global Changes etc. have generated a lot of interest among the rural masses. An exhibition currently on display in BITM is 'A world in Darkness' for the visually challenged people. Keeping in mind the importance practical experimentation, interactive multimedia softwares Virtual Laboratories on 'Chemistry' and 'Zoology' have been developed and are currently available from BITM reception. 2500 sq.ft. air-conditioned hall regularly host exhibitions on science & technology organized by BITM. Subject to availability, it is also given to other institutions, for holding exhibitions on scientific topics, against license fee.

INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE

The Indian Association for the Cultivation of Science (IACS), founded on July 29, 1876 by Dr Mahendra Lal Sircar, is an autonomous Institute. It is the oldest research institute in India. The institute is devoted to the pursuit of fundamental research in the frontier areas of Physics, Chemistry, Biology, Energy, Polymer and Materials. In each field, IACS nurtures young and innovative research fellows in their doctoral programs. Sir C. V. Raman worked at IACS during 1907 to 1933 on various topics of Physics making discovery of the celebrated effect on scattering of light in 1928, which bears his name and that brought many accolades including the Nobel Prize (Noble Lecture by Sir C V Raman and Presentation Speech by Professor H. Pleijel, Chairman of the Nobel Committee) in 1930. The American Chemical Society designated the Raman Effect as an International Historic Chemical Landmark in 1998.

The Indian Association for the Cultivation of Science, established in July 1876 at 210 Bowbazar street, Kolkata, is a national institution for higher learning whose primary purpose is to foster high quality fundamental research in frontier disciplines of the basic sciences. Founded by Dr. Mahendra Lal Sircar, a philanthropist, the



activities at the Association in the very early years were supported by generous public contributions. It was conceived and planned in the backdrop of the great cultural and intellectual awakening of the nineteenth century Bengal and was desired by its founder to be an institution 'solely native and purely national'. The original objective of the Association, which continues even today, was to cultivate science in all its departments both with a view to its advancement by original research and to its varied applications to the arts and comforts of life.

Till the early decades of this century the Association was the only place in India where higher research in Physical Sciences could be carried out. As a result students from all over India began assembling at Calcutta to work in the creative atmosphere of the Association. Many distinguished scientists of modern India had carried out research here. This was the place where Sir C V Raman did his monumental work, on Physical Optics leading to the discovery of the celebrated Effect which bears his name and won for him and India the first Nobel Prize in Science. K S Krishnan, S Bhagavantam, K Banerjee, L. Srivastava, N K Sethi, C Prasad and M N Saha are some illustrious names out of scores of other eminent Indian Scientists who also worked here and enriched the research culture of the Association in the early decades.

In 1946 the Association embarked upon a new development plan under the dynamic leadership of Dr. Meghnad Saha envisaging the creation of an active research school for investigation on the problems continuing with the fundamental studies in X-rays, Optics, Magnetism, and Raman Effect in which the Association had specialised in early years. A new campus was opened at Jadavpur which became a sprawling complex of educational research and industrial establishments, where the laboratories were shifted from Bowbazar Street. Dr. Bidhan Chandra Roy played a key role to provide the land for the new campus in jadavpur through a gazette notification of November 20, 1947 of government of West Bengal .

Now it is an autonomous institution which controlled by a General Body and Governing Council. IACS receives fund from the Department of Science and Technology (DST), Government of India and Government of West Bengal, many Public agencies (DST, CSIR, DAE, MNES etc.), Private Companies as well as Foreign sources (NSF, UNDP, Japan, European Union, Sweden etc.). A number of specific projects raised by individual scientists or groups of scientists are being supported by different funding agencies such as CSIR, DAE, DNES, DST, DOS, DSIR, ICMR, INSA, NSF, UGC and UNDP. At present there are about 80 faculty members working in physics, and chemistry. The present Director of the Institute is Prof. Kankan Bhattacharyya. The Institute has dynamic programmes for the pursuit of research leading to the doctoral degree and for post-doctoral work and has Visiting Scientists Scheme. There is an excellent library, good computing facilities and is connected to Internet.

CAMPUS: Located in South Kolkata (you will find a guide to Calcutta here) the Institute is adjacent to the Jadavpur University and Indian Institute of Chemical Biology. The quiet surroundings and a commitment to a green environment make IACS a haven for scholarly pursuits. Situated in Jadavpur, the institute enjoys the conveniences of the metropolis and yet is withdrawn from the bustle of the city center. The main building house the Auditorium (MLS Hall), Seminar Rooms, Council Room, almost all departments, administrative hall etc. Within the walled campus there is a modern library, Energy Research Building, Biological Chemistry Building, Computer Centre, Workshop, Liquid Nitrogen Facility, Canteen, essential staff quarters, Research Scholars' hostels, pool, play ground and a beautiful lawn. The land area of the Association premises is 9.54 acres

ACADEMIC PROGRAMMES

DOCTORAL PROGRAMME

Motivated students aspiring to do high quality research in Physics and Chemistry are selected every year. The



selection is through an interview. The students have access to all facilities in the institute and can stay in the hostel within the institute campus.

POST-DOCTORAL PROGRAMME

Candidates with a PhD degree from leading institutions are encouraged to apply for Post-doctoral fellowships tenable for a period of one to two years.

The primary objective is to offer research oriented multi-disciplinary courses, including not only the basics of Organic, Inorganic, Physical and Analytical Chemistries but also covering modern areas of Material Science and Biology which bear a close kinship and an almost compulsory overlap with these traditional branches.

Summer School on Basic Sciences for School Leaving Students

The theme of this program is to drive home the point that understanding a subject is the first step to loving the subject, that true love comes from true understanding and eventually this abstract love can be real enough to partially counter the love for material well-being. The school normally begins in the last week of April after the IIT JEE and the state JEE are over and runs for two months. There are normally two to four lectures per day, five days a week making a total of 80 lectures. The afternoon session involves computer classes - both theoretical and practical. The lectures are basically of three categories

- A) 6-9 lecture course on the basics of a subject
- B) 2-4 lecture course on some frontier area
- C) Special lectures on diverse topics

SUMMER PROJECT FELLOWSHIP

Applications are normally invited from the under-graduate and post-graduate students of mathematical, physical, chemical and biological sciences/ Engineering of the allied discipline of Indian Universities/Institutes/Colleges for the posts of Summer Project Fellow at IACS during March - April. Each Fellowship is tenable for two months.

VISITING SCIENTISTS PROGRAMME

Internationally reputed, front-ranking scientists from the world over visit the Institute frequently for periods ranging from a few weeks to several months. They collaborate with the IACS scientists and give seminars and colloquia. Over the years IACS has been privileged to have several Nobel Laureates and Fields Medalists among its distinguished visitors.

ACADEMIC MEETINGS

Workshops and Symposia in various fields are organized frequently by the Institute. We also take part in the Theoretical Physics Seminar Circuit (TPSC) under which physicists can visit leading research centers in India and lecture on their work. IACS actively participates in advanced schools like those conducted by the Science and Engineering Research Council (SERC) of the Department of Science and Technology (DST). The Institute actively encourages its members to collaborate with scientists elsewhere, and provides the required help.

HISTORY: Founded on July 29, 1876 by Dr Mahendra Lal Sircar, IACS is the oldest institute in India devoted to the pursuit of fundamental research in the frontier areas of basic sciences. Professor C V Raman worked at IACS during 1907 to 1933, and it is here that he discovered the celebrated Effect that bears his name and for which he was awarded Nobel Prize in Physics in 1930.

Activities of the Association at 210 Bowbazar Street, Calcutta, in the very early years were supported by generous public contributions. It was conceived and planned in the backdrop of the great cultural and intellec-



tual awakening of the nineteenth century Bengal and was desired by its founder to be an institution 'solely native and purely national'. intellectual The original objective of the Association, which continues even today, was to cultivate science in all its departments with a view to its advancement by original research and its varied applications to the arts and comforts of life. In the early phase, the list of lecturers in Science in IACS included all the luminaries of the era: Father Lafont, Jagadish Chandra Bose, Asutosh Mukherjee, Chunilal Bose and Pramathanath Bose. Pandit Iswar Chandra Vidyasagar and Kesab Chandra Sen were among the members of the first Trustee Board of IACS, with Dr. Sircar himself as the first Honorary Secretary. Apart from these great scholars, the stalwart public figures like Gurudas Banerjee, Rajendralal Mitra and Surendranath Banerjee were its patrons. Raja Peary Mohan Mukherjee was the first Indian to take the position of the President of IACS in 1912. His other distinguished successors have been Dr. Nilratan Sircar, Jnan Chandra Ghosh and Satyendra Nath Bose.

The IACS entered a new phase with the emergence in the scene of C V Raman in 1907. He initiated serious research in IACS as a part-time worker, while carrying out his duties in the Accountant General's office in Calcutta - under the inspiring leadership of Dr. Sircar's son Amrita Lal Sircar - the then secretary of IACS. The rest was history. The celebrated Raman Effect was discovered in 1928, which culminated in Raman's receiving the Nobel Prize in Physics in 1930. Raman started a vibrant school of research, which attracted quite a few talented scientists, who furthered the progress of research along Raman. After the departure of Raman, K S Krishnan started the pioneering school of modern magnetism and structural physics. K Banerjee pioneered the early development of the direct method of crystallography

Till the early decades of this century the Association was the only place in India where higher research in Physical Sciences could be carried out. As a result, students from all over India began assembling at Calcutta to work in the creative atmosphere of the Association. Many distinguished scientists of modern India had carried out research here. S Bhagavantam, L Srivastava, N K Sethi, C Prosad, M N Saha and a host of other eminent Indian Scientists worked here to enrich the research culture of the Association

INDIAN INSTITUTE OF CHEMICAL BIOLOGY

The Institute was established in 1935 as the first non official centre in India for biomedical research and was included within the aegis of CSIR in 1956. IICB today is engaged in research on diseases of national importance and biological problems of global interest, employing sophisticated state-of-the-art technology in keeping with the rapid and unprecedented momentum that life science research has gained globally over the last 50 years. The scientific staff has expertise in a variety of areas including chemistry, biochemistry, cell biology, molecular biology, neurobiology and immunology which promotes productive interdisciplinary interaction. IICB is one of the major laboratories in India which initiated, right from its inception, multidisciplinary concerted efforts for conducting basic research on infectious diseases, specifically leishmaniasis and cholera, along with the development of technologies for the diagnosis, immunoprophylaxis, and chemotherapy of the diseases. A neurobiology group is involved in research on the development of the vertebrate brain and also the genesis of human movement disorders. Bioactive substances from natural sources and chemically synthesized new molecules are being explored as potential drugs. Other areas being actively pursued are gastric hyperacidity and ulcer, muscular dystrophy and related disorders, macromolecular structure function analysis, development of targeted drug delivery systems, sperm biology and protein chemistry and enzymology.

The institute has developed an oral vaccine for cholera, herbal products for controlling gastric ulcer, empirical treatment for vitiligo, diagnostic kits for malignancy and hormonal disorders, fungal enzymes of industrial importance, radiopharmaceuticals for evaluation of the functional status of renal and hepatobiliary systems and



a device for early detection of Parkinson's disease. Although the strength of IICB has always been basic biomedical research, during the last decade emphasis is being given on goal oriented research directed towards commercial exploitability. Efforts are now on to convert the knowledge gained over the years through high quality basic research into wealth.

SAHA INSTITUTE OF NUCLEAR PHYSICS

The Institute grew out of the Palit Research Laboratory in Physics of the University of Calcutta (CU). Professor M N Saha came back from Allahabad in 1938 to succeed Sir C V Raman in the Palit Chair of Physics. In the discovery of Nuclear Fission by Otto Hahn and Fritz Strassman in 1939, he had seen immense potential of nuclear science for betterment of the country. By 1940 he had had the syllabus of the Post-Graduate Physics reorganised to include Nuclear Physics in the Physics curriculum. Multifarious experiments in Nuclear Physics and instrumentation had started in his laboratory. Soon a small-scale cyclotron was felt necessary for gaining a first-hand knowledge in this virgin field. He decided to have it built here rather than buying one. Thanks to Jawaharlal Nehru's help and Dorabji Tata's generosity, fund was soon available for procurement of parts of the machine. Courtesy to the University a piece of land became available within the University College of Science campus in Rajabazar at 92 Upper Circular Road (now known as Acharya Prafulla Chandra Road) for erecting a building to house the machine. In fact, the laboratory was already too small to contain the spate of activity. Soon after laying of the Foundation Stone for the building by Dr Syamaprasad Mookerjee the Institute of Nuclear Physics was founded. The year is 1949. When the building was formally inaugurated by Madame Irene Joliot-Curie on 11 January 1950, a date now accepted as the Foundation Day, the Institute was fully functional. Foundation stone for a students' Hall, on a piece of land just behind the campus was laid by K D Malavya in early January, 1956. A few days later, on 16th February Professor Saha passed away. Some time after this the Institute was renamed as Saha Institute of Nuclear Physics.

The Biophysics group in the Palit Laboratory had moved in the new building as soon as it was complete. It soon became a Division and called for a separate building to which it moved out in 1964. It was located in the northern part of the city of Kolkata called Belgachia.

The Institute shifted to its new building in Bidhannagar in the late eighties. The Biophysics Division also shifted completely to the Bidhannagar campus after 2000. Basic research is carried out in frontline areas of Physical, Electronic and Biophysical sciences. Such activity is coordinated by various research divisions in the institute. The institute also has various teaching and training programs.

The Institute grew out of the Palit Research Laboratory in Physics of the University of Calcutta (CU). Professor M N Saha came back from Allahabad in 1938 to succeed Sir C V Raman in the Palit Chair of Physics. In the discovery of Nuclear Fission by Otto Hahn and Fritz Strassman in 1939, he had seen immense potential of nuclear science for betterment of the country. By 1940 he had had the syllabus of the Post-Graduate Physics reorganised to include Nuclear Physics in the Physics curriculum. Multifarious experiments in Nuclear Physics and instrumentation had started in his laboratory. Soon a small-scale cyclotron was felt necessary for gaining a first-hand knowledge in this virgin field. He decided to have it built here rather than buying one. Thanks to Jawaharlal Nehru's help and Dorabji Tata's generosity, fund was soon available for procurement of parts of the machine. Courtesy to the University a piece of land became available within the University College of Science campus in Rajabazar at 92 Upper Circular Road (now known as Acharya Prafulla Chandra Road) for erecting a building to house the machine. In fact, the laboratory was already too small to contain the spate of activity.

Soon after laying of the Foundation Stone for the building by Dr Syamaprasad Mookerjee the Institute of



Nuclear Physics was founded. The year is 1949. When the building was formally inaugurated by Madame Irene Joliot-Curie on 11 January 1950, a date now accepted as the Foundation Day, the Institute was fully functional. Foundation stone for a students' Hall, on a piece of land just behind the campus was laid by K D Malavya in early January, 1956. A few days later, on 16th February Professor Saha passed away. Some time after this the Institute was renamed as Saha Institute of Nuclear Physics.

The Biophysics group in the Palit Laboratory had moved in the new building as soon as it was complete. It soon became a Division and called for a separate building to which it moved out in 1964. It was located in the northern part of the city of Kolkata called Belgachia.

The Institute shifted to its new building in Bidhannagar in the late eighties. The Biophysics Division also shifted completely to the Bidhannagar campus after 2000. Basic research is carried out in frontline areas of Physical, Electronic and Biophysical sciences. Such activity is coordinated by various research divisions in the institute. The institute also has various teaching and training programs.

Initially a part of the University of Calcutta, the Institute was accorded autonomy in 1951. Since then a Governing Body (Council from 1972), chaired by the Vice-Chancellor of the University of Calcutta and having representatives from the University of Calcutta, the Union Government and the Government of West Bengal, was in the management until 1992 when this tripartite agreement came to an end. The Institute entered a contract with the Department of Atomic Energy, Government of India by which SINP retains its autonomy with the administrative control now passing on to the DAE. It has the recognition of the University of Calcutta as a Centre for conducting research for doctoral degrees and providing facilities for teaching and research in Physical and Biological Sciences. The Chairman of the Atomic Energy Commission, India (and Secretary, DAE, Govt of India) chairs the governing council with members comprising three scientists nominated by the DAE, two representatives of the DAE, two nominees of CU, one nominee of Govt. of West Bengal and the Director of the Institute.

SURVEY ANALYSIS

The sample survey has been randomly conducted among 110 respondents. Among them ten have expressed their extreme lack of knowledge about the science institutes of Kolkata. Thus the analysis will be based on the other hundred respondents who know more or less about the science institutes. The first question of our sample survey is "Do you have any idea regarding the existing science institutes of Kolkata?" 110 respondents have been asked this particular question. Rest of the questions is being asked to hundred respondents.

The second question of our sample survey is "Do you think that the science institutes are popular to the common mass?"

Among the 100 respondents 35 have said 'yes', 25 said 'no', 30 said 'more or less' and 10 said 'don't know'. It seems that majority holds a positive perspective about the popularity of science institutes in Kolkata.

The third question of our sample survey is "Are you aware of the activities carried out by the science institutes?"

Among the 100 respondents 30 have said 'yes', 40 said 'no', 20 said 'more or less' and 10 said 'scarcely'. It seems that majority lacks the knowledge of the activities of science institutes in Kolkata.

The fourth question of our sample survey is "Do you think that the science institutes in Kolkata must be more active to enter the public arena?"

Among the 100 respondents 50 have said 'yes', 10 said 'no', 30 said 'definitely' and 10 said 'don't know'. It seems that majority holds the perspective that the science institutes in Kolkata must be more active to enter among the mass.



The fifth question of our sample survey is "Where from do you get the information about the activities of the science institutes?"

Among the 100 respondents 30 have said 'directly from the institute', 15 said 'other sources', 30 said 'from media' and 25 said 'don't get'. It seems that media plays a major role to disseminate information about the science institutes in Kolkata.

The sixth question of our sample survey is "How far the innovations or activities of the science institutes are useful to the common mass?"

Among the 100 respondents 20 have said 'extremely', 15 said 'to a certain extent', 30 said 'rarely' and 35 said 'don't know'. It seems that the activities or innovations of science institutes in Kolkata are less useful to the mass.

The seventh question of our sample survey is "Have you ever visited the science institutes of Kolkata?"

Among the 100 respondents 25 have said 'many times', 15 said 'sometimes', 30 said 'rarely' and 30 said 'no'. It seems that the common mass is not that much in touch with the science institutes in Kolkata.

The eighth question of our sample survey is "Do you think that the science institutes of Kolkata are holding leading position in India?"

Among the 100 respondents 35 have said 'yes', 15 said 'definitely a few', 25 said 'no' and 25 said 'don't know'. It seems that majority holds a positive perspective about the popularity of science institutes of Kolkata at national level.

The ninth question of our sample survey is "Do you think that there must be more science institutes in Kolkata?"

Among the 100 respondents 50 have said 'yes', 10 said 'no', 30 said 'perhaps' and 10 said 'don't know'. It seems that majority holds the perspective that there should be more science institutes in Kolkata.

The tenth question of our sample survey is "What should be the future plans of the existing science institutes in Kolkata?"

Among the 100 respondents 60 have said 'Extend their activity among the mass', 20 said 'To be more committed to their research projects', 15 said 'Continue with their existing plans' and 5 said 'don't know'. It seems that majority holds the perspective that the science institutes in Kolkata must widen their activities among the mass.

REFERENCES

<http://www.arvindguptatoys.com/arvindgupta/bs14snbose.pdf> accessed on 2.10.2012

<http://www.vigyanprasar.gov.in/scientists/snbose/bosenew.htm> accessed on 2.10.2012

<http://www.bangiyabijnanparishad.in> accessed on 2.10.2012

Websites: http://en.wikipedia.org/wiki/Post-industrial_society & [http://ssr1.uchicago.edu/PRELIMS Political/promisc1.html](http://ssr1.uchicago.edu/PRELIMS_Political/promisc1.html) accessed on 3.8.12.

Ghose Benoy, 1994. *Metroplitan Mon-Madhyabitta-Bidroha*, Orient Longman Limited, Kolkata, *Selected Works of Raja Rammohan Roy*, Publications Division, New Delhi, 1977

Ghose Benoy, 1973. *Vidyasagar-o Bangali Samaj*, Orient Longman, Kolkata,

Kumar Deepak, 1995. *Science and the Raj*, Oxford University Press, Delhi,

Lahiri Ashish, 2002. *Anya Kono Sadhanar Fal*, Pavlov Institute, Kolkata,

Aparajito (a periodical), Special issue on Jagadish Chandra Bose, January-June, 2004



- Russell Bertrand, 1993. *History of Western Philosophy*, Routledge, London,
- Majumder Partha Pratim, 1994. *Prasanta Chandra Mahalanobis (1893-1972)*, in *Janma Shatabarshe Shradhanjali*, Published by Kolkata Municipal Corporation,
- Dutta Majumder Dwijesh, 1996. *Thoughts on Emergence of IT Activities in India*, in Dr. Utpal K. Banerjee(ed.), *Computer Education in India : Past , Present and Future*, The Institution of Electronics and Telecommunication Engineers,
- Mukherjee Mohi, 1996. *The First Computer in India*, in Dr. Utpal K. Banerjee(ed.), *Computer Education in India : Past , Present and Future*, The Institution of Electronics and Telecommunication Engineers, 1996
- Bhar J.N., *Looking Back*, in *Institute of Radio Physics and Electronics, Silver Jubilee(1949-1974) Commemoration Volume*
- Dutta Majumder Dwijesh, op. cit.
- www.jadavpur.edu/academics/engg_electronics.htm accessed on 4.8.12
- Professor Dutta Majumder Dwijesh, op. cit.
- Recorded interview with Professor Dwijesh Dutta Majumder and Professor Jayanta Kumar Ghosh
- BRIEF HISTORY OF THE INSTITUTE**, in *Sixty Seventh Annual Report:1998-99* (of the Indian Statistical Institute, Kolkata)
- <http://www.isical.ac.in> accessed on 5.9.12
- Organization Profile*, Regional Computer Centre, Kolkata (a brochure)
- Financial Express, Kolkata, 19th December, 1999
- Gill S.S., 2004. *Information Revolution and India – A Critique*, Rupa & Co., New Delhi,
- Survival Primer, Down To Earth*, New Delhi, 2001
- <http://www.iacs.res.in/intro.html> accessed on 5.9.12
- <http://www.iacs.res.in/cc.html> accessed on 5.9.12
- Interview with Dr. Indranil Manna, Director, CGCRI, 5.8.12
- Interview with Dr. Samaresh Bhattacharya, Professor Dept. of Chemistry, JU, 4.12.11



Biodiversity of Freshwater Shrimps In the district of South 24 Parganas

Krishnendu Das* and Aditi Roy Sarkar**

Abstract: Different sites of South 24 Parganas district were selected and a large number of specimens were collected from these sites, which were later screened, preserved and identified. Out of screened specimens only eight species were recorded, among which four specimens belong to Family Palaemonidae and the other four specimens belong to Family Penaeidae. A comparative study was made among these two families and also among the individual members of the Family.

The district of South 24 Parganas is located on the gangetic delta drained by river Hooghly, the distributary of river Ganges. It has numerous freshwater bodies which thrive with aquatic biodiversity. Several studies have been made on the ichthyological aspect of the area, however, investigation of the edible crustaceans which is the important part of the fishery industry still remains scanty.

The word "shrimp" is used interchangeably with "prawns", however, prawn is applied to the member of infraorder Penaeidae and the term "shrimp" is applied to the member of infraorder Caridae. Therefore an effort has been taken to study the decapods crustaceans of the area— South 24 Parganas.

REVIEW OF LITERATURE

The economic importance of prawns in Indian coast was studied in details by Kemp et al. (1993) Their work is mainly reflected on taxonomy of marine forms. Rajyalakshmi (1968) mainly worked on estuarine prawns. In contrast the studies of freshwater prawns were made by Tiwari (1963) & Chopra (1947) mainly focusing on economic aspect. Studies on freshwater prawns of Indian rivers were made by Central Inland Fisheries Research Institute, Barrackpore. Works were also carried out on several cultural experiments in the ponds (Raman, 1970-71; Rajyalakshmi T. 1971).

MATERIALS AND METHODS

Collection & Preservation:

The materials were collected from the different parts of the district of South 24 Parganas. The collection were made throughout the year starting from middle of March 2011 till December 2011 using fine mosquito net at early hour of the day and the bamboo made box (locally called 'ghuni'). A large number of specimen were collected from every sites irrespective of sex which was later screened and then identified. The procedures of preservation of the specimens were followed as per the guidance of ZSI (Crustacea Dept.). Just after collection, the prawns were washed thoroughly and preserved temporarily in 70% alcohol. The permanent preservation was made after 48 hours of temporary preservation by transferring the specimens from 70% alcohol to 4% formalin. Photograph of the specimen were taken by using Canon Powershot A3000IS; for the better clarity of the specimen microscopes were used whenever necessary.

General Characteristics of Prawns/Shrimps

It is important to understand the different parts of a prawn necessary for the identification. The body of a prawn is more or less comma-shaped (,) bearing 19 pairs of appendages divisible into 2 regions – an anterior cephalothorax with 13 pairs (5 pairs cephalic appendages + 8 pairs thoracic appendages) and a posterior abdomen

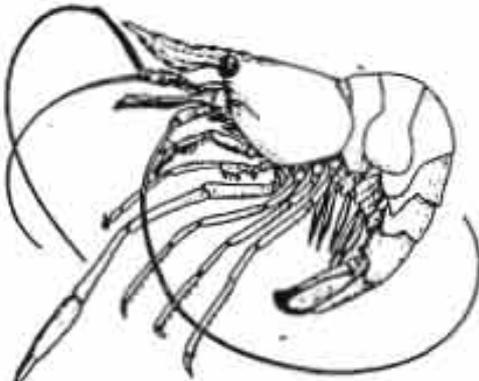
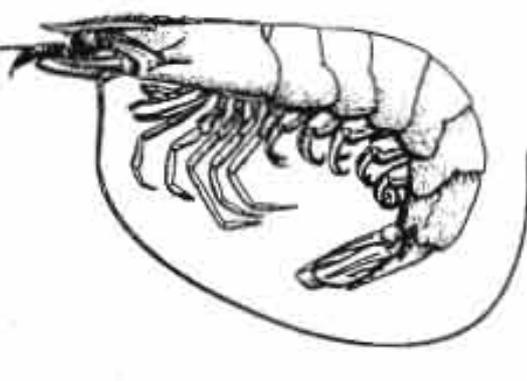
* Student, Department of Zoology, Vivekananda College, Kolkata-700063, Email: Krish7das007@gamil.com.

** Associate Professor, Department of Zoology, Vivekananda College, Kolkata-700063, Email: aditikanu@rediffmail.com.



containing six pairs. Amongst the thoracic appendages the anterior three pairs form the maxillipedes or foot-jaws; and the posterior five pairs the pereopods or "walking legs". The five pairs of walking legs differ from the maxillipedes in their greater size and absence of exopodites & epipodites. The six pairs of abdominal appendages called pleopods or "swimming legs". The cylindrical basis of pleopods bears two flattened, leaf-like branches: the inner and smaller endopodite and the outer and larger exopodite.

Distinguishing features between Family Palaemonidae & Family Penaidae

Family Palaemonidae	Family Penaidae
<p>Rostrum with ~12 dorsal spines & ~4 ventral spines.</p> <p>2nd abdominal body covering overlaps partly 1st & 3rd segment.</p> <p>First 2 cephalothoracic appendages are chelated – 2nd one is largest (2nd chelated appendage is spiny in case of male & non-spiny in case of female).</p> <p>Abdomen show sharp Caridean bend.</p> <p>Gills phyllobranchiate type</p> <p>Eggs are small in size and not released in water- remain berried.</p>	<p>Rostrum with ~5-11 dorsal spines & with or without ventral spine.</p> <p>1st abdominal body covering overlaps the 2nd, 2nd overlap the 3rd and so on.</p> <p>All 3 cephalothoracic appendages are Chelated but comparatively small.</p> <p>Abdomen lacks the sharp bend.</p> <p>Gills dendrobranchiate type.</p> <p>Eggs are comparatively larger and are released in water.</p>
<p>Systematic Position</p>	<p>Systematic Position</p>
<p>Order Decapoda (Latreille, 1803)</p>	<p>Order Decapoda (Latreille, 1803)</p>
<p>Suborder Pleocyemata (Burkenroad, 1963)</p>	<p>Suborder Dendrobranchiata (Bate, 1888)</p>
<p>Infraorder Caridea (Dana., 1852)</p>	<p>Infraorder Penaeidea (Rafinesque-Schmaltz, 1815)</p>
<p>Superfamily Palaemonoidea (Rafinesque, 1815)</p>	<p>Superfamily Penoidea (Rafinesque-Schmaltz, 1815)</p>
<p>Family Palaemonidae (Rafinesque, 1815)</p>	<p>Family Penaidae (Rafinesque, 1815)</p>
	



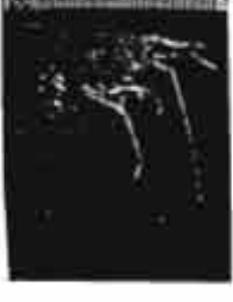
Results & Discussion: Four specimens (specimen A, B, C and D) of Family Palaemonidae and four of Family Penaeidae (specimens A, B, C, D) were chosen for their identification. The respective characteristics were given in the tabulated form.

Family Palaemonidae

Characteristics	Specimen-A	Specimen-B	Specimen-C	Specimen-D
Body Length	4.9 cm - 5.2 cm	4.9 cm - 7.2 cm	4 cm - 5.8 cm	4.3 cm - 8.6 cm
Size of Carapace	1.7 cm - 1.9 cm	1.9 cm - 3.2 cm	1 cm - 1.6 cm	1.8 cm - 3.3 cm
Rostrum size	0.8 cm - 1 cm	1 cm - 1.6 cm	0.3 cm - 0.5 cm	1 cm - 1.9 cm
Rostral spines:				
a. Dorsal	7 + 1(2*)	9 + 1(2-3*)	(14-16)+1 (3-4*)	(5-7) + 1 (2-3*)
b. Ventral	4 - 5	7 - 9	0 - 2	8 - 9
Discussions:	Rostrum triangular, slender, upturned distally or straight, Extends antennal scales, Well marked ridge separates dorsal & ventral edge.	Rostral margin slightly convex, projects beyond antennal scales.	Rostrum short broad, dorsal side of the ridge is high, never projects beyond antennal scales,	Rostrum abruptly tapered beyond the eye, margin convex projects beyond antennal scales,
(* - Post orbital (eyes) spines)				
Scientific Name:	<i>Macrobrachium dayanum</i> Henderson 1893)	<i>Macrobrachium lamarrei</i> (H.M. Edwards, 1837)	<i>Macrobrachium mirabile</i> (Kemp, 1917)	<i>Exopalaemon styliferus</i> (H.M. Edwards, 1840)
Photos:				



Family Penaidae

Characteristics	Specimen-A	Specimen-B	Specimen-C	Specimen-D
Body Length	4.8 cm - 6 cm	6.4 cm - 8.2 cm	3.9 cm	8.9 cm
Size of Carapace	1.1 cm - 1.6 cm	1.9 cm - 2.6 cm	1.3 cm	3.1 cm
Rostrum size	0.3 cm - 0.5 cm	0.7 cm - 2.6 cm	0.5 cm	1.4 cm
Rostral spines				
a. Dorsal	6+1	(7-10) + 1(3*)	8 + 1 (2*)	9 + 1 (3*)
b. Ventral	1 - 2	5 - 6	2	5
Discussions	Rostrum post-orbital in nature, short, triangular in shape, doesn't exceed antennal scales	Rostrum long, Slender & gradually tapering, projects beyond antennal scales, dorsal rostral teeth prominent, whereas ventral teeth are fine spines;	Rostrum gradually tapered, almost equal to antennal scales.	Rostrum gradually tapering with slight convexity extends beyond antennal scales. (Mainly a marine form but well adapted in freshwater also)
(* - Post orbital (eye) spines)				
Scientific Name	<i>Metapenaeus lysianassa</i> (De Man, 1888)	<i>Metapenaeus monoceros</i> (Fabricius, 1798)	<i>Metapenaeus dobsoni</i> (Miers, 1878)	<i>Parapenaeopsis scuptilis</i> (Heller, 1862)
Photos				



Conclusion

The biodiversity of freshwater shrimps collected and studied from different parts of the district constituted only a little part in comparison to the total population present. A whole lot of biodiversity studies need on extensive field works with a large financial support. We have tried to do our best or our part to enlighten ourselves as well as people surrounding us about the biodiversity of shrimps.

The process of identification was laborious since the morphological characteristics of juvenile, male and female of the same species varies widely. Due to this reason, initially it seemed that a large variety of specimens were collected but, after scientific analysis it was revealed that they were actually different forms of the same species.

The identified specimen *Parapenaeopsis scuptilis* is mainly a marine form but it has been collected from fresh water bodies several times, it can be concluded that it is well adapted in freshwater also.

Biodiversity studies of shrimps help us to understand their natural habitat, ecological as well as economical importance of the species.

ACKNOWLEDGEMENTS

We acknowledge our Principal, Vivekananda College, Kolkata-700 063 for granting the fund for the project VC/RGC/09/11. We also thank Dr. Kandasamy Valarmathi & Director, ZSI, Kolkata for their help in identification of the specimens.

REFERENCES

- Kemp S. 1913. Percy Sladen trust Expedition to the Indian Ocean. Pelagic Decapod. Trans. Linn. Soc. London (Zool., 16(2): 53-68.
- Rajyalakshmi, T.S. 1966. On the age and growth of some estuarine prawns. Proc. Indo-Pacif. Fish. Count, 11(2): 52-83.
- Tiwari, K. K. 1947. Description of a new species from the Benaras, Rec. Indian Mus., 45(4): 333-345.
- Chopra, B. N. 1947. Prawn fisheries of India, Curr. Sci., 12(2): 71.
- Raman, K. and Menon, M. K. 1963. A preliminary note on an experiment in paddy field prawn fishing, Indian J. Fish, 10A (1): 33-39.



An Ecological Study On Wastewater Fisheries Of Mudialy Fishermen's Co-operative Society

Meenakshi Mukhopadhyay* and Debduitta Bhattacharjee**

Urban and Industrial waste-water treatment is a major environmental concern today. In developing countries like India conventional waste water treatment plants have various problems in their management and are a costly affair. The sewage fed wetlands and fisheries have gained considerable importance in this regard where waste water is purified through biological means and water is recycled and reused. An area at Taratala in south west Kolkata, which was previously a marshy sewage fed wetland serving as a dumping ground of domestic and industrial waste, has been promoted by Mudialy Fishermen's Co-operative Society and is well known as Nature Park where waste water is purified through bioremediation and wealth is generated from wastes. This project deals with the physico-chemical analysis of the few parameters of the waste water and the purified water of the sewage-fed fisheries of Nature Park, Kolkata. The results were analyzed graphically and compared with the previous works. Also the other different aspect of the wetland were studied. In one word this paper aims to show how sewage fed wetlands and fisheries can be successfully utilized in the treatment of waste water.

Sewage-fed fisheries are unique systems where 'waste is a resource'. Under the scope of study, it is envisaged: To assess the present status of water quality of Nature Park with respect to a few physico-chemical parameters of the water of Ghasbari Jheels.

STUDY SITE AT A GLANCE

MUDIALY FISHERMEN'S CO-OPERATIVE SOCIETY

The Mudialy Fishermen's Cooperative Society, 167/1 Santoshpur Road, Kolkata-700024 is located in a densely populated area about 10 kms south-west from heart of Kolkata and is based on about 80 hectares of wetland leased in from the Kolkata Port Trust(KPT). It is located at Taratala and well connected to the city.

Mudialy Fishermen's Co-operative Society (MFCS) came into existence on 21st November of 1961, but it officially opened in 2005. It is a good example of how the coasian negotiation process allows for a value-maximizing allocation of property rights over complex natural resources in favour of the most intimate stakeholder. After leasing this unused marshy wetland from the KPT, the poor fishermen of the MFCS cleared it not only of the natural weeds, but also of local anti-socials, and used it for waste water fisheries. In the process of cleaning the water they converted the area into 'smiling' Nature Park, as it is known today.

THE ENVIRONMENTAL CO-OPERATIVE

MFCS is a fishermen's cooperative in formal terms but informally it is an environmental co-operative. Using an indigenous method of cleaning water of heavy metals and other pollutants, MFCS has promoted the Nature Park. It has been not only purifying the waste water of the city, but also nourishing pisciculture along with horticulture, floriculture, animal husbandry and farm forestry-all thriving on the micro-nutrients present in the purified waste water. In the process, MFCS has thus diversified itself into various allied activities, displaying the potential of the soil-water system of the Indo-Gangetic plains. Being an environmental cooperative, the society has also enjoyed immense support from various eminent environmentalists and environmental groups.

* Assistant Professor, Department of Botany, Vivekananda College, Kolkata-700063

** Former Student, Vivekananda College, Kolkata-700063



NATURAL TREATMENT OF WASTE WATER IN MFCS

Here in Nature Park, the waste water is treated naturally. Generally 70% of the water are generated from the industry and the rest 30% are from domestic slums.

STEPS OF TREATMENT

- Step 1: Through a common inlet the sewage enters the anaerobic digester.
- Step 2: The waste water is first generated in the primary settling tank. Here the water is kept for about 2 days and is treated.
- Step 3: Then it is passed to the secondary settling tank whose depth is quite higher than that of the primary one.
- Step 4: The waste water is then passed through a long macrophyte canal (Fig 1) having a depth of 14-15 ft. The aquatic macrophytes and the phytoplanktons of the macrophyte canal absorb the heavy metals, oil and other pollutants and thus the purification of the waste water is done through the process of phytoremediation. In the canal some spaces are left cleared of the macrophytes for the purpose of the penetration of sunlight in the canal which initiates the growth of phytoplanktons there. The air breathing fishes in the canal act as bioindicators for analyzing incoming water quality. The phytoplanktons produced serve as the fish foods. This is the basic chain. In the canal regularly the waste water quality is treated or tested clockwise. If it is found very much polluted, then the water is again treated by mixing anti clockwise purified water.
- Step 5: After the phytoremediation of water through the long canal the DO level rises and the treated water is stored in the stabilization tank for 15-20 days. Here within this time large amount of phytoplanktons and zoo-planktons are grown naturally which serve as the naturally growing rich nutrient for pisciculture.
- Step 6: The plankton-rich (phyto- & zoo-planktons) water is fed into different ponds. There are about 10 ponds (locally called 'Jheels'). All are interconnected. In these ponds by the photosynthesis process and with the nutrient rich water from the stabilization tank more phytoplankton algae grow which provides fish food and emits oxygen. Luxuriant growth of the fishes is thus maintained by the waste water and the penetration of sunlight.

MATERIALS AND METHODS

CHOICE OF THE SAMPLING SITE

A functionally significant Jheel at the Nature Park, locally known as "Ghasbari" (formerly known as Khudi-2 Jheel), was selected for sampling. Ghasbari consists of two interconnected jheels- Ghasbari-1 and Ghasbari-2 (Fig 2). In both of the jheels pisciculture is done. Varied water surface conditions and site positions were chosen for sampling. 13 sampling points (Fig 5), 1 in the macrophyte canal (Fig 1), 9 in Ghasbari 1 jheel and 3 in Ghasbari 2 jheel were selected for sampling keeping in view the surface area and the depth of the jheel. Ghasbari 1 jheel is interconnected to Ghasbari 2 jheel and the latter is connected to the outlet (Fig 4) near the sampling site S13 from where the treated water goes to the Moni Khal and then to the river Ganga. The sampling point in the macrophyte canal was chosen near the inlet end (Fig 3).

COLLECTION OF DATA

Recording of data were carried out during the study period. Sampling was done four times in the entire study period, once in two weeks and in this way for 8 consecutive weeks from September 2011 to October 2011.



Information regarding the different species of birds, plants, animals and fish were also collected from the associated staffs of the Nature Park.

PARAMETER STUDIED

Five parameters concerning physico-chemical characteristics of this wetland were selected for study.

A. Physical characteristics

1. Temperature was determined on the spot with the thermometer.
2. pH was tested at the Vivekananda College Laboratory with pH meter.
3. Transparency was determined on the spot by Secchi Disc. method

B. Chemical characteristics

1. Dissolved Oxygen (DO) was determined by Winkler's method in the Vivekananda College Laboratory
2. Biological Oxygen Demand (BOD)₃ was determined from the initial and the final DO values after the 3 day BOD test.

The tests were performed by the following standard methods given by American Public Health Association (APHA, 1992), Jadav and Joghana (1993) Central Pollution Control Board (CPCB, 1978); Tribedi and Goel (1992).

RESULTS

Average Physico-chemical data of four weeks

Site No	Temperature (°C)	pH	Transparency (cm)	Turbidity (ppm)	Initial DO (mg/l)	BOD ₃ (mg/l) at 20°C
S1	25.17	7.98	13.6	70	3.83	12.33
S2	26	6.88	26.55	33	7.65	4.56
S3	25.82	6.98	32.69	20	9.14	3.14
S4	25.95	6.72	25.85	35	8.44	5.2
S5	26.4	7.33	24.37	36	6.8	4.5
S6	26.4	6.88	22.65	40	6.57	4.42
S7	25.55	6.76	23.56	38	6.7	4.22
S8	26.17	7.14	28.12	27	7.25	3.89
S9	25.97	7.13	27.16	30	7.42	3.54
S10	26.1	6.82	26.34	33	9.29	4.04
S11	26	7.25	28.8	27	9.69	3.37
S12	26.07	7.27	29.26	26	9.85	3.04
S13	26.07	7.18	30.01	25	10.28	2.89



ANALYSIS OF RESULTS AND DISCUSSIONS

The average physico-chemical data as obtained from the above Table was plotted for each parameter separately against the sampling sites and the variation of the physico-chemical parameters was analyzed graphically. After the analysis of the physico-chemical parameters, the following points were found:-

TEMPERATURE

The water temperature of the jheels were found to be about 25.17°C at the inlet end and 26.07°C at the outlet end (avg). A minimum value of 25.17°C (avg) at the macrophyte canal and a maximum of 25.55°C (avg) at the Ghasbari 1 jheel were noticed. There was a difference of about 3-4°C with the ambient temperature. The difference in the temperatures at the different sites of the same jheel might be due to the presence of microbial activity in the water, the position of the sampling sites and the varied weather conditions prevailing during the study period. Previous studies of Deb (1988-89) showed it was about 26°C and difference of 3-4°C with the ambient temperature. This is in close agreement with the result obtained in the present study. The variation of Temp with the sampling sites is shown in the Fig 6.

pH

pH was found to vary between 7.98-6.72 (avg value) with 7.98 at the inlet end and 6.72 at the site S4. Higher values denoting a slightly basic nature was noticed in the macrophyte canal. In the Ghasbari 1 & 2 jheel pH values are near about neutral ranging from 6.72 to 7.18. This may be due to the phytoremediation of the effluent water at the macrophyte canal and absence of lime treatment of the jheel water during the entire study period. The pH of the outlet end was 7.18 and this was in well agreement with the environmental standards of water quality criteria of CPCB. In the previous studies by Deb (1988-89) pH was found to be higher i.e 7.5-9.0 and Basu, (2006) showed that the pH ranges 6.0-8.5 in the inlet water and varies to 6.5-8.5 in the outlet water. This difference may be due to the different study period and different experimental conditions prevailing then. The variation of pH with the sampling sites is shown in Fig 7.

TURBIDITY

Turbidity values were found to be 70 ppm at the inlet end of macrophyte canal and 25 ppm at the outlet end of Ghasbari 2 jheel. Ghasbari 1 jheel showed a minimum value of 20 ppm to a maximum value of 40 ppm and Ghasbari 2 showed a minimum of 25 ppm to a maximum of 27 ppm. Minimum values are recorded at sites having clean and transparent water with least algal growth whereas higher values are noticed at the sites covered with algal scum and sites having dirty stagnant water surfaces. The water of the macrophyte canal is blackish and the most turbid. The findings showed that the transparency value ranges from 17.78-39.37ft. This value is in well agreement with the values found in the places where there is less algal growth. The variation of turbidity with the sampling sites is shown in Fig 8.

DISSOLVED OXYGEN

DO concentrations had a minimum value of 3.83 mg/l at the inlet end of the macrophyte canal and a maximum value of 10.28 mg/l near the outlet at the Ghasbari 2 jheel. Ghasbari 1 jheel shows a minimum DO value of 6.57 mg/l and a maximum DO value of 9.29 mg/l. The water entering the Ghasbari 1 jheel through the site S2 posses a higher value of dissolved oxygen of 7.65 mg/l due to the dilution of the treated effluent water while entering the Ghasbari 1 jheel. The DO value of Ghasbari 2 jheel ranges from 9.69-10.28 mg/l. However all the sites in the ponds have DO values well in accordance with the CPCB permissible limits given for pisciculture.



The obtained result is quite low compared to the previous study done by Deb (1988-89) and Gupta (2008) which showed the DO value ranges within 9.8-19.4 mg/l and 6.8-12.8 mg/l respectively. Algal scum prevents dissolution of oxygen at the air-water interface and as most of the sites were covered by algal scum this could be a reason of lowering of DO values in the present study. The variation of DO with the sampling sites is shown in the Fig 9.

BOD

There was a gradient of BOD₅ values in the jheels ranging from 2.89 mg/l (at the outlet) to 12.33 mg/l (at the inlet). The polluted water in the macrophyte canal has a highest BOD₅ value of 12.33 mg/l. But when it enters Ghasbari 1, at S2 the BOD₅ value was drastically lowered to 4.56 mg/l. This might be due to the fact that the water of the canal gets diluted on entering the Ghasbari 1 jheel and the BOD₅ get drastically lowered. Then there occurs a gradual lowering in the BOD₅ values when it enters Ghasbari 2 with a value of 3.37 mg/l and leaves the Ghasbari 2 at the outlet with a BOD₅ value of 2.89 mg/l. In general it was found that the Ghasbari 1 jheel has a BOD₅ range between 5.2-3.14 mg/l. Ghasbari 2 jheel and the water at the exit point maintains the permissible limit of BOD₅ value at 20°C of 3 mg/l or less than as given by CPCB. In the previous studies Gupta (2008) showed that there was a gradient of BOD₅ values ranging from 25.9 ppm in the outlet to 37 ppm at the inlet. However that supports the occurrence of BOD level well below the permissible limit according to the CPCB criteria for BOD₅ at 27°C. The variation of BOD with the sampling sites is shown in the Fig 10.

According to the Central Pollution Control Board there are certain permissible limits for inland surface water and fisheries. The values of the parameters were compared with the permissible limits of CPCB and it was found that the values of the water quality parameters are in accordance with those values given by CPCB and within the permissible limits. It is shown in the following

Permissible limits and the obtained values

Parameters	CPCB Permissible limits for fisheries	Values obtained	
		Inlet	Outlet
pH	5.5-9	7.98	7.18
DO	Above 4mg/l	3.83 mg/l	10.28 mg/l
BOD ₅	3 mg/l or below at 20°C for 3 days	12.33 mg/l	2.89 mg/l
Temperature	Should not exceed 5°C above ambient temp.	25.17 °C	26.07°C

CONCLUSION

On the basis of the results and the discussions the following conclusions can be made:

1. The study area water polluted with industrial wastes is successfully purified through bioremediation and utilized to generate wealth from waste water.
2. Aquatic macrophytes like *Eichhornia crassipes*, *Lemna minor* etc can be promising plant species for remediation of sewage water rendering it suitable for pisciculture.



3. Nature Park, Taratala, Kolkata can be truly acclaimed as an environmental co-operative showing how waste can be converted into wealth with an environmentally and ecologically beneficial approach. Waste management through natural process has become a reality in the study area by (a) recycling polluted water by natural mechanism, (b) planting various species of trees, shrubs etc. (c) conserving different animal and bird species.
4. Adoption of biological means i.e. phytoremediation or bioremediation to purify waste water or industrial effluent can be a best alternative for developing countries.

On the basis of the conclusions the following recommendations can be made:

- 1) The physico-chemical analysis can be supplemented with the analysis of conductivity, COD, Total Suspended Solids, Total Dissolved Solids and Free CO₂.
- 2) The experimental analysis can be extended to find the presence of heavy metals in the pond water and in the anatomy of fishes.
- 3) Researches could be done on the planktonic growth and the breeding of fishes in MFCS.
- 4) Experimental studies can be done regarding the successful utilization of biologically purified water for different commercial purposes.

REFERENCES

- APHA, 1998. Standard methods for the examination of water, sewage and industrial waters published by American Public Health Association (20th edition) New York pp : 522
- Banerjee. R.K, Karmakar. H.C, Chatterjee. S.K and Saha. S.K, 1990. Evaluation of nutrient loss from sewage-fed fish ponds. *Environmental Ecology*, 8(1B) : 450-453
- Banerjee. L.K. & Venu.P, 1994. Wetlands plant resources for conservation. *ENVIS (Newsletter of Botanical Survey of India, Calcutta)*. 1:2-3
- Basu. K., 2006. Mudially Model, a sustainable Natural way to treat Industrial Waste Water and its pollution evaluation by bio-Mapping (from www.worldwaterweek.org)
- Central Pollution Control Board (CPCB), official website : <http://www.cpcb.nic.in>
<http://www.naturepark1962>.
- Deb. S. C., 1990. Water Quality Studies Of the Jheel In Calcutta Port Trust Area, National Environment Engineering Research Institute , sponsored by Calcutta Port Trust.
- Edwards. P, 1996. A note on waste water fed aquaculture systems: Status and Prospects. *NAGA ICLARM*, 19(1), : 33-35
- Environmental Protection Agency (EPA) 1999. Sediment Quality Guidelines development to the national status and trends program. Report number 6.12.99.
- Ghosh . S, 2001. Indigenous Technology in Waste water recycling, Calcutta case study. International Congress in Irrigation and drainage. Seoul, September 2001.
- Gupta.B,(2007), Environmental factors affecting planktonic growth and its relationship with fish production in sewage-fed fisheries: A case study of Mudially Fishermen's Co-operative society.



- Hejkal. T.W, 1983. Bacteriological, virological and chemical evaluation of a waste water aquaculture system. *Wat. Res.*, 17(12) : 1749-1755
- Jadav. H.V, Jogand.S.N, 1993. Environmental, chemical and biological analysis, Himalayan Publishing House, New Delhi
- Nandeesh. M,C, 2002. Sewage fed aquaculture systems of Kolkata: a century-old innovation of farmers. *Aquaculture Asia VII* [2] : 28-32
- Pradhan. A, 2007. Phytoplankton diversity as indicator of water quality for fish cultivation , *American journal of Environmental sciences* 4 (4) : 271-276 , 2008
- Sengupta. Archana, 2008. Ecological Impact Study of the Effects of Toxic Pollutants from Urban Sewage Water and/or Industrial Effluents Used in Mudialy Fishermen's Co-operative Society Ltd., Taratala, Kolkata sanctioned by WBPCB
- Tribedi . R.K and Goel. P.K, 1992. Chemical and biological methods for water pollution studies. *Environ Media*, Karad, India
- Central Pollution Control Board (CPCB) official website: <http://www.cpcb.nic.in>
<http://www.naturepaark1962>



SAMPLING SITES



Fig1. The macrophyte canal



Fig 2. Interconnected Ghasbari 1 & 2 jheels



Fig 3. The inlet end of Nature Park



Fig 4. The outlet end of Nature Park



Fig. 5 Sampling points of Ghasbari 1 and Ghasbari 2 jheels

GRAPHICAL REPRESENTATION OF DATA

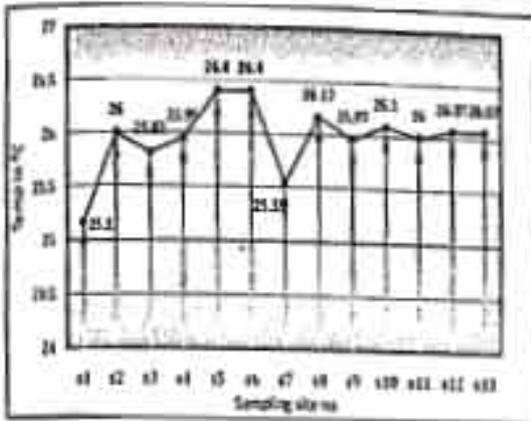


Fig.6. Sampling site vs Temperature graph



Fig.7- Sampling site vs PH graph

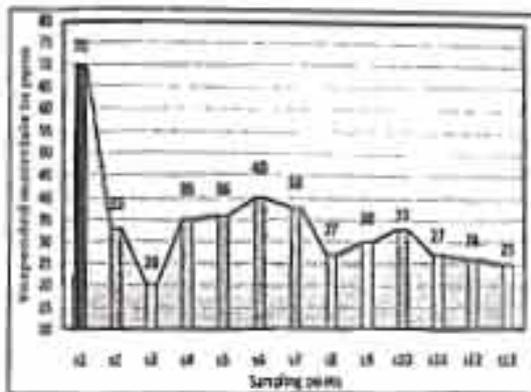


Fig.8-Sampling site vs turbidity graph

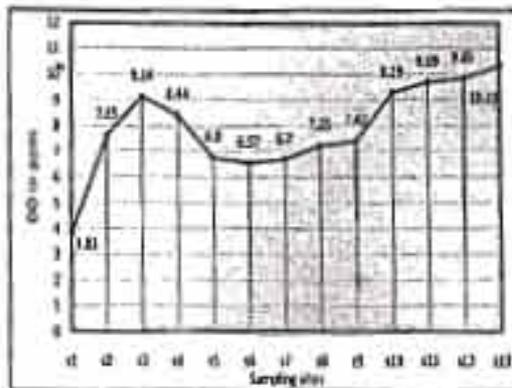


Fig.9-Sampling site vs DO graph

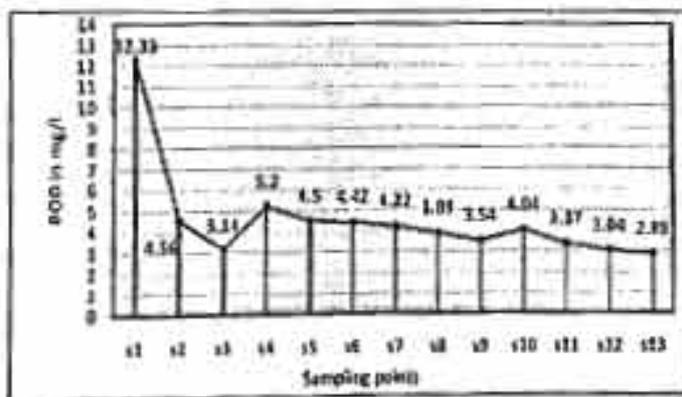


Fig.10-Sampling site vs BOD graph



Evaluating sustainability of Urban and Peri-urban water bodies in and around South Kolkata followed by identification of the prevalent species of fishes available in such conditions.

Aditya Mitra*, Arnab Biswas*, Moumita Sarkar*, Pallabi Mukherjee*,
Soma Maji* and Malabika Bhattacharjee**.

Abstract: Kolkata, the second largest metropolis in the country, has about 3000 ponds of different sizes spread within its municipal corporation boundary. These ponds are used as multiple resources – about a million people use it for bathing, washing, pisciculture, performing religious rites and also use its adjoining areas as city parks. The ponds also have a great ecological importance in urban environment – from microclimate control to biodiversity. The present study is based on an extensive survey of Kolkata ponds (the first such study on Kolkata ponds), to find its prime uses and users. The main observations of the study are; a) Of the 42 species of fishes that were observed to harbour in these ponds, *Mystus vittatus* (Desi tangra) topped the list as it seems to play a major role in nutritional requirement of the backward economic class. Moreover from a fishery point of view, it can be cultured easily as it can thrive in all kinds of shallow fresh water habitat. Being a “jeol fish”, an additional advantage is that it can be cultured with ease in hypoxic water also; b) sustainability from the viewpoint of human use and sustainability from the viewpoint of pisciculture may have some mutual incompatibility and therefore requires an integrated approach and c) proper community management can attain sustainability without compromising on quality of life

Gradual polluting of the city based water bodies by a host of anthropogenic activities ultimately leads to choking of the resultant water bodies. In such oxygen deficient areas, where algal bloom seems to be a prominent feature, we still do observe certain fish species trying their best to survive. The present work on one hand thus focused on analyzing the hydroparameters viz. CO₂, O₂, pH and turbidity of the urban and peri-urban polluted water bodies, in and around South Kolkata. Secondly the present work also screened for the fish diversity available in these polluted water bodies.

MATERIAL AND METHODS

MARKET SURVEY AND COLLECTION OF WATER SAMPLES

15 markets of different localities were visited. They are as follows:

Sl. No.	Name of market	Address	Location for collecting H ₂ O samples	Address
1.	Bansdroni market	Bansdroni Rd, Kol-70	Bakrahat(Nodakhali)	Bakrahat Rd,Nodakhali. S.24 Pgs-743318
2.	Kabardanga market	M.G. Road, Kol-108	Behala(Charaktala)	R.B. Road, Kol-53

* Student, Department of Zoology, Vivekananda College, Kolkata-700063

** Assistant Professor, Department of Zoology, Vivekananda College, Thakurpukur, 269, D.H.Road, Kolkata-700063.
e-mail: malabika.bhattacharjee07@gmail.com; dr.malabika07@gmail.com



Sl. No.	Name of market	Address	Location for collecting H ₂ O samples	Address
3.	Thakurpukur market	D.H. Road, Kol-63	Behala(jorabot tala)	R.B. Road, Kol-34
4.	Parnasree market	U.B. Road, Kol-60	Behala(Parnasree)[A]	Parnasree Pally, Kol-60.
5.	Lake Gardens Bazar and Super Market	Lake gardens, Kol-45	Behala(Parnasree)[B]	Surya Sangha, Kol-60.
6.	Sakherbazar market	D.H. Road, Kol-8	Behala(Parnasree)[C]	U.B. Road, Kol-60.
7.	Behala Bazar	D.H. Road, Kol-34	Behala(Senhati)	R.B. Road, Kol-53
8.	Garia	Garia, Kol-84	Haridebpur	M.G. Road, Kol-82
9.	Silpara (night market)	D.H. Road, Kol-8	Karunamoyee	Karunamoyee Ghat Rd, Kol-82
10.	Pailan market	Pailan, S.24 Pgs	Naktala	Sreeguru Ashram, Kol-47.
11.	Lake market	Lake gardens, Kol-45	Nodakhali(Sehai)[A]	Bakrahat Road, Nodakhali, Sehai. S.24 Pgs-743318.
12.	Jinjira Bazar	Brace bridge Rd, Kol-88	Nodakhali(Sehai)[B]	Bakrahat Rd, Nodakhali, Sehai. S.24 Pgs-743318
13.	Bakrahat market	Bakrahat Rd, S.24 Pgs	Ranikuthi	Ranikuthi Road, Kol-40.
14.	Simultala market	D.H. Road, Kol-34	Tollygunje	N.S.C Bose Road, Kol-92.
15.	Keorapukur Bazar	M.G. Road, Kol-82		

During the market survey the main points that were sought for were- I. Types of fishes being sold and II. Number of fishmongers selling each type of fish.

pH ESTIMATION OF THE WATER BODIES OF THE AREAS WHERE THE MARKETS WERE SELECTED

Water samples from water bodies of 14 localities as mentioned in Table.1 were collected for testing the pH of the water. With the help of a watchmaker forceps that was heat sterilized, a strip of pH paper was dipped in the water sample that was collected. The process was repeated for each water sample separately and with extreme care. The color change in the pH paper was observed and according to that the pH of the water sample was determined.

DISSOLVED CO₂ ESTIMATION

Water samples from water bodies of 14 localities were collected for testing the CO₂ of the water. The standard procedure for determination of free CO₂ by Alkali titrimetric method was used.

DISSOLVED O₂ ESTIMATION

Water samples from water bodies of 14 localities were collected for testing the O₂ of the water. The standard Winkler's method of determination of dissolved O₂ based on 2 oxidation-reduction reaction was followed.

ESTIMATION OF TURBIDITY

Turbidity is a measure of the transparency of water. It can be measured with a Secchi disc. A Secchi disc is a circular plate divided in quarters alternatively painted black and white. A Secchi disc is usually mounted onto a



rod that is marked off in centimeters or inches. For Secchi disc measurement, the disc is lowered into the water and when the disc first disappears from view, this depth is recorded as the Secchi disc measurement. A circular tin plate with a hole at the center and colored white and black alternatively was made. A nylon rope was attached to the hole in the centre. It was taken to the 14 ponds under consideration and the depth was measured standing on the four sides of the pond and the average value was considered.

RESULTS

MARKET SURVEY OF FISHES

Since it becomes difficult to directly visit all the wetlands of the different localities and assess the existing fish population when they are being caught, so a new strategy was adapted. Since everyday catch is sold off at the local market, hence to have an insight of the fish catch we visited the local markets twice a week (approximately 30 such visits were made covering 15 markets) and each individual market was visited two times with a gap of one month in between to cross check with our previous data. Below is the list of fishes we observed at the local markets:

SL.NO.	SCIENTIFIC NAME	FAMILY	COMMON NAME
1.	<i>Channa striatus</i>	Ophiocephalidae	Shol
2.	<i>Channa marulius</i>	Ophiocephalidae	Shal
3.	<i>Channa punctatus</i>	Ophiocephalidae	Lata
4.	<i>Channa gachua</i>	Ophiocephalidae	Chang
5.	<i>Glossobius giuris giuris</i>	Gobiidae	Bele
6.	<i>Eleotris fusca</i>	Gobiidae	Kalo Bele
7.	<i>Heteropneustes fossilis</i>	Siluridae	Shingi
8.	<i>Clarias batrachus</i>	Siluridae	Magur
9.	<i>Ompok pabda</i>	Siluridae	Pabda
10.	<i>Pseudotropius atherinoides</i>	Siluridae	Bathasi Tangra
11.	<i>Mystus vittatus</i>	Siluridae	Desi Tangra
12.	<i>Wallage testudineus</i>	Siluridae	Boyal
13.	<i>Anabus testudines</i>	Labyrinthici	Koi
14.	<i>Colisa lalius</i>	Labyrinthici	Guri Kholshes
15.	<i>Colisa fasciata</i>	Labyrinthici	Pata Kholshes
16.	<i>Badis badis</i>	Nandidae	Pod Koi
17.	<i>Nandus nandus</i>	Nandidae	Nadosh
18.	<i>Macrogonathus aculeatus</i>	Rhynchobdellidae	Pankal
19.	<i>Mastacembelus punctatus</i>	Rhynchobdellidae	Goje Pankal
20.	<i>Mastacembelus parvatus</i>	Rhynchobdellidae	Ban Pankal
21.	<i>Rhinomugil corsula</i>	Mugilidae	Kharshula
22.	<i>Chanda ranga</i>	Percidae	Gol Chanda
23.	<i>Chanda nama</i>	Percidae	Kath Chanda
24.	<i>Puntius sophore</i>	Cyprinidae	Punti



25.	<i>Amblypharyngodon mola</i>	Cyprinidae	Mourola
26.	<i>Esomus danricus</i>	Cyprinidae	Ghora Daria
27.	<i>Chela laubuca</i>	Cyprinidae	Daria
28.	<i>Puntius ticto</i>	Cyprinidae	Tit Punti
29.	<i>Puntius sarana sarana</i>	Cyprinidae	Shor Punti
30.	<i>Salmostoma bacaila</i>	Cyprinidae	Chala
31.	<i>Labeo rohita</i>	Cyprinidae	Rohu
32.	<i>Catla catla</i>	Cyprinidae	Catla
33.	<i>Labeo calbasu</i>	Cyprinidae	Calbosh
34.	<i>Cirrhinus mirgala</i>	Cyprinidae	Mrigel
35.	<i>Labeo bata</i>	Cyprinidae	Bata
36.	<i>Notopterus chitala</i>	Notopteridae	Chittal
37.	<i>Notopterus notopterus</i>	Notopteridae	Folui
38.	<i>Aplocheilus panchax</i>	Cyprinodontidae	Techokha
39.	<i>Anguilla bengalensis bengalensis</i>	Muraenidae	Bangosh
40.	<i>Monopterusuchia</i>	Symbranchidae	Cuche
41.	<i>Lepidocephalus guntia</i>	Cobitidina	Gunte
42.	<i>Xenentodon cancila</i>	Scombresocidae	Kaklesh

The data that were obtained were then graphically presented to get a view of the different families of fishes that were thriving in the hypoxic waters. The prevalence of the fishes according to their families have been thus been represented in graphical manner- Fig.1.

pH ESTIMATION ALONG WITH PHYTOPLANKTONS FOUND

The standard level of free pH should be between 6.5-8.5 for a fish pond.

SL. NO.	LOCATION	pH	TYPE	FISHING	PHYTOPLANKTONS FOUND
1.	Bakrahat(Nodakhali)	8	Basic	Yes	<i>Lemna sp., Pistia sp.</i>
2.	Behala(Charaktala)	8	Basic	No	<i>Eichhornia sp.</i>
3.	Behala(jorabot tala)	7	Neutral	No	<i>Eichhornia sp., Pistia sp.</i>
4.	Behala(Parnasree)[A]	8	Basic	No	<i>Lemna sp.</i>
5.	Behala(Parnasree)[B]	8	Basic	Yes	<i>Lemna sp., Eichhornia sp., Pistia sp.</i>
6.	Behala(Parnasree)[C]	7.5	Slightly basic	Yes	<i>Lemna sp., Pistia sp.</i>
7.	Behala(Serhati)	9	Quite basic	No	<i>Eichhornia sp.</i>
8.	Haridebpur	7.5	Slightly basic	Yes	Nothing
9.	Karunamoyee	8	Basic	Yes	<i>Lemna sp.</i>
10.	Naktala	7.5	Slightly basic	No	<i>Eichhornia sp.</i>
11.	Nodakhali(Sehai)[A]	7.5	Slightly basic	No	<i>Lemna sp.</i>
12.	Nodakhali(Sehai)[B]	7	Neutral	No	<i>Eichhornia sp.</i>
13.	Ranikuthi	7	Neutral	Yes	Nothing
14.	Tollygunje	7.5	Slightly basic	No	<i>Lemna sp.</i>



DISSOLVED CO₂, O₂ AND TURBIDITY ESTIMATION

The standard level of free CO₂ should be less than 10mg/lit. However CO₂ should be less than 3mg/lit for a fish pond. The standard level of O₂ should be between 6-10mg/lit for a fish pond.

Dissolved CO₂, O₂ and turbidity estimation

SL. NO.	LOCATION	CO ₂ [mg/lit]	O ₂ [mg/lit]	Turbidity	FISHING
1.	Bakrahat(Nodakhali)	17.2	6.23	4.5	Yes
2.	Behala(Charaktala)	39.4	0.65	8.8	No
3.	Behala(jorabottala)	24.6	1.29	8.2	No
4.	Behala(Parnasree)[A]	30	0.84	7.8	No
5.	Behala(Parnasree)[B]	10	5.33	4.5	Yes
6.	Behala(Parnasree)[C]	6.6	7.56	4.1	Yes
7.	Behala(Senhati)	38	0.69	8.6	No
8.	Haridebpur	18	7.73	4.7	Yes
9.	Karunamoyee	9.2	8.92	4.8	Yes
10.	Naktala	22.66	0.87	7.9	No
11.	Nodakhali(Sehai)[A]	28	1.8	6.8	No
12.	Nodakhali(Sehai)[B]	28	1.32	6.7	No
13.	Ranikuthi	37.3	6.57	3.6	Yes
14.	Tollygunje	15.2	4.02	6.8	No

DISCUSSION

Of the 42 species of fishes in our market survey *Mystus vittatus* (Desi tangra) belonging to Family-Siluridae topped the list (Fig.1). Desi tangra was found in maximum number of markets. Such abundance of a particular species could be attributed to its being palatable to the local taste and simultaneously being economic. It seems to play a major role in nutritional requirement of the backward economic class. Moreover from a fishery point of view, it can be cultured easily as it can thrive in all kinds of shallow fresh water habitat. Being a "jeol fish", an additional advantage is that it can be cultured with ease in hypoxic water also.

Another intriguing feature of our market survey was the sporadic occurrence of *Xenentodon cancila* (Kaklesh) belonging to the family scombresocidae. Although the fish is cost effective it seems that the fish fails to gain popularity in the market. Preliminary analysis identified the difficulty of fishermen to culture this fish as it thrives on a narrow range of diet (mainly crustaceans and frogs) and sometimes attacks the smaller fishes for food (exhibits a carnivorous nature). The most popular method of culture – "composite culture" cannot be applied to this fish as it might attack its co-cultured species resulting in economic loss of the local farmer. Only monocultures of this fish might occur, but then because of its preference in diet it might not be a suitable option for the farmer as the culture process will become too costly. Thus *Xenentodon cancila* even though being socio-economic in terms of market value fails to get popularity among the farmers and hence it occurs in such sporadic instances.

After collecting various samples of water from different odd wetlands of Kolkata, a pH test was conducted on each one of them. pH is a measure of hydrogen ion concentration in water to analyze the acidic or basic nature of the water body. It has direct effects on fish growth and survival of food organisms. Hence, to achieve



good fish production pH of the water should be monitored regularly to ensure its optimum range of 6.5-8.5 (Banerjee, 1967). It also exerts considerable influence on toxicity of ammonia and hydrogen sulphide as well as solubility of nutrients and thereby water fertility. To our great astonishment, when the water sample from the 14 localities were tested for pH, none of them proved acidic. They were either neutral or a bit alkaline. The results show that the wetlands, though some of them now in eutrophic conditions, were once, or still are, extensively used for bathing and/or washing. As we know that detergents and soaps are highly responsible for the alkaline nature of these wetlands. The acidic character is largely attributed to extensive use of pesticides or insecticides in the water. As our result confirms only the basic quality, we can confidently rule out the possibilities of use of any sorts of pesticides in water. In our quest for water samples, we also came across a huge population of floating hydrophytes such as *Lemna sp.*, *Pistia sp.* and *Eichhornia sp.* Thus, we can conclude that most of the wetlands, which are cut off from waste water supply or any sorts of industrial effluents are usually alkaline in nature due to extensive quantity of soaps and detergents in them.

The primary sources of carbon dioxide in fish ponds are derived from respiration by fish and the microscopic plants and animals that comprise the fish pond biota. Freshwater fish pond should contain a low concentration of free CO_2 (<3 mg/litre), although it can tolerate high concentrations of CO_2 (Boyd, 1978). Aeration and increasing of pH can control the high concentration of CO_2 (Adhikari, 2006). As stated earlier the standard level of free CO_2 should be less than 10mg/lit but CO_2 should be less the 3mg/lit for a fish pond. Comparing the CO_2 data of the 14 localities in our study it was observed that only two localities viz. Behala (Parnasree)[C] (6.6mg/lit) and Karunamoyee (9.2 mg/lit) had a value less than 10mg/lit while all the other localities had a quite high free CO_2 concentration, the maximum being at Behala(Charaktala) (39.4 mg/lit) and Behala(Senhati) (38 mg/lit) where no fishing was observed. But none of the localities had a free CO_2 less the 3mg/lit clearly indicating that none of the bodies are suitable for ideal fish culture. However sporadic fishing is observed in 6 of the 14 localities of which Ranikuthi(37.3 mg/lit) had the highest free CO_2 concentration.

Dissolved oxygen is one of the most important chemical parameters in aquaculture ecosystem (Hutchinson, 1975). It has been established that the optimal dissolved oxygen content of pond water lies in the range of 5-110 mg/litre. When we compared the dissolved O_2 data of the 14 localities in our study, it was observed that Behala (Parnasree)[C] (7.56 mg/lit), Haridebpur (7.73 mg/lit) and Karunamoyee (9.2 mg/lit) had the highest dissolve O_2 . Thus high O_2 concentration in Behala (Parnasree)[C] (7.56 mg/lit) and Karunamoyee (9.2 mg/lit) was marked with comparatively low free CO_2 concentration Behala (Parnasree)[C] (6.6mg/lit) and Karunamoyee (9.2 mg/lit). However an intriguing feature that was observed was in case of Ranikuthi. The water body in Ranikuthi with a high free CO_2 concentration(37.3 mg/lit) and a moderate O_2 (37.3 mg/lit) concentration still served to fishing purpose.

Turbidity is a term that refers to the suspended solids particles, planktonic organism and humic substances produced through decomposition of organic matter. In aquaculture ponds, turbidity from planktonic organism is often desirable to an extent, where as that caused by suspended particles is undesirable (Mc Combie, 1953). Optimum Secchi-disc visibility of fish ponds is considered to be 30-40 cm (Romaine and Boyd, 1978). When we compared the turbidity data of the 14 localities in our study it was observed Behala(Charaktala) (8.8m) and Behala(Jorabot tala)(8.2m) had the lowest turbidity indicating that these were oligotrophic bodies with very low productivity and as obvious no fishing was observed in the water bodies of the said locality. The water body at Ranikuthi had a very high turbidity (3.6m) indicating a very high productivity, where the water body seems to be approaching towards eutrophication. Thus even with a high concentration of CO_2 (37.3 mg/lit) and a moderate concentration of O_2 (37.3 mg/lit) its productive waters still served to fishing purpose. Except for Ranikuthi the other water bodies where fishing is observed seem to be mesotrophic (moderate productivity) in nature.



All the above four parameters viz- free dissolved CO₂, dissolved O₂, pH and turbidity were compared between the 14 localities-Fig.2. Dissolved CO₂ and O₂ shows a high level of fluctuations in the water bodies of the 14 localities while variation in the pH in the 14 localities is comparatively mild. However turbidity also shows higher fluctuations clearly indicating the trophic status of the waters. Specially of importance are two localities: Behala(Parnasree)[C] and Karunamoyee where free dissolved CO₂ concentration is low but O₂ concentration is high and again turbidity is high indicating productive water bodies. The trophic status of the water bodies in these two localities seems to be in upper mesotrophic range thus gradually tending towards eutrophication if proper sustainable approach is not immediately undertaken. Thus the water bodies of these two localities seems to be somewhat better for planning a sustainable development programme from the viewpoint of human use and that from the viewpoint of pisciculture thereby integrating the two. Another interesting observation was that in the water bodies where no fishing was observed, most of them were oligotrophic with very little productive value in term of pisciculture.

REFERENCES

- Banerjea, S.M. 1967. Water quality and soil condition of fish ponds in some states of India in relation to fish production. *Indian J. Fish.* 14: 115-144.
- Boyd, C.E. 1978. Water quality in warm water fish ponds. Technical Bulletin No. 47. Alabama Agricultural Experiment Station, Auburn, Alabama, p.132
- Adhikari, S. 2006. Soil and water quality management in aquaculture, p. 1-30. *In. Hand Book of Fisheries and Aquaculture.* Indian Council of Agricultural Research, New Delhi.
- Hutchinson, G. E. 1975. A treatise on Limnology. Vol.1, Part 2- Chemistry of lakes, John Wiley and Sons, Inc. USA, p.1015
- McCombie, A. M. 1953. Factors influencing the growth of phytoplankton. *J. Fish. Res. Bd. Can.* 10: 253-282
- Romaire, R. P. and Boyd, C. E., 1978. Predicting night time oxygen depletion in cat fish ponds. Alabama Agric. Exp. Stn. Bull. 505. Auburn University, Auburn.

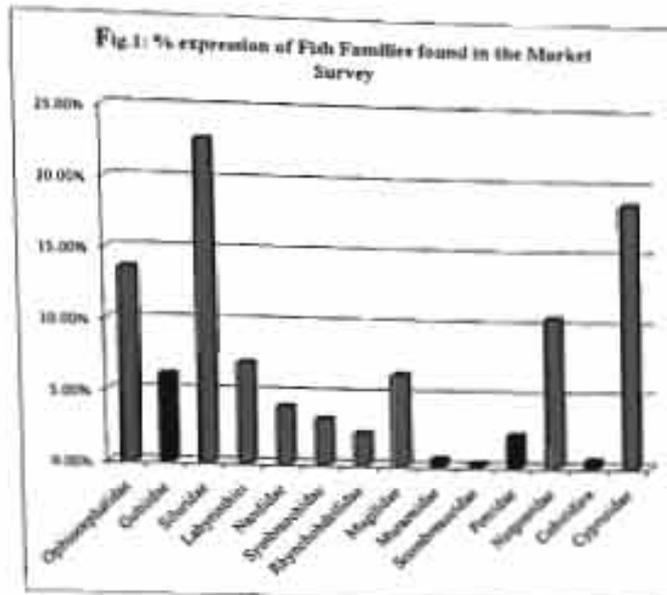


Fig. 1: This is a graphical representation of the abundance of the 14 fish families found in our market survey. Of the 42 species of fishes belonging to the above mentioned 14 families, observed in our market survey, *Mystus vittatus* (Deal tangra) belonging to Family Sisoridae topped the list.

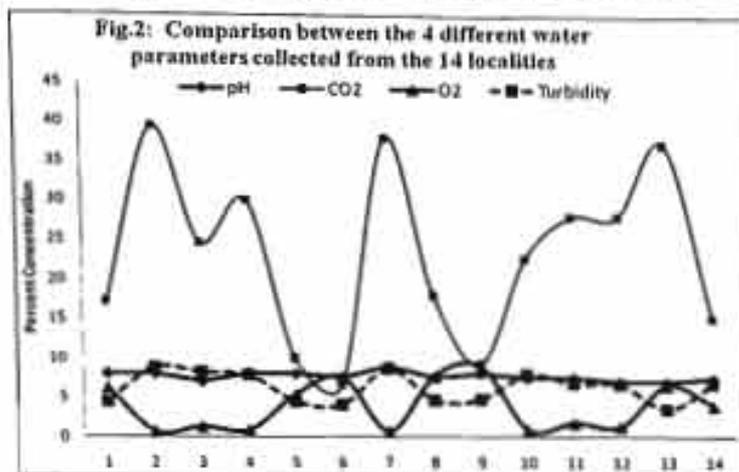


Fig. 2: This is a graphical representation of the pH, dissolved CO₂ and O₂ and turbidity. Numbers 1 to 14 indicate the 14 localities from which water sample had been collected: 1-Bakrahat(Nodakhali); 2-Behala(Charakatala); 3-Behala(Joribotola); 4-Behala(Parnasree)[A]; 5-Behala(Parnasree)[B]; 6-Behala(Parnasree)[C]; 7-Behala(Senhali); 8-Haridebpur; 9-Karunamoyee; 10-Naktala; 11-Nodakhali(Sehai)[A]; 12-Nodakhali(Sehai)[B]; 13-Ranikuthi; 14-Toltyganje. Dissolved CO₂ and O₂ shows a high level of fluctuations in the water bodies of the 14 localities while variation in the pH in the 14 localities is comparatively mild. However turbidity also shows higher fluctuations clearly indicating the trophic status of the waters. Speciality of importance are two localities: 6-Behala(Parnasree)[C] and 9-Karunamoyee where free dissolved CO₂ concentration is low but O₂ concentration is high and again turbidity is high indicating productive water bodies. Thus the water bodies of these two localities seems to be somewhat better for planning a sustainable development programme from the viewpoint of human use and that from the viewpoint of pisciculture thereby integrating the two.



The Effect Of Climate Change And Pollution On Nesting Habits Of Birds: A Study In Specific Areas Of Kolkata

Aritra Mishra*, Dola Roy*, Sromona Das*, Mukta Basu*, Morium Begum*, Soma Murmu*,
Piyali Dalapati*, Priyanka Naskar*, Labani Sarkar* and Samita Kundu**

**Corresponding author

Abstract: For the past few years climate change has had a tremendous impact on the distribution of animals, notably the birds. Moreover pollution has also its impact particularly in urban areas. To evaluate the impact of pollution mediated climate change, we have ventured on a study on birds localizing in and around south-west Kolkata. The present work includes extensive bird watching and field study of the local bird species inhabiting a major area along the Diamond Harbour Road, from Taratala to Joka. The diversity of the birds has been noted with particular emphasis on their nesting and breeding habits. Our area of study which is mostly a suburban region distinctly marks the shift in the local environment due to a change from city climate to a village climate within a distance of 4.2 km. This has further distinctly showed the change in biodiversity due to change in habitat.

The success of birds has been largely due to the great variety and ingenuity displayed in finding situations suitable for food and reproduction. Their power of habitat selection allows diversification of species by reducing inter-specific competition. Observations of the familiar birds of town and country reveal that they are at home in diverse situations than could be tolerated by most animals, and that within limits they can adapt their behavior to each situation (Young, 1981).

Global climate change and human invasions has already had a detectable effect on terrestrial and marine environments (Walther *et al.*, 2002). Keeping this in mind, we have ventured on a study to examine how birds of Kolkata have adapted to natural fluctuations in climatic conditions. The study also tried to understand which group of birds might be most adaptable to such effects by utilizing their ingenious ways of coping with the climate change and struggle for holding their abode against human invasions.

Kolkata, today, is reported to be India's pollution capital and is carrying a huge burden of suffering a rapid ecological degradation. The unprecedented hike in pollution levels has taken its toll not only on the health of human beings, but also many varieties of flora and fauna has become completely locally extinct. One of the most noticeable factors is the distribution of birds in and around Kolkata. Most of the bird species have become isolated in pockets in comparatively less polluted spots of the city like Narendrapur Bird Sanctuary, Tollygunge Club, Joka, Nalban, Central Park, etc. which can still provide a greener and peaceful environment. While the heart of the city is only flanked by scavengers like crows, sparrows, common myna, etc., beautiful oriental birds like Long Tailed Shrike, Grey Heron, Yellow Wagtail, Jacanas and Bitterns are found in the less polluted places. Birds like Brahminy kite have already become locally extinct. Interestingly, we can still get to see birds like night heron, rose ringed parakeet, house swift, etc. nesting in groups along roadsides in this pollution capital. We can presume that they might have coped up with the changing atmosphere around them and what they are searching for is only a safe habitat or a niche and availability of food which, in fact, are the basic needs for all organisms.

* Student, Department of Zoology, Vivekananda College, Kolkata-700063.

** Assistant Professor, Department of Zoology, Vivekananda College, Kolkata



MATERIALS AND METHODS

Materials required

The study mainly required books on bird (Ali and Ripley, 1983; Grimmett *et al.*, 1998; Ali, 2002), notepads and a 10x-40x binocular.

Areas of study

The search was intensified in five areas in between Joka and Taratala namely Joka Kalimandir, Joka Charial Khal, Vivekananda College Campus, Behala Chowrasta and Pora-Ashyottala. The bird survey was done in each spots centering a water body.

Timings of study

The field works were generally carried out from 7 A.M. to 11 A.M. and sometimes from 4 P.M. to 6 P.M. In every spot 2 surveys were carried out per month.

Method of study

Bird census was done following the Point Count Method, where, a particular spot was chosen on every day and watched from a fixed point.

Measurement of water parameters

The pH and BOD of local waters were estimated following the standard methods.

OBSERVATIONS

The five spots selected mainly shows five different kinds of habitats within a distance of 4.27 km. The two spots Joka Charial Khal and Joka Kalimandir are purely wetland areas with marshy cultivating fields having tall grasses and frequent meadows. Vivekananda College is situated almost at the outskirts of the main city of Kolkata. Its huge backyard field with a small dense plantation area by the side of a small pond provides an excellent habitable place for different birds. Chowrasta present on the D.H. Road, is a very crowded, polluted and noisy place.

A list of the various bird species observed and identified in the selected places has been prepared. The density pattern of the various birds have also been arbitrarily ascertained (Table I). A maximum number of bird species have been identified at Joka Charial Khal and is followed by Joka Kalimandir. Vivekananda College Campus comes after Joka. The minimum number of bird species variety has been found along the D.H. Road. Even if we go along the D.H.Road, then its interiors show a much diverse variety than have been seen on the main road (Fig. 1). Apart from house crows and sparrows, the birds that seem to be most abundant in this present climatic condition are the Blue Throated Barbet and the White Breasted Kingfisher, whereas the least abundant are the Common Kingfisher and the Alexandrine Parakeet. The measurement of the pH and BOD level of the water bodies from the five spots show that both these water qualities are tending towards becoming normal as we move forward from the city to the Joka area.

DISCUSSION

Climate change has occurred at an unprecedented rate during the last few decades. Rapidly changing environmental condition poses special problems for organisms because they are generally assumed to be adapted to prevailing conditions (Walther *et al.* 2002; Root *et al.* 2003; Moller *et al.* 2004). Many different organisms have responded to these changes in environmental conditions either through phenotypic plasticity and / or evolutionary responses (Parmesan & Yohe 2003; Moller *et al.* 2010). Moreover, organisms typically reproduce at the most favourable time of the year, when food abundance peaks (Lacks, 1954). Birds mainly prefer those places as their habitat where they can nest, feed and breed with comfort and safety. A degradation of those



habitats generally leads to their extinction from that place. However, certain birds like mynas and pigeons have adjusted with their surroundings and now they only look for creeks and crevices of houses to build their nests. Again, some get affected by decreased availability of food. Black kite mainly feeds on carcass of dead animals and preys on small mouse, lizards. So their concentration is high in the open city but in country sides with such scanty food, they become locally extinct.

With these parameters being taken into consideration, we set out on our project on the birds inhabiting south-west Kolkata on Diamond Harbour Road from Taratala towards Joka. The comparative study of the levels of different bird species in the five areas selected gives an overall account of the environmental conditions of the areas. The Joka Charial Khal is a mixed wetland-grassland ecosystem and the main vegetation in the tropical grassland part is dominated mainly by *Phragmites*, *Saccharum*, *Erianthus*, *Imperata*, *Desmostachya* and *Achyranthes* spp. The freshwater wetland part is seasonally covered by *Typha*, *Sagittaria*, *Cryptocoryne*, *Cyperus*, *Acrostichum*, *Ipomoea*, *Eleocharis* and other species. The rest of the spots are more or less within the main stream city of Kolkata and are flanked by vegetations like *Clerodendron*, *Ricinus*, *Solanum*, *Commelina*, *Blumea*, *Eclipta*, *Cocos*, *Ficus*, *Neolamarckia*, *Nyctanthes* spp. The maximum number of bird species has been identified at Joka Charial Khal followed by Joka Kalimandir, Vivekananda College Campus comes next to Joka. Along the D. H. Road, the interiors show a much diverse variety than on the main road (Fig. 1). Thus, there is clearly a decline in the species variety as we move from the peaceful and almost pollution-less interiors of Kolkata to the busy roads of the city where both air and noise pollution is at its peak. A majority of Kolkata's population resides along the sides of D. H. Road and a huge number of vehicles ply across this stretch. Undoubtedly, the number of the bird species noted is comparatively much less here than in the other areas.

We have also deduced that the Blue Throated Barbet and White Breasted Kingfisher have always maintained a constant level of density in all the five spots, while the Common Kingfisher and Alexandrine Parakeet have very low density. Our study has been focused particularly on the two varieties of Kingfishers because not only these birds are both kingfishers, both are noted to have the same kind of breeding habits of making nests by the pond banks and are also reported to be primarily feeding on fishes. A cardinal point here is that in spite of being birds of the same group, the Common kingfisher (*Alcedo atthis*) is found in a much lesser density within the specified areas of our field than the White breasted, also known as the white throated kingfisher (*Halcyon smyrnensis*) (Fig. 2).

White-breasted Kingfisher, the state bird of West Bengal (Bengali name – sadabuk maachhranga), is very common in a variety of habitats, mostly open country in plains with trees, electric wires and other perches. It had a much better abundance in the city and is able to cope up with a wide range of climatic change and rapid urbanization because of its feeding habits. The White-breasted kingfisher had a wide range of food habits like crustaceans, small crunchy insects, fishes, snakes, frogs, etc. (Sen, 1944). Sometimes they even feed on small birds like Oriental white eye (Roberts and Priddy, 1965) and so do not have to face the food scarcity. Thus in spite of the climate change, their number is not at all at a downfall.

Common Kingfisher (Bengali name – chhotto maachhranga) prefers to live near streams, slow flowing rivers, ponds and lakes and thus is exclusively restricted to the fresh water zones. This bird restricts its feeding habits to only small fresh water fishes like *Puntius*, *Amblypharyngodon*, *Glossogobius*, *Chanda*, *Colisa* spp. etc. They are facing obstacles to survive in the city with excess of pollution and greenhouse gases. The average temperature here is on the rise, which is indirectly effecting on the water bodies to induce rapid growth of exotic plant species like *Eichhornia crassipes* and a variety of algae. The water bodies also get polluted by



the dumping of waste materials, which increase the ionic and heavy metal concentration leading to the rapid vanishing of small fish populations on which they feed. In many parts of the survey we have come across water bodies where large fishes like *Labeo*, *Catla*, *Cirrhinus* spp. are cultured for commercial purpose, and so the common kingfisher has vanished from these places. Thus they are decreasing within the cities and are getting restricted in wetland areas of Joka.

To study the spatial change in distribution of the two species we have taken into consideration some important parameters, namely pH of the water bodies and the adjoining soil and BOD of water bodies. The analysis of the soil pH has been done to check the correctness of the water pH since both are highly interdependent on each other. It was noticed that there was a constant level of improvement of water quality as we moved from the city towards the Joka-Charial Khal region. Simultaneously there was a constant increase in the Common Kingfisher population with the maximum number of Common Kingfisher being spotted in Joka-Charial Khal while the White-breasted kingfisher population remained the same. The Joka Kalimandir area deserves special mention, because the Central Kolkata Drainage Canal flows through and there is a drastic change in pH and BOD of the place. But the Joka Charial Khal is completely a wetland area dominated by huge grasses like Bene ghash (Bengali name). Moreover, the fishes on which Common Kingfishers feeds on mainly thrive in the waters with pH of 5 - 7 and low light penetration. The water bodies of Joka Charial-Khal and to a little extent the Vivekananda College and the Douglas Ground pond fulfill the above parameters. Thus Joka-Charial Khal provides an appropriate food habitat for the Common Kingfisher. Though the College pond has noted the presence of Common kingfisher, but the Douglas Ground pond does not record any such species because it is mostly used for commercial pisciculture. Another indicator species for the decrease in water quality in the Joka Kalimandir, Douglas Ground and Pora-Aswathatala area compared to those of Charial khal and Vivekananda College is that the water body in Joka Kalimandir, Douglas Ground and Pora-Aswathatala are marked by seasonal growth of water hyacinth (*Eichhornia* sp.), which directly specifies the abundance for heavy metals in the water of these regions.

Though the White breasted kingfisher primarily aims at making nests by the pond banks, they have also been seen to make nests in mango trees, cracks and crevices of village huts and also have been noted to make nests within the dry drain pipe of an old house. So they are also able to change their natural breeding habit of making nests according to the environment in which they are living. But the Common kingfisher is always reported to make nests on pond banks. This difference in the habit of the two species seems to be a factor towards the spatial distribution of the two birds. In the urban region, most of the water body banks are concretized as can be seen in the water bodies of Pora-Aswathatala and Douglas Ground. Moreover, the pond banks are the main merging areas for terrestrial and aquatic habitat, so this region can be called an ecotype characterized by maximum interaction of different species and a gradual flow of energy. Thus, if the banks are embanked this ecotype will be lost leading to a decrease in the food resource for the fishes on which the Common kingfisher feeds on. But the water bodies of the Vivekananda College and the Charial-Khal are natural water bodies and mainly provide a nesting place for the Common Kingfisher.

Thus, from the ecological study of these two bird species, we can see that it is not actually the climate change that is posing problems on the nesting pattern and distribution of the two birds, but it is mostly urbanization, pollution and anthropogenic activities that is leading to destruction of habitat and decreasing availability of food resources that are ultimately pushing the Common kingfisher to decrease in number. Among the two species, the White-breasted kingfisher is able to cope up with the basic amenities in life due to its spatial adaptations while the Common Kingfisher is not able to do so leading to a lower population count. Thus, the fittest White breasted kingfisher survives here.



ACKNOWLEDGEMENT:

Thanks are due to Vivekananda College, Thakurpukur, for providing the grant to carry out this project under a student research scheme. Thanks are also due to all the faculties and staff of the department of Zoology of this college for their timely help. A special word of thanks to Sri Shuvendu Das and Sri Susanta Kumar Bag.

REFERENCES

- Ali S. 2002. The book of Indian birds. (ed. 13). Bombay Natural History Society: Mumbai.
- Ali S. and Ripley S.D. 1983. Handbook of Birds of India and Pakistan. Oxford University Press: Bombay.
- Grimmett R., Inskipp C., Inskipp T. 1998. Birds of the Indian subcontinent. Christopher Helm: London.
- Lack D. 1954. The natural regulation of animal numbers. Oxford, Clarendon Press.
- Møller A.P., Fiedler W. and Berthold P. (eds) 2004 Effects of Climatic Change on Birds, Elsevier, Amsterdam, the Netherlands.
- Møller A.P., Flensted-Jensen E., Klarborg K., Mardal W. and Nielsen J.T. 2010. Climate change affects the duration of the reproductive season in birds. *Journal of Animal Ecology*, 79: 777-784.
- Parmesan C. and Yohe G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, 421: 37-42.
- Roberts T.J. and Priddy C. 1965. Food of the White-breasted Kingfisher *Halcyon smyrnensis*. *Journal of the Bombay Natural History Society*, 62 (1): 152-153.
- Root T.L., Price J.L., Hall K.R., Schneider S.H., Rosenzweig C. and Pounds A.J. 2003. Fingerprints of global warming on wild animals and plants. *Nature*, 421: 57-60.
- Sen S.N. 1944. Food of the White-breasted Kingfisher (*Halcyon smyrnensis fusca*). *Journal of the Bombay Natural History Society*, 44 (3): 475.
- Walther G.-R., Post E., Convey P., Menzel A., Parmesan C., Beebee T.J.C., Fromentin J.-M., Høgh-Guldberg O. and Bairlein F. 2002. Ecological responses to recent climate change. *Nature*, 416: 389-395.
- Young J.Z. 1981. The life of vertebrates. Clarendon: Oxford.



Table 1. An overview of the level of bird diversity in the five different areas along Diamond Harbour Road from Joka to Taratala

Species	Scientific Name	Number of places spotted	No. of places spotted	Average density
1.	Alexandrine Parakeet	<i>Psittacula eupatria</i>	1	Very low
2.	Ashy Wood Swallow	<i>Artamus fuscus</i>	1	Very low
3.	Asian Koel	<i>Eudynamis scolopacea</i>	4	Medium
4.	Asian Openbill	<i>Anastomus oscitans</i>	4	Medium
5.	Asian Palm Swift	<i>Cypsiurus balasiensis</i>	3	Medium
6.	Barn Swallow	<i>Hirundo rustica</i>	2	Low
7.	Baya Weaver	<i>Ploceus philippinus</i>	2	Low
8.	Bengal Bushlark	<i>Mirafra erythroptera</i>	1	Very low
9.	Black Bittern	<i>Dupetor flavicollis</i>	1	Very low
10.	Black crowned night heron	<i>Nycticorax nycticorax</i>	2	Low
11.	Black drongo	<i>Dicrurus macrocercus</i>	5	Medium
12.	Black headed munia	<i>Lonchura malacca</i>	3	Low
13.	Black hooded oriole	<i>Oriolus zanthornus</i>	3	Medium
14.	Black kite	<i>Milvus migrans</i>	4	Medium
15.	Black rumped flameback	<i>Dinopium benghalense</i>	4	Medium
16.	Black shouldered kite	<i>Elanus caeruleus</i>	2	Very low
17.	Blue throated barbet	<i>Megalaima asiatica</i>	3	High
18.	Blyth's reed warbler	<i>Acrocephalus concinense</i>	2	Very low
19.	Bronze winged jacana	<i>Metopidius indicus</i>	2	Very low
20.	Brown shrike	<i>Lanius cristatus</i>	2	Very low
21.	Cattle egret	<i>Bubulcus ibis</i>	3	Medium
22.	Chestnut tailed starling	<i>Sturnus malabaricus</i>	4	Very low
23.	Common hawk cuckoo	<i>Hierococcyx varius</i>	2	Very low
24.	Common kingfisher	<i>Alcedo atthis</i>	4	Very low
25.	Common Myna	<i>Acridotheres tristis</i>	4	Medium
26.	Common tailorbird	<i>Orthotomus atrogularis</i>	1	Low
27.	Coppersmith barbet	<i>Megalaima haemacaphala</i>	3	Very low
28.	Cotton pygmy goose	<i>Nettapus coromandelianus</i>	1	Very low
29.	Crested serpent eagle	<i>Spilornis cheela</i>	1	Very low
30.	Eurasian collared dove	<i>Streptopelia decaocta</i>	3	Very low
31.	Fulvous breasted woodpecker	<i>Dendrocopos macei</i>	2	Very low
32.	Great egret	<i>Casmerodius albus</i>	2	Very low
33.	Greater coucal	<i>Centropus sinensis</i>	4	Very low
34.	Green bee eater	<i>Merops orientalis</i>	1	Very low
35.	Grey wagtail	<i>Motacilla cinerea</i>	1	Very low
36.	Hoopoe	<i>Upupa epops</i>	1	Very low
37.	House crow	<i>Corvus splendens</i>	5	Very high
38.	House sparrow	<i>Passer domesticus</i>	5	Very high
39.	House swift	<i>Apus affinis</i>	2	Low
40.	Indian pond heron	<i>Ardeola grayii</i>	5	Medium



41.	Indian roller	<i>Coracias bengalensis</i>	1	Very low
42.	Intermediate egret	<i>Mesophoyx intermedia</i>	2	Very low
43.	Jungle babbler	<i>Turdoides striatus</i>	3	Very low
44.	Jungle myna	<i>Acridotheris fuscus</i>	4	Very low
45.	Large billed crow	<i>Corvus macrorhynchos</i>	1	Very low
46.	Lesser whistling duck	<i>Dendracygna javanica</i>	1	Very low
47.	Little cormorant	<i>Phalacrocorax niger</i>	4	Very low
48.	Little egret	<i>Egretta garzetta</i>	2	Very low
49.	Long tailed shrike	<i>Lanius schach</i>	2	Low
50.	Oriental magpie robin	<i>Copsychus saularis</i>	2	Low
51.	Oriental skylark	<i>Mirafra assamica</i>	1	Very low
52.	Paddyfield pipit	<i>Anthus rufulus</i>	2	Very low
53.	Pheasant tailed jacana	<i>Hydrophasianus chirurgus</i>	1	Very low
54.	Pied harrier	<i>Circus macrourus</i>	1	Very low
55.	Pied starling	<i>Sturnus contra</i>	5	Medium
56.	Plane prinia	<i>Prinia inornata</i>	3	Very low
57.	Purple heron	<i>Ardeola insignis</i>	3	Very low
58.	Purple sunbird	<i>Nectarinia asiatica</i>	4	Low
59.	Purple rumped sunbird	<i>Nectarinia zeylonica</i>	4	Low
60.	Red rumped swallow	<i>Hirundo daurica</i>	1	Very low
61.	Red vented bulbul	<i>Pycnonotus cafer</i>	3	Low
62.	Red wattled lapwing	<i>Vanellus indicus</i>	2	Very low
63.	Rock pigeon	<i>Columba livia</i>	2	High
64.	Rose ringed parakeet	<i>Psittacula krameri</i>	4	High
65.	Rufous treepie	<i>Dendrocitta vagabunda</i>	4	Low
66.	Scaly breasted munia	<i>Lonchura punctulata</i>	2	Low
67.	Shikra	<i>Accipiter badius</i>	4	Low
68.	Spotted dove	<i>Streptopelia chinensis</i>	5	Medium
69.	Spotted owlet	<i>Athena brama</i>	1	Very low
70.	Stork billed kingfisher	<i>Halcyon capensis</i>	3	Low
71.	Streak woodpecker	<i>Picus squamatus</i>	1	Very low
72.	Swinow's snipe	<i>Galinago megala</i>	1	Very low
73.	Watercock	<i>Gallirex cinerea</i>	1	Very low
74.	White breasted kingfisher	<i>Halcyon smyrnensis</i>	3	High
75.	White breasted waterhen	<i>Amaurois phoenicurus</i>	4	Medium
76.	White throated kingfisher	<i>Halcyon smyrnensis</i>	1	Very low
77.	White wagtail	<i>Motacilla alba</i>	2	Very low
78.	Wood sand piper	<i>Tringa glareola</i>	1	Very low
79.	Yellow bittern	<i>Ixobrychus minutus</i>	1	Very low
80.	Yellow footed green pigeon	<i>Treron phoenicoptera</i>	2	Very low
81.	Yellow wagtail	<i>Motacilla cinerea</i>	3	Very low
82.	Zitting cisticola	<i>Cisticola juncidis</i>	2	Very low

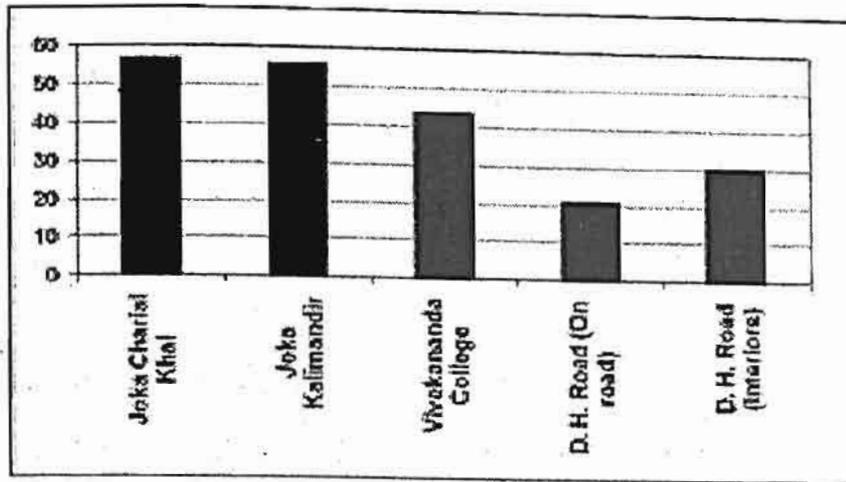


Fig. 1: The number of different types of bird species identified at the 5 spots along Diamond Harbour Road from Joka to Taratola

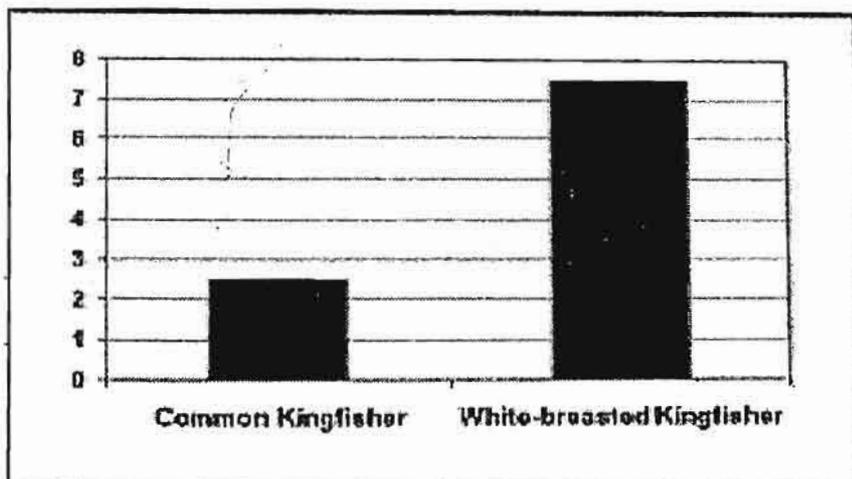


Fig. 2: Average density of White breasted kingfisher and Common kingfisher observed at the 5 spots along Diamond harbour Road from Taratola to Joka.



Algal Diversity at Amtala and Sarsuna, South 24 Parganas

Sutapa Rai*, Arup Das[§], Sreemanti Banerjee[§] and Abantika Ghosh[§]

Algae constitute a large and diverse group of simple, typically autotrophic organisms, ranging from unicellular picoplankton (0.2-20 μ m) to complex multicellular forms, such as the giant kelps of the eastern Pacific that grow to more than 60 meters in length and form dense marine forests (van den Hoek *et al.*, 1994). These photosynthetic organisms occur in most habitats, ranging from marine and freshwater to desert sands and from hot springs to snow and ice. They are unexcelled for variation in structure, range of habitat and diversity of role. With a phenomenal increase in population, a few of the major problems faced by the human society are those of quantity and quality of food, fodder and drinking water, disposal of sewage and industrial wastes and proper conservation of soil and water. Properly regulated algal growth can help tackling these problems. Chlorophycean algae are important as primary producers of organic matter at the base of the food chain in most aquatic ecosystems and also provide oxygen for other aquatic life. More than 75% of freshwater fishes feed on phytoplankton. The potential of micro algae in metal biosorption process has been studied extensively due to their ubiquitous occurrence in nature (Davis *et al.*, 2003; Hashim and Chu, 2004; Romera *et al.*, 2006). Many algal genera are found to have capabilities to accumulate heavy metals, thereby reducing their toxic effects (Lodeiro *et al.*, 2005; Abirhire and Kadiri, 2011). In recent times there is a renewed interest in using microalgae as a source of biofuel because of the escalating price of petroleum and the emerging concern about global warming that is associated with burning of fossil fuels (Hossain *et al.*, 2008; Schenk *et al.*, 2008; Vijayaraghavan and Hemanathan, 2009; Scott *et al.*, 2010). Experts say that farming algae in less than 1 per cent of India's total land area can make the country self-sufficient in liquid fuel.

Rapid urbanisation and economic development have resulted in unfavourable changes in the hydrology and ecology of freshwater and marine ecosystems, which are felt most acutely in the developing countries. The present study was undertaken to assess the algal diversity in two small areas in south 24 parganas undergoing rapid urbanization and development and emphasize the need for conservation of this valuable natural resource.

Materials and Methods

Study Area

Work on algal diversity was carried out at two different sites, Amtala and Sarsuna. Amtala is a census town under Bishnupur police station of Alipore Sadar subdivision in South 24 Parganas district in the Indian state of West Bengal. It is located at 22-22°N 88-17°E. Sarsuna is a neighbourhood in South West Kolkata. Part of the greater Behala region it is reachable through Chowrasta or through the narrow lanes of Barisha. It is bordered by Barisha in the East and Shakuntala Park to the West.

Sampling and Observation

A total of 30 algal samples were collected from the 2 sites—Amtala and Sarsuna, comprising various habitats namely ponds, drains and walls. The collections were made in the months of November and December 2011. Algal samples collected using forceps, scalpels and needles and kept in a tea strainer under running water to remove mud and dirt. They were stored in small sample bottles containing fresh 4%(v/v) formaldehyde. Each sample was assigned a voucher number along the date of collection. For the detailed study of the algal

*Associate Professor, Department of Botany, Vivekananda College, Kolkata-700063.

[§] Student, Department of Botany, Vivekananda College, Kolkata-700063.



specimens temporary slides, were prepared by staining the algae with cotton blue, mounting in lactophenol and sealing with paraffin. The slides were examined under low and high power objective lens of compound light microscope. Drawings of the dominant algae in each slide were made with a drawing prism along with magnification using stage micrometer under high power objective of compound microscope. Also microphotographs were taken using a digital camera. The algae were identified following monographs for various algal groups (Desikachary, 1959; Philipose, 1967; Desikachary, 1989; Prasad and Mishra, 1992; Rath and Adhikary 2005)

Results and Discussion

A total of 33 different species of algae were collected from both sites from three different habitats namely wall, drain & pond, belonging to three classes, Cyanophyceae, Chlorophyceae and Bacillariophyceae. 27 species were recorded from Amtala (Table: i) and 15 from Sarsuna (Table: 2). A comparison between between the two sites showed a high degree of dissimilarity in species richness and composition (Figs. 1 and 2). This difference may be due to difference in the degree of urbanization in the two areas.

Morpho-taxonomic descriptions of the specimens found

Class Cyanophyceae

Oscillatoia: Order: Nostocales; Family: Oscillatoriaceae

Thallus dark blue green, trichomes single, straight, cylindrical, sheath absent, tips not attenuated or constricted, showing oscillating movement. Cells upto 1/3 as long as broad.

Phormidium: Order: Nostocales; Family: Oscillatoriaceae

Thallus blue green, filaments cylindrical, apex attenuated, straight or bent, many together forming a leathery stratum, thallus attached by the lower side or floating in water with torn margins, more or less firm sheath present.

Lyngbya: Order: Nostocales; Family: Oscillatoriaceae

Thallus blue green, trichomes single or in a thin to massive thick firm colourless sheath, straight, not constricted at cross walls. Attached or free floating.

Microcoleus: Order: Nostocales; Family: Oscillatoriaceae

Thallus blue green, filaments straight, unbranched, sheath colourless, many trichomes closely grouped, coiled like a rope, ends straight, attenuated, end cell usually conical. Growing on muddy substratum.

Nostoc: Order Nostocales; Family: Nostocaceae

Thallus blue green, mucilaginous, gelatinous, globose, solid. Trichomes densely aggregated, curved, entangled within mucilaginous sheath, sheath diffluent, cells spherical, heterocysts intercalary. Free floating or epiphytic.

Merismopedia: Order: Chroococcales; Family: Chroococcaceae

Cells many in regular transverse and longitudinal rows in flat tabular colonies, arranged in a homogeneous mucilage, generally in fours, arranged in a single plane, sub-spherical, pale bluish green free floating. Growing on wet soil.

Scytonema: Order: Nostocales; Family: Scytonemataceae

Thallus blue green, trichomes showing false branching, formed laterally, generally in between heterocysts; trichomes single in each sheath, straight. Growing in stagnant water.



Spirulina: Order: Nostocales; Family: Oscillatoriaceae
Trichomes multicellular, filamentous, cylindrical, sheath absent, coiled in to a more or less spiral. Planktonic.

Class Chlorophyceae

Rhizoclonium: Order: Cladophorales; Family: Cladophoraceae
Plants filamentous, simple, unbranched, entangled, rather stiff, cells elongated, thick-walled. Chloroplast reticulate, parietal, with pyrenoids, often densely packed with starch. Growing in fresh or salt water.

Eudorina: Order: Volvocales; Family: Volvocaceae colonial green algae consisting of 32 individual cells grouped together. Each individual cell contains flagella which allow the colony to move as a whole when the individual cells beat their flagella together.

Pandorina: Order: Volvocales; Family: Volvocaceae
Colonial, composed of 8, 16, or sometimes 32 cells, held together to form a globular colony surrounded by mucilage. All cells of colony alike in size. The colonies coordinate their flagellar movement to create a rolling, swimming motion. Planktonic.

Sirocladium: Order: Zygnematales; Family Sygnemataceae
Thalli comprised on unbranched uniseriate filaments intertwined to form skeins. Cells cylindrical and curved. Chloroplasts two per cell; plate-like. Growing in freshwater or terrestrial habitats.

Chlorococcum infusorium: Order: Chlorococcales; Family chlorococcaceae
Thallus unicellular with spherical or slightly oblong cells of varied size. The cells may be solitary or may form irregular clumps sometimes forming films on moist surfaces. The mucilage is thin and inconspicuous.

Cladophora glomerata: Order: Cladophorales; Family: Cladophoraceae
Plants filamentous, profusely branched, dark olive green coloured, branches arising below the septa, branching on one side. Show variation in appearance according to habitat, age and environmental conditions. Free floating

Cladophora oligoclona: Order: Cladophorales; Family: Cladophoraceae
Plants filamentous, profusely branched, dark olive green coloured, branches arising below the septa. Branches arising from both sides. Free floating.

Deasonia: Order: Chlorococcales; Family: Actinochloridaceae
It is a colonial green alga. Colonies globose.

Pediastrum sp.: Order: Chlorococcales; Family: Hydrodictyaceae
with circular, colonial, free floating alga, with 2 to 128 polygonal cells arranged in a stellate plate, one cell in thickness.

Printzina lagenifera: Order: Trentepohliales Family: Trentepohliaceae
Thalli microscopic, primarily forming prostrate wide-spreading open networks of coarse filaments. Cells, cylindrical to ellipsoid to globular. Growing on sub-aerial habitats.

Scenedesmus: Order: Chlorococcales; Family: Scenedesmaceae
Flat, 4 plate-like oblong cells arranged in a row with their long axes parallel to one another, apices rounded, closely appressed to each other, cell wall smooth. Planktonic.



Spirogyra sp.: Order: Zygnematales; Family: Zygnemataceae

Thallus unbranched filamentous forming floating or submerged mats. Helical or spiral arrangement of the chloroplasts in diagnostic of the genus.

Class Bacillariophyceae

Synedra ulna: Order Bacillariales; Sub-Order Fragilariineae; Family: Fragilariaceae

Cells narrowly linear-lanceolate, tapering at poles, ends rounded, growing in stellate colonies. Valves 112-130 μ long, 7-8 μ broad. Planktonic.

Navicula cryptocephala: Sub-Order Bacillariaceae family Naviculaceae

Valves linear, Lanceolate or elliptical, 15-30 μ long and 4-5 μ broad. Ends rounded. Attached to submerged substratum.

Navicula radiosa: Order: Bacillariales; Sub-Order: Bacillariaceae; Family: Naviculaceae

Valves broadly lanceolate, with acutely rounded ends, 65-75 μ long, 9-12 μ Broad. Planktonic.

Pinnularia: Order Bacillariales; Sub-Order Bacillariaceae; Family: Naviculaceae

Cells rectangular in girdle view, valves lanceolate, sometimes with rounded ends, 50 μ long and 9-10 μ broad. Planktonic.

Cymbella: Order Cymbellales; Family: Cymbellaceae

Valves with a highly arched dorsal margin. ventral margin straight, with a tumid area in the center, The axial area narrow, slightly enlarged at the center to form an ovoid to irregular central area.

Thalassiosira: Order: Thalassiosirales; Family: Thalassiosiraceae

A centric diatom shaped like a short cylinder and varies in size from 4 to 32 μ in diameter. It tends to be larger in winter, typically 15 μ in diameter, but smaller in summer (5 μ). It occurs both singly and in groups and may be embedded in a gelatinous matrix. It is very tolerant to poor water quality

Gomphonema: Order: Cymbellales, Family: Gomphonemataceae

Valves only slightly asymmetrical Valves can appear almost lanceolate. Apices rounded. There is a single H-shaped chloroplast with a central pyrenoid.

Stauroneis: Order: Naviculales; Family: Stauroneidaceae

Cells symmetrical to the apical axis. Valves linear-lanceolate to lanceolate. Apices subcapitate. Raphe straight.

Nitzschia amphibia: Order: Bacillariales; Family: Bacillariaceae

Cells solitary or forming short band-like colonies. Frustules isopolar, bilaterally symmetrical, linear or lanceolate. Central part of the valve sometimes have very slightly concave margins. Poles usually slightly rotated. Planktonic.

Summary and Conclusion

A great amount of algal diversity exists in the state of West Bengal (Sarma, *et.al.* 1984) as is evident from the wide variety of algae encountered in two small areas Amtala and Sarsuna of South 24 Parganas. This diversity can be put to use in the reclamation of wastelands. The occurrence of alkaline and saline soils is widespread in many parts of India especially as a result of deforestation. However, such areas are suitable for algal growth and cultivation (Kumar, 1999). The members of Charales are very suitable as manure because of their calcium



encrustation which helps to prevent acidity of the soil and also dense clayey soil from forming clumps (Sen and Naskar, 2003). Natural changes in environmental conditions exert direct control on the population dynamics of aquatic organisms, which gives rise to characteristic biological communities within different ecosystems. However, pollution and other human activities also disturb these community profiles significantly and serve as an indicating system. Diatoms are important contributors to the primary production in aquatic ecosystems and are good indicators of the environmental integrity (Padhi et. al., 2010); remediation and protection of freshwater ecosystems is increasingly important but water quality management requires reliable long-term data on water quality and how remediation work affects the water. Moreover, information about natural, baseline, conditions in undisturbed ponds, lakes and rivers is needed against which polluted bodies of water undergoing remediation might be gauged and this is done by comparing the inhabitant algae. Also value of algae as nutritious food, fodder, their therapeutic value and potentialities as biofertilizer and biofuel is gaining widespread acceptance all over the world (Varfolomeev and Wasserman, 2011).

In conclusion it can be said that with effective research in this area the economic and ecological potentialities of the diverse assemblage of algae can be exploited. Therefore it is high time that we become aware of the importance of this neglected group of cryptogams and take immediate steps for their conservation.

Table 1: Class-wise distribution of the specimen found at Amtala

Cyanophyceae	Chlorophyceae	Bacillariophyceae
Oscillatoia sp.	Rhizoclonium sp.	Pinnularia macra
Lyngbya sp.	Pandorian sp.	Gomphonema micropus
Phormidium sp.	Eudorina sp.	Pinnularia Viridis
Microcoleus sp.	Cladophora glomerata	Navicula major
Merismopedia sp.	Cladophora oligoclona	Nitzschia linearis
Scytonema sp.	Deasonia sp.	Cymbella tumida
	Scenedesmus sp.	Navicula sp.
	Sirocladium sp.	Synedra ulna
	Printzina lagenifera	Thalassiosira sp.
	Chlorococcum sp.	Gomphonema sp.

Table 2: Classwise distribution of the specimens found at Sarsuna.

Cyanophyceae	Chlorophyceae	Bacillariophyceae
Oscillatoria sp.	Rhizoclonium sp.	Stauroneis Sp.
Spirulina sp.	Pediastrum sp.	Gomphonema micropus
Nostoc sp.	Spirogyra sp.	Synedra ulna
	Deasonia sp.	Cymbella turgidula
	Chlorococcum infusorium	Nitsschia amphibia
	Cladophora glomerata	Pinnularia viridis

Fig. 1: Comparison of algal diversity between Amtala and Sarsuna (Habitatwise)

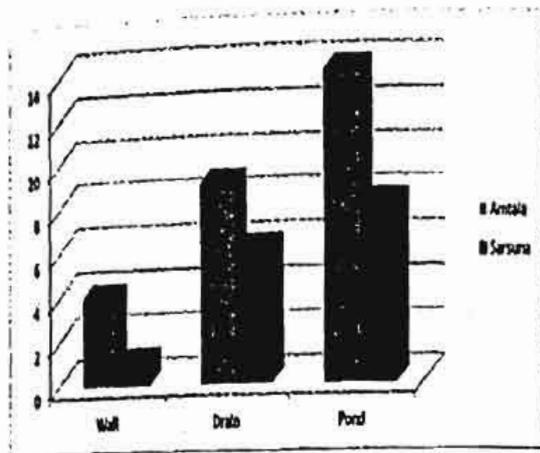
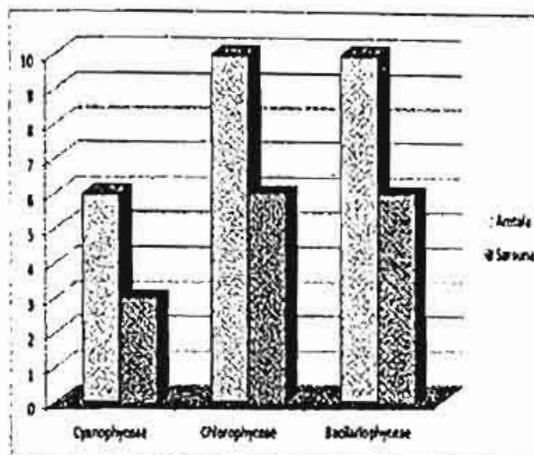


Fig. 2: Comparison of algal diversity between Amtala and Sarsuna (Classwise)



REFERENCES

- Abirhire, O. and Kadiri, M.O. 2011. Bioaccumulation of heavy metals using microalgae. *Asian J. Micro Biotech. Environ. Sci.* 13: 91-94.
- Davis, T. A., Volesky, B. and Mucci, A. 2003. A review of the biochemistry of heavy metal biosorption by brown algae Volume 37, *Water Research* 18: 4311-4330.
- Desikachary, T.V. 1959. *Cyanophyta*. I.C.A.R. Monograph on Algae. New Delhi. Pp 686.
- Desikachary TV (1989). *Atlas of Diatoms (Marine diatoms of the Indian Ocean region)*. Madras Science Foundation, Madras. Vol VI: 1-13, 622-809
- Hashim, M.A. and Chu, K.H. 2004. Biosorption of Cadmium by Brown, Green and Red Seaweeds. *Chem. Eng.J.* 97(2-3): 249-255.
- Hossain, S., Salleh, A., Nasrullag Boyce, A., Chowdhury, P., and Naquiuddin, M. 2008. Biodiesel Fuel Production from Algae as Renewable Energy. *American Journal of Biochemistry and Biotechnology*. 4(3): 320-254.
- Kumar, H.D. 1999. *Introductory Phycology*. Affiliated East-West Press Private Ltd. New Delhi: 651.
- Lodeiro, P., Cordero, B. Barriada, J.L. Herrero, R. And Sastre de Vicente M.E. 2005. Biosorption of Cadmium by Biomass of Brown Marine Macroalgae. *Bioresource Technol.*, 96(16): 1796-1803..



- Padhi, B.K., Rath, J. and Padhy, P.K. 2010. Diatoms for assessing the ecological condition of inland freshwater bodies. *World Review of Science, Technology and Sustainable Development* 7(4): 352-359.
- Philipose M.T. 1967 Chlorococcales. I.C.A.R. Monographs on Algae, New Delhi, Pp: 365.
- Prasad, B. N. and Misra, P. K. 1992. Fresh water algal flora of Andaman and Nicobar Islands, Vol. II. B. Singh and M.P. Singh, (eds) Deharadun, India, 248.
- Rath J. and Adhikary S.P. 2005. Algal Flora of Chilika Lake. Daya publishing house, Delhi. 206 pp.
- Romera, E., Gonzalez, F., Ballester, A., Blazquez, M. L. and Munoz J. A. 2006. Biosorption with Algae: A Statistical Review. 26(4): 223-235.
- Sarma, Y.S.R.K., Chandarana, R.B., Ramavat, B.K. and Tarwadi, S.J. 1984. Utilization of seaweed for liquid fertilizer energy and poultry feed, In: Proceedings Seminar on Sun, Sea and Shore, 90-91
- Schenk, P., Thomas-hall, S., Stephens, E., Marx, U., Mussnug, J., Posten, C., Kruse, O., and Hankamer, B. 2008. Second Generation Biofuels: High-efficiency Microalgae for Biodiesel Production. *Bioenergy Res.* 1:20-43.
- Scott, S.A., Davey, M.P., Dennis, J.S., Horst, I., Howe, C.J., Lea-Smith, D.J. and Smith, A.G. 2010. Biodiesel from Algae: Challenges and Prospects. *Current Opinion in Biotechnology* 21 (3): 277-286
- Sen, N. and Naskar, K. 2003. Algal Flora of Sundarbans Mangal. Daya Publishing House, Delhi.
- van den Hoek, C., Mann, D. and Jahns, H. M. 1994. Algae: An Introduction to Phycology. Cambridge University Press.
- Varfolomeev S. D. and Wasserman L. A. 2011. Microalgae as source of biofuel, food, fodder, and decicines. *Applied Biochemistry and Microbiology* 47(9): 789-807.
- Vijayaraghavan, K. and Hemanathan, H. 2009. Biodiesel Production from Freshwater Algae. *Energy Fuels*. 32: 5448-5453

NOTES TO CONTRIBUTORS

Bodhi is an official journal of the Vivekananda College, Kolkata. Each volume of this journal includes three issues viz. *Bodhi arthan*, *Bodhi Lata* and *Bodhi Tajwar*, one issue per year. We accept any original article or review not published elsewhere. But, under any condition, the Editorial Board of Vivekananda College will not shoulder the responsibility of the views or criticisms expressed by the authors or reviewers.

The articles should be written with clarity and simplicity so that an undergraduate student from any branch of studies can understand and enjoy it. But in no way should fidelity of facts and concepts be compromised. Preference would be on new findings and/or new conceptual developments that might have important scientific, social or policy implications. Articles of interdisciplinary nature or transcending into a philosophical height will be a welcome.

General Guidelines

- The manuscript should be typed either in English or in Bengali in 12pt Times of MS word, both one soft copy and one hard copy have to be submitted. They will not be returned. The drawings or BW photographs are to be digitised as ".tif" files or a neat copy has to be sent along with the text.
- Articles must be not more than 8000 words including notes, tables and references.
- Authors are requested to prepare their soft copies in text format. PDF versions cannot be processed by Bodhi. Authors are encouraged to use UK English spelling.
- Authors are requested to provide full details for correspondence: Designation, postal and email address and phone number.

Letter

Readers of Bodhi are encouraged to send comments and suggestions (300-400 words) on published articles. All letters should have the writer's full name, designation and postal and email address.

Reference

The reference used in an article should be placed in appropriate position within brackets by author(s) name(s) followed by the year of publication (e.g. Ricklefs and Miller, 2006).

For Books

Khan, M.Y. and Jain, P.K. 2005. *Financial Management*. 1st Edn. Tata McGraw Hill, New Delhi.

For Journals

Hornell, J. 1912. New cestodes from Indian fishes. *Rec. Indian Mus.* 7: 197-209.

All the submissions will be peer reviewed by subject expert(s) of repute and decision by the Editorial Board on acceptance or refusal for publication will be final.

Author will receive two copies of the journal free of cost.

All manuscripts are to be sent to -

The Principal

Vivekananda College

269, Diamond Harbour Road

Kolkata - 700 063.

E-mail: vivekanandacollege63@gmail.com

CALL FOR PAPERS

bodhi bijnan - a journal of Science, published by Vivekananda College, Kolkata, invites articles for the next issue of *bodhi bijnan*.

The last date for submission is 31st December 2014.

Principal

Vivekananda College

CONTENTS

Green Roof: A Ray of Hope	Tapan Kumar Poddar	3
Dimensional Analysis in Physics	Debnarayan Jana	8
জ্ঞানই জগৎ জয় করে	(সংগঠিত রচনা)	11
A Tribute to Srinivasa Ramanujan	Debasish Sengupta	16
Are you a Fibonacci Fanatic?	Tapanyoti Das	19
Death on The Track	Sreejata Biswas	29
Polycystic Ovary Syndrome: An Enigma	Soma Aditya (Bandyopadhyay)	35
Pheromones and Chemical Communication	Mohua Guha and Anjan Guha	40
Detection of beta thalassaemia trait and identification of the mutant locus among the school/college students in Barrackpore region by HPLC and ARMS PCR	Paromita Sarbhadhikary et.al	47
Brownian Motion - An Eclectic Potpourri	Saugata Bhattacharyya	54
The Blinding Tree <i>Eyecuscutia ugallocha</i> L. (Euphorbiaceae): a Review	Asis Kumar Pal and Kuntal Narayan Chaudhuri	70
ভিক্টোরিয়ার প্রথমদশাব্দিক জীববিজ্ঞানের ১০০ বছর	স্বপ্নাশীলিকা	89
Science Communication and Science Institutions: An Overview of Contemporary Kolkata	Arnab Kumar Banerjee	93
Biodiversity of Freshwater Shrimps in the district of South 24 Parganas	Krishanendu Das and Aditi Roy Sarkar	110
An Ecological Study On Wastewater Fishness Of Midahy Fishermen's Co-operative Society	Meenakshi Mukhopadhyay et.al	115
Evaluating sustainability of Urban and Peri-urban water bodies in and around South Kolkata followed by identification of the prevalent species of fishes available in each condition	Aditya Mitra et.al	124
The Effect Of Climate Change And Pollution On Nesting Habits Of Birds: A Study In Specific Areas Of Kolkata	Arma Mishra et.al	132
Algal Diversity at Armitah and Sarason, South 24 Parganas	Sutapa Rai et.al	140

We are here: www.vivekananda-college.org

Published by: Tapan K. Poddar, Principal, Vivekananda College, from 269 D. H. Road, Kolkata-63
 Printed by: Harmana, 6/7 Bijoygarh, Kolkata-52, Ph: 6451 3342