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Logo Description : It symbolizes an elephant within an ecological frame of peace and harmony moving towards prosperity and posterity. **Cover photo** (Anticlockwise from top) ; 1. Scanning Electron Micrographs of SPI + urea resins, 2. The male gharial with its snout out near the satakosia gorge 3. *Aglaia cucullata* Roxb of Bhitarakanika 4. Blue jay (*Corasius bengalensis*), the state bird of Orissa 5. Environmental enrichment in captive tiger of Nandankanan **Cover background photo** : *Exacum panicum* of Deomali hill range, Koraput, Orissa, (By Mr. Prasad).

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EDITORIAL

The course of evolutionary process has brought many changes to our mother Earth. The life that emerged is quite mysterious and the different dimensions of living beings are further interesting. The biotic and abiotic elements are constantly interacting with each other. The fluctuating temperature has created atoms and molecules to split and unicellular animals formed in the water later changed to multicellular eukaryotes. The significant characteristics in all the flora and fauna have become complex with differentiation and integration of the functions of the different structures of each species. The time of evolution is measured with the generations and the other abiotic changes are having no specific measurement. But the different chemicals, drugs and cosmetics produced for different purposes have huge propensity of a change once that come in contact with the living beings. As there is exponential growth of chemicals, it has become difficult for all the species to adapt to the changes.

The overloading of these chemicals creates health hazards to all species including human beings. In addition, the climate change and global warming further impair the process of adaptation. Some of the penguins of Antarctica have been detected to have D.D.T (Dichloro-Diethyl Trichloro Ethane) in their body. We use DDT as fly and musquito repellant which is not bio-degradable. We have not yet freed ourselves from the deleterious effects of wide usage of plastics. Vultures have been reached at a stage of extinction from Indian sub-continent because of rampant use of diclofenac group of NSAID(Non-steroidal Anti-infammatory Drugs) those were marketed in the last decade. Population of fruit eating bats is drastically decreased due to use of insecticides to control pests and in the process destroying the insects those are the important sources of food to the bats. Lemurs made their way to Madagascar from the larger African continent millions of years ago and have since adapted and evolved into the diversified number of species we see today although lemurs itself face a situation of extinction. Industry effluents released into water and harmful gas and oil leak cause severe pressure on survival of aquatic animals. Since the sex of a sea turtle is determined by the temperature at which its egg is kept, due to climate change and rise of temperature, only females of the species would be born inviting imbalance leading to loss of species.

E-planet endeavours to focus on features common to all lives, wherever it evolves. We are concentrating on developing robust understanding of the general sequence of progressive evolutionary change that will unfold wherever life arises. In this issue the pollution aspects causing severe detriments to life in industrial zone are dealt with equal concern for fast deterioration of mangrove forests of Bhitar Kanika or about threatened species of gharials that have been reintroduced into Satkosia Gorge Sanctuary. We are trying to illustrate how the evolutionary sequence unfolds present overloading of carbon footprints and our consideration of them will always find a place in forms of research articles to help prevent our planet from further damage. We should now evaluate the best fitments of situations that will ensure humanity and all other living beings to stay in harmony as the evolution process itself was never a chaos but a cosmos until the human anthropogenic pressure continued to stir the earth.

(Dr. R.K.Samantaray)
Editor-in-Chief

SYNTHESIS AND CHARACTERIZATION OF BIODEGRADABLE PLASTICS FROM SOY PROTEIN ISOLATE MODIFIED WITH UREA

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ABSTRACT

Expanding global production and consumption of polymer and plastic materials, together with increasing public awareness of environmental issues have created serious concern about the problems related to the disposal of plastic waste. Biodegradable plastics and composites find a broad acceptance in public as natural and environment -friendly materials. Soybean proteins, the by-products of soybean oil industry, are recently considered as a petroleum polymer alternative in the manufacture of biodegradable molded products and films. In the present research program, the spectral, thermal, morphological properties and the biodegradability of the urea-modified soy protein isolate(SPI) has been investigated using FTIR, TGA, DSC, XRD, SEM and soil burial test respectively. From all the above findings, it has been ascertained that, urea acts as a modifier to improve some of the properties of the SPI-plastic to make it processable. The biodegradability of the modified SPI-plastic indicates that they degrade within reasonable time period. It is expected that, this urea-modified SPI resin with reduced moisture sensitivity, improved as well as desired properties and controlled life time could be commercially used for making molded products and help in keeping the environment clean and green.

Key Words: Soy Protein Isolate (SPI), thermogravimetric analysis, biodegradation

INTRODUCTION

The persistence of petrochemical-based plastic materials in the environment beyond their functional life has resulted in a broad range of pollution, litter, and waste disposal problems for modern society. Research to alleviate these problems includes efforts to develop plastics that degrade more rapidly in the environment. Biodegradable plastics derived from agricultural feed stocks are a new generation of materials capable of reducing the environmental impact in terms of energy consumption and green-house effect in specific applications to perform as traditional plastics when in use and are completely biodegradable within a composting cycle through the action of living organisms when engineered to be biodegradable (Nayak 1999, Swain *et al*., 2004 a, b, c, 2005, Lodha *et al*., 2005, Nanda *et al*.,2006).

These new materials from renewable resource offer a possible alternative to traditional materials when recycling is unpractical or not economical or when environmental impact has to be minimized. Among all the agricultural products, soy protein is a good candidate which is considered to have high potential for engineering applications. In order to make soy plastics immediately competitive with petrochemical plastics, it is desirable to focus on the development of soy plastics for engineering structural applications where the overall cost of producing soy plastics may be competitive with their petrochemical counterparts.

Soy protein mainly consists of the acidic amino acids of aspartic acid (asparagines) and glutamic acid (glutamine), nonpolar amino acids (glycine, alanine, valine and leucine) and basic amino acids (lysine and arginine) and less than 1% cysteine. About 90% of soy proteins are storage proteins, consisting of 35% conglycine and 52% glycinin. Soy protein has an isoelectric point at ca. pH 4.5 & at this pH; the soy protein has least net charge and thus is the most water-resistant. It is known that when the pH drops from 6 to 4.5, water absorption of the plastics decreases from 80% to 30% after 25 hours submersion in water at 25^{O} C (Nanda et al., 2007 a, b, c, Nayak et al.,2008, Kumar et al., 2010, Su *et al*.,2008, Dean *et al*., 2005).

Soy protein possesses many side reactive groups such as –NH_2, -OH, and –SH which are susceptible to cross-linking reactions, in addition to naturally existing disulfide cross-links. Cross-linking leads to the formation of larger aggregates accompanied by an increase in molecular weight, reduction of solubility and reduced elasticity (Wolf 1970). Investigations by several authors have shown that unmodified soy proteins are highly hydrophilic and plastics made from them, are water sensitive

resulting in poor mechanical properties (German et al., 1985, *Mo et al.*, 1999). The functional properties of soy protein are highly related to its structure. Protein modification is designed to improve functional properties by tailoring protein structures through physical, chemical, and enzymatic methods. It is well known that protein modification including denaturation can improve functional properties of food proteins, such as solubility, foaming, emulsifying, gelation, and viscosity (Kumar *et al.*, 2002). Denaturation is defined as the modification of the secondary, tertiary, and quaternary structure of protein molecule without breaking covalent bonds present in the protein molecule. Methods of denaturation of proteins include exposure to heat, acid, alkali, detergent, or organic solvents. Nitrogen and sulphur compounds like urea, thiourea, semicarbazide and thiosemicarbazide are used as denaturing agent for protein (Wu *et al.*, 1974). In the present research programme, the spectral, thermal and morphological properties along with biodegradability of the urea- modified soy protein for various commercial applications are reported. The thermal degradation behaviour of the modified soy-protein isolate has been monitored by TG analysis. A computerized method, LOTUS software, was used for evaluating the kinetic parameters.

MATERIALS AND METHODS

SPI powder with moisture content less than 5.0% prepared at acid precipitation and containing more than 90% protein was provided by Archer Daniels, Midland (Decatur, IL, USA) as a gift sample. Urea (GR), obtained from Germany (Merk), was used without further purification for protein modification. All other ingredients were of analytical grade. The SPI powder (at a weight ratio of 1:10 of distilled and deionised water) was added to solutions of urea [0.0, 5, 10, 20 % w/w) of SPI & 2M] while stirring. It was stirred and allowed to react for 6 hours at room temperature and was allowed to stand for 24h. Then the pH of the slurry was adjusted to 4.5 by adding propionic acid drop wise. Since it is the isoelectric point of the protein, it has the least net charge at this pH value, and thus is most water resistant. Then it was centrifuged to remove excess water (Sorval Superspeed RC-B) at 4541g, for 10min and the precipitated residue was dried for 24h in a convection oven at d" 50^{O}C until a moisture content of 10% was reached. The dried modified soy protein isolate (SPI) was then milled (Cyclone Sample Mill, UDY Corporation, Fort Collins, CO, US) to pass through a 35- mesh sieve (Swain *et al.*, 2004b).

RESULTS AND DISCUSSION

Moisture content and water absorption

Moisture content and water absorption of the molded SPI-plastic samples was measured following ASTM standard method, ASTM D570-81. Unmodified SPI resin as well as the compression molded SPI (control) plastic sheet showed a higher percentage of moisture content. The moisture content as well as water absorption of the modified resin samples decreased with increase in concentration of the modifier up to 10%, after which it showed an increasing trend as evident from Fig. 1. In case of the modified SPI, urea could be the main contributor to the loss of soluble material. The molecular aggregate/entanglements and the amount of urea in the molded plastics would be the major factors influencing water absorption. Protein with more entanglements would absorb less water.

FTIR analysis of the resin

The FTIR spectra of the neat SPI [Urea-0% and SPI modified with urea-20% (Fig. 2) were recorded with Perkin –Elmer 1720spectrophotometer using KBr pellets.

The absorption bands related to C=O stretching at 1625 cm^{-1} (amide 1), N-H bending at 1520 cm^{-1} (amide II), C-H deformation at 1446 $cm^{-1,}$ C-N stretching and N-H bending vibrations at 1230 cm^{-1} were observed in both. The broad absorption band around 3271cm^{-1} was observed in both and is attributed to the free and bounded O-H and N-H groups. The O-H and N-H groups in SPI and the O-H in absorbed water are certainly able to form inter- and intra- molecular hydrogen bonding with the C-O moiety of the amino acids (peptide and carboxyl groups) in the protein structure. The characteristic C-H stretching of the CH_2 and CH_3 groups of saturated structures is observed around 2926cm^{-1}. These findings are in agreement with Moharram *et al.* (1994).

There is no change in the absorption band of the neat SPI and SPI modified with urea. They absorbed almost at the same wavelength regions, which clearly indicated that, urea is not a cross-linker; rather it acts as a modifier to enhance some of the properties of soy protein.

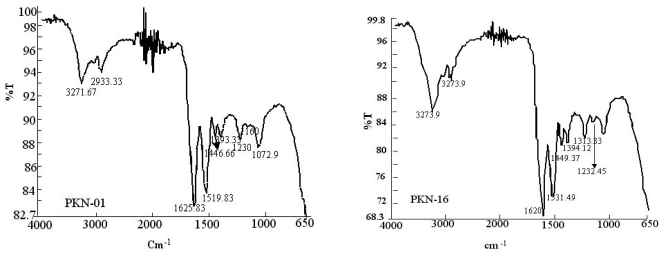

Fig. 1 : FTIR spectra of SPI-Urea resins (PKN-1 (1a), PKN-16 (1b)

Thermogravimetric analysis

Thermal degradation pattern of the modified biopolymers were studied using thermogravimetic analyzer (TGA 7, Perkin Elmer, Norwalk, CT) in N_2 atmosphere. The temperature range for scanning was from room temperature to 800°C at 10°C min^{-1} increment. The thermal degradation data of the modified SPI are furnished below (Table -1). The various kinetic equations used and the method of calculation of the kinetic parameters has been described in our previous publication (Swain *et al.*, 2004b).

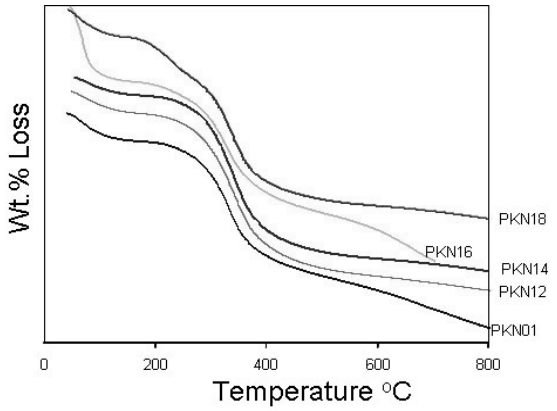

Fig. 2 : Comparative thermograms of SPI resins modified with different percentage of urea

A perusal of the thermograms of the urea- modified soy protein isolate could be dissected into four steps (Fig.3). For example , in case of sample PKN-12, the first break takes place around 114°C having weight loss about 7%, the second break takes place around 242°C having weight loss of about 12% the third break takes place around 364°C having weight loss about 51% and the fourth break takes place around 800°C having weight loss around 78%. In case of sample PKN-14 the first break takes place around 107°C having weight loss about 8%, the second break takes place around 250°C having weight loss of about 14%, the third break takes place around 358°C having weight loss about 52% and the fourth break takes place around 800°C having weight loss around 78%.

In case of sample PKN-18 (Fig.3), the break of the TG-thermogram showed a different trend as it has six breaks. The first break takes place around 103°C having weight loss about 9%, the second break takes place around 177°C having weight loss of about 13%, the third break takes place around 245°C having weight loss about 24%, the fourth break takes place around 286°C having weight loss around

Table 1: Thermal decomposition data of modified SPI with Urea in Propionic acid medium

Sample Code	% of Urea	Mass loss % at various temperatures in °C							
		100	200	300	400	500	600	700	800
PKN-01	00	8	12	25	55	63	68	76	83
PKN-12	05	6	10	23	60	68	71	74	77
PKN-14	10	8	11	24	63	70	73	75	78
PKN-16	20	9	14	19	58	66	73	83	91
PKN-18	2M	9	16	34	67	73	76	78	81

Table 2: Kinetic Parameters of SPI resins modified with urea

Sample Code Steps	Temp Range Start-end	Model	Constant	Err. Y	R.Squared	Activation Energy E(kj/mole)	Frequency Factor	slope
PKN01_1	38-105	B1	8.2249	0.0216	0.9863	20.10	12508.0	-1097.7
PKN01_2	106-250	B1	7.1167	0.0413	0.9509	15.56	3195.5	-849.4
PKN01_3	251-353	B1	9.4523	0.0368	0.9708	42.59	90425.3	-2325.5
PKN01_4	354-800	B1	7.3215	0.0390	0.9740	22.80	5746.4	-1244.6
PKN12_1	44-114	B1	8.0905	0.0240	0.9822	19.55	10634.5	-1067.5
PKN12_2	115-242	B1	7.3320	0.0388	0.9540	17.30	4407.2	-944.6
PKN12_3	243-364	B1	8.9910	0.0368	0.9739	37.85	50653.5	-2066.3
PKN12_4	365-800	B1	7.3058	0.0403	0.9671	21.85	5422.1	-1193.0
PKN14_1	47-107	H5	7.5245	0.0025	0.9996	16.66	5143.8	-909.4
PKN14_1	47-107	H5	7.5245	0.0025	0.9996	16.66	5143.8	-909.4
PKN14_2	108-250	B1	7.1396	0.0398	0.9531	15.80	3320.3	-862.6
PKN14_3	251-358	B1	9.3257	0.0367	0.9722	41.45	77534.2	-2263.1
PKN14_4	359-800	B1	7.2654	0.0408	0.9657	21.04	5015.4	-1148.9
PKN16_1	40-85	B1	9.1553	0.0054	0.9989	25.40	40071.5	-1387.0
PKN16_2	86-321	P1	6.6348	0.0333	0.9767	12.32	1562.7	-672.6
PKN16_3	321-705	B1	7.2434	0.0460	0.9572	20.85	4860.0	-1138.2
PKN18_1	36-103	B1	7.9884	0.0201	0.9863	18.43	9049.0	-1006.0
PKN18_2	104-177	B1	7.8698	0.0352	0.9407	20.40	8899.0	-1113.9
PKN18_3	178-245	B1	9.6178	0.0335	0.9650	38.34	96048.5	-2093.5
PKN18_4	246-286	B1	11.6895	0.0299	0.9555	62.06	1234184.7	-3388.5
PKN18_5	287-352	B1	10.8303	0.0326	0.9657	58.25	490604.5	-3180.6
PKN18_6	353-800	B1	7.2420	0.0399	0.9676	20.73	4825.2	-1131.6

45%, the fifth break around 352°C with a weight loss of 60% and the sixth break takes place around 800°C with weight loss of 81%.

This can be explained by considering the complex structure of soy-protein. It is well known that the three dimensional structure of soy-protein is governed by its primary structure, i.e. the sequence of amino acids. Two kinds of covalent bonds mainly found in proteins: one is the peptide bond between the amino acid residues and the other is the disulfide bond. The other non-covalent bonds present in protein are electrostatic and hydrophobic interactions and the hydrogen bonding (Bjorksten 1951).

In case of samples PKN-01, PKN-12, PKN-14 & PKN-16, the first break around 110°C is attributed to the elimination of absorbed water and the

dissociation of the quaternary structure of proteins. Further it is well known (Nanda *et al*., 2007c) that, beyond 100°C the protein denatures their subunits and promotes the formation of protein aggregates via electrostatic, hydrophobic and disulfide interchange bonding mechanisms. This has been recently substantiated by Kilara and Sharkasi (1986). It is generally accepted that, hydrophobic and disulfide bonding is involved and responsible for protein-protein aggregation caused by heating to temperature above 100°C. Further during this period the electrostatic and hydrogen bonding is also affected. The second break between 100°C to 250°C is mainly due to the cleavage of the covalent bonding between the peptide bonds of amino acid residues. During this period 69% of phenylalanine and tryptophan residues and 80% of tyrosine residue are burnt. Further heating also causes three simultaneous reactions in the structure of soy protein First, the dissociation of 7S and 11S protein subunits; second, the unfolding of the subunit secondary structure and third, the re-association of denatured subunits via disulfide, hydrophobic, electrostatic and other important bonding forces. The third break between 250-360°C is probably due to cleavage of S-S, O-N and O-O linkages of the protein molecule. The fourth break between 360-800°C is attributed to complete decomposition of protein molecule forming various gases like CO, CO_2, NH_3, H_2S and other gases. Beyond 800°C only the char residue remains.

But in case of sample PKN-18, the six-step breakage of the thermogram may be due to the presence of higher concentration of urea entangled into the protein matrix, which causes greater denaturation. It is observed in samples PKN-12 and PKN-16 that, all the four steps of degradation followed B1 mechanism. But in case of PKN-14, the first step of degradation is due to H5 mechanism & the second, third & fourth steps are due to B1 mechanism. On the other hand, all the six steps of PKN-18 follow B1 mechanism

A cursory glance at Table -2 regarding the values of activation energy for various steps of degradation is very interesting. The degradation as depicted in the thermogram takes place in four steps. The value of the activation energy, in case of all the first four samples, in the first step is comparatively high indicating slow degradation process. Subsequently the activation energy decreases in the second and then increases in the third step and subsequently decreases in the final step. In the initial step the degradation is slow because of the elimination of the entrapped moisture in the polymer matrix, In the second step, the breakage of hydrogen bonds, disulphide and other weak bonds most probably is very fast and hence the low activation energy. In the third step again the energy of activation is higher indicating the slow process. In the third step, most probably the hard peptide and other disulphide bonds break with high activation energy thereby decreasing the rate of the reaction. Hence the mechanism of degradation of the method soy-protein isolate agrees well with the predicted mechanism as evidenced from the computed values of the energy of activation.

Differential scanning calorimetry

The differential scanning calorimetry of the samples was monitored in a DuPont 2100 Thermal Analyzer from room temperature to 600°C at the heating rate of 10°C/min. The DSC thermo grams of the SPI modified with 0%, 5%, 10% and 20% urea are furnished in Fig.4 . The glass transition temperature (Tg) and melting temperature (Tm) of the modified samples corresponding to 0, 5, 10 and 20% urea were found to be 150, 152, 155 & 158°C, and 382, 404, 412 and 416°C respectively. Hence, the Tg and Tm increase with increase in urea concentration. This might be due to the fact that with increasing urea concentration soy protein may be converted from the native state to the more denatured state accompanied by unfolding and disrupting of the intermolecular bonding (Wu *et al*.,1974). The modified products can be considered as amorphous polymers that are not arranged in order crystals, but randomly strewn together in the formation of solid state (Liang *et al*., 1999).

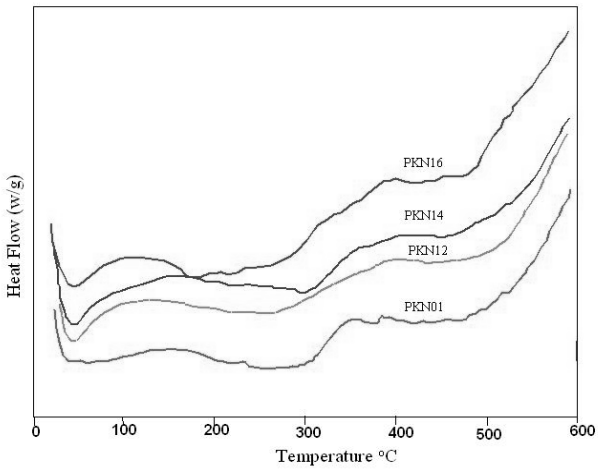

Fig. 3 : Comparative DSC-thermograms of SPI resins modified with different percentage of urea

X-Ray diffraction studies

The X-ray diffraction pattern of the unmodified and modified SPI exhibit very strong and distinct peaks at 2 è at 88, 21, 38, 44, 72, 19, 72, 73, 72, 72 (Fig.6) and 88 for PKN-1, PKN-12, PKN-14,PKN-16 and

PKN-18 respectively. The small degree of crystallinity of SPI powder and neat SPI resin (PKN-01) is not very much affected by the introduction of the modifier and the resins remain mostly in the amorphous state without being an ordered structure (Xcr. 15-24 %) as evident from the Table 3. By increasing the modifier concentration, the % of crystallinity first increased in the initial stages (in PKN-12) and decreased with further increase. Further investigation is required to ascertain the change of crystallinity with increasing concentration of the modifier beyond 20%.

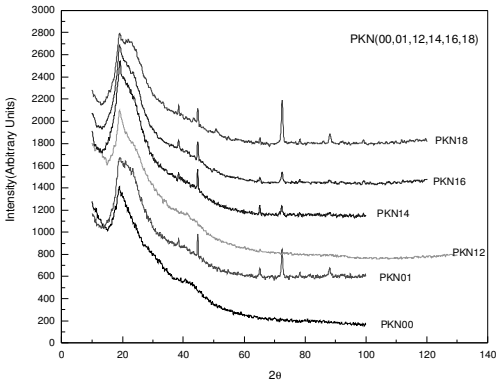

Fig. 4 : Comparative XRD graph of SPI and SPI modified with urea (different %)

Table 3 : Evaluation of crystallinity of SPI modified with Urea

Sample	2è	Peaks	Xcr	Average Xcr	%age Xcr
PKN00	19.35	1	0.17395	0.17395	17.395
PKN01	21.85	1	0.27975	0.15457	15.457
	38.75	2	0.01385		
	44.75	3	0.11749		
	72.40	4	0.23826		
	88.15	5	0.12345		
PKN12	19.20	1	0.23314	0.23314	23.314
PKN14	19.25	1	0.31451	0.22045	22.045
	44.70	2	0.15351		
	65.15	3	0.17923		
	72.40	4	0.23456		
PKN16	19.25	1	0.34284	0.21084	21.084
	38.45	2	0.16459		
	44.70	3	0.21006		
	65.15	4	0.13726		
	72.55	5	0.19909		
PKN18	19.05	1	0.33532	0.21375	21.375
	38.50	2	0.14598		
	44.75	3	0.14966		
	72.45	4	0.25546		
	88.25	5	0.18236		

Scanning electron microscopy

It is well known that, at relatively low concentrations (5%), urea may serve as a good plasticizer, which increases the plastic strain at break. At very high concentrations, urea may act as good filler, which increases the plastic thickness. Nearly linear elastic deformation and brittle fracture behaviors were observed for the unmodified SPI plastics (Fig. 5) The plastics from urea-modified SPI showed great deviation from linear deformation. All plastic samples modified with different concentrations of urea displayed rough and fluctuant fracture surfaces. Both deformation behavior and fracture surface indicatedthat plastics from urea-modified SPI were tougher than that from the unmodified SPI. As the concentration of urea increases, the surface of the plastics become more homogeneous indicating that at higher concentration it acts as good filler.

Biodegradability test

The biodegradability of compression molded modified SPI resins were investigated using aerobic biodegradability procedure (ASTM D 5209-92). All the resin samples about 10g each were placed in non-woven polypropylene bags, which were then placed in the compost mix for microbial degradation. The composting conditions such as moisture, temperature and pH were monitored periodically. The degradation was primarily attributed to the activity of mesophilic microorganisms, actinomycetes and fungi. Within a short period of time, the samples displayed excellent microbial growth on the surface. The samples were taken out periodically at regular intervals of time, washed thoroughly, pressed with paper towel, dried and weighed. The data is represented in Fig. 7 taking day's interval and %

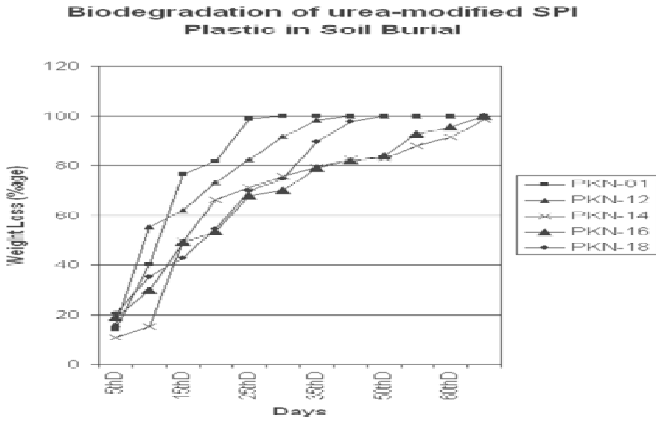

Fig. 5 : Biodegradation of molded urea-modified SPI sheet in soil burial

weight loss with time (Jindal et al., 2011). It was found that they degrade within reasonable time period (almost 80% by 35th day) and after about 55days, the amount of broken mass left was almost negligible indicating complete degradation of the sheets.

Soy protein isolate is considered as a potential substitute to petrochemical plastics for the manufacture of plastics because it is agro-based, cheap, and biodegradable. Considering the present global environmental problem and future shortaged of petroleum-based plastics this is indeed a good

candidate in the twenty first century for the production of environmental-friendly plastics for specific applications and save our valuable foreign exchange. These biodegradable products are with better thermal stability, strength and controlled life time and once they become waste, can be collected, ground and reused as animal feed or soil conditioners enhancing soil fertility, thus reducing environmental pollution.

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IN VITRO HYDROPONIC STUDIES ON ALLEVIATION OF NICKEL TOXICITY IN CROP PLANTS

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ABSTRACT

Nickel, being one of the important metal pollutants in the environment, is of considerable concern, because its concentration is rapidly increasing in soils of different parts of the world. The objective of this study is to evaluate the biochemical alterations and attenuation of nickel toxicity effects in wheat and mustard seedlings under combined applications of Ni ions, metal chelators (DTPA/EDTA/EDDHA/Citric Acid) and other metal ions (Zn^{2+}/Mg^{2+}). Wheat (*Triticum aestivum* L. cv. UP 262) and mustard (*Brassica campestris* L.) seedlings were grown hydroponically using different concentrations of Ni up to 7 days along with chelators and metal ions for study. The shoot growth was maximum with $NiCl_2$–EDTA (100µM) and minimum with $NiCl_2$–EDDHA (100µM) treatments whereas the root growth was maximum with $NiCl_2$–EDTA (100µM) and minimum with $NiCl_2$–CA (100µM) treatments in wheat seedlings. Whereas shoot length of mustard seedlings treated with 5µM-Ni^{2+} was the highest as compared to all other Ni^{2+} treatments followed by $NiCl_2$–EDTA (100µM) treatment. Total chlorophyll content was highest in the seedlings treated with $NiCl_2$-Mg^{2+} (100µM) and lowest in $NiCl_2$-Zn^{2+} (100µM). In case of mustard seedlings, there was remarkable total chlorophyll content in 10µM-$NiCl_2$ followed by 100µM-Mg^{2+}-$NiCl_2$ treatment. The seedlings treated with $NiCl_2$-$Zn^{2+}$and $NiCl_2$-EDTA showed enhanced carotenoid content in wheat and mustard respectively. $NiCl_2$ – EDTA (100µM) showed less Fo and Fm values and therefore, a trend in the decrease in OJIP transient indicates the maximum alteration of photochemical activity of PS-II in presence of $NiCl_2$–EDTA (100µM) treatment. Similar observation was found by $NiCl_2$–EDTA (250µM) treatment where Fo and Fm values were noted to decline. In mustard seedlings, there was a high variation of OJIP transient in different concentrations of $NiCl_2$ as compared to Control and decrease of Fm, Fo, J and I steps in the transient with increase in concentration of Ni.

Key Words : Chelating agents, biochemical alterations, OJIP analysis

INTRODUCTION

A major environmental concern due to dispersal of industrial and urban wastes (Ghosh and Singh, 2005) generated by human activities is the contamination of soil. Controlled and uncontrolled disposal of waste, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for the migration of contaminants into non-contaminated sites as dust or leachate and contribute towards contamination of our ecosystem. A wide range of inorganic and organic compounds cause contamination, these include heavy metals, combustible and putriscible substances, hazardous wastes, explosives and petroleum products.

Nickel is a essential micronutrient for the plant growth, but at higher concentration it inhibits the plant growth (Rao and Sresty, 2000 and Wang *et al*., 2002). Wide-ranging indication of nickel toxicity are stunted growth of root and shoots, poor branching, various plant parts deformity i.e. the effects are manifested at morphological, physiological and biochemical levels. Nickel is emitted in the environment from a variety of natural and anthropogenic processes and consequently its concentration becomes considerably high in the environment. Natural process includes weathering of minerals and rocks, whereas different compounds of nickel (such as nickel acetate, nickel carbonate, nickel hydroxide and nickel oxide) are used in a variety of industrial process (Cempel and Nikel, 2006). These compounds ultimately accumulate in the soil and environment, and can be easily taken up by plants. Thus, they can enter in the food chain and cause deleterious effects on animals and human lives (Nieboer and Nriagu, 1992 and Cempel & Nikel, 2006). The lower concentration of nickel has been reported to play a variety of roles in plant growth and metabolism. However, it shows deleterious effects at high concentration (Eskew *et al*., 1983; Kochian, 1991; Welch, 1995; Hasinur *et al*., 2005). Although, the toxic effects of excess nickel are evident through crop development, the germination stage is regarded as the most sensitive particularly to nickel toxicity (Viano *et al*., 2005). For example, the increasing concentration of Ni^{2+} has been shown to inhibit seed germination and seedling growth of different plant species (Viano *et al*., 2005, Farooqi *et al*., 2009).

As we know it is impossible to imagine soil without at least trace levels of heavy metals. However, natural and anthropogenic activities have concentrated some of the areas up to dangerous levels for living organisms (Chatterjee and Chatterjee, 2000). An excessive accumulation of heavy metals can have deleterious

effects on soil fertility, affect ecosystem functions and constitute health risk to animals and human beings. The major problem hindering plant remediation efficiency is that some of the metals are immobile in soils and their availability and phytoextraction rate are limited by solubility and diffusion to the root surface. Therefore, Chelating agents are used to increase metal mobility, thereby enhancing phytoextraction (Chen and Cutright, 2001 and Chen *et al*., 2001). Nickel, being one of the important metal pollutants is of considerable concern, because its concentration is rapidly increasing in soils of different parts of the world (Echevarria *et al*., 1998; Faryal *et al*., 2007 and Atiq-ur-Rehman and Iqbal, 2008).The present study reveals some toxic effects of $NiCl_2$ and its uptake in presence of different chelating agents and metal ions like Citric Acid, DTPA, EDTA, EDDHA, $MgSO_4$ and $ZnSO_4$.

MATERIALS AND METHODS

Plant materials

Graded dry seedy of wheat (*Triticum aestivum* L. cv. UP 262) and mustard (*Brassica campestris* L.) were obtained from National Seed Corporation, Bhubaneswar (India) and Orissa University of Agriculture and Technology, Bhubaneswar (India), respectively. Uniform sized seeds were selected and surface sterilized with 0.1% mercuric chloride ($HgCl_2$) for about five minutes and then was washed several times with tap water followed by distilled water. The surface sterilized seeds were placed in sterilized petriplates over saturated cotton pads for germination. Twenty five milliliters of either distilled water (control) or solutions of nickel chloride ($NiCl_2.7H_2O$) containing specific concentrations of nickel were poured into each petriplate. The seeds were germinated under controlled condition at 25º C in darkness for two days. Emergence of 2 mm primary root was used as the operational definition of germination.

Seedling Growth

Two-days-old uniform surface sterilized germinated seeds were transferred to well aerated Hoagland's nutrient solution (half strength) and Hoagland's solution supplemented with varying concentrations of nickel chloride placed in hydroponic culture vessels for seedling growth. The seedlings were grown in the growth chamber and the white light was provided (12h photo period) by white fluorescent tubes (36 W Philips TLD) with a photon flux density of 52 $\mu Em^{-2}\ S^{-1}$ (PAR).

Growth Parameters

The growth parameters like root length, shoot length, fresh matter, dry matter etc. of seven days old wheat and mustard seedlings were used for study. Different nickel chloride concentrations (10µM, 100µM, 200µM, 400µM, 800µM and 1000µM) were chosen for growth treatment. $NiCl_2$-chelating agents (100µM) and $NiCl_2$-metal ions (100µM) were also used for growth parameter analysis. For study of root and shoot length of 7 days old seedlings, the root and shoot were first detached from each other and individual length of root and shoot was measured in centimeter. Fresh matter content of both control and nickel chloride treated samples were recorded for assessment. Both nickel chloride treated and control seedlings were kept in an oven at 80º C for a period of 3 days or more (till constant weight was attained) for dry weight determination.

Analysis of Chlorophyll Content

The extraction of chlorophyll using acetone was done following the method of Porra (2002). 0.5 gm of leaves cut into small pieces were taken in 10 ml of 80% acetone and kept in dark in refrigerator for 28 hours or more (48 hours) at 4^0C. The absorbancy of extracted liquid was observed at 663.6 nm and 646.6 nm for Chlorophyll-*a* and Chlorophyll-*b* respectively and at 470 nm for carotenoids in a spectrophotometer.

Analysis of Chlorophyll-*a* fluorescence

The Chlorophyll-*a* fluorescence was measured from the upper surface of the four fully open leaves from the growing apex using a handy PEA (Hansatech Instruments, Norfolk, UK). Prior to measurement, a leaf clip (4mm diameter measuring area) with closed lid was inserted into the leaf and dark adaption was made for 10 minutes, after which fluorescence rise was induced on application of red light saturation pulse (3000µmole photon/m^2s; Strasser *et al*., 1995). The OJIP fluorescence levels were recorded after 50ms (Fo), 2ms (Fi), 30ms (Fi) and 400ms (Fm) respectively.

RESULTS AND DISCUSSION

Changes in growth parameters:

There were considerable changes in different growth parameters of seven days old wheat seedlings with application of various concentrations of Ni^{2+} as observed from Fig. 1 and 2.

Shoot Length

Shoot length decreased markedly with increase in Ni^{2+} concentrations. The changes in shoot growth of the seedlings treated with $NiCl_2$ and chelating agents/ metal ions is in the similar order as observed in root growth study. The shoot length of the seedlings treated with 10µM-Ni^{2+} and 5µM-Ni^{2+} was the highest respectively in wheat and mustard as compared to all other Ni^{2+} treatments. The seedlings treated with 1000µM-Ni^{2+} had minimum length in both the seedlings as shown in Fig.1 and Table 1.

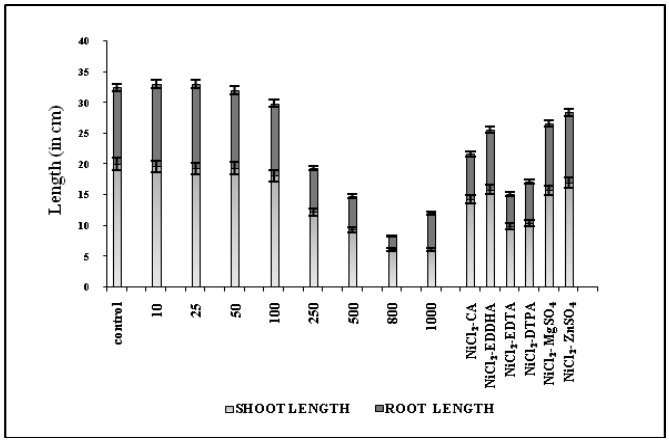

Fig.1: Effect of different concentrations of $NiCl_2$ on shoot and root length of wheat Seedlings (Mean ± S.E.).

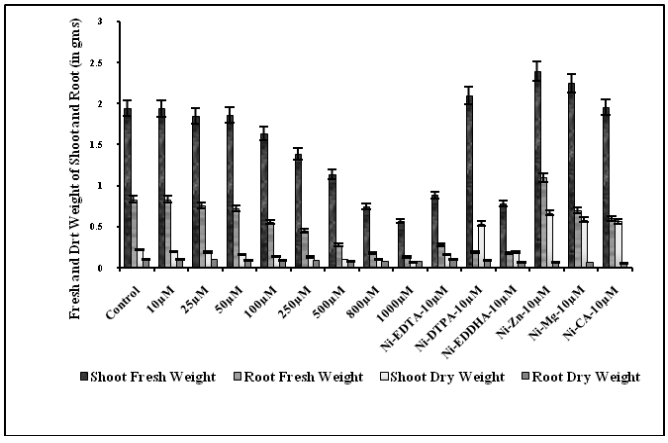

Fig.2: Effect of different concentrations of $NiCl_2$ on fresh and dry weight of shoot and root of wheat seedlings (Mean ± S.E.).

Root Length

The root length substantially decreased with increasing $NiCl_2$ concentrations in the growth medium. The remarkable root length was marked in seedlings grown in control. The seedlings treated with 1000µM-Ni^{2+} had minimum length in both wheat and mustard seedlings.

This might be due to the stimulation of some phytohormones or some enzymes by $NiCl_2$ which result in increased seedling growth at 10µM level. Possibly, higher nickel concentration inhibits all physiological activities which lead to poor seedling growth.

Fresh Weight

The shoot fresh weight of wheat seedlings gradually decreased with increase in the concentrations of $NiCl_2$. However, the seedlings treated with $NiCl_2$-Mg^{2+}/ Zn^{2+}/DTPA/CA (10µM) showed a boost in the biomass production unlike addition of chelating agents like EDDHA/ EDTA (Fig.2). Whereas the mustard seedlings treated with $NiCl_2$-Mg^{2+}/EDTA/ DTPA/CA (100µM) indicated a hike in the biomass production unlike addition of chelating agents like EDDHA/ Zn^{2+} (Table-1).

Analysis of the wheat root fresh matter indicated a sharp bio-mass decline except in the application of CA and Mg^{2+} as shown in Fig.2. There was enhanced root fresh weight in mustard seedlings treated with 5µM-Ni^{2+}. When complexed with chelators, there was significant rise in root fresh matter except the application of CA in mustard seedlings (Table 1).

Dry Weight

Similarly, dry biomass production of root was found to deteriorate in seedlings treated with EDDHA/ CA/

Table 1: Effect of Nickel ions, chelating agents and metal ions on growth parameters of 7 days old mustard seedlings.

Treatments	Root length (cm)	Shoot length(cm)	Root fresh weight(gm)	Shoot fresh weight (gm)	Root dry weight(gm)	Shoot dry weight(gm)	Root Dry Wt. /Shoot Dry Wt.
Control	5.66±0.038	9.35±0.05	0.082±0.002	0.624±0.002	0.035±0.001	0.132±0.002	0.2
5µM	5.44±0.041	9.20±0.025	0.086±0.002	0.670±0.004	0.033±0002	0.135±0.002	0.2
10µM	4.91±0.035	8.82±0.031	0.071±0.001	0.581±0.003	0.025±0.001	0.127±0.002	0.1
25µM	4.54±0.040	7.62±0.025	0.059±0.001	0.523±0.002	0.026±0.001	0.116±0.001	0.2
50µM	3.65±0.043	6.18±0.023	0.052±0.001	0.469±0.002	0.019±0.002	0.109±0.002	0.2
100µM	3.14±0.035	5.86±0.029	0.047±0.001	0.323±0.002	0.018±0.001	0.102±0.001	0.1
250µM	2.89±0.006	4.72±0.023	0.039±0.002	0.286±0.002	0.019±0.002	0.093±0.002	0.2
500µM	2.22±0.023	3.36±0.025	0.032±0.001	0.225±0.030	0.017±0.001	0.082±0.002	0.2
800µM	1.83±0.023	2.87±0.031	0.021±0.001	0.173±0.001	0.011±0.012	0.072±0.002	0.1
1000µM	1.45±0.031	2.33±0.023	0.004±0.001	0.1130.001	0.007±0.014	0.051±0.001	0.1
CA-$NiCl_2$ (100µM)	1.23±0.006	6.23±0.023	0.031±0.001	0.585±0.002	0.011±0.002	0.222±0.002	0.04
DTPA-$NiCl_2$ (100µM)	3.96±0.021	6.86±0.019	0.079±0.002	0.490±0.003	0.039±0.001	0.121±0.003	0.3
EDDHA- $NiCl_2$ (100µM)	2.69±0.015	4.98±0.034	0.063±0.003	0.285±0.002	0.013±0.021	0.063±0.001	0.2
EDTA-$NiCl_2$ (100µM)	4.81±0.031	8.52±0.020	0.092±0.002	0.724±0.001	0.043±0.002	0.313±0.001	0.1
$MgSO_4$–$NiCl_2$ (100µM)	2.88±0.015	7.21±0.015	0.073±0.003	0.580±0.003	0.017±0.002	0.243±0.027	0.06
$ZnSO_4$-$NiCl_2$ (100µM)	2.16±0.017	5.33±0.020	0.050±0.002	0.232±0.002	0.022±0.002	0.052±0.002	0.4

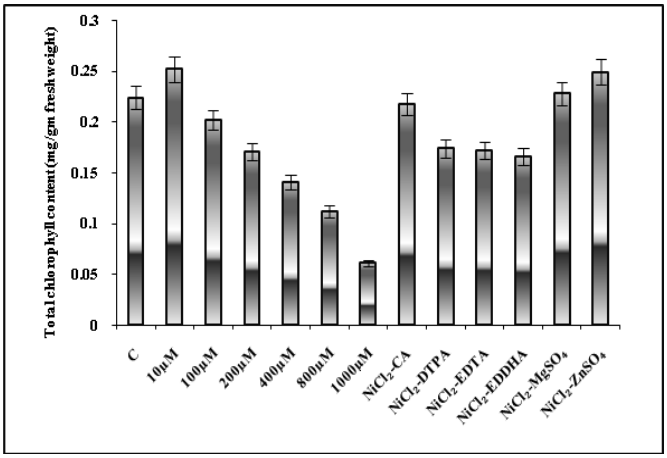

Fig.3: Effect of different concentrations of $NiCl_2$ on total chlorophyll content of wheat seedlings (Mean ± S.E.).

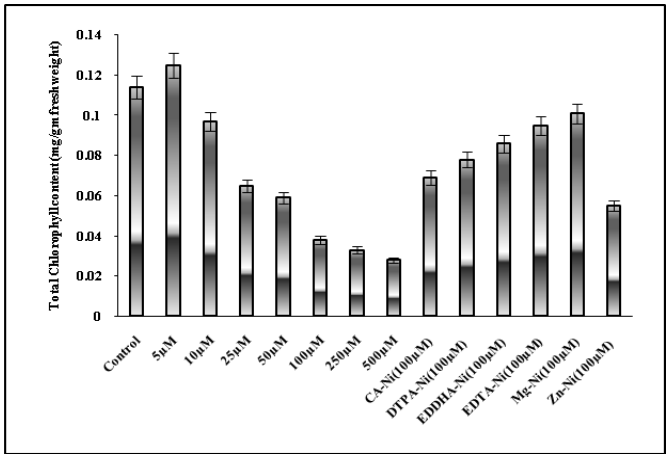

Fig.4: Effect of different concentration of Nickel ions, chelating agents and metal ions on chlorophyll content of 7 days old mustard seedlings (Mean ± S.E.).

Mg^{2+} and in shoots with EDDHA/ Zn^{2+} in wheat and in seedlings treated with EDDHA / Zn^{2+} in mustard.

Chlorophyll and Carotenoids:

The effects of varied concentrations (5µM, 10µM, 100µM, 200µM, 400µM, 800µM and 1000µM) of $NiCl_2$ on chlorophyll synthesis in absence and presence of chelating agents (DTPA, EDDHA, EDTA, CA) and metal ions (Zn^{2+}/Mg^{2+}) in wheat and mustard seedlings have been depicted in Fig.3 and Fig.4.

The decrease in chlorophyll-*a* content was found with the increase in concentration of $NiCl_2$ except 10µM in wheat and 5µM in mustard seedlings which might be due its inhibitory effect. The chlorophyll-*a* content in wheat was found maximum with 10µM-$NiCl_2$ treatment and minimum in 1000µM-$NiCl_2$. Whereas maximum amount of chlorophyll-*a* content was observed in 10µM-$NiCl_2$ treatment in wheat and reduced amount in 1000µM-$NiCl_2$ treatments of mustard seedlings. Among the seedlings treated with metal ions (Zn^{2+}/Mg^{2+}), the chlorophyll-*a* content was maximum in the seedlings treated with 10µM-Zn^{2+}-$NiCl_2$ and minimum in 10µM-EDDHA-$NiCl_2$ in wheat. In case of chlorophyll-*b*, maximum content was found with $MgSO_4$-$NiCl_2$ (10µM) and the lowest amount are found with EDDHA- $NiCl_2$ (10µM).

Whereas the mustard seedlings treated with metal ions (Zn^{2+}/Mg^{2+}), the chlorophyll-*a* content was maximum in the seedlings treated with 100µM-Mg^{2+}-$NiCl_2$ and minimum in 100µM-Zn^{2+}-$NiCl_2$. The elevated chlorophyll-*b* content was found with $NiCl_2$–EDTA (100µM) and the lowest amount was found with $NiCl_2$–DTPA (100µM) as depicted in Table 2. The enhancement may be due to the accelerating mechanism of chlorophyll biosynthesis in presence of metal ion and chelators.

Similar trend was observed in total chlorophyll content where it was remarkable in 10µM-$NiCl_2$ treatment and minimum in 1000µM-$NiCl_2$ in wheat (Fig.3). The total chlorophyll content was noteworthy in 5µM–$NiCl_2$ and abridged in 500µM – $NiCl_2$ treatments in mustard seedlings (Fig.4). When

Table 2: Effect of Nickel ions, chelating agents and metal ions on chlorophyll and carotenoid content of 7 days old mustard seedlings.

Treatments	Chlorophyll-amg/ gm fr. wt.	Chlorophyll-bmg/ gm fr.wt.	Chlorophyll a//b	Carotenoidmg/ gm fr.wt.
Control	0.102± 0.002	0.011± 0.001	9.27	0.131± 0.001
5µM - $NiCl_2$	0.111± 0.003	0.011± 0.002	10.09	0.148± 0.001
10µM - $NiCl_2$	0.087± 0.002	0.007± 0.001	12.42	0.122± 0.002
25µM - $NiCl_2$	0.056± 0.001	0.006± 0.001	9.33	0.107± 0.002
50µM - $NiCl_2$	0.052± 0.002	0.003± 0.001	17.33	0.095± 0.001
100µM - $NiCl_2$	0.033± 0.002	0.004± 0.001	8.25	0.082± 0.002
250µM - $NiCl_2$	0.030± 0.002	0.003± 0.001	10.00	0.076± 0.001
500µM - $NiCl_2$	0.026± 0.001	0.003± 0.002	8.66	0.062± 0.001
CA - $NiCl_2$(100µM)	0.060± 0.002	0.008± 0.002	7.50	0.039± 0.002
DTPA - $NiCl_2$(100µM)	0.071± 0.002	0.005± 0.001	14.20	0.035± 0.001
EDTA - $NiCl_2$(100µM)	0.083± 0.002	0.010± 0.001	8.30	0.071± 0.001
EDDHA - $NiCl_2$(100µM)	0.075± 0.002	0.008± 0.002	9.37	0.063± 0.002
$MgSO_4$- $NiCl_2$(100µM)	0.091± 0.002	0.008± 0.002	11.30	0.098± 0.002
$ZnSO_4$- $NiCl_2$(100µM)	0.047± 0.001	0.007± 0.001	6.71	0.017± 0.001

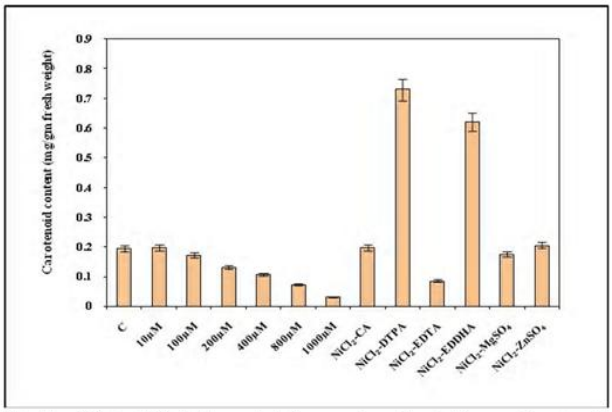

Fig.5: Effect of Nickel ions, chelating agents and metal ions on Carotenoid contents of 7 days old wheat seedlings (Mean ± S.E.).

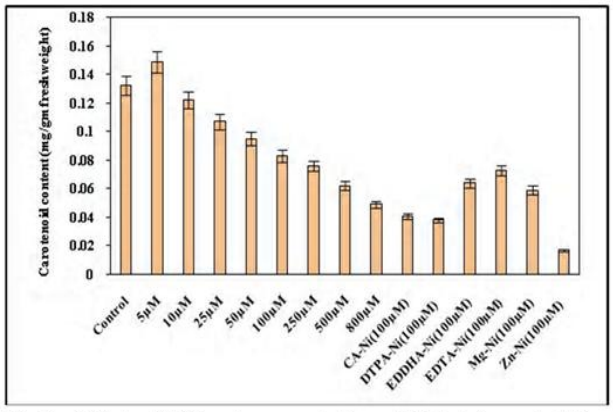

Fig.6: Effect of different concentration of Nickel ions, chelating agents and metal ions on carotenoid content of 7 days old mustard seedlings (Mean ± S.E.).

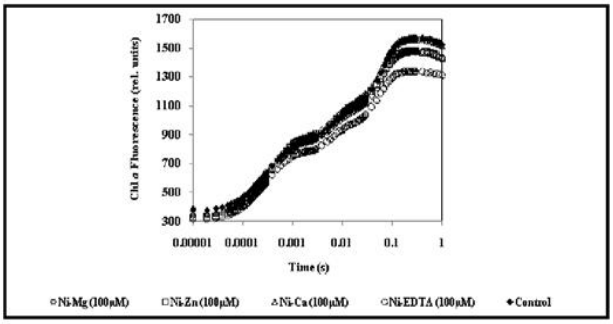

Fig.7: Effects of different concentrations of $NiCl_2$ (100µM) on chlorophyll-a fluorescence in wheat seedlings.

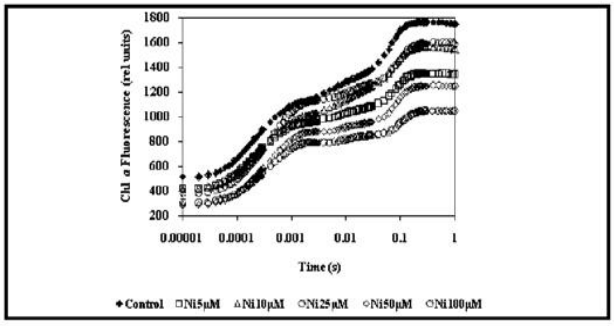

Fig.10: Effects of different concentrations of $NiCl_2$ on chlorophyll-a fluorescence in mustard seedlings.

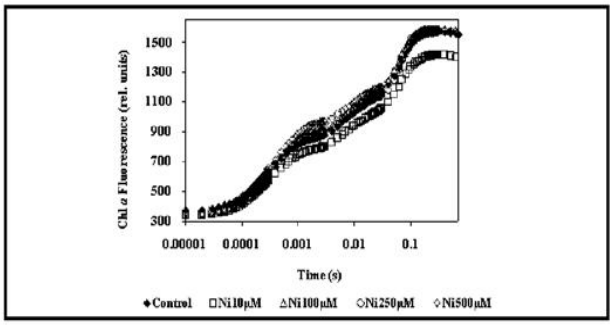

Fig.8: Effects of different concentrations of $NiCl_2$ on chlorophyll-a fluorescence in wheat seedlings.

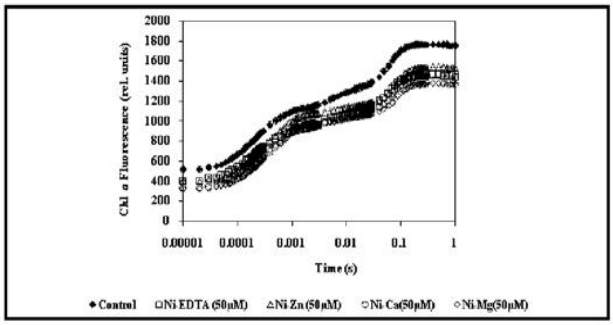

Fig.11: Effects of different concentrations of $NiCl_2$ (50µM) on chlorophyll-a fluorescence in mustard seedlings.

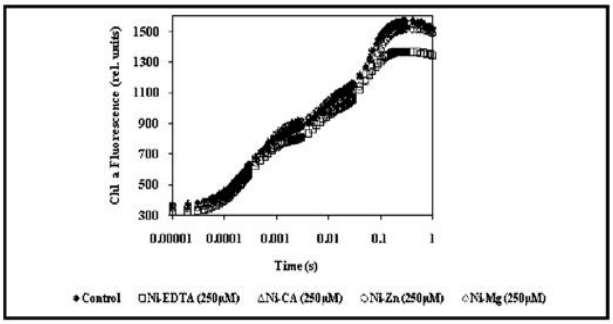

Fig. 9 : Effects of different concentrations of $NiCl_2$ (250µM) on chlorophyll-a fluorescence in wheat seedlings.

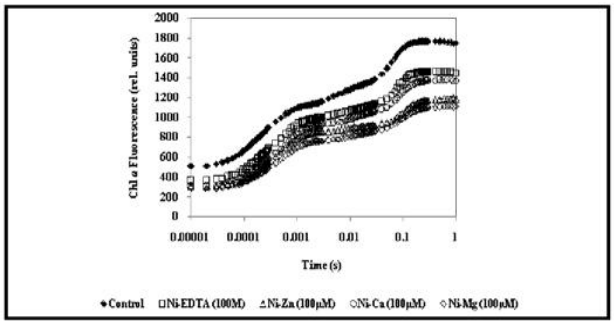

Fig.12: Effects of different concentrations of $NiCl_2$ (100µM) on chlorophyll-a fluorescence in mustard seedlings.

treated with chelating agents and metal ions, there was enhanced total chlorophyll content with 10µM-Zn^{2+}-$NiCl_2$ and 100µM-Mg^{2+}-$NiCl_2$ in wheat and mustard respectively may be due to stimulation of chlorophyll biosynthesis by nickel in combination with Zn^{2+} and Mg^{2}. There was reduction with 10µM-EDDHA-$NiCl_2$ treatment in wheat and in mustard with 100µM-Zn^{2+}-$NiCl_2$.

There was a marked decline in carotenoid content with increase in concentration except in the seedlings treated with 10µM-$NiCl_2$ in wheat and 5µM-$NiCl_2$ treatments in mustard. However, the wheat seedlings treated with DTPA – $NiCl_2$ (10µM) and mustard in combination with $NiCl_2$-Mg^{2+} indicated enhanced carotenoid content (Fig.5 and Fig.6).

The seedlings treated with $NiCl_2$-Zn^{2+} and $NiCl_2$-CA reported enhanced carotenoid content which showed a Zn^{2+} and CA dependent carotenoid biosynthetic pathway. The decrease in carotenoid content may be due to possible inhibition of carotenoid biosynthesis by $NiCl_2$.

Analysis of Chlorophyll-a Fluorescence

OJIP analysis of Fig.7 illustrated that $NiCl_2$ – EDTA (100µM) showed decreased Fo and Fm values in wheat seedlings. There was a decrease of OJIP transient. It indicates that there was maximum alteration of photochemical activity of PS-II in $NiCl_2$ – EDTA (100µM) treatment. In Fig.8, among all the treatments, there was no significant change in Fo value. But Fm value along with the transient decreased in treatments of $NiCl_2$ (10µM). But in other treatments the OJIP transient did not show much variation. Similar observation was seen in Fig.9 where the decrease in Fo and Fm value was observed in $NiCl_2$ –EDTA (250µM) treatment.

In mustard seedlings (Fig.10), there was a high variation of OJIP transient in different concentrations of $NiCl_2$ as compared to Control. There was a decrease of Fm, Fo, J and I steps in the transient with increase in concentration of Ni which indicated the structural and functional damage of PS-II in different concentrations of $NiCl_2$. Similar observation was indicated by Fig.11 and Fig.12 with application of different chelating agents in combination with Ni at varying concentrations (50 µM and 100 µM).

The possible competitive uptake role of EDTA with Ni caused inhibition in wheat and Mg^{2+} in mustard seedlings suppressing the entry of Ni to plants, otherwise Ni would have exerted stimulatory effects as noticed with Mg^{2+}-100µM-$NiCl_2$ application. Decreased chlorophyll-a fluorescence content associated with heavy metal stress may be the result of inhibition of the enzymes responsible for its biosynthesis.

CONCLUSION

Unlike organic molecules, heavy metals can not be degraded but only be remediated. It requires consequently intervention by mankind. Soils act as a natural sink for toxic materials present in municipal and industrial wastes and sludges. As well these are the only source for producing food, fiber, fuel and fodder. Agricultural use of heavy metal-contaminated sewage and organics has to result in bio-assimilation and bio-concentration and ultimate entry into food chain, which could pose serious health hazards. Once a metal is introduced into the soil environment, it may undergo a number of transformations.

Heavy metal solubility and availability in soils is governed by the fundamental reactions between metals and soil constituents. Crops may assimilate them and/or could leach down the profile. This mobility and bioavailability of metals in soils depends not only on the level of contamination (total concentration) but also on the origin of metals and on physical as well as chemical properties of soils.

Chelation of heavy metals is a ubiquitous detoxification strategy described in wide variety of plants. Natural element hyperaccumulator plant species can be effective in phytomining or phytoextraction of particular elements from contaminated or mineralized soils (Lasat, 2002; Mc Grath *et al.*, 2002; Chaney *et al.*, 2005; Banuelos, 2006). The present study with the applications of metal ions and chelators provides an incite for phytodetoxification and phytoremediation strategies to be taken up in future experiments.

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ENVIRONMENTAL MANAGEMENT IN DRI STEEL PLANTS IN ORISSA

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ABSTRACT

The rapid industrialization in India has currently increased the consumption of natural resources with consequent generation of wastes and pollutants. This has serious consequences on the human health and the environment. The tremendous demand for steel and shortage of steel scrap in the world market boost the efforts to develop alternative steel making process other than the conventional Blast Furnace (BF) – Basic Oxygen Furnace (BOF) route giving birth to Directly Reduced Iron (DRI/Sponge iron) process during eighties. DRI has been proved to be the prime feed stock to replace scrap in Electric Arc furnace /Induction Furnaces and even in Blast Furnaces for manufacturing steel. Due to boom in steel market, during the last 8 years there has been rapid growth of coal based sponge iron plants and integrated steel plants (DRI route) in iron and coal rich states like Orissa , Jharkhand, Chhatisgarh, West Bengal and Andhra Pradesh of India. A large number of iron ore crushers, ingot plants, Ferro alloy plants and coal washeries have been established and mining activities have been intensified. The sudden boom in the industrial scenario has increased environmental burden and it is required to combat pollution problems in proper manner. This paper deals with the various pollution problems encountered, control measures adopted in DRI Steel/ Sponge iron plants of Orissa for control of pollution and protection of environment.

Keywords : DRI, sponge iron, pollution, particulate matter

INTRODUCTION

Steel making through sponge iron route involves the separation of iron from iron ore by reduction in a kiln at appropriate temperature and pressure. Direct reduction of Iron (DRI) is defined as a process used to make solid metalized iron product named as sponge iron from iron ore or pellets using natural gas or a coal-based plant. DRI steel industry in India is growing since introduction use of sponge iron in 1980 as a substitute for ferrous-scraps in secondary steel production and knows as one of the mineral based industry. In less than a quarter century, Indian sponge iron industry has earned the distinction of being world's largest producer of sponge iron. India became the major destination for establishment of DRI sponge iron/ integrated steel plants due to its huge mineral reserve of suitable grade of iron ore and non-coking coal. All these new capacities are mostly coal based. But due to limited availability of natural gas in India, coal-based DRI steel units have witnessed exponential growth in recent past. The sector is attracting investment mainly due to short gestation period, proven technology and equipment, assured market, quick pay back and growth potential and of course, high remuneration. Additionally, sponge iron for the blast furnace will continue to receive attention for high productivity or lower coke rate for an existing blast furnace. In the recent months, some for the major integrated steel plants of the country have made trials to use sponge iron in blast furnaces to decrease the costly and scarce coke. Orissa having huge reserves of iron ore of all grades and non-coking coal has attracted entrepreneurs to establish coal based DRI steel/ sponge iron plants. Most of these plants have come up in clusters especially in the areas having coal or iron ore. All these units depend on high grade Iron ore (+65% Fe content) in the form of Hematite available from Keonjhar and Sundargarh districts and coal from M/s Mahanadi Coalfields Ltd. of Orissa. In addition to 50 TPD/ 100 TPD (ton per day) large DRI steel plants, smaller plants have also come up in the state having multiple kilns of capacity of 300/350/ 500 TPD. Table -1 shows the number of sponge iron plants currently operating in Orissa having 244 rotary kilns and installed capacity of around 33225 TPD (about 10 million TPA). The trend of growth of sponge iron plants in Orissa is given in figure 1. Government of Orissa in the mean time have signed Memorandum of Understanding (MOU) with some leading mega industrial houses for establishment of new integrated steel plants/ capacity expansion of existing plants which are mostly DRI/ Blast furnace based. The integrated steel plants coming up through DRI route consists of coal washery, iron ore crushers, DRI kilns, WHRB (Waste heat recovery boiler)/ AFBC (Aerated Fluidized bed boiler), steel melting shops (induction furnaces/ arc furnaces), re-rolling

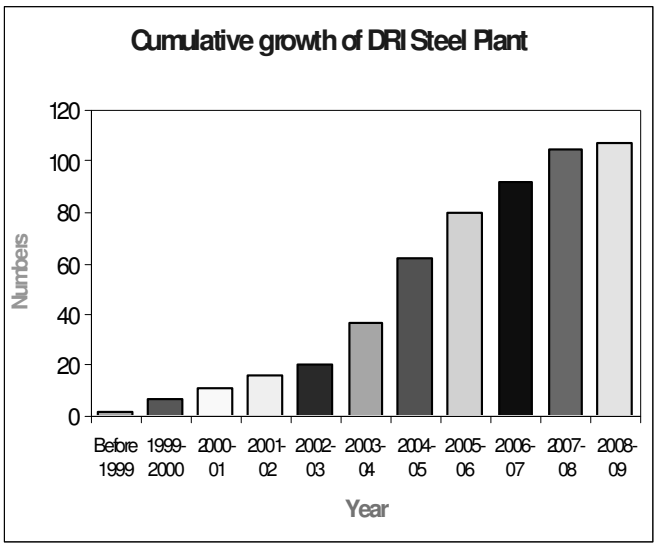

Fig. 1 : Cumulative growth of sponge iron plants in Orissa

mills, blast furnaces,Ferro-Alloy Plants(FAP), Captive Power Plant (CPP), inside the same premises. The sponge iron plants are mostly concentrated in nine districts of Orissa. The district wise distribution of sponge iron industries operating in Orissa is given in figure 2. It is observed that around 62% of Sponge Iron Plants are located in two mineral rich districts like Sundargarh and Keonjhar of Orissa.

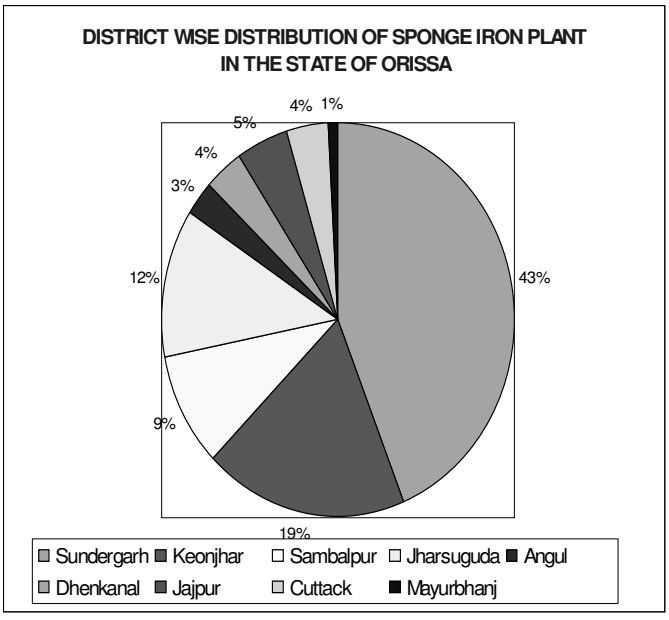

Fig.2 : Distribution of sponge iron plants in 9 districts of Orissa

POLLUTION POTENTIAL OF DRI STEEL PLANTS

Air pollution potential and its control :

After direct reduction of iron in the rotary kiln, the hot flue gas with high temperature at about 1000 ^{o}C at a rate of 24,000 Nm^3 /hr/ 100 TPD kiln containing high concentration of fine dust particles (PM: 30 gm/Nm^3) is released to the atmosphere through After Burning Chamber (ABC) of stack of height 35 m. The residual carbon or CO is burnt by excess air made

Table 1 : Number of kilns and production capacity

Kiln Capacity	No. of kilns Production	Installed Capacity (TPD)
No. of 25 TPD Kilns	01	25
No. of 40/50 TPD Kilns	62	3,050
No of 100 TPD Kilns	141	14,100
No. of 300/350 TPD Kilns	22	7,300
No. of 375/500 TPD Kilns	18	8,750
Total	244	33,225

Maximum annual production potentiality of sponge iron (DRI) in Orissa – 10 million TPA (ton per annum)

Table 2 : Sponge iron plants operating in different districts of Orissa (No. of kilns and production capacity)

District	No	Kiln Capacity (TPD)/ No. of Plants				
		25 TPD	40/50 TPD	100 TPD	300/350 TPD	375/500 TPD
Sundergarh	47	01(01)	40(20)	65(27)	02(02)	0
Keonjhar	20	Nil	15(07)	28(11)	05(05)	04(02)
Sambalpur	10	Nil	02(01)	10(05)	04(02)	05(02)
Jharsuguda	13	Nil	01(01)	22(08)	06(04)	0
Angul	03	Nil	0	03(02)	02(02)	0
Denkanal	04	Nil	0	02(01)	02(02)	06(01)
Jajpur	05	Nil	02(01)	05(03)	02(01)	0201
Cuttack	04	Nil	02(02)	04(01)	0	01(01)
Mayurbhanj	01	Nil	0	02(01)	0	0
Total	107	01	62	141	23	18

available in ABC before the flue gas is taken through heat exchanger/ waste heat recovery boiler/ ESP. Rotary Kiln is the measure source of air pollution in a DRI manufacturing process besides a number of material transfer points where fugitive dust is generated. Considering the above figures, it is calculated that 17,280 kg of dust would be emitted to the atmosphere per day from each 100 TPD rotary kiln in the absence of air pollution control device. This is the main source of air pollution in the vicinity. In ideal condition with the operation of adequate pollution control devices like ESP, the emission of particulate matter is expected to meet the standard of 100 mg/Nm^3 and in such condition 57.6 kg/day of dust is emitted from the chimney of ESP/GCP (Gas Cleaning Plant) of a 100 TPD kiln.

Table 3 : Sources of fugitive dust in DRI steel plants and prescribed control measures

Sl. No.	Sources of fugitive dust emission	Control measures Prescribed by SPCB, Orissa
1	Raw material handling and preparation area	Automised water spraying system. Work zone to be concreted.
2	Crushing and screening of coal (Coal circuit)	Pulse jet Bag Filter & automised water spraying nozzles (Dry fog system)
3	Crushing and screening of iron ore (Iron ore circuit)	Pulse jet Bag Filter & automised water spraying nozzles
4	All material transfer points and conveyor belt	Enclosures with hood and suction arrangement followed by Pulse jet Bag Filter
5	Material transfer points and vent of Raw material storage bins	Pulse jet Bag Filter
6	Raw material feeding point into kiln	Pulse jet Bag Filter
7	Coal injection point into kiln	Pulse jet Bag Filter with recycling of coal fines back into the coal injection system
8	Leakage from slip rings of the rotary kiln	Realignment of the kiln and changing of seal/ packing materials during shutdown period
9	Cooler discharge circuit	Pulse jet Bag Filter
10	Intermediate bins in between cooler discharge area and product separation unit	Pulse jet Bag Filter
11	Product separation unit	Pulse jet Bag Filter
12	Induction Furnaces/ Arc Furnaces	Hood and suction arrangement followed by Pulse jet Bag Filter
13	Blast Furnace	Gas conditioning plant (GCP) consisting of scrubber
14	Coal crusher and screen in coal washery	Combination of dry fog system and Pulse jet Bag Filter
15	Windblown dust from solid waste dump yard	Provision of boundary wall around the dump yard, covering by earth and automised water spraying on the dump area by rotating nozzles.
16	Handling of fine dust retained in the hoppers of the ESP	Air locking valves, enclosures, pneumatic dust handling system followed by pug mill for the plants above 200 TPD kiln capacity
17	Handling of fine dust retained in the hoppers of the Pulse jet Bag Filters	Air locking valves, enclosures, pneumatic dust handling system followed by pug mill installed in some of the plants above 300 TPD kiln capacity
18	Internal roads/Transport roads	Construction of Black topped/ concrete internal roads and approach roads. Installation of rotating type water sprinkling nozzles along the roads. Periodical cleaning by road sweeper, cleaning by water hose or by a dedicated team of sweepers.
19	Care during transport of materials/ solid waste	Vehicles should be covered

The State Pollution Control Board, Orissa has stipulated stringent emission standard of 100 mg/ Nm^3 for kiln ESP/ GCP stack and 100 mg/Nm^3 for Bag Filter stack. To achieve the prescribed emission norm, varieties of air pollution control systems are adopted in Indian sponge iron plants to clean the particulate matter from the flue gas emitted from the sponge iron kilns. These can be broadly classified into wet system and dry stem. Due to the fact that most of the sponge iron plants are located in water scarce areas of Orissa, these plants have adopted dry system. It is observed that 100 TPD or larger capacity sponge iron plants generally have installed Heat Exchanger/Gas Conditioning Tower/ WHRB followed by ESP, whereas 50 TPD plants have mostly installed Gas Cleaning Plants (GCP) consisting of Heat Exchangers followed by Cyclone and Pulse Jet Bag Filters. However, only two 50 TPD plants have adopted Heat Exchanger with ESP. The kiln flue gas is passed through heat exchanger or WHRB or GCT to bring down temperature from 900 ^oC to about 180^oC as per the design requirement of ESP/ Bag Filter. Then the cooled gas is passed through either ESP/ Pulse Jet Bag Filter. Lot of fugitive dust is generated during crushing of raw material like iron or coal and at all material transfer points along conveyor line. The sources of fugitive dust generation in the sponge iron plants and the prescribed control measures are given in Table 3.

Operational and Technological Bottlenecks causing air pollution :

A. Emission of untreated flue gas through kiln cap by-passing ESP/ GCP of the kiln

Many sponge iron industries are found to emit untreated flue gas through kiln caps by-passing air pollution control devices (ESP/GCP). This happens due to the following reasons.

(i) Malfunctioning of pollution control devices like ESP, Bag Filters, dust handling systems

(ii) Inadequacy of the existing pollution control devices

(iii) Extreme unstable condition of the rotary kilns

(iv) Pollution control devices when not operated to save energy

(v) Power failure from the grid
(vi) Technological limitation like opening of cap during start up and shutdown period of the rotary kiln
(vii) Failure of grid/ failure of WHRB

B. Air pollution caused due to other non-compliances

Even after installation of all pollution control devices in the plant, the ambient air quality with regard to SPM and RPM, do not meet the standard many times due to generation of dust from the following sources,

(i) Bad house-keeping,
(ii) Internal and approach roads not black topped/ concreted, work zone not concreted. Loose dust periodically not removed from roads, which become airborne.
(iii) Unloading of raw materials, loading of chars and fines carelessly. Trucks not covered and there is spillage of materials on the road during transportation.
(iv) Fine loose dust form the work zone and raw material and solid waste dump yards become wind borne during stormy weather.
(v) Leakage of flue gas through kiln cap in between power failure and start up of D.G.
(vi) Inadequate dust suppression
(vii) ESP/ BF dust handling system not mechanized in smaller capacity plants. Dust collection points under the hoppers are not enclosed properly.
(viii) If the plant do not have dedicated team for proper housekeeping and attending to pollution problems.
(ix) Non-availability of experienced technical manpower
(x) Extra dust load to the system due to bad coal quality in the region
(xi) Lack of maintaining proper maintenance schedule of the pollution control equipments.

Sources of water pollution and its control

Water requirement generally varies in the range of 3-5 m^3 per tonne of product, which is used mostly for the pure cooling, boiler feed, scrubbing, coal washery, water sprinkling for dust suppression, domestic purposes and plantation. All efforts should be made to reuse and re-circulate the water and maintain zero effluent discharge.

Status of water pollution control

It is observed that water used for cooling of rotary cooler is completely recycled in all the units. The sludge generated at the bottom of the wet scrapper of Burning Chamber of the kiln is collected in settling tanks and the settled water is so scanty that it gets evaporated and not recycled. Most of the water injected into Gas Conditioning Tower to bring down the flue gas temperature from 900 to 180 ^oC in a few plants get evaporated and the remaining water that is collected in tanks is recycled after settling. The domestic effluent is generally discharged to septic tanks and soak pits. Large plants are adopting STP. The integrated steel plants (DRI route) have provided neutralization system for DM plant effluent. The boiler blowdown and cooling tower blowdown is used for dust suppression. Large scale plantation paves the way for dust suppression. In rainy season, the chances of surface runoff and seepage of rain water through solid waste dumps are very high. The water coming from all around the dump area contains high concentration of Total Suspended Solids (TSS). Since this type of plant handles lot of fine dusty materials, the storm water from factory premises during rains also contains high TSS. The polluted runoff water when finds its way to the nearby land or stream create water/ land pollution problem and invites public complaints. Many of the industries in the meantime have constructed garland drains and settling tanks at the end of runoff drains to prevent discharge of solids to outside. Now it has been made mandatory to construct settling tanks for settling of runoff water and prevent the solids to go out of the factory premise. The coal washeries are required to clarify the effluent and fully recycle the water in the process.

ENFORCEMENT MECHANISM

The following enforcement mechanism has been adopted by the State Pollution Control Board (SPCB), Orissa to ensure effective pollution control in DRI steel/ sponge iron plants.

(i) All the plants are required to obtain consent to establish and operate from SPCB, Orissa under the provision of Water (Prevention and Control of Pollution) Act, 1974 and Air (Prevention and Control of Pollution) Act, 1981 and the amendments made thereafter.

(ii) The operation time of coal crushers of the sponge iron plants shall be restricted to 6.00 A.M. to 6.00 P.M. The crusher shall be operated along with adequate pollution control measures. Under no circumstance, the coal circuit shall be operated during 6.00 P.M. to 6.00 A.M.

(iii) Installation of separate energy meter for ESP/ GCP and bag filters is mandatory and furnishing energy meter readings and production figures every month to the State Pollution Control Board (SPCB) to cross check if the pollution control devices are operated continuously.

(iv) Presently pneumatic dust handling system/ screw conveyor is being installed to handle ESP / GCP dust of the kilns. Henceforth, all the sponge iron units shall also install mechanical dust handling system like screw conveyor with water jets at the hopper of each bag filters to control fugitive emission.

(v) Accumulated dust from process area shall be removed on daily basis. The solid waste generated from the plant including char and fines shall be transported to the dump site by covering the truck/ dumper with tarpaulin. The solid waste shall be dumped only in the designated site approved by the Board and shall be leveled with earth cover and compressed from time to time. The active portion of the dump shall be wetted periodically through spraying of water mixed with special chemicals to control propagation of dust from the dumping site.

The inactive portion of dump and the slopes shall be adequately covered with tarpaulin immediately to prevent air borne dust. The slope of the dumps shall be stabilized by putting coir mats and soil followed by plantation of grass or other suitable plant species.

(vi) Utilization of Char and Solid Waste have been planned as follows :

The industry shall utilize 20% of the char generated in the 1st year and progressively increase by 20% of char each year. At the end of 05 years, 100% of char shall be utilized.

It shall be mandatory for the sponge iron plants having kiln capacity of 200 TPD or more to install WHRB and AFBC boiler to utilize char as well as to ensure continuous power supply for ESPs and other pollution control devices. All the sponge iron industries with the capacity of 200 TPD and above will install fly ash brick manufacturing unit within a period of 6 months to utilize the fine dust captured by ESP/GCP/bag filters/Boilers. All sponge iron plants shall install coal brequitting plant and adopt other available methods for effective utilization of char and solid wastes.

(vii) Dedicated D.G. sets of adequate capacity shall be installed to ensure sufficient standby power supply to run all pollution control devices of the plant in the event of power failure. D.G. sets should be equipped with A.M.F. (Auto Mains Failure Panel) for auto change over of power supply from grid power to D.G. power in the event of power failure. The AMF panel shall be PLC (Programmable Logic Control) based.

(viii) Adequate sealing arrangement shall be made at the emergency cap of each rotary kiln to prevent leakage of flue gas when cap is closed. Except very emergency situation the cap shall not be opened during operation of the kiln and all kiln gas shall be passed through ESP or GCP. The practice of frequent opening of caps shall be stopped and the industry shall train its kiln operators immediately to control kiln pressure by synchronizing the I.D Fan with variable speed drive and heat exchanger/GCT with ESP/GCP system without frequent opening of the kiln caps. The industry shall keep a record of events of cap leakages in a register and inform to Regional Office immediately by Fax or SMS justifying the cause.

(ix) Overstretching the campaign period of the kilns increases generation of dust from different points of the kiln and cap leakage. The kilns shall not be operated beyond the normal period of campaign and shall take shut down as soon as the following conditions are noticed.

(a) When back flow of raw materials like coal/iron ores starts (whichever is earlier).

(b)When kiln rpm, ID fan rpm and kiln pressure starts exceeding the normal range.

The achievements made in implementation of pollution control measures in DRI steel/ Sponge Iron Plants in Orissa have resulted that about 200 ESPs and 43 GCPs have now been commissioned and in operation 107 DRI plants of Orissa.

CONCLUSION AND RECOMMENDATIONS

The steel making and mineral processing is inevitable. However the economic growth vis-à-vis environmental degradation should be balanced and sustenance needs to be maintained with the following emerging concepts.

(i) All the steel plants (DRI route)/ sponge iron plants should be operated with the best available technologies.

(ii) Continuous power supply from the grid is essential. Alternatively the industries should install captive power plant along with Waste Heat Recovery Boilers to ensure continuous supply of power to the pollution control devices to prevent air pollution. Initiation should be taken to further encourage the potential industries to implement WHRB-CPP system and clean technologies in their plants in Orissa to minimize the GHG emission.

(iii) Technical solution should be evolved to provide appropriate pollution control device to prevent direct emission of flue gas through the chimney of the Kilns during the start up and shut down of the kilns, when the flue gas cannot be taken through existing ESP/ GCP.

(iv) Better technology for proper sealing of ABC cap is essential to control cap leakages from the rotary kilns.

(v) Coal based DRI process has been proved to be highly air polluting. Alternative clean process technology like gas based should be adopted.

(vi) Complete recycling of cooling, scrubbing water, settling tank and rainwater harvesting structure will minimize water consumption.

(vii) Process modernisation and reducing water consumption, adopting optimum recirculation for reusing treated effluent and utilising maximum quantity of treated effluent for plantation and agriculture is essential

(viii) Maximum utilization of solid waste like char, fines, slags for briquitting, brick making, cement making should be emphasized. Rest should be filled in mine pits/ low lying area. Prime agricultural land should not be used for dumping of wastes. Management of natural resources vis-a-vis waste utilisation is an important area to think of.

(ix) Most of the proponents outsource the environmental issues to their consultants. But sufficient awareness and training is required for the shop floor people, managers on possible impact of their projects on environment and consequences thereof. Pollution control and production activities should go side by side. The proponents/ occupier of the industry should personally review the pollution control activities and local environmental issues to avoid exploitation by the litigant public, penal action and closure direction from statutory authorities and to build up public image and gain confidence of the financiers in order to achieve better production and business promotion. All the sponge iron/steel plants must adopt ISO 14000 international standards for environmental practices to improve their house keeping, environmental management system and productivity.

(x) A software controlled interlocking facility should be installed in order to prevent bypassing of untreated flue gas through emergency cap of the rotary kiln of the DRI plant and non-operation/ malfunctioning of ESP or any other pollution control devices attached to the kiln. This interlocking system shall ensure automatic stoppage of raw material feed conveyor to the kiln based on the real time data with provision for password, temper proof, keep a log with printing option and online data transmission of non-compliance reports to the regulator.

(xi) To develop the mechanism of voluntary compliance at the state level like CREP (Corporate Responsibility for Environmental Protection) guideline adopted at center, to adopt cleaner technology/pollution reduction to meet the stringent norms.

(xii) To adopt latest technologies like open path monitoring/ on line monitoring and display system for monitoring of ambient air quality of polluted areas/ cities. To develop web-based database management system and development of network for data sharing among industries, regional offices and head office of the board and stake holders.

(xiii) To develop a mechanism for public awareness by providing a platform for regular industry–public interface, so that a congenial atmosphere can be created for effective control of pollution and sustainable development in the State.

(xiv) Cleaner production is the final answer in any waste reduction, pollution prevention and it holds the key to sustainable industrialization.

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IMMOBILIZATION OF WATER LEACHABLE METALS OF FLYASH

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ABSTRACT

Disposal of flyash as a by-product of thermal power plant results in significant environmental problems due to the possible leaching of different pollutants. The aim of the study is to investigate the leaching behaviour of flyash and its immobilization to prevent environmental pollution. Leaching study was conducted with the flyash samples collected from two different thermal power plants. In the present paper calcined magnesia has been added for immobilization of toxic elements. A remarkable variation is found in the leaching of toxic metals such as PO_4, F, Mn and Zn. The difference between these two types of flyash leachate is due to addition of magnesia. If the fly ash will be activated before disposal, it may minimize the load of pollution.

Keywords: Flyash; disposal; leaching; immobilization

INTRODUCTION

Coal is the most abundant and widely spread fossil energy resource in the world (Benito *et al*, 2001). Fly ash is a residue of pulverized coal that throws out as a waste material in a large quantity in the thermal power plant. Generally coal used in Indian power plants has high ash content (35-45%) and is of lower quality (Mathur *et al*, 2003). In India presently about 110 million tonnes of coal ash is generated from more than 70 thermal power plants (Sarkar *et al*, 2005). It is predicted that, 170 million tones of fly ash will be generated per annum by the year 2012 (Rujamane 2003). The requirement of land for disposal of flyash slurry will go up to 1000000 acres by 2012 (Verma *et al*, 2007). It is a concern over flyash study because it is the largest component of coal combustion by-product and consequently have the biggest disposal problem. The major constituents of flyash are identical to earthy materials. Oxides of iron, calcium, aluminium, silicon, magnesium, constitute about 98-99% of the composition of fly ash, other elements such as Potassium, sodium, titanium, chromium, cobalt etc occur only in traces.

Leaching of heavy metals from disposed flyash has been observed by earlier researchers (Fliszar *et al*, Wassa, 1992; Reardon *et al*, 1995; Hassett *et al*, 1994; Fleming *et al,* 1996) but the non metal has attracted considerably less attention. Arsenic released from the flyash leachate stand out as potentially harmful to both vegetation and animals (Vander Hoek and Comans1994; Vander Hoek *et al*, 1996 and Cox *et al*, 1978). Under natural leaching conditions the fluoride levels may exceed legal standards for drinking water by attaining a level of 5.8 ppm (Hassett *et al,* 1994). A laboratory scale experiment was carried out on dumping of flyash into deep sea water resulting potential leaching of Cd, and Cr (Kress *et al*, 1993). It is reported that higher aqueous concentration of Al, NH_3 , As, Ba, Cd, Cl, Cr, Pb, Hg, Ni, Se, SiO_2, SO_4 and Zn in the effluents from ash ponds for the coal fired power plant of the Tennessee Valley (Ruane *et al* 1983). The presence of heavy metals in flyash leachates causes soil contamination and ground water pollution (Gravess and Clement, 1983 and Kapoor 1982).

Earlier authors have investigated some possibilities of reduction of pollution caused due to the leaching of toxic elements present in flyash. One of the ways of abating environmental pollution due to flyash is to immobilize or desorb the metal component as these metals contaminate the soil as well as ground water.

MATERIALS AND METHODS

Flyash is the solid component of the coal residue, which enters the flue gas stream as a very fine particulate material and it is collected through the electrostatic precipitator (ESP) in the hoppers. The samples of 100 kg each have been collected from two different plants. By following the method of coning quartering samples are collected from two different power stations. Two kg of each representative samples are prepared to study the physical, chemical and mineralogical behaviour of the flyash.

Material processing

During the present study the experiment is also designed for immobilization of metals. So flyash was activated mechanically by mixing with light calcine magnesia powder. The light calcine magnetite of below 200 mesh has been prepared by grinding. The magnesite rock calcined at 600 ^{0}C has been drawn to below 200 mesh size for preparation of light magnesite. The light calcined powder consisting of mostly active magnesia (MgO) has been mechanically blended 3% by weight with fly ash. Both the original and activated flyash were used in this experiment to observe the leaching characteristics.

Leaching experiment

To understand the short term leaching effect static leaching method was conducted for both the original flyash and activated flyash samples. In order to better simulate the natural conditions and susceptibility to release a lower liquid-to-solid (L/S) ratio was used. A series of batch leaching experiment and TCLP (Toxicity Characterization Leaching Procedure) method were used to evaluate the leaching and pollution potentials of the original flyash and activated flyash samples. These experiments were carried out in the batch reactors at 1: 10 solid/liquid ratio. All the experiments were carried out at room temperature and agitation was performed for 24 hours. At the end of each experiment the mixtures were filtered and then pH of the filtrates was measured by a pH meter. The filtrates were centrifuged to get a clear solution for analysis. The filtrates were acidified with 1ml of HNO_3 to prevent the precipitation of metal ion and then were analyzed. The leachate was undergone for different physico-chemical parameters such as pH, conductivity, Ca, Mg, Fe, PO_4, F, Ni, Pb, Mn, and Zn etc. to predict pollution potential. The experiments were carried out at room temperature and agitation was done for 24 hours.

Method of analysis

The bulk density and specific gravity of the dry ash sample is determined with the help of a measuring beaker and a pychometer or specific gravity bottle respectively. The chemical composition of these two different flyash samples has been determined by X-ray fluorescence, pH, conductivity and F of the leaching solution was measured by respective meters. The analysis of Ca, Mg, Fe and PO_4 was done by using the standard procedures (APHA). The toxic elements such as Ni, Pb, Mn, and Zn were determined by the Atomic Absorption Spectro-photometer. The experiments were performed in duplicate and mean values were taken into account. The standard solutions were prepared by using analytical reagent grade chemicals and dilutions were made by distilled water. All the experiments were carried out at identical condition.

RESULTS AND DISCUSSION

The physical properties of the flyash sample are shown in Table–1.

Table-1 (Physical properties of fly ash)

Type of Fly Ash	Appearance	Bulk density (kg/m3)	Specific gravity
1	Grey with carbon particle	960	2.03
2	Dark grey with carbon particle	830	2.16

Both the fly ash samples looks grey and contain carbon particle. Due to the presence of more carbon particles the flyash - 2 looks dark grey. Bulk density of two fly ash samples are 960 and 830 kg/m^3 respectively. Similarly the specific gravity of fly ash is 2.03 and 2.16 respectively. The chemical composition of the two different flyash samples is given in Table-2.

Table-2 (Chemical composition of coal ash)

Type of Fly Ash	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	LOI
1	59.03	25.86	5.81	1.71	1.07	0.68	1.89	0.07	0.72	0.14	1.8
2	60.11	30.03	0.9	0.98	0.77	0.42	1.09	0.04	0.44	0.06	1.94

It is observed that silica is the major constituents, which is 59% in flyash in sample -1 and 60% in flyash -2. The alumina content of the flyash samples are 25.86% and 30% respectively. Except flyash and alumina there are some other trace elements like oxides of Fe, Ti, Ca, Mg, P, and S. It shows that the flyash is rich in silica and alumina. The particle size of flyash ranges within 37-500 micron. From the particle size distribution graph (Figure-1) it can be concluded that flyash-1 contains more fine ash than flyash -2. Both the original fly ash samples have neutral pH (7.65 & 7.19); where as the activated flyash samples are alkaline in nature (9.44 & 9.53). Addition of magnesia increases the pH of sample. But other elements like Ca, PO_4, F, Ni, Cu, Fe, Pb, Mn, and Zn etc. are more in original flyash leachate (Table - 3).

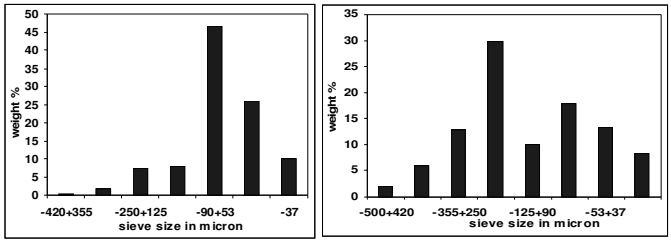

Fig -1 and 2 Particle size distribution in ash-1 and 2

Remarkable variation is found in the concentration of toxic metals such as PO_4, F, Mn and Zn. The concentration of F in original flyash samples are 5.73 and 5.70 ppm respectively but in leachate of activated samples the concentration is 0.21 and 0.25 ppm. The difference between these two types of flyash leachate is due to addition of magnesia. Addition of magnesia changes the mineral structure which helps in immobilization of some of the toxic and trace elements. The results of this study indicate that (given in Table-3) the leaching of toxic metals is less in activated ash. So from this work it is observed that

activation of flyash by addition of magnesia can be a solution to minimize pollution before disposal.

Table–3 Concentration of different elements in fly ash leachate

Element	Original Fly Ash -1	Activated Fly ash - 1	Original Fly ash - 2	Activated Fly ash - 2
pH	7.65	9.44	7.19	9.53
Conductivity	237	524	210	521
Ca	270.2	60.0	200	120
Mg	70.9	171.1	92.9	190.7
PO_4	230.65	61.1	270.2	70.5
F	5.73	0.210	5.70	0.25
Ni	0.32	0	0.56	0.09
Cu	0.47	0.08	-	-
Fe	11.79	9.5	2.16	0.434
Pb	1.30	0.02	0.325	0.846
Mn	5.13	0.45	5.31	0.45
Zn	6.34	1.66	5.048	1.24

CONCLUSION

The concentration of flyash leachate is evaluated in original ash and activated ash. All the elements except conductivity and magnesium in original ash leachate are in more concentration than activated ash. So immobilization of metals of flyash before disposal is essential, which prevents pollution. Depending upon the physical, chemical, mineralogical characteristics, the flyash is used for various purposes such as additive to cement and concrete and preparation of building bricks and blocks. Flyash can be used in electronic application due to its dielectric property. The phenomena of the flyash mostly depend on the particle fineness and the presence of reactive silica. Further study is required to immobilize all the toxic metals present in fly ash leachate which will give a solution for safe disposal of flyash.

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STUDIES ON PHYSICO-CHEMICAL PROPERTIES OF WATER IN USE BY WORKERS' COMMUNITY IN CHANDAKA SMALL SCALE INDUSTRIAL ZONE OF BHUBANESWAR

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ABSTRACT

The physico-chemical properties of tap and hand pump water in use by workers' community in Chandaka industrial zone of Bhubaneswar have been analyzed for one year from 2007-2008. The tap water was found to have average pH- 7.0, conductivity- 1.176 m.mho, total alkalinity- 52mgl-1,hardness- 68 mgl-1, Chloride content-17 mgl^{-1}, iron content of 0.31 mgl^{-1}, dissolved oxygen- 7.3 mgl^{-1}, free carbon dioxide of 0.283 mgl^{-1} . The water from hand pump was found to have pH- 5.8, conductivity of 0.136 m.mho, total alkalinity- 90mgl^{-1}, hardness of 53 mgl^{-1}, chloride content- 13.5 mgl^{-1}, iron content- 2.03 mgl^{-1}, dissolved oxygen- 3.7mgl^{-1} and free CO_2 6.2 mgl^{-1}. This study indicated that in Banshi Vihar area, water is more alkaline with less conductivity, and dissolved oxygen more CO_2, chloride, iron. Suggestions were given to immediately go for water purification measures to protect the people of the particular area from possible health hazards.

Key words : Physico-chemical properties, water, Chandaka Industrial Zone, Bhubaneswar

INTRODUCTION

Water is a wonderful gift of nature and is the only inorganic liquid which occurs naturally on the earth (Razvi, 2001). It is commonly agreed that all people, whatever their stage of development and their social and economic conditions may be, should have the right to access drinking water (Al-Eshawi, 1992, Antwi and Ofori-Danson, 1993 and Bose, 2001). Pollution of water bodies like rivers, lakes, estuaries, coastal waters and of underground water reservoirs has resulted from industrial activity (Tiwari, 2000). Consumption of polluted water (underground) led to be diseases such as enteritis, hepatitis, polio, enteric fever and diarrhoea. At the study zone i.e. Chandaka Industrial zone, there are two main water resources i.e. tap water and hand pump. Workers' community use both tap water and hand pump water for washing, bathing, drinking, cooking etc. The present study elucidates certain physico-chemical properties of water bodies in use by the workers' community in the study zone, to analyze the water quality standard which would act as an indicator to combat the possible health hazards of the workers community.

MATERIALS AND METHODS

Study was undertaken in five different localities of the said zone collecting samples from both tap and hand pump water from five different areas as Adarsha Vihar, Prasanti Vihar, Niladri Vihar, Surya Vihar and Banshi Vihar. Water samples were collected in sample bottles (cornings). The samples were then fixed with fixative i.e. 5% chloroform and taken to the laboratory for further analysis. The physico- chemical parameters such as pH, conductivity, total alkalinity, hardness, chloride content, iron content, dissolved oxygen and free CO_2 were estimated scientifically by digital pH meter(Voznaya,1981), modified Volumetric Winkler's method, Borax Buffer method (Jhingran,1991).

RESULTS AND DISCUSSION

The physico-chemical properties of the tap water and the hand pump water from five different sources as analyzed were presented in Table 1 and Figs. 1 (a, b), 2(a, b) , 3(a, b) , 4(a, b), 5(a, b), 6(a, b), 7(a, b) and 8(a, b), bars represented as AV, PV, NV, SV, and BV denotes localities such as Adarsh Vihar, Prasanti Vihar, Niladri Vihar, Surya Vihar and Banshi Vihar. The tap water provided by city water management after evaluation had average pH 7.0, average conductivity 0.176 m.mho, average total alkalinity 52 mgl^{-1}, hardness 68 mgl^{-1} and chloride content 17 mgl^{-1}, while the average iron content was 0.31 mgl^{-1}. It's dissolved oxygen content being 7.3 mgl^{-1},free carbon dioxide content was 0.283 $mgl^{-1.}$ Water of hand pump of the said localities had an average pH 5.8, conductivity 0.136 m.mho.

total alkalinity 90 mgl^{-1} , Hardness 53 mgl^{-1}, chloride 13.5 mgl^{-1}, iron content 2.03 mgl^{-1}, dissolved oxygen content 3.7 mgl^{-1} and free CO_2 content of 6.2 mgl^{-1}.

Table 1 : Physico- Chemical parameters of water bodies of Chandaka Industrial Zone, Bhubaneswar

Sl. No.	Parameters	Tap Water	Hand pump water
1	P^H	7.0	5.8
2	Conductivity(m.mho)	0.176	0.136
3	Total Alkalinity (mgl^{-1})	52	90
4	Hardness (mgl^{-1})	68	53
5	Chloride (mgl^{-1})	17	13.5
6	Iron (mgl^{-1})	0.31	2.03
7	Dissolved Oxygen (mgl^{-1})	7.3	3.7
8	Free CO_2 (mgl^{-1})	0.283	6.20

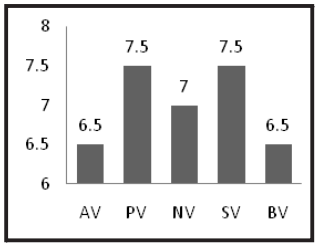

Fig. 1 (a) : pH of tap water of Chandaka Industrial Zone, Bhubaneswar

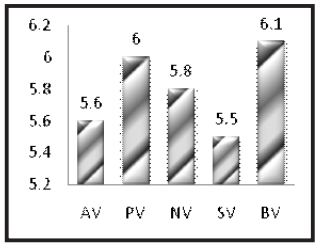

Fig. 1 (b) : pH of hand pump water of Chandaka Industrial Zone, Bhubaneswar

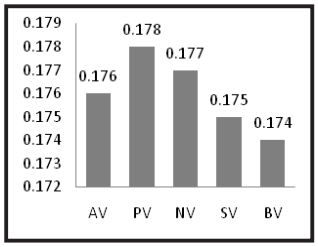

Fig. 2 (a) : Conductivity of Tap water of Chandaka Industrial Zone, Bhubaneswar

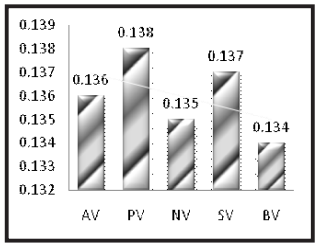

Fig. 2 (b) : Conductivity of hand pump water of Chandaka Industrial Zone, BBSR

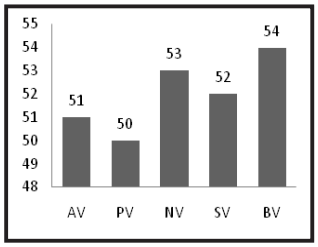

Fig. 3 (a) : Total alkalinity of tap water of Chandaka Industrial Zone, BBSR

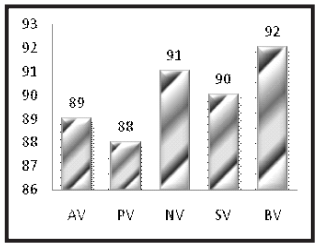

Fig. 3 (b) : Total alkalinity of hand pump Water of Chandaka Industrial Zone, BBSR

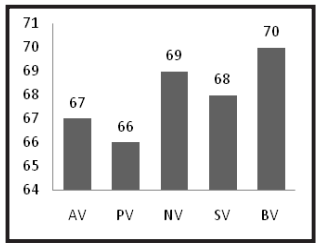

Fig. 4 (a) : Hardness of tap water of Chandaka Industrial Zone, Bhubaneswar

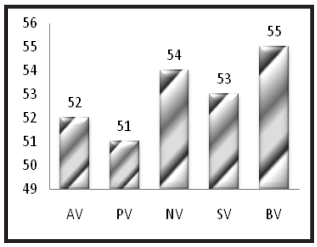

Fig. 4 (b) : Hardness of hand pump water of Chandaka Industrial Zone, BBSR

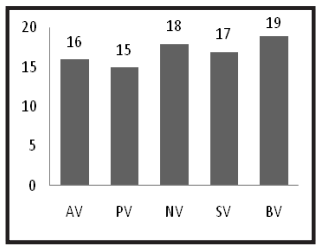

Fig. 5 (a) : Chloride content of tap water of Chandaka Industrial Zone, Bhubaneswar

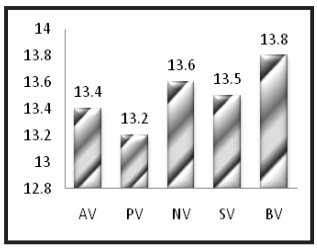

Fig. 5 (b) : Chloride content of hand pump water of Chandaka Industrial Zone, Bhubaneswar

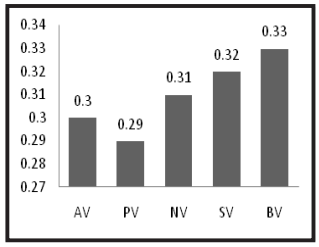

Fig. 6 (a) : Iron content of tap water of Chandaka Industrial Zone, BBSR.

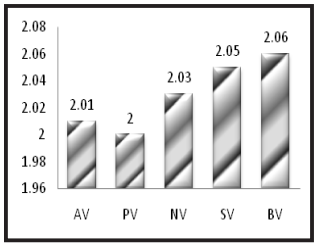

Fig. 6 (b) : Iron content of hand pump water of Chandaka Industrial Zone, BBSR.

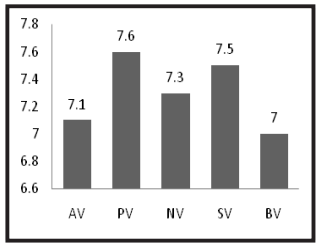

Fig. 7 (a) : Dissolved oxygen content of tap water of Chandaka Industrial Zone, BBSR

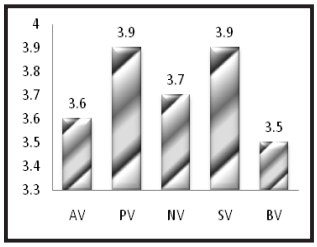

Fig. 7 (b) : Dissolved oxygen content of tap water of Chandaka Industrial Zone, BBSR

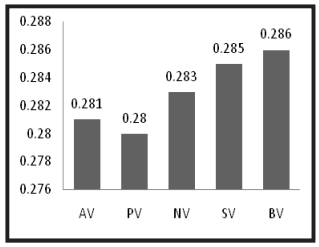

Fig. 8 (a) : Free carbon dioxide content of tap water of Chandaka Industrial Zone, Bhubaneswar

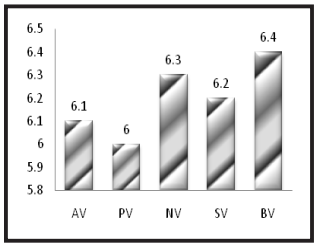

Fig. 8 (b) : Free carbon dioxide content of hand pump water of Chandaka Industrial Zone, Bhubaneswar

The degree of pollution is generally assessed by studying physico-chemical characteristics of water body (Mishra & Saxena,1971). pH is defined to be the negative logarithm of hydrogen ion concentration of the aquatic environment (Jhingran,1991). The pH value of tap water at different localities such as Adarsha Vihar, Prasanti Vihar, Niladri Vihar, Surya Vihar and Banshi Vihar were 6.5, 7.5, 7.0, 7.5 and 6.5 respectively. It indicated that in the said zone tap water was neither highly acidic nor highly alkaline. It was in the neutral zone. The pH value of hand pump water was 5.6,6.0,5.8,5.5 and 6.1 in the said localities. It indicated that the water was somewhat acidic in nature. Workers' community should not use this hand pump water as it is unsafe and would create definite health hazards.

Conductivity is defined as the capacity of water to carry electrical currents. The conductivity of tap water at five different localities of Chandaka Industrial Zone were 0.176,0.178,0.177,0.175 and 0.174 m.mho respectively. The conductivity of hand pump water of same localities were found to be 0.134,0.136,0.138,0.135,0.137 m.mho respectively.

Alkalinity is used as an important measure to determine the quality of water (Jhingran, 1991). The desirable limit of alkalinity is 200 mgl^{-1}. The total alkalinity of tap water was analyzed to be 52 mgl^{-1} and that of hand pump water was 90 mgl^{-1}. Though alkalinity was found to be within permissible limit, ground water was comparatively more polluted.

Hardness is defined as the sum of calcium and magnesium ion concentration in water. The hardness of tap water of AV, PV, NV, SV and BV were 67, 66, 69, 68 and 70 mgl^{-1} respectively. The hardness of hand pump water of same localities were evaluated to be 52, 51, 54, 53, 55 mgl^{-1}. The water from hand pump being soft, tap water indicated little more hardness and was of medium standard.

The desirable limit of chloride is 250 mgl^{-1}. The chloride content of tap water of AV, PV, NV, SV and BV were 16, 15, 18, 17 and 19 mgl^{-1} respectively and the chloride content of hand pump water of same areas were found to be 13.4, 13.2, 13.6, 13.5 and 13.8 mgl^{-1} respectively. The chloride value of water bodies of Chandaka Industrial Zone, Bhubaneswar city does not exceed the tolerance range. The presence of chloride in hand pump water might be due to the result of washing out of salts from the ground water surface, rocky bed, organic decomposition, run-off water from domestic sewage contamination. The higher concentration of chloride in tap water is due to industrial effluents toxicity in nearby river. Sharma and Pandey (1998) have observed that human body releases a very high quantity of chlorine i.e. 6 mgl^{-1}/ person day.

The iron content of a water body is dependent on the amount of terrestrial run off received by it. Iron has more solubility of acidic pH and therefore large quantities of iron are leached out from the soil by acidic water. The iron content of tap water of different localities of Chandaka Industrial Zone such as AV, PV, NV, SV and BV were 0.20, 0.29, 0.31, 0.32 and 0.33 mgl^{-1} respectively and that of hand pump water of same area were 2.01,2.00,2.03,2.05 and 2.06 mgl^{-1} respectively. The tap water had iron content which was within safe range and thus suitable for drinking and consumption. However, the hand pump water had a very high iron content indicating that it was unsafe for human consumption. Health hazards have already been reported among the people using water having iron content of 0.3 mgl^{-1}(Mitra, 1982 and Das *et al.,* 1992)

The dissolved oxygen value determines whether the water is suitable for consumption or not. Drinking water is required to have a dissolved oxygen value above 5mgl^{-1}. The low value of dissolved oxygen indicates high growth of bacteria that utilize oxygen for their metabolic activities (Ahmed and Krishnamurthy, 1990 and Pandey, *et al*,1992). The water from hand pump has a low dissolved oxygen value and is thus not suitable for human consumption. Chandrasekhar *et a*l (1991) reported that the increased pollutants lower the oxygen level in water.

In Chandaka Industrial zone the dissolved oxygen content of tap water was more than that of hand pump water.

The higher carbon dioxide content generally indicated greater pollution. The abundance of CO_2 exerts certain specific effects on aquatic biota (Golterman,1975). The amount of free CO_2 present in tap water of different localities of Chandaka Industrial Zone such as AV, PV, NV, SV and BV were 0.281, 0.280, 0.283, 0.285 and 0.286 mgl^{-1} respectively. The free CO_2 of tap water was very much within the safe range of usage. The amount of free oxygen present in hand pump water of Chandaka Industrial Zone in different localities such as AV, PV, NV, SV and BV were analyzed to be 6.1, 6.0, 6.3, 6.2 and 6.4 mgl^{-1} respectively. The water from hand pump had a very high value of free CO_2 which was due to sewage inflow and discharge of acidic effluents with higher temperature causing decomposition of flora and fauna. Boralkar (1981) had stated that the sewage inflow may correlate including the human influence by way of faecal matters and organic pollutants as well.

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ANTIBACTERIAL ACTIVITIES OF NEEM BIOPESTICIDE TO *Aeromonas hydrophila and Edwardsiella tarda*

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ABSTRACT

Multineem a biopesticide consists of azadirachtin (300ppm) is used in agricultural field for control of target oriented diseases in crops without any harmful effect. Multineem at concentrations (0.75mg/l, 1.5mg/l, 3mg/l, 3.75mg/l, 4.5mg/l) were used for antibacterial effects on fish pathogens such as *Aeromonas hydrophila* and *Edwardsiella tarda*. The growth of all strains of *A. hydrophila* and *E. tarda* were inhibited over 96h exposure periods as well as in increased concentration. The percentage reduction was more than 85 percent in 96h exposure period in *A. hydrophila* (ATCC 49140, CAHH14) and *E. tarda* (ATCC 15947). At 4.5mg/l concentration of multineem, there was absolute mortality in *A. hydrophila* (CAHH14) strain and 98 percent mortality in *E. tarda* (ATCC 15947). From the above study, it was concluded that neem based biopesticides could be used effectively for controlling the *A. hydrophila* and *E. tarda* at low concentration.

Keywords : Biopesticides, multineem, *Aeromonas hydrophila, Edwardsiella tarda*

INTRODUCTION

Neem biopesticides is a naturally plant derivative pesticides consists of Azadirachtin to control pests in crop by nontoxic mechanisms. This is used in the agriculture sector for control of disease in an integrated pest management manner without hampering the environment.

Plant products were used in aquaculture to control bacterial infections in fish (Behera, 1994; Das *et al.,* 1999; Das *et al.,* 2002). Aquaneem, as emulsified product prepared from the neem kernel was used as an antibacterial agents to control *Aeromonas hydrophila*, *Pseudomonas fluorescence*, *Myxobacteria* and *E. coli* (Das *et al.,* 1999). The antibacterial activity of neem has been known from ancient times (Chaurasia and Jain, 1978; Chawla *et al.,* 1994). Antibacterial properties of neem extract on human being have been reported (Chopra *et al.,* 1956). Bacterial and fungal infection greatly increases the mortality rate in fishes. Neem @1ppm can control the pathogenic bacteria and fungus of freshwater fish and prawn (Sahu *et al.,*1996). Increasing failures in antibiotic resistance exhibited by microbial pathogens has led to screening of several medicinal plants for their potential antimicrobial activity (Ritchkro *et al.,* 1996; Colombo *et al.,* 1996; Martins *et al.,* 2001; Scazzocchio *et al.,* 2001). Use of antibiotics and chemicals has affected the ecosystem as well as immune system of aquatic animals (Richards *et al*., 1991).

Aquaculture, in recent years has encountered serious set back due to disease problems and as a consequences; the use of antimicrobial agents has increased significantly in aquaculture practices. Traditional herbal based therapy has added advantages over the antibiotics and chemical substances because of its nontoxic effect. Biopesticides is an alternative to present day antibiotics which would facilitate the multiple use of water without any side effect. In order to have a eco-friendly alternative to antibiotics, multineem, a neem biopesticide has been used to observe the impact on *Aeromonas hydrophila* and *Edwardsiella tarda* at various doses.

MATERIALS AND METHODS

Experimental Biopesticide

A commercially available Neem biopesticides (neem oil based) which was popularly used by the local agriculture farmers "Multineem"(M/S Multiplex Agricare Pvt. Ltd., Karnataka) was purchased from the local market containing azadirachtin 0.03%E.C. (300ppm). Dilutions (10^{-1}) 30ppm were prepared with distilled water as stock solution and used for the experiment.

Bacteria

The fish microbial pathogen such as different strains of *Aeromonas hydrophila* (CAHH14 CAHH15 ATCC 49140), *Edwardsiella tarda* (ATCC 15947) etc. were used for the study from the pure stock culture that were maintained in Fish Health Management Division, of Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar. Then broth culture of the respective samples were prepared in nutrient broth (Hi Media, Mumbai) by inoculating the sample aseptically and incubated at 37^{0}C for 24 hours.

Experimental Design

For each strain, 50 ml of nutrient broth were prepared and were divided into the different test tubes each containing 2ml of nutrient broth and were sterilized.

Then 50µl of broth culture of each bacterium were inoculated into 18 different test tubes. Further 50µl, 100µl, 200µl, 250µl, 300µl of neem pesticides containing 0.75mg/l to 4.5mg/l of azadirachtin were added to these test tubes in triplicate and in control no neem biopesticides were added. Control tube was also maintained in triplicate form. Then the test tubes were incubated at 37°C for 96 h. Observation were recorded for the growth of microbes at 24h, 48h, 72h and 96h intervals. At 10^{-4} dilution, the number of colony obtained at different incubation period was determined through spread plate method. Growth of bacterial population in CFU/ml. was calculated for each bacterium.

Data Analysis

All the data were analysed through General Linear model program available in SAS software. The means were compared using Duncan's multiple range test (Duncan, 1955) to find the difference at 5% ($P<0.05$) level.

RESULTS AND DISCUSSION

Since ages neem oil, neem leaf and bark extract are known for their insecticidal/pesticidal properties. Various products of neem in its various forms have now come into aquaculture/agriculture practices since last couple of years. Intensification of aquaculture harbors various infectious and parasitic diseases. In order to overcome these diseases various chemicals and pesticides are used which has detrimental effect on the environment (Pena-Llops *et al.,* 2003; Sweilum 2006 & El-Sayed *et al.,* 2007). These detrimental effects led to the change the trends of research worker to look for biopesticide of high safety (Boeke *et al.,* 2004; Subapriya and Nagini 2005). Neem plants have been used, particularly as an antifeedant, antiattractant or repellent (Sharma & Dhiman 1993). Neem kernel has been used as a bactericidal and fungicidal agent in aquatic medium for controlling pathogen (Das *et al.,* 1999). Sahu *et al* (1996) reported that aquaneem 1ppm could control pathogenic bacteria and fungus of freshwater fish and prawn. Neem extract have been reported to control *A. hydrophila, P. fluorescences, E. coli, Flavobacterium columnare* infection (Behera 1994; Das *et al* 1999). Patel & Trivedi (1962) and Satyavati *et al* (1976) reported inhibition of growth of *Vibrio cholerae* due to *Neem azadirachta* at 200µg/ml and that of *Klebsiella pneumoniae* at 500µg/ml respectively. In the present experiment, growth of *A. hydrophila* (CAHH14 CAHH15 ATCC 49140) and *E. tarda* (ATCC 15947) were inhibited remarkably.

Table 1 : Logarithimic growth of different strain of *A. hydrophila* and *E. tarda* at different concentration of biopesticide multineem. (Data are expressed as mean log CFU/ml±SE, Mean±SE bearing common superscript across the column are not significant to each other at 5%)

Bacterial pathogens	Multineem Concentration (mg/l)	Logarithimic growth at different duration 24 hr	48 hr	72 hr	96 hr
Aeromonas hydrophila (CAHH14)	0	2.735±0.040^{a}	2.740±0.026^{a}	2.749±0.026^{a}	2.763±0.025^{a}
	0.75	2.273±0.128^{b}	2.131±0.031^{b}	1.950±0.055^{b}	1.880±0.019^{b}
	1.5	2.277±0.073^{b}	2.016±0.016^{bc}	1.871±0.027^{bc}	1.837±0.057^{b}
	3	2.281±0.028^{b}	1.856±0.107^{cd}	1.837±0.097^{bc}	1.723±0.093^{b}
	3.75	2.189±0.082^{b}	1.716±0.133^{ed}	1.622±0.183^{cd}	0.602±0.173^{c}
	4.5	2.160±0.082^{b}	1.611±0.043^{e}	1.522±0.087^{d}	0.000±0.0^{d}
Aeromonas hydrophila (CAHH15)	0	2.809±0.007^{a}	2.820±0.010^{a}	2.825±0.016^{a}	2.841±0.018^{a}
	0.75	2.797±0.007^{a}	2.719±0.059^{ab}	2.649±0.040^{ab}	2.595±0.080^{b}
	1.5	2.717±0.004^{ab}	2.662±0.046^{bc}	2.611±0.128^{b}	2.596±0.028^{b}
	3	2.642±0.056^{b}	2.593±0.006^{c}	2.578±0.012^{b}	2.402±0.012^{c}
	3.75	2.646±0.018^{b}	2.582±0.026^{c}	2.494±0.045^{b}	2.388±0.066^{c}
	4.5	2.408±0.086^{c}	2.369±0.012^{d}	2.289±0.055^{c}	1.644±0.072^{d}
Aeromonas hydrophila (ATCC 49140)	0	2.30±0.049^{a}	2.359±0.033^{a}	2.397±0.037^{a}	2.472±0.011^{a}
	0.75	2.211±0.039^{a}	2.120±0.089^{ab}	2.044±0.045^{b}	1.55±0.153^{b}
	1.5	2.166±0.070^{a}	2.092±0.089^{ab}	1.972±0.038^{b}	1.481±0.123^{b}
	3	1.954±0.007^{b}	1.907±0.066^{b}	1.856±0.107^{bc}	1.282±0.105^{bc}
	3.75	1.88±0.013^{bc}	1.798±0.058^{bc}	1.654±0.026^{c}	1.169±0.105^{bc}
	4.5	1.738±0.095^{c}	1.502±0.19^{c}	1.295±0.123^{d}	0.99±0.235^{c}
Edwardsiella tarda (ATCC 15947)	0	1.986±0.085^{a}	2.011±0.057^{a}	2.033±0.053^{a}	2.075±0.055^{a}
	0.75	1.414±0.082^{b}	1.305±0.066^{b}	0.401±0.265^{b}	0.518±0.139^{b}
	1.5	1.304±0.100^{b}	1.234±0.077^{b}	0.518±0.139^{b}	0.433±0.132^{bc}
	3	1.009±0.114^{c}	0.359±0.359^{c}	0.518±0.041^{b}	0.318±0.159^{bc}
	3.75	0.937±0.017^{c}	0.602±0.173^{c}	0.460±0.087^{b}	0.100±0.100^{c}
	4.5	0.842±0.036^{c}	0.577±0.100^{c}	0.159±0.159^{b}	0.100±0.100^{c}

The present study demonstrated the antibacterial properties of a neem biopestcide (Multineem) to three strains of *Aeromonas hydrophila* (CAHH14, CAHH15, ATCC49140) and one strain of *Edwardsiella tarda* (ATCC 15947). Two strain of *Aeromonas hydrophila* i.e. CAHH14 & CAHH15 were isolated from Indian major carps *Catla catla* and *Labeo rohita* showing abdominal dropsy (Sahu *et al.*, 1996). The results are presented in Table 1 and Fig 1,2,3 & 4. It was noticed that the growth of all strains of *Aeromonas hydrophila* and *Edwardsiella tarda* were inhibited over 96h exposure periods as well as increased concentration (Table 1). The antibacterial activity of multineem was significantly (Pd"0.05) decreased over 72h and 96h exposure period over all the concentration tested. The percentage reduction was more than 85 percent in 96h exposure period in *A.hydrophila* (ATCC 49140) (Fig 3), CAHH14 (Fig 1) & *Edwardsiella tarda* (ATCC 15947) (Fig 4). At 4.5mg/l concentration of multineem, there was absolute mortality in *A.hydrophila* (CAHH14) strain and 98 percent mortality in *E.tarda* (ATCC 15947). Though, the bacterial density was very high in the control, it was noticed that multineem could inhibit the log CFU of *A.hydrophila* (ATCC-49140) even if at 0.75mg/ml concentration from 18.81 percent at 24h to 86.53 percent at 96h exposure period. It was noticed that the inhibition of *A.hydrophila* (CAHH15) strain was very low as compared to the other strain of *A.hydrophila* and *E.tarda*.

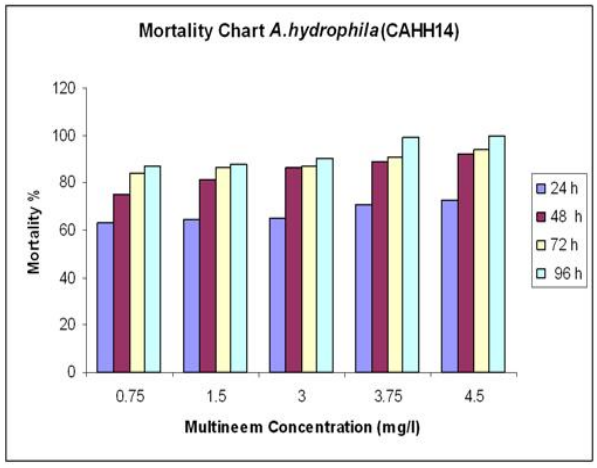

Fig. 1 : Percentage reduction of *Aeromonas hydrophila* (CAHH14) at different concentration of multineem

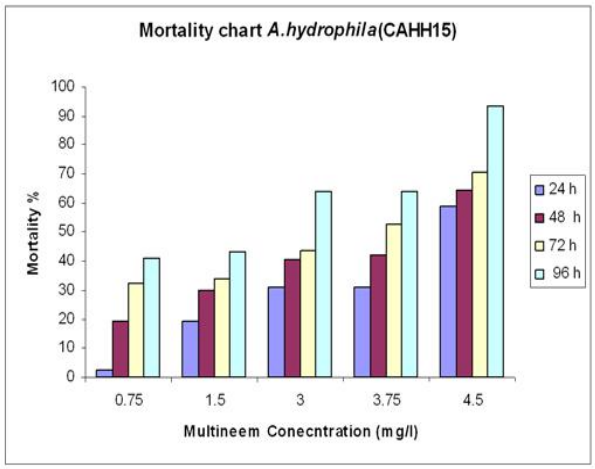

Fig. 2 : Percentage reduction of *Aeromonas hydrophila* (CAHH15) at different concentration of multineem.

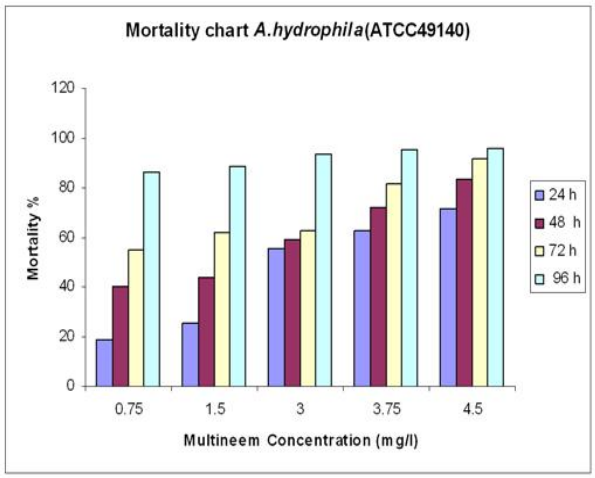

Fig. 3 : Percentage reduction of *Aeromonas hydrophila* (ATCC 49140) at different concentration of multineem.

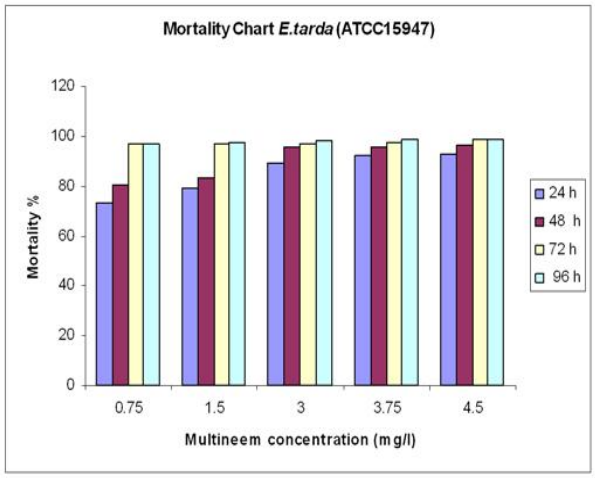

Fig. 4 : Percentage reduction of *Edwardsiella tarda* (ATCC 15947) at different concentration of multineem.

In freshwater fish culture, *A.hydrophila* and *E.tarda* are generally regarded as important diseases causing bacterial pathogen and cause mortality and hence the present study has its significant importance in fish health management. Biopesticides have low environmental effect and has a wider application for pest control as well as act as a medium to enhance the productivity. Neem extract has been tried against marine bacterial isolates e.g.*A. hydrophila, Eterobcter* sp.*, Vibrio cholerae, V. alginolyticus, V. parahaemolyticus,* and *Yersinia* sp. and reported that methanolic and ethanolic extract was highly effective (Dayanithi *et al.,* 2010).

It is clearly evident from the above study that multineem causes inhibition of *A. hydrophila* and *E.tarda* even at 0.75mg/l concentration over a period of 96h exposure. As carp culture is expanding and needs a sustainable development both from production side as well as from environment, it is high time to use such type of environment friendly chemicals/biopesticides to counter disease problems in the aquaculture sector.

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FLORA OF BHITARAKANIKA MANGROVE ECOSYSTEM OF ORISSA

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ABSTRACT

The current status of flora and vegetation of Bhitarakanika mangrove ecosystem of Orissa coast was assessed. The true mangroves, its associates and other plants of entire sanctuary was surveyed with special emphasis on flora of more diversified localities like Gupti, Khola, Dangamala, Kalibhanjadia Island, Bhitarakanika and Ekakula. A total 168 angiospermic plant species belonging to 131 genera under 66 families have been collected during the study along with three pteridophytes. Of these, 25 species belong to true mangrove category, 19 are mangrove associates and 18 plant species are classified under back mangroves. These include 2 plant species chareteristic of coastal sand-dunes and 107 non-mangrove taxa. The rare and endangered plant species occurring in Bhitarkanika mangrove forests have been identified. An enumeration of all species collected from the region has also been provided in the paper.

Key words : Bhitarakanika mangrove ecosystem, current status, flora, vegetation

INTRODUCTION

Mangroves are the characteristic complex-plant-communities of tropical and sub-tropical sheltered coast-lines such as coast of small bays, river estuaries, lagoons, creeks and sea-channels separating islands. The mangrove forest is one of the most productive wetlands on the earth. The plant species occurring in this ecosystem are habitat-specific, economically valuable and attract the attention of botanists and ecologists world-wide by exhibiting peculiar morphological and anatomical adaptations (Alongi, 1996). Because of peculiar habitat requirement, ecological adaptations and their dwindling population, the study and conservation aspects of mangroves have attained priority in biodiversity and ecosystem reserch in India, about 4461 sq.km area is covered under mangroves, which is 0.14% of the country's total geographic area and approximately 5% of the world's mangrove vegetation. Nearly 57% of the Indian mangroves are found along the east coast. Bhitarakanika mangrove ecosystem lies in the deltaic region of north- eastern coastal plain of Kendrapara district of Orissa along the east coast of India. Located between 20^0 4'- 20^0 8' N latitude, 86^0 45'- 87^0 5' E longitude, it occupies an area of 672 sq km of which mangrove forests extend over nearly 130 sq km (Mishra *et al*., 2005). It is surrounded by the Bay of Bengal on the east, the villages of Kendrapara district on the west, Baitarani and Dhamra rivers on the north and the Mahanadi river on the south. In the past, Bhitarkanika possessed very rich and diverse mangroves vegetation because of its peculiar geographic location and edaphic and climatic variables. The diversity of mangroves remain unexplored till the floristic work of Haines (1921-25) and Mooney (1950), the two British forest officers and pioneer plant explorers for Bihar and Orissa. However, Mooney's (1950) survey was confined to Mahanadi delta alone. Rao and Banerjee (1967 & 1982), Rao *et al*. (1970), Banerjee and Das (1972), Rao and Shastry (1974) and Banerjee (1986) have studied the flora and vegetation of coastal Orissa including tidal swamp forests and added a number of species for the flora of Orissa. Thereafter, Banerjee (1984), Choudhury (1984, 1986, 1987,1990a, 1990b), Samal and Patnaik (1989), Biswal and Choudhury (1993) and Reddy *et al*. (2006) have conducted floristic studies in the Bhitarakanika Wildlife Sanctuary with special emphasis on mangroves as well as their socio-economic importance. Choudhury *et al*. (1991) and Choudhury (1994, 1998, 2001) have discussed the biological diversity and conservation of the mangroves of the Bhitarkanika. The present study highlights the current status of flora and vegetation of this interesting habitat based on recent field studies along with listing of rare and endangered taxa. Plants belonging to different ecological categories have been enumerated in this paper.

MATERIALS AND METHODS

The current survey was conducted to reasses the vegetation status of the Bhitarakanika mangroves ecosystem by undertaking intensive survey in floristically diversifies localities. The major areas include Gupti (Krisnapriyapur, Gupti check gate, Sunei Rupei, Patsala nala and Baunsagarh nala), Khola (Khola check gate, Barhapita, Khola nala), Dangamala (Talachua Port, Salendra Sarai and Sanjog Nala to Mundha Jhora) which spreads over an area of 636.00 hectare , Kalibhanjadia island (Dhamra river, Sapua river and Chandbali), extends over an area of 819.00 hectares and Bhitarakanika covering Sanjog nala and Bhitarakanika nala spreads over an area of 1712.40 hectares and Ekakula (located close to the Bay of Bengal) which is mainly composed of sandy and muddy beach. The map showing the location of different study sites is given below (Fig. 1).

Fig. 1 : Map showing the location of different study sites of Bhitarakanika mangrove ecosystem

Bhitarkanika experiences three distinct seasons namely summer, rainy and winter. Summer starts from mid February and extends up to mid June. Summer is followed by rainy season, which continues till end of October. November-February constitute the winter months characterized by low temperature accompanied by low rain fall. The average annual rainfall is about 1642 mm, bulk of which is received during the period June to October (Mishra *et al*., 2005). Wind velocity is about 40 km per hour during the monsoon, which is recorded in the ranges of 15-25 km/hr during winter. Sometime the depressions in the Bay of Bengal accelerate the wind velocity to a considerabale extent. From the meteorological data of last ten years it is revealed that the maximum and minimum relative humidity ranges from 83 % to 49.25% at 8.30 am and from 76% to 46.5 % percent at 5.30 pm respectively.

Regular surveys were made in different localities spread across the entire area through out the year with more emphasis on collection from vegetationally diversified habitats. During each field trip, besides ecological studies, plants were collected and detailed field notes recorded on spot which includes field number, date of collection, collection locality, habit, habitat, phenology, plant association, pattern of distribution, abundance/rarity and plant characters those can not be detected from dried specimens. In case of small herbaceous plant, the whole plant was uprooted but for shrubs and trees, the branches, preferably flowering or fruiting ones, were cut out and preserved for subsequent identification or herbarium preparation. The specimens were identified with the help of regional floras *i.e*., "The Botany of Bihar and Orissa" by Haines (1921-25) and its supplement by Mooney (1950), "Flora of Orissa" (Saxena and Brahmam, 1994-96), other floras, monographs and revisionary works. The collected specimens were either preserved in closed polythene bags or pressed among blotters in the field. To avoid fungal infection or rotting of specimens, the blotters were frequently changed till the specimens were completely dry. The dried specimens were dipped in a solution of $HgCl_2$ (4%) in absolute alcohol for poisoning and allowed to dry within blotters under pressure for about a week. The specimens were then mounted on to standard acid-free herbarium mount boards (42 x 28cm) by application of glue and all field data transferred to the herbarium labels to be pasted on the lower right hand corner of the mount board.

RESULTS AND DISCUSSION

A total of 168 angiospermic plant species belonging to 131 genera under 66 families have been collected during the present survey besides three pteridophytes. Of these, only 24 species belong to monocots and rest 144 belong to dicots *i. e.* in the ration of 1:6. The details of genera and species under these two broad groups are presented in Table 1. Out of 168 angiospermic species, 25 plant species are classified as true mangroves (Table 2), 19

species as mangrove associates (Table 3) and 18 plant species as back mangroves (Table 4). Two species characteristic to sand dunes and beach flora (Table 5) and 107 non-mangrove species (Table 6) are also included in the list. The list of apparently rare and endangered species occurring in Bhitarkanika Mangrove forest is given in Table 7 and Fig. 1-6.

Fig. 2 : *Heritiera fomes* Buch.-Ham

Fig. 3 : *Aglaia cucullata* Roxb

Fig. 4 : *Merope angulata* (Kurz.) Swingle

Fig. 5 : *Xylocarpus granatum* Koen

Fig. 6 : *Cerbera manghas* L

Fig. 7 : *Mucuna giganteana* (Willd.) DC

Table 1 : Flora of Bhitarakanika mangrove forests.

Sl.No.	Types of plant	No. of families	No. of genera	No. of species
1.	Dicotyledons	58	112	144
2.	Monocotyledons	8	19	24
Total		66	131	168

Table 2 : The enumeration of true mangroves of Bhitarkanika mangrove ecosystem.

Sl.No.	Plant Species	Family	Distribution in Bhitarakanika
1	*Aegialitis rotundifolia* Roxb.	Plumbaginaceae	Bhitarkanika, Salendrasarei, Kalibhanjadia, Ekakula.
2	*Aegiceras corniculatus* (L.) Blanco	Myrsinaceae	Khola, Bhitarkanika, Dangamal, Kalibhanjadia.
3	*Avicennia alba* Bl. Bijdr. 821	Avicenniaceae	Khola,Dangamal,Gupti, Kalibhanjadia, Talachuaport,Ekakula, Sunei Rupei, Salendra Sarai.
4	*Avicennia marina* (Forssk.)	Avicenniaceae	Gupti, Sunei Rupei.
5	*Avicennia officinalis* L. Sp. Pl.	Avicenniaceae	Bhitarkanika, Dangamal, Gupti, Kalibhanjadhia, Ekakula, Talachua port, Sunei Rupei, Salendra sarai.
6	*Brownlowia tersa* (L.) Kosterm.	Tiliaceae	Khola, Bhitarkanika, Dangamal,Kalibhanjadia, Sunei Rupei.
7	*Bruguiera cylindrica* (L.) Bl.	Rhizophoraceae	Ekakula, Gupti, Sunei Rupei, Salendra sarai.
8	*Bruguiera parviflora* (Roxb.)	Rhizophoraceae	Kalibhanjadia.
9	*Bruguiera sexangula* (Lour.)	Rhizophoraceae	Khola, Dangamal, Bhitarkanika, Salendra Sarai.
10	*Bruguiera gymnorrhiza* (L.) Savigy.	Rhizophoraceae	Gupti
11	*Ceriops decandra* (Griff.) Ding-Hou in	Rhizophoraceae	Kalibhanjadia,Ekakula, Gupti Krisnapriapur, Sunei Rupei, Dangamal, Bhitarkanika.
12	*Excoecaria agallocha* L. Sp. Pl.(ed.2).	Euphorbiaceae	Dangmal, Gupti, Khola, Bhitarkanika, Ekakula,Sunei Rupei, Salendra Sarai.
13	*Heritiera fomes* Buch.–Ham.	Sterculiaceae	Kalibhanjadia, Bhitarkanika Dangamal.
14	*Heritiera littoralis* Dryand. in Aiton,	Sterculiaceae	Khola, Bhitarkanika, Dangamal, Kalibhanjadia, Sunei-Rupei.
15	*Kandelia candel* (L.) Druce,	Rhizophoraceae	Khola, Kalibhanjadia, Gupti, Talachua port.
16	*Lumnitzera racemosa* Willd.	Combretaceae	Bhitarkanika, Gupti, Kalibhanjadia, Dangamal, Ekakula, Salendra Sarai.
17	*Phoenix paludosa* Roxb. Fl. Ind.	Arecaceae	Bhitarkanika, Dangmal, Gupti, Khola, Kalibhanjadia, Sunei Rupei, Salendra Sarai.
18	*Rhizophora apiculata* Bl. Enum.	Rhizophoraceae	Bhitarkanika, Khola, Dangmal, Gupti, Sunei Rupei.
19	*Rhizophora mucronata* Poir. in Lamk.	Rhizophoraceae	Bhitarkanika, Gupti, Kalibhanjadia Dangmal,Sunei Rupei.
20	*Sonneratia alba* J. Smith in Rees,	Sonneratiaceae	Khola
21	*Sonneratia apetala* Buch.	Sonneratiaceae	Bhitarkanika, Kalibhanjadia, Dangmal, Ekakula,Gupti, Sunei, Rupei.

22	*Sonneratia caseolaris* (L.)	Sonneratiaceae	Khola, Ekakula.
23	*Xylocarpus granatum* Koen.	Meliaceae	Khola, Bhitarkanika, Dangmal, Sunei Rupei,Gupti, Kalibhanjadia.
24	*Xylocarpus mekongenesis*	Meliaceae	Khola, Bhitarkanika, Dangamal, Gupti, Ekakula.
25	*Xylocarpus gangeticus* (Prain)	Meliaceae	Bhitarkanika.

Table 3 : The enumeration of mangroves associates of Bhitarkanika mangrove ecosystem.

Sl.No.	Plant Species	Family	Distribution
1	*Acanthus illicifolius* L. Sp. Pl. 639.	Acanthaceae	Khola, Dangamal, Bhitarkanika, Kalibhanjadia, , Gupti, Sunei Rupei, Salendra sarai.
2	*Acrostichum aureum* L. Sp,	Acrostichaceae	Bhitarkanika, Dangmal, Khola.
3	*Aglaia cucullata* Roxb. Corr.	Meliaceae	Bhitarkanika, Khola, Dangmal.
4	*Cerbera manghas* L. Sp. Pl .208.	Apocynaceae	Dangamal, Bhitarkanika, Khola, Gupti.
5	*Clerodendrum inerme* (L.) Gaertn. Fruct	Verbenaceae	Dangamal, Bhitarkanika, Ekakula, Gupti, Sunei Rupei.
6	*Cynometra iripa* Kostel., Allg. Med.	Fabaceae	Khola, Bhitarkanika, Dangamal, Kalibhanjadia, Sunei Rupei.
7	*Dalbergia spinosa* Roxb. Fl. Ind. 3:223.	Fabaceae	Dangmal, Gupti, Sunei Rupei, Bhitarkanika.
8	*Derris trifoliata* Lour. Fl. Cochinch.	Fabaceae	Khola
9	*Derris scandens* (Roxb.) Benth. J. Linn.	Fabaceae	Dangamal
10	*Dodonaea viscosa* N. Jacq. Encl.	Sapindaceae	Ekakula
11	*Myriostachya wightiana* (Nees ex Steud.)	Poaceae	Bhitarkanika, Gupti, Sunei-Rupei, Kalibhanjadia, Dangamal, Ekakula.
12	*Pentatropis capensis* (L.f.) Bullock,	Asclepiadaceae	Gupti, Sunei Rupei.
13	*Porteresia coarctata* (Roxb.)	Poaceae	Bhitarkanika, Kalibhanjadia, Dangmal.
14	*Salacia chinensis* L. Mant. Pl. 2:293.	Poaceae	Dangamal, Kalibhanjadia, Sunei Rupei, Salendra Sararai.
15	*Salicornia brachiata* Roxb. Fl.	Chenopodiaceae	Bhitarkanika, Salendra sarai.
16	*Sarcolobus carinatus* Wall. As.	Asclepiadaceae	Khola
17	*Sarcolobus globosus* Wall. As.	Asclepiadaceae	Khola
18	*Sesuvium portulacastrum* (L.) L. Syst.	Aizoaceae	Kalibhanjadia, Gupti.
19	*Suaeda maritima* (L.) Dumort.	Chenopodiaceae	Kalibhanjadia, Bhitarkanika, Ekakula, Salendra Sarai.

Table 4 : The list of back mangrove species occurring in Bhitarkanika mangrove forests.

Sl.No	Plant Species	Family	Distribution
1	*Barringtonia acutangula* (L.) Gaertn.	Barringtoniaceae	Bhitarkanika
2	*Caesalpinia bonduc* (L.) Roxb.	Caesalpiniaceae	Dangamala, Ekakula.
3	*Caesalpinia crista* L. Sp. Pl. 380. 1753;	Caesalpiniaceae	Dangmal,Khola,Gupti, Sunei Rupei.
4	*Crateva magna* (Lour.) DC. Prodr.	Capparaceae	Bhitarkanika, Dangamal, Sunei Rupei
5	*Cuscuta reflexa* Roxb. Pl. Corom. t.	Cuscutaceae	Bhitarkanika, Salendrasarai.
6	*Dendrophthoe falcata* (L.f.) Etting in	Loranthaceae	Dangmal
7	*Pongamia pinnata* (L.) Pierre,	Fabaceae	Bhitarkanika, Khola, Kalibhanjadia, Dangamal, Ekakula, Gupti, Sunei Rupei.
8	*Diospyros ferrea* (Willd.) Bakh. Gard.	Ebenaceae	Bhitarkanika
9	*Dolichondrone spathacea* (L.f.) K. Schum.	Bignoniaceae	Bhitarkanika
10	*Hibiscus tiliaceous* L. Sp. Pl. 1753;	Malvaceae	Bhitarkanika, Dangmal, Khola, Gupti, Sunei Rupei, SalendraSarai.
11	*Hoya parasitica* (Roxb.) Wall. in Wt.	Asclepiadaceae	Bhitarkanika

12	*Lannea coromandelica* (Houtt.)	Anacardiaceae	Dangamal
13	*Manilkara hexandra* (Roxb.)	Sapotaceae	Damgmal
14	*Pandanus fascicularis* Lam.	Pandanaceae	Bhitarkanika, Khola,Dangamal.
15	*Pandanus foetidus* Roxb. Fl.	Pandanaceae	Bhitarkanika
16	*Thespesia populnea* (L.) Sol. *ex* Corr.	Malvaceae	Dangmal, Kalibhanjadia, Ekakula, Gupti, Sunei Rupei.
17	*Tinospora cordifolia* (Willd.) Hook. f.	Menispermaceae	Bhitarkanika
18	*Tylophora fasciculata* Buch-Ham.ex	Asclepiadaceae	Bhitarkanika

Table 5 : The list of sand dune taxa of Bhitarkanika mangrove ecosystem.

Sl.No	Plant Species	Family	Distribution
1	*Ipomoea pes-caprae* (L.) R. Br. in Turkey,	Convolvulaceae	Ekakula
2	*Canavalia maritima* (Aubl.) Thouars,	Fabaceae	Ekakula

Table 6 : The enumeration of non-mangroves of Bhitarkanika mangrove ecosystem.

Sl. No.	Plant Species	Family	Distribution
1	*Alphonsea ventricosa* (Roxb.).	Annonaceae	Dangmal
3	*Polyalthia cerasoides* (Roxb.)	Annonaceae	Bhitarkanika
4	*Polyalthia suberosa* (Roxb.) Thw.	Annonaceae	Bhitarkanika
5.	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	Bhitarkanika
6.	*Capparis sepiaria* L. Syst. Nat.	Capparaceae	Gupti, Sunei Rupei.
7	*Flacourtia indica* (Burm.f.) Merr.	Flacourtiaceae	Bhitarkanik, Kalibhanjad, Dangamal, Sunei Rupei .
8	*Tamarix dioca* Roxb. Fl. Ind. 2:101.	Tamaricaceae	Dangmal, Kalibhanjadia, Ekakula, Sunei Rupei,Salendra-Sarai.
9	*Garcinia xanthochymus* Hook. f. ex T.	Clusiaceae	Bhitarkanika
10	*Sida cordata* (Burm.f.) Borssum.	Malvaceae	Ekakula
11	*Sida cordifolia* L .Sp. Pl. 684. 1753;	Malvaceae	Ekakula
12	*Grewia disperma* Rottl.in Spreng.	Tiliaceae	Bhitarkanika
13	*Glycosmis mauritiana* (Lam.) Tanaka,	Rutaceae	Bhitarkanika
14	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	Bhitarkanika, Dangmal.
15	*Merope angulata* (Kurz) Swingle in Journ.	Rutaceae	Dangmal
16	*Toddalia asiatica* (L.) Lam. Tabl. Encycl.	Rutaceae	Bhitarkanika
17	*Ochna obtusata* DC. Ann. Mus.	Ochnaceae	Bhitarkanika
18	*Azadirachta indica* A. Juss. Mem. Mus.	Meliaceae	Dangmal, Ekakula, Salendra Sara
19	*Olax psittacorum* (willd.) Vahl, Enum:	Olacaceae	Khola
20	*Maytenus emarginatus* (Willd.) Ding	Celastraceae	Bhitarkanika, Dangamal.
21	*Ziziphus oenoplia* (L.) Mill. Gard.	Rhamnaceae	Sunei Rupei
22	*Cayratia trifolia* (L.) Domin. Biblioth.	Vitaceae	Bhitarkanika, Sunei Rupei, Khola.
23	*Allophylus serratus* (Roxb.) Kurz. J. Asiat.	Sapindaceae	Sunei- Rupei
24	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sapindaceae	Bhitarkanika, Dangmal.
25	*Anacardium occidentale* L. Sp.	Anacardiaceae	Dangmal, Ekakula.
26	*Caesalpinia digyna* Rottl. in Ges.	Caesalpiniaceae	Bhitarkanika
27	*Intsia bijuga* (Colebr.) O.Kuntze,	Caesalpiniaceae	Khola, Dangmal
28	*Parkinsonia aculeata* L. Sp.	Caesalpiniaceae	Ekakula
29	*Acacia nilotica* (L.) Deliee subsp.	Mimosaceae	Gupti
30	*Accacia pennata* (L.) Willd.	Mimosaceae	Bhitarkanika

31	*Dichrostachys cinerea* (L.) Wt. and	Mimosaceae	Dangmal
32	*Mimosa himalayana* Gamble,	Mimosaceae	Sunei- Rupei
33	*Acacia auriculiformis* A.Cunn.ex	Mimosaceae	Bhitarkanika, Kalibhanjadia.
34	*Pithecellobium dulce* (Roxb.)	Mimosaceae	Dangmal, Gupti, Sunei Rupei
35	*Crotalaria retusa* L. Sp. Pl. 715. 1753;	Fabaceae	Sunei-Rupei, Bhitarkanika,
36	*Dalbergia candenatensis* (Dennst.)	Fabaceae	Bhitarkanika, Dangmal, Gupti, Kalibhanjadia.
37	*Dalbergia volubilis* Roxb .Pl.	Fabaceae	Khola
38	*Desmodium triflorum* (L.) DC. Prodr.	Fabaceae	Dangmal
39	*Mucuna gigantea* (Willd.) DC.	Fabaceae	Khola
40	*Kalanchoe pinnata* (Lam.) Pers.	Crassulaceae	Dangmal
41	*Eugenia rothii* Panigr. J. Ecom. Tax.	Myrtaceae	Dangmal, Bhitarkanika.
42	*Syzygium cumini* (L.) Skeeds in	Myrtaceae	Dangmal, Bhitarkanika.
43	*Memecylon umbellatum* Burm. f.	Melastraceae	Dangmal, Bhitarkanika.
44	*Mollugo pentaphylla* L. Sp. Pl. 89.	Molluginaceae	Bhitarkanika
45	*Hydrocotyle sibthorpioides* Lam.	Apiaceae	Salendra sarai
46	*Catunaregam spinosa* (Thunb.)	Rubiaceae	Bhitarkanika
47	*Dentella repens* (L.) Forst. and Forst.	Rubiaceae	Bhitarkanika
48	*Haldina cordifolia* (Roxb.) Ridsd.	Rubiaceae	Bhitarkanika
49	*Hedyotis aspera* Heyne, ex Roth,	Rubiaceae	Gupti
50	*Hedyotis puberula* (G.Don) Arn.	Rubiaceae	Gupti
51	*Ixora pavetta* Andrews,	Rubiaceae	Dangamal
52	*Sigesbeckia orientalis* L. Sp. Pl. 900.	Asteraceae	Khola
53	*Vernonia cinerea* (L.) Less.	Asteraceae	Bhitarkanika, Dangmal, Salendra Sarai.
54	*Lobelia alsinoides* Lam. Encycl. 3:558.	Lobeliaceae	Sunei -Rupei
55	*Mimusops elengi L.* Sp. Pl. 349. 1753;	Sapotaceae	Sunei-Rupei, Bhitarkanika.
56	*Diospyrus malabarica* (Desr.) Kostel.	Ebenaceae	Bhitarkanika, Dangamal.
57	*Azima tetracantha* Lam. Encycl. 1:343.	Salvadoraceae	Kalibhanjadia, Salendra Sarai.
58	*Salvadora persica* L. Sp. Pl. 122.	Salvadoraceae	Dangamala,Bhitarknika, Kalibhanjadia, Ekakula, Gupti, Sunei rupei, Salendra sarai.
59	*Carissa spinarum* L. Mant.	Apocynaceae	Bhitarkanika, Dangamal, Kalibhanjadia.
60	*Ichnocarpus frutescens* (L.) Ait. F.	Apocynaceae	Bhitarkanika
61	*Parsonsia alboflavescens* (Dennst.)	Apocynaceae	Khola, Sunei Rupei,Bhitarkanika.
62	*Hemidesmus indicus* (L.) R. Br in Aiton,	Periplocaceae	Bhitarkanika
63	*Calotropis gigantea* (L.) R. Br. in Aiton.	Asclepiadaceae	Bhitarkanika
64	*Tylophora indica* (Burm. f.) Merr.	Asclepiadaceae	Bhitarkanika
65	*Tylophora tenuissima* (Roxb.)	Asclepiadaceae	Bhitarkanika, Salendra sarai.
66	*Strychnos nux-vomica* L. Sp. Pl.	Strychnaceae	Bhitarkanika, Dangamal.
67	*Ipomoea sepiaria* J. Koen. *ex* Roxb.	Convolvulaceae	Bhitarkanika
68	*Solanum nigrum* L. Sp. Pl. 186.	Solanaceae	Sunei- Rupei
69	*Solanum virginianum* L. sp. Pl. 187.	Solanaceae	Sunei- Rupei
70	*Rungia pectinata* (L.) Nees, in	Acanthaceae	Bhitarkanika
71	*Lantana camara* L. var. aculeata (L.)	Verbenaceae	Bhitarkanika,Dangamal.
72	*Pygmaeopremna herbacea* (Roxb.)	Verbenaceae	Khola

73	*Litsea glutinosa* (Lour.) C. B.	Lauraceae	Bhitarkanika, Dangamal.
74	*Antidesma ghaessembilla* Gaertn.	Euphorbiaceae	Bhitarkanika, Sunei- Rupei
75	*Euphorbia hirta* L. Sp. Pl. 454. 1753;	Euphorbiaceae	Khola
76	*Jatropha gossypifolia* L. Sp. Pl. 1006.	Euphorbiaceae	Bhitarkanika, Kalibhanjadia.
77	*Ricinus communis* L. Sp. Pl. 1007.	Euphorbiaceae	Kalibhanjadia, Bhitarkanika.
78	*Sapium indicum* Willd. Sp. Pl. 4:572.	Euphorbiaceae	Khola
79	*Sapium insigne* (Royle) Benth. In Benth.	Euphorbiaceae	Khola
80	*Suregada multiflora* (Juss.) Ball. Etud.	Euphorbiaceae	Bhitarkanika
81	*Ficus benjamina* L. Mant.	Moraceae	Dangmal
82	*Ficus racemosa*L.Sp.Pl.1060.753	Moraceae	Bhitarkanika
83	*Ficus religiosa* L. Sp .Pl. 1059. 1753;	Moraceae	Dangamal
84	*Streblus asper* Lour. Fl. Cochinch.	Moraceae	Bhitarkanika, Dangmal.
85	*Casuarina equisetifolia* L. Amoen.	Casuarinaceae	Bhitarkanika, Dangamal, Salendra Sarai, Ekakula.
86	*Asparagus racemosus* Willd. Sp.	Liliaceae	Sunei-Rupei
87	*Monochoria hastata* Solms in A.DC.	Pontederiaceae	Sunei-Rupei
88	*Flagellaria indica* L. Sp. Pl. 333. 1753;	Flagellariaceae	Dangmal,Khola,Kalibhanjdia
89	*Borassus flabellifer* L. Sp. Pl. 1187.	Arecaceae	Bhitarkanika
90	*Cryptocoryne retrospiralis* (Roxb.)	Araceae	Khola, Dangamal
91	*Pistia stratiotes* L. Sp. Pl. 963.	Araceae	Bhitarkanika
92	*Cyperus conglomeratus* (Rottb)	Cyperaceae	Dangamal
93	*Cyperus corymbosus* Rottb. Descr.	Cyperaceae	Dangamal
94	*Cyperus platystylis* R. Br. Prodr. Fl.	Cyperaceae	Dangmal
95	*Fimbristylis acuminata* Vahl, Enum.	Cyperaceae	Khola, Bhitarkanika.
96	*Fimbristylis bisumbellata* (Forssk.)	Cyperaceae	Sunei- Rupei
97	*Fimbristylis ferruginea* (L.) Vahl,	Cyperaceae	Bhitarkanika
98	*Schoenoplectus articulatus* (L.) Palla,	Cyperaceae	Bhitarkanika
99	*Cyrtococcum trigonum* (Retz.) Camus	Poaceae	Bhitarkanika
100	*Digitaria longiflora* (Retz.) Pers.	Poaceae	Bhitarkanika
101	*Imperata cylindrica* (L.) *Raeusch var.*	Poaceae	Khola
102	*Ischaemum indicum* (Houtt.) Merr.	Poaceae	Bhitarkanika
103	*Oplismenus burmannii* (Retz.) P. Beauv.	Poaceae	Dangamal
104	*Phragmites karka* (Retz.) Trin. ex Steud.	Poaceae	Khola
105	*Pronephrium nudatum* (Roxb.ex Griff.)	Thelypteridaceae	Bhitarkanika
106	*Stenochlaena palustris* (Burm.f.) Beed.	Stenochlaenaceae	Bhitarkanika
107	*Acrostichum aureum* L. Sp, Pl. 1069.	Acrosticaceae	Bhitarkanika

Table 7 : The List of rare and endangered species

Sl. No.	Plant Species	Family	Distribution
1.	*Mucuna giganteana* (Willd.) Dc.	Fabaceae	Khola
2.	*Xylocarpus granatum* Koen	Meliaceae	Kalibhanjadia, Bhitarkanika, Dangamal, Gupti
3.	*Aglaia cucullata* Roxb.	Meliaceae	Bhitarkanika, Khola, Dangamal
4.	*Merope angulata* (Kurz.) Swingle	Rutaceae	Dangamal
5.	*Heritiera fomes* Buch.-Ham	Sterculiaceae	Kalibhanjadia, Bhitarkanika, Dangamal
6.	*Cerbera odollam* Gaertn	Apocynaceae	Dangamal, Bhitarkanika, Khola, Gupti

The mangrove and associate flora of Bhitarkanika has been degraded considerably during the last few decades due to biotic factors of different kinds and magnitudes. Mangrove forests have been over-exploited by the local people for their material needs such as food, fodder, shelter, tannin and dye since long. Habitat destruction/ conversion for agriculture, prawn culture, human habitation and other activities resulted in depletion of mangrove forests in to scrub jungles. Many species having extremely narrow range of distribution have become rare and threatened. So, it is high time to conserve these rare plant species before further genetic erosion takes place. Interestingly, *Cerbera manghas, Xylocarpus granatum, Xylocarpus moluccensis, Heritiera littoralis, Sapium indicum, Amoora cucullata, Intsia bijuga, Salicornia brachiata* etc. are presently seen only in Bhitarkanika National Park and exhibit very poor distrubution. The species like *Merope angulata, Sarcolobus carinatus, Sonneratia caseolaris and Acanthus volubilis*, which were abundant in the past, are now represented by a few viable populations. The area of occurrence of species like *Cerbera manghas* and *Xylocarpus granatum* has shown considerable shrinkage in the recent times. The mangrove forests of Bhitarkanika National Park are under severe biotic and natural pressure. This is largely due to reclamation of the mangrove forests for paddy cultivation, prawn culture, establishment of port and factories, forest clearing for human settlement and over exploitation of economically important mangrove taxa to meet the ever increasing human needs. Mangroves are well known to prevent oceanic cyclones, soil erosion and sea surges. Due to the destruction of these forest eco-systems, the devastation by the severe super cyclone of 1999 along the entire Orissa coast was further enhanced many–fold in the absence of wild barriers. Thus, it is high time to conserve the existing mangrove forests and take up reforestation of the degraded mangrove areas on an urgent basis to maintain the ecological balance of the sensitive coastal zone of Orissa. Though it is late, still there is time to set priority for conservation and protection of the existing mangrove ecosystem, which have profound ecological and economic utility for the state.

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INFLUENCE OF EXCESS NUTRIENTS ON EUTROPHICATION BEHAVIOUR OF CHILIKA LAGOON

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ABSTRACT

The effects of water soluble wastes containing NO_2^-, NO_3^-, PO_4^{3-}, NH_4^+ and Na^+ on eutrophication behavior of Chilika Lagoon have been investigated by following standard procedures. From the evaluation parameters it was found that Nitrogen is introduced into the aquatic environment through the discharge of domestic sewage and organic industrial waste. The discharge of excessive quantities of nitrogenous compounds into rivers and lakes resulted excessive growth of algae and macrophytic plants. This phenomenon which is known as eutrophication, resulted algae death and were degraded by decay organisms, which used dissolved oxygen in the process. Thereby, the destabilization of aquaculture environment is established.

Keywords : Eutrophication, decay organisms, aquaculture

INTRODUCTION

Chilika is the largest lagoon along the East Coast of India, situated between Latitude $19^0$28' and $19^0$54' N and Longitudes $85^0$05' and $85^0$23' E.

The lagoon is a unique assembles of marine brackish and fresh water ecosystems with estuarine characters. This fragile ecosystem is a hot spot of biodiversity that shelters a number of endangered species. It is also an avian grandeur and the wintering grand for more than one million migratory birds. The highly productive lagoon eco-system with its rich fishery resources sustains the livelihood of more than 0.2 million fisher folk who live in and around the lagoon. Due to severe degraded condition around Chilika, the change in the ecological character surfaced. This resulted in the loss of productivity and loss of biodiversity. Increased turbidity, shrinkage of area due to choking of inlet rivers for shore sedimentation, decrease of salinity due to inflow of NO_3^- containing liquid, the depletion of fishery resources are been observed (Cloren JE, 2001, Jorgensen BB *et al*., 1996 and Bhasin SK *et al*., 2006) Present study was undertaken to ascertain the influence of NO_2^-, NO_3^-, PO_4^{3-}, NH_4^+ and Na^+ ions on the behavior of eutrophication, especially gain or loss of NO_3^- and PO_4^{3-} in Chilika water and reasoned out the gradual reduction of fish production (Goel and Trivedy, 2006 and RK Trivedy, 1997).

MATERIALS AND METHODS

The excess nutrients like NO_2^-, NO_3^-, PO_4^{3-}, NH_4^+ and Na^+ ions which are regarded as a measure of eutrophication (Nutrient Index) are studied qualitatively as well as quantitatively as per the scheme given below.

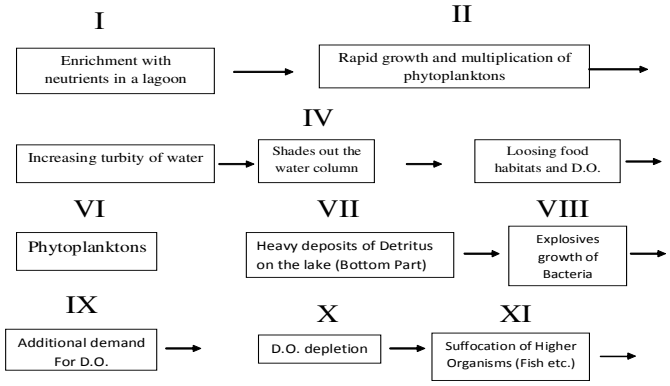

Fig.1: Flow sheet diagram of eutrophication studies

Considering the sensitive ecosystem of the lagoon, a closed monitoring was carried out to assess the impact of various management interventions of the lagoon. This was carried out from three fixed stations (S_1-Southern Zone, S_2^- Northern Zone and S_3-Central Zone) covering all the ecological zones and the data collected at 30days intervals from the month of January' 09-Nov'09. In the present study the neutrients like Nitrogen in the form of nitrites (NO_2^-), Nitrates (NO_3^-) and Ammonia (NH_4^+) and Phosphorus in the form of Orthophosphate (PO_4^{3-}) have been qualitatively estimated during the study period. These values have

been obtained by dividing the lagoon into three zones as indicated earlier. Dissolved Oxygen (DO) of the lake water was analysed by Winklers Method. To determine the BOD, samples were incubated at 20°C for 5 days and COD was carried out according to standard methods. The value of sodium (Na) was also analysed by following the standard procedure. All such data have been tabulated in Table 1 and Table 2.

RESULTS AND DISCUSSION

From the above data it can be construed where the value is < 3, especially on inorganic nutrients the region was found to be oligotrophic in nature. The high nutritional values in some regions indicate the nutrient rich fresh water from agriculture run off through major river systems. High Ammonia index

Table 1 : Nutrient index Values

Sl. No	Parameters	Stations (Zones)	Jan	Feb	Mar	Apl	May	June	July	Aug	Sept	Oct	Nov
1	Nitrite	S_1	4.0	3.99	4.0	3.98	3.99	4.0	3.99	3.98	3.98	4.0	4.0
		S_2	3.8	3.76	3.78	3.8	3.77	3.76	3.78	3.79	3.8	3.79	3.8
		S_3	3.2	3.19	3.19	3.18	3.2	3.18	3.19	3.19	3.2	3.18	3.18
2	Nitrite	S_1	2.6	2.59	2.58	2.6	2.58	2.59	2.6	2.6	2.58	2.8	2.6
		S_2	2.4	2.39	2.36	2.4	2.4	2.39	2.37	2.37	2.39	2.4	2.4
		S_3	2.45	2.43	2.43	2.45	2.45	2.44	2.43	2.44	2.44	2.45	2.44
3	Phosphate	S_1	2.8	2.8	2.79	2.79	2.78	2.78	2.79	2.8	2.8	2.78	2.8
		S_2	2.7	2.69	2.7	2.66	2.68	2.7	2.7	2.69	2.68	2.69	2.7
		S_3	2.5	2.48	2.5	2.49	2.48	2.5	2.5	2.48	2.48	2.49	2.48
4	Ammonium	S_1	4.6	4.6	4.5	4.59	4.56	4.6	4.6	4.59	4.58	4.58	4.59
		S_2	4.2	4.2	4.98	4.96	4.2	4.96	4.98	4.98	4.2	4.96	4.2
		S_3	3.2	3.19	3.19	3.2	3.19	3.2	3.18	3.1	3.18	3.18	3.2
5	Sodium	S_1	20.0	19.05	21.0	21.0	20.99	20.98	18.06	17.05	19.10	18.0	20.01
		S_2	20.1	19.00	21.00	21.00	20.99	21.00	18.96	17.00	19.09	18.08	20.01
		S_3	20.2	19.2	21.00	21.19	21.00	20.98	18.96	17.45	19.30	18.10	20.00

Table 2 : Oxygen Level parameters

Sl. No	Parameters	Stations (Zones)	Jan	Feb	Mar	Apl	May	June	July	Aug	Sept	Oct	Nov
1	DO	S_1	4.9	4.7	4.6	4.1	4.6	4.6	4.3	4.2	4.6	4.9	4.5
		S_2	4.8	4.6	4.8	4.4	4.5	4.6	4.3	4.2	4.8	4.8	4.6
		S_3	4.8	4.6	4.2	4.5	4.3	4.1	4.1	4.4	4.3	4.9	4.8
2	BOD	S_1	6.2	6.19	6.17	6.2	6.2	6.19	6.17	6.1	6.1	6.18	6.17
		S_2	6.15	6.17	6.19	6.2	6.2	6.2	6.16	6.1	6.19	6.18	6.18
		S_3	6.2	6.19	6.2	6.19	6.2	6.2	6.17	6.18	6.1	6.1	6.1
3	COD	S_1	81.2	81.19	81.19	81.25	81.27	81.2	81.19	81.17	81.1	81.0	81.0
		S_2	81.0	81.09	81.1	81.2	81.2	81.19	81.1	81.1	81.08	81.08	81.09
		S_3	81.2	81.18	81.19	81.2	81.2	81.18	81.1	81.1	81.09	81.08	81.00

value relates to organic decomposition of weeds or prawn farming activities. Moreover use of inorganic fertilizers enriched values to make the region oligotrophic, mesotrophic etc. A potentially significant factor affecting nutrient loads in this lagoon is the materials used in the watershed especially the spreading of inorganic fertilizers, animal/birds manure. The use of fertilizers with high phosphorus and nitrogen content can increase the nutrient loads in land run off, compared to that of unfertilized soils. Moreover it is also found that after the reopening of the entry points of Sipakuda (a canel) as well as Gabakunda (also another canel) to Chilika lagoon, the water flow to Chilika through Gabakunda canal is again flowing back through Sipakuda and therefore the salinity of Chilika lagoon is decreasing.

Moreover as the concentration of Dissolved Oxygen (DO) highly depends on the amount of pollutants, the oxygen level becomes low and makes it difficult for species to survive and many aquatic organisms especially fishes die due to the fall of Oxygen level below 5 ppm. Further, it is observed that under eutropic conditions dissolved oxygen greatly increases during the day but is greatly reduced after dark by the respiring algae and by micro-organisms that feed on the increasing mass of dead algae. The BOD values are found to be in high level which indicate the deterioration of water quality. The COD is linked with heavy effluents and domestic sewage. The high values depict deteriorating water quality.

The concentration of Sodium is found to be in a state of variation. Hence, it can be construed that salinity is gradually decreasing.

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BEHAVIOURAL RESPONSES TO ENVIRONMENTAL ENRICHMENT IN CAPTIVE TIGERS (*Panthera tigris*) AT NANDANKANAN ZOOLOGICAL PARK, ORISSA.

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ABSTRACT

Environmental enrichments have been used in a number of studies of captive animals to increase activity, behavioural diversity and environment utilization and reduce stereotypic behaviours. A sequence of baseline behavioural observation of tigers and observation with three different enrichment materials (card board box, urine and de-skinned chicken) were taken at Nandankanan Zoological Park. Behavior without any enrichment was compared with that of during different environmental enrichment. The results indicate that introduction of urine and de-skinned chicken hanged from the tree can be used to increase explorative behaviours and decrease stereotypic behaviour of tigers in captivity, supporting the hypothesis. Environmental enrichment, availability of shade, the presence of water body, cage size, vegetation, substrate type, and the presence of conspecifics had statistically significant effects on reducing stereotypic and promoting exploratory behaviours of tigers in captivity.

Key words: Environmental enrichment, tigers, Nandankanan, stereotypic behaviour

INTRODUCTION

Wild animals are maintained in Zoological Parks for the purposes of education, conservation, research, and recreation (Mench and Kreger, 1996). Tiger (*Panthera tigris tigris*, Linn.), the National animal of India is the centre of attraction in zoos, sanctuaries and National Parks (Palita, 1993). Successful captive propagation of tiger requires natural behavioural pattern. Eisenberg (1981) described the normal behaviour as "the exhibition of a phenotypic trait within the environmental context for which primary selective forces have shaped it, the outcome of which being maximal, inclusive fitness". The ability of a species to respond to captive conditions with behaviour from its normal repertoire depends on the degree to which the particular captive condition resembles its natural environment (Carlstead and Shepherdson, 1994). Sensory input from natural environments promotes the display of normal behaviours, whereas lower level of sensory input hinders the normal behavioural pattern. But, animals in captivity are subjected to environments that may differ vastly from the natural environment for which they have evolved, causing a risk of reduced welfare (Carlstead, 1996). The lower sensory inputs inside the enclosures induce stereotypic behaviour which is defined as behavioural patterns that are repetitive, relatively invariant in form and apparently functionless (Mason and Latham, 2004).

Environmental enrichment is any modification in the environment of the captive animals that seeks to enhance its physical and psychological well-being (Baumans 2000; Young, 2003). As the term implies, enrichment involves the identification and addition to the zoo environment a specific stimulus that the occupant wants or needs but which was not previously present (Neptune and Walz, 2005). Enrichment studies not only contribute to animal well-being, but promote reproduction by reducing stress and improving behavioural competence (Carlstead and Shepherdson, 1994). The objective of this study is to examine the impact of enrichment practices on the behavioural activity pattern of tigers with respect to enclosure size, sex and phenotype.

MATERIALS AND METHODS

Nandankanan is located between 20^0 23' 08" N to 20^0 24' 10" N latitude and 85^0 48' 09" E to 85^0 48' 13" E longitude spreading over an area of 362 ha (Fig.-1).

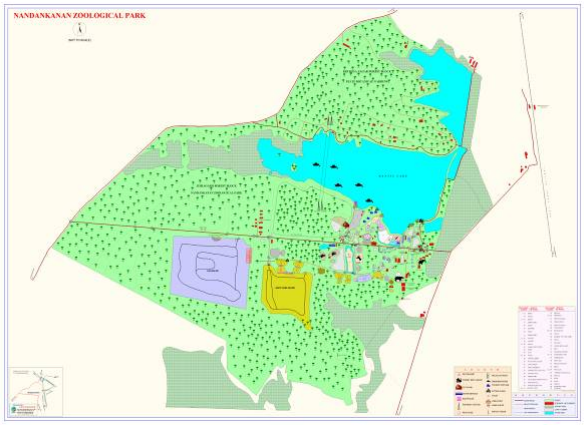

Fig.1 : Map of Nandankanan Wildlife Sanctuary

It's undulating topography with natural moist deciduous forest, water bodies and enchanting landscape provide zoo inhabitants an appropriate ambience to live in harmony with the nature.

For the above study, three normal coloured (N) and three white coloured (W) tigers were taken into account. Each category has an adult male, an adult female and a cub (Table.1).

Table 1 : Background information on study animals.

Date of birth.	Phenotype of tiger	Age (as on date..)	Name of the tiger	Sire	Dam
26.02.1996	NM	16	NISHAN	SANGRAM	JANHABI
19.12.1995	NF	14	SUSAMA	DEBASHIS	JAMUNA
28.12.1999	WF	10	KUSUM	RAMA	SHRIYA
28.12.1999	WM	10	KISHAN	RAMA	SHRIYA
20.10 2008	WF	0.7	KHUSI	NISHAN	KUSUM
20.10.2008	NF	0.7	PAYAL	NISHAN	KUSUM

Table 2 : Evaluation of enclosure variability of animal studied at NKZP.

Tiger	Encl. No.	Size	Length (in m)	Breadth (in m)	Substrate	Pool	Vegetation Coverage
KHUSI	31D	Medium	16.1	12.7	Natural	Present	Medium
PAYAL	31D	Medium	16.1	12.7	Natural	Present	Medium
KUSUM	31D	Medium	16.1	12.7	Natural	Present	Medium
SUSAMA	33D	Medium	16.5	13.5	Natural	Present	Medium
KISHAN	28	Large	56	50	Natural	Present	High
NISHAN	31B	Large	31	30.5	Natural	Present	High

The study was carried out for three months time period from June to August 2009. Cardboard box for exploration enrichment, urine for olfactory enrichment and chicken for nutritional enrichment were studied with respect to their behavioural pattern. Data were recorded using a data sheet and a stop watch. Thirty five behaviours (Table.3) were recorded, which were classified in to major behavioural category (Table - 3) like explorative (EX), resting (RE), stereotypic (ST) and inside feeding cubicle (FC). Observational data were collected for 4 hours (8:00 AM to 12:00 noon) following instantaneous scan sampling of 10 seconds at 10 minutes interval (Bettinger, et al., 1994 and Lyons, et al., 1997). Data was collected for each animal for 12 observational days (3 days without enrichment and 3 days each for different enrichment) to record its activity pattern. Behavioural data were compared with that of normal behaviour and induced behaviour by different enrichment (cardboard box, urine tiger of opposite sex and de-skinned chicken) applications.

Table 3 : Ethogram of captive tigers at Nandankanan Zoological Park.

Behavioural Pattern	Details of behavioural recorded
Explore (EX)	Aggressive, alert/alarmed, clawing, climbing tree, digging, drinking, nibbling grass, eating given food, grooming, gasping, jumping, licking, laying in pool, laying in moat, playing, roll over, running, scratching body against object, standing straight on wall, standing on ground, standing straight on tree, scent marking, smelling, stalking, swimming, vocalization, walking, yawning
Resting (RE)	Laying on back, resting awake, sitting, sleeping
Stereotypic (ST)	Pacing
Others	Within Feeding Cubicle (FC)

Session score for each behavioural category for each individual was calculated by dividing the observational points of each major behavioural category by the total number of observation points (24 nos.). Session scores for all the animals were calculated by following the above formula. Then the average of session scores for each of the behaviour was calculated. The same principle was followed for calculating the average session score with different enrichment.

RESULTS AND DISCUSSION

The results of this study showed that the presentation of environmental enrichment significantly increase explorative behaviour and reduce stereotypic behaviour (Fig.2).

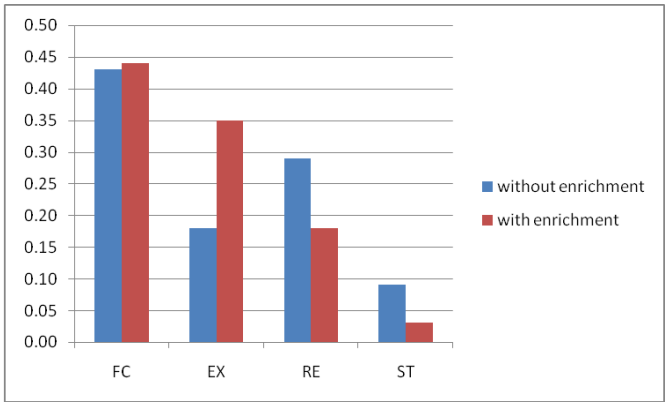

Fig. 2 : Behaviour of tigers with and without enrichment.

Tiger cubs had not shown any stereotypic activity. They had shown a significant increase in the explorative activity during the enrichment day, especially with respect to the de-skinned chicken hanged from the tree as enrichment and card board boxes as enrichment. A comparison between the normal coloured tigers and white coloured tigers revel that normal coloured tigers exhibit more explorative behaviour, but more prone to exhibit stereotypic behaviour, than its counter part (Fig.6). Our study found that, male and female tigers exhibit apparently similar type of behaviour with an increased level of exploration during the enrichment days (Fig. 3, 4 and 5).

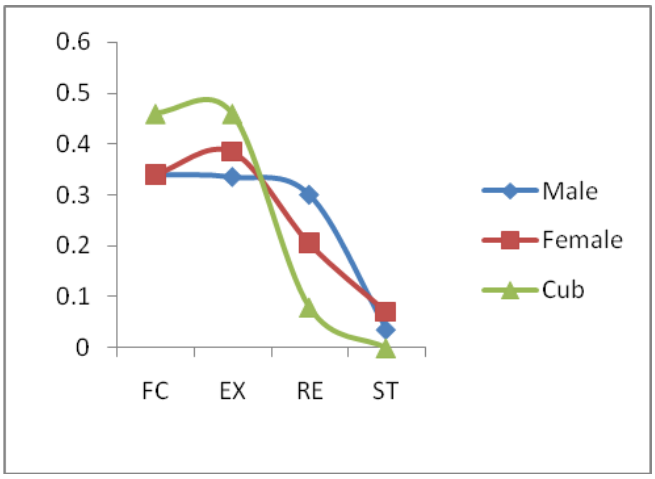

Fig.3 : Behaviour of tigers during box enrichment.

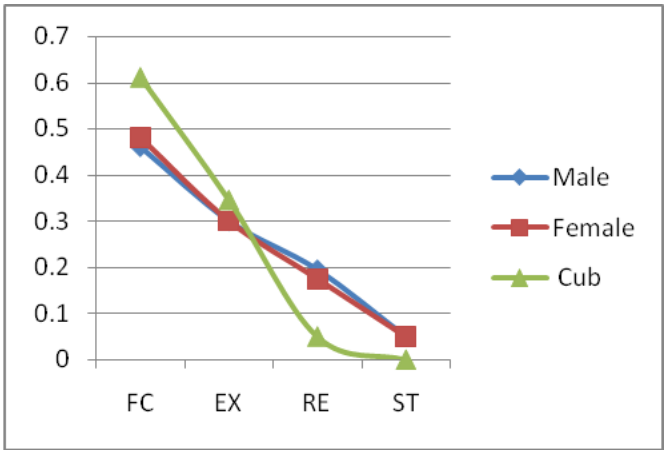

Fig.4 : Behaviour of tiger during urine enrichment.

The result shows that the tigers housed in large enclosures with high vegetation coverage exhibited less stereotypic pacing than that housed in medium sized enclosure with medium vegetation coverage (Fig.7). Captive tigers exhibit habitat preference within the enclosures to exhibit specific behavioral patterns. They used the edges of the enclosure for stereotypic

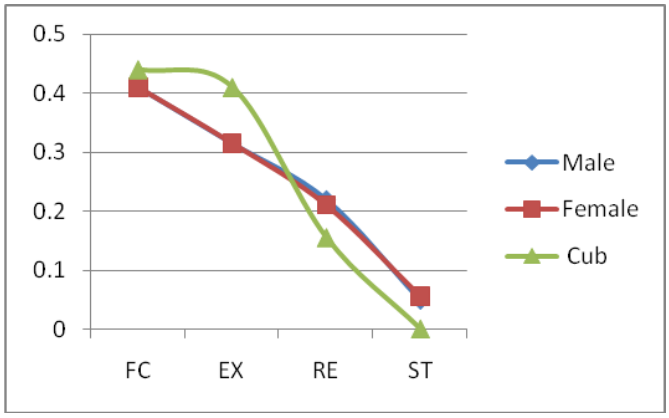

Fig.5 : Behaviour of tiger during chiken enrichment

pacing and the rear of the enclosure for resting. Shade and pool/moat in the enclosure also influence the activity pattern.

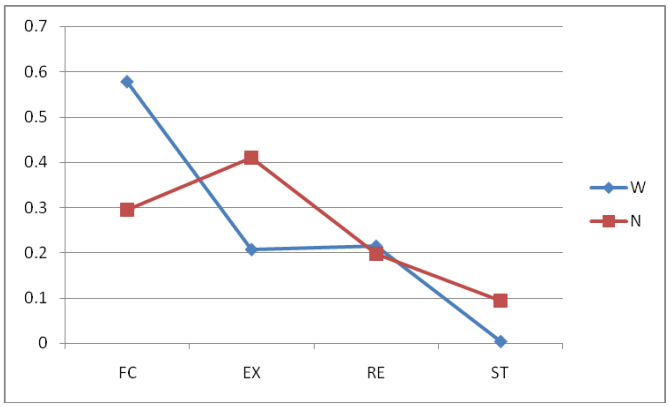

Fig.6 : Comparision of stereotypic behaviour behaviour of tigers with reference to their phenotype.

The normal presence of the keeper does not affect the activity of tigers but animal keeper with food trolley significantly induces increase in the restlessness and aggression among tigers which continues until the food was given.

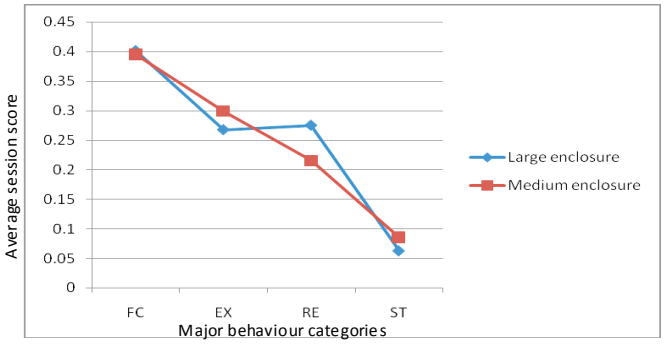

Fig.7 : Comparision of stereotypic behaviour of tigers with reference to size and complexity of enclosure.

Captive tigers of Nandankanan Zoological Park live on substituted food of fresh buffalo meat provided by park authority. Even though large open air enclosures are provided, it has no prey population to attack and kill unlike that natural forest ecosystem. In the study, it was found that feeding enrichment i.e., de-skinned chicken hanged from trees can increase exploratory behaviour and time spent in feeding. The study was in favour of Shepherdson and his co-workers (1993). They described the method and timing of food delivery, such as randomized feeding schedules and the unpredictability of food delivery help encouraging food intake duration and reduce the frequency of stereotypic behaviours. Feeding, explorative and interacting with foreign objects have been known to reduce stereotypic behavioural patterns (Carlstead, 1998). Artificial objects like card board box can be used to encourage exploratory behaviours. Tiger may rip a cardboard box assuming it as its prey and pursue to capture that which may be beneficial for locomotory activity, scanning and mental stimulation (Lindburg, 1988), which was supported by the above study. Carnivores have complex social systems through communication and scent marking by way of faeces, urine, and glandular secretions which furnish conspecifics with information regarding animal territories and movement. The function of social odours is often used for identification of individuals and reproduction (Ewer, 1973). The study found that presenting urine as olfactory enrichment can stimulate increased activity level in captive tigers. Olfactory enrichment has been used to increase the scanning, smelling, locomotive and social behaviours than the normal day observations. A comparison of behaviours basing on the enclosure variability i.e., large enclosures with high vegetation coverage and medium sized enclosure with medium vegetation coverage (Table.2) reveals the exhibition of more stereotypic behaviour in smaller enclosures with less complexity (Fig.7). In the above study, the animals (mother and its 2 cubs) that were housed together in Enclosure 31-D, appeared to enjoy one another's presence and did not exhibit any pacing behaviour. In the above study, male and female tigers show apparently similar type of activity pattern with increased in explorative behaviour in response to chicken and urine as enrichment (Fig. 4 and 5); with a little deviation during box enrichment days (Fig.3). Animal keeper's presence did not significantly affect tiger behaviour, but it was observed that the animals became vigilant when a keeper was nearby. The above study showed a marked difference in behavioural pattern between the two colored counterparts (Fig.6).

A major consequence of zoo exhibits is the reduction of space and complexity compared with the animals' natural habitat. This reduction in complexity includes both the physical environment, which is relatively unchanging and spatially limited in captivity, and the complexity of the behavioural repertoire exhibited (Mallapur *et al.* 2002). The natural environment provides a wide range of stimulation to the brain and so the captive environment should provide a similar range of stimulation. Smaller enclosures are usually devoid of visibility barriers, shorter flight and visitor distances. So tigers prefer to use the rear of the enclosure for resting to maintain maximum visitor distance and the edges of enclosure for pacing. Large enclosures have more visibility barriers, structurally enriched features, more natural and complex environment that stimulate to exhibit species-specific behavioural patterns in tigers. Tigers appear to enjoy the water, and swimming provides an alternate form of exercise and enrichment (Bush *et al.,* 2002). Tigers prefer shaded area for their resting. Data of environmental parameters were also recorded but it has no significant difference observed because of same season. Similar research conducted in other seasons might reveal any seasonal differences in showing stereotypy.

Each enrichment plan should be based upon the animals' biological, social and cognitive needs; contingent upon encouraging species-appropriate behaviours and mediated by the animals' individual history. The effect of environmental enrichment on animal welfare can be assessed using a variety of different measures. Often behaviour in an enriched cage is compared with baseline measures of behaviour in the home cage. But it is important to assess whether changes in behaviour are short or long-term effects (Van de Weerd and Baumans 1995).The likely impact of enrichment on experimental results depends on the type of enrichment used, the parameter studied and strain of the animal (Van de Weerd *et al.*, 2002). The overall goal of enrichment is typically to encourage species-appropriate behaviours, give animals some choices within their environment or to reduce the occurrence of stereotypic behaviours. Providing any initiative to animals has some risk associated with it. So safety is always a concern when developing enrichment ideas.

CONCLUSION

Environmental enrichments provide a more complex environment that stimulates species specific behaviours and reduce stereotypic behaviour in captive tigers. Behaviours of captive tigers are significantly influenced by enclosure features. Suboptimal sensory input stimulates stereotypic behaviour in captive tigers. Environmental enrichment can be used to reduce stereotypic pacing and stimulate species appropriate behaviour in captive tigers (*Panthera tigris tigris*). These results suggest that captive tigers should be housed in large enclosures containing natural substrate and vegetation, water pools, ample shade, a variety of resting locations and with a variety of non invasive enrichment items.

ACKNOWLEDGEMENT

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GHARIAL (*Gavialis gangeticus)* IN THE MAHANADI RIVER SYSTEM OF ORISSA, INDIA : ON THE BRINK OF EXTINCTION.

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ABSTRACT

Among seven crocodiles of the world, gharial (*Gavialis gangeticus*) is the most threatened one and so is the state in the whole country as well. Earlier, many rivers in Orissa were inhabited by gharial, but by mid 70s they got restricted to Mahanadi river only. The species was literally brought back from extinction by restocking programs initiated in the country in the year 1975. In spite of initial success in a desperate attempt by the state to save the species through captive breeding and subsequent release in the wild, their number has dwindled again. Realising the grave situation, we thought to extend our conservation efforts by surveying and monitoring for a period of two consecutive winter seasons in the entire Mahanadi river in Orissa and to our disappointment found only a male and a female existing in the system.

Keywords : Gharil, Mahanadi river, Satkosia gorge, Tikarpada, conservation

INTRODUCTION

Gharial (*Gavialis gangeticus)*, the 65 million years old crocodilian, is one of the largest riverine crocodiles existing in the world. The species once inhabited Bangladesh, Nepal, Pakistan, Burma and India is now breathing its last chance and has already been extinct from most of the countries. The species is listed as endangered. The native range of gharials extended throughout the Gangetic plain, on the west up to the Indus river of Pakistan in the north and north-east up to Nepal and Bhutan, in the east to Myanmar and in the south up to Orissa in India.The Gharial *Gavialis gangeticus* (Gmelin, 1789) is endemic to the Indian sub-continents occurring in the Indus, Ganges, Brahmaputra and Mahanadi river systems (Smith, 1939; Singh, 1978; Groombridge, 1987; Whitaker, 1987; Hussian, 1999).

The conservation of gharials was initiated in India in the year 1975 by the establishment of Gharial Research and Conservation Unit (GRACU) which was first of its kind at Tikarpara under the supervision of Dr. H. R. Bustard along with other scientists to augment the conservation measures through captive breeding and later releasing them into the river (Fig. 1 and 2). In India, over 4000 juveniles were released by this program at 12 sites, mainly in Ganges drainage (Chambal, Ramganga, Girwa and Sarada) and Mahanadi river. By 1994, the wild population in India was estimated at around 1500 of which about 1000 were found in Chambal river alone (Rao and Singh, 1994).

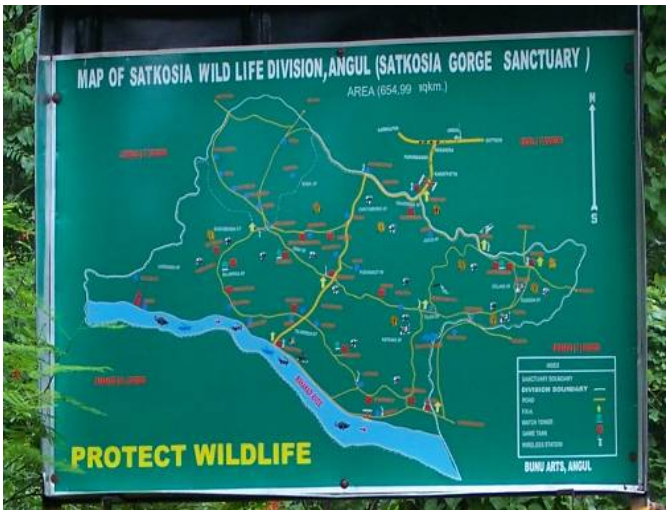

Fig. 1 : Map of the designated Tikarpara sanctuary

Fig. 2 : The place where the initial project started at Tikarpara

Among all the states of India, Orissa has the distinction of having all three species of crocodiles viz., Gharial (*Gavialis gangeticus*), marsh crocodile popularly known as Magur (*Crocodylus palustris*) and salt water crocodile (*Crocodylus porosus*). Gharial once inhabited all the major river systems of Orissa, namely, Mahanadi, Brahmani and Baitarani, besides some tributaries of Godavari river system. However, prior to 1907's only little thantia and fish eating gharials were reported in large rivers of Mahanadi, Brahmani while large size crocodiles were frequently reported in the rivers near Cuttack (Senapati and Tripathy, 1972). O'malley (1932) cited that, in Sambalpur the crocodile and gharials were not common while Senapati and Mahanti (1971) cited that crocodiles and alligators are common in Hirakud lake. On the otherhand, in river Devi, a branch of Mahanadi, gharial and muggers are commonly observed (Senapati and Kuanr, 1977). Perhaps gharial was mistakenly called as alligator. Behuria (1996) cited the increase in number of crocodiles and alligators, turtles, terrapins, in the large rivulets, nallahas, and creeks of major river system. But, by mid 70s they were all restricted to Mahanadi only. At one time there were only 5 gharials left in the Mahanadi, 2 males and 3 females and 3 sub-adults were in Nadankanan along with four juveniles during the start of the project. Since then, 700 numbers of gharials have been released in Satkosia gorge sanctuary in the river Mahanadi in between Boudh and Katarang including 381 from captive rearing at Nadankanan which virtually brought back the animal from the verge of extinction by 1981. In the wild, the survival rate of young hatchings is not more than one percent (Singh, 1978). Uncontrolled exploitation of the species and rapid habitat loss in Asia dropped down its population to 150 – 200 animals during the early 1970s (Singh, 1978). Besides the releases of 164 gharials in the sanctuary since 1981 to till date (Sharma et al., 1999) the survival rate of gharial in the Sanctuary is very low. However, Sharma et al. (1999) indicates that an increment rate of adult female in the sanctuary was 18.4%. The increase sightings of this species spoke the success story of the crocodile conservation project. Subsequent natural breeding at some of the restocked locations was also observed. But astonishingly, the population of gharial again drastically reduced. This is evident from their rare sighting and no nesting in the sanctuary area. During December 1987 to January 1988 assessment, only 25 gharials were reported in the total length of the river from Hirakud reservoir to tidal limit (Mishra *et al.*, 1996).

Later on certain significant conservation breeding programmes were taken up with an intention to manage gharial as the "flagship species" in the Mahanadi. Regulation of fishing in Mahanadi was done by issuing permits to authorized fisherman only. Fishing camps on the river banks were banned and the fisherman were suggested with alternative measures for replacing the open-cast fishing techniques with inland fish farming to make them independent of river-fishing. In spite of all these efforts initiated to conserve gharial, the status of gharial is still precarious. After a long time, crocodile census was carried out to find only one gharial within the designated sanctuary area. Unfortunately, no systematic monitoring of the releases was carried out and their numbers declined leaving the reasons unnoticed, thereby again pushing these animals back to the dangerous level in the river system, though individuals have been found straying out to different tributaries, canals, lagoon and beaches. Looking at the precarious condition of gharial, our above project was initiated to study the entire Mahanadi river system

Fig. 3 : Courtship of a male and female gharial as reported near the gorge area

Fig. 4 : The male gharial with its snout out near the satakosia gorge

to assess the exact status of the species, causes of its depletion in the wild and suggest remedial measures.

MATERIALS AND METHODS

The survey was conducted in the entire length and breadth of Mahanadi river system, starting from the Hirakud reservoir in Sambalpur district of Orissa (20º 44'N & 82 º 39'E) till to its mouth in the Bay of Bengal near false point (20 º 18' N & 86 º 43' E). The study was conducted over a period of one and a half-year involving two winter surveys in the biennium 2005-06. The map of the area of Mahanadi river system were studied in detail by procuring the 1:1,000, 000 topo-sheet and then the sites were divided into strategic segments as to which part shall be ideally covered by water route and the rest to be covered by land. The entire water route system was divided into three groups such as Satkosia gorge (starting midpoint), Upstream of the gorge (toward Sambalpur) and Down stream of the gorge (downward up to Munduli)

Satkosia gorge (Tikarpara)

The entire gorge was covered by water route. The northern bank of the river covering Angul, Athamalik, and Atthagarh was first surveyed followed by southern bank of the side Boudh and Nayagarh district.

Upstream (Binkei : Dist. Boudh to Huma : Dist. Atthagarh)

Satkosia gorge was chosen as the starting point for the upstream survey and the team moved upwards to reach Hirakud reservoir (Dist- Sambalpur).

Downstream (Barmul : Dist- Nayagarh to Naraj: Dist - Cuttack)

For the downstream survey the team moved down the river from Satkosia gorge to reach Munduli bridge near Naraj. Local boats were hired to carry out the investigation on both the sides of the river bank and the survey was conducted from the morning 8 am to evening 5 pm. Binoculars were used to sight gharials in water as well as on the sand banks taking advantage of their sun basking, imprints on the mud etc. During evening time, meetings/interaction session with the local people were arranged and all the information available with them regarding gharials sighting, nesting, last seen, availability of suitable habitat, threats etc. were discussed and documented according to a prepared questionnaire. During survey, it was kept in mind to cover almost all the villages on either side of the bank for the collection of data.

RESULTS AND DISCUSSION

The river near Tikarpara (District: Angul ; 20º35' N & 84º47' E), forms a picturesque Satkosia gorge, spreading over 4 districts such as Cuttack and Angul in north and Nayagarh and Boudh in south covering a length of approximately 24 Kms. The water is usually clear during summer and turns muddy or murky during rainy season throughout the length of the river system. This is because the river covers a large area, draining an extensive flood plain and river basin, carrying with it huge volume of water along with silt and sediments to the down stream, thereby raising the water level to an incredibly high, which goes more than 100 feet near the gorge area. This immense water volume brings with it strong current which erodes both the side of the river edges, washing off the banks and bringing down many trees from forest on the banks.

During the winter survey of 2005, a pair of mature and full grown gharial was sighted near Binkei, a place nearly 5 to 7 Km from the gorge area (Fig. 3). The water depth around the Binkei varied from 4 to 6 mts. Water was free flowing, clear and pH of the water varied between 7.2 - 7.4. The male and the female were approximately 4 mts and 3.5 mts long respectively. The couple was constantly seen moving around together from one bank to the other in the same area for 3-4 days and shared the same sandy bank.

The gharials were always reported to be in the middle sandbanks of Majhipara to Binkei (Fig. 4) where the conditions were very conducive for crocodiles to bask and nest without much human interference. They were never seen nor reported in the rocky riverbanks. The sand bank was located on the opposite bank of the Binkei temple. During the winter survey of 2006, the team succeeded in tracing the same pair of gharial, but unfortunately they were not seen moving around together.

But interestingly the mugger population is quite high in the Mahanadi river and seems to have better adapted in the system. They were frequently observed in between Majhipara to Baramul and on rare occasion it has been reported beyond Majhipara to Binkei and Baramul upto Naraj bridge. During the study, the team could sight muggers only in the gorge area where, the water depth was pretty high. The team never came across a single mugger, where water depth was low or shallow. During the investigation, typical mugger trailing marks over the mud and sands were seen. On the contrary to mugger, we could hardly trace any trailing mark of gharials on either side of the mud or sand bank excepting a single direct sighting.

The mugger population was found in between 30-35 during the team's winter survey of 2005, while the number slightly varied in between 40-45 during the 2006 winter survey. During the survey, the team succeeded in tracing 6-7 nesting sites of mugger with good number of mugger hatchlings in the river bank of Binkei to Baramul. Apart from the hatchlings that have just moved into the water, we also found dead hatchling in the nesting sites of mugger near Majhipara. The reason for the death seems to be of malnutrition origin, predation and of parasitic infestation. Even though the team could not ascertain the exact cause of death.

Other aquatic fauna that were seen includes a wide range of fish population in the entire Mahanadi river system. Apart from the Indian Major Carps (*Labeo rohita, Catla catla, Cirhhinus mrigala*), the other kind of fishes that were encountered include *Labeo calbasu, Mystus mystus, Notopterus notopterus, Notopterus chitala, Labeo bata, Puntius sarana, Puntius ticto, Pangassius pangassius,* etc. Similarly, in the reservoir, *Notopterus chitala, Ctenopharingodon idella, Heteropneustes fossilis, Clarias batrachus,* etc are found more often. Along with fish, several varieties of freshwater prawns were also found in the river system. Besides fish and prawns, some freshwater turtles were frequently encountered in the entire river system with more abundance in between Athamalik to Naraj. However, their intensity was high in the gorge area where they are usually observed in the rocky surfaces for basking and also near lower stream. Suitable nesting sites are found near Munduli bridge. During the survey in the lower stream we could able to record a good number of turtle's population belonging roofed turtle (*Kachuga* sp.) and narrow headed softshell turtles (*Chitra indica*).

CONCLUSION

The present investigation was conducted to know the status of gharial in the Mahanadi river system for a period of one and half years involving two winter survey in the biennium 2005-06. During the study, approximately 40-45 numbers of full grown muggers with 6-7 nesting sites and hundreds of mugger hatchlings were recorded in between Binkei to Barmul. On the contrary, only one pair of full grown gharial was sighted in the sand banks near Binkei. The male and the female were approximately 4 mts and 3.5mts long respectively. Recently we have also confirmed the presence of the gharial pair with increase in gharial hatchlings as per the annual survey of government of Orissa. As of now, the census stands at three gharials in the system. Looking at the grave situation, a serious conservation efforts and measures should be put in place in order to save this animal from extinction. Moreover, the local native people should be involved to make the effort fruitful by creating awareness about the species and their requirement for the ecosystem.

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IMPACT OF HYDROLOGICAL INTERVENTION ON THE FISHERIES OF CHILIKA LAKE

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ABSTRACT

Fisheries output of Chilika lake declined sharply from 8926 t (1986-87) to 1745.75 t (1999-00) due to continued natural changes and incessant anthropogenic pressure. Chilika Development Authority (CDA) carried out hydrological intervention in Chilika lake during 2000 by opening a new mouth. Average fisheries out put (total catch of fish, prawn and crab only) for four years (2000-01 to 2003-04) after intervention, registered a spectacular increase of more than six folds, as compared to the average catch for four years (1996-97 to 1999-2000) before intervention. Total landings of fish (10286.34 t), prawn (3611.37 t) and crab (155.51 t) during 2003-04 were recorded as all time high. Four years average catch of fish, prawn and crab during post-hydrological intervention registered more than 5, 13 and 12 fold increase respectively, as compared to the average catches before intervention. Analysis of commercial catches and fisheries monitoring at the fishing grounds in four ecological sectors of the lake indicated positive impact of the hydrological intervention on various aspects of fisheries enhancement.

Keywords : Fisheries of Chilika lake, hydrological intervention, commercial catches

INTRODUCTION

Chilika lake with rich fisheries resources and biodiversity, is the largest coastal wetland ecosystem in the Indian sub-continent. The economic valuation of Chilika ecosystem has distinctly established the importance of fisheries resources, which accounts for more than 71% of the total value in monetary term (Ritesh Kumar, 2003). Nearly 0.2 million people depend on the lake fishery for food and livelihood security. Fisheries of the lake has been supporting the state economy to a considerable extent. The shrimp exports from Chilika lake contributes more than 6% to the state's seafood export by value. However, fisheries of the lake suffered severe set-back during the critical eco-degradation phase in last few decades due to continued natural changes and incessant anthropogenic pressure. As a result, fisheries output decreased from the highest ever record of 8926 t (1986-87) to the lowest of 1274 t (1995-96). Keeping this in view, Chilika Development Authority (CDA) carried out hydrological intervention in the year 2000, which was intended to restore the lake and to enhance its fisheries.

Based on the findings from the two dimensional numerical model studies by the CWPRS, Pune, an artificial mouth (new mouth) was opened on 23rd September, 2000 by CDA, which reduced the length of the outer (inlet) channel by 18 km. The location of the new mouth with effective width of 240 m and depth of 5.5 m was just 11 km from the lake proper. A lead channel (3.2 km long, 100 m width and 3 m depth) was dredged at Maggarmukh, the gateway between the lake proper and the outer channel. The lead channel was further extended with same width and depth up to river mouth (outfall) in the northern sector (25.7 km). Another 2.8 km long dredged channel with same specification as lead channel was extended westward from Maggarmukh. The Palur canal (16.5 km long including 2.5km extension in to the lake, 22 m wide and 2 m depth at low tide) was renovated and became functional from August 2004 with free connection between the Palur Bay of Chilika lake (southern sector) and the Rushikulya river mouth. The details of hydrological intervention in Chilika lake have been reported by Pattnaik (2001).

MATERIALS AND METHODS

With a view to studying the changes in fisheries of Chilika lake, monitoring was carried out as a collaborative effort, between CDA and the Department of Fisheries (DoF), Govt. of Orissa,

since September, 2000 as a regular programme. Systematic sampling method with landing centre approach (Biradar, 1988 and Gupta *et al*., 1991) was adopted to collect and estimate the fisheries production in Chilika lake. All the established fish landing centers representing all the 4 ecological sectors, 14 capture shrimp collection centers and 2 daily fish markets in the island villages were sampled for 6 days a month (2 consecutive days in every 10 days). Fortnightly sampling of catches from different fishing gears at the fishing grounds in four sectors were carried out. Collection of fish, prawn and crab specimen for faunal inventorisation was done both at the landing centers and fishing grounds. At fisheries monitoring/ sampling stations, round mouth (1m dia) monofilament shooting net (0.6mm mesh) was operated in the outer channel during spring and neap tides and during day and night covering both full and new moon phases to estimate seed incursion. The mean water spread area (WSA) of the lake before and after the intervention were taken into account for computation of productivity [P = Annual yield (fisheries out put) in t / Mean WSA (km^2)].

In-situ measurement of water depth, temperature, transparency and salinity were conducted at 4 sampling stations representing 4 ecological sectors using graduated gauge, thermometer, secchi disc and ATAGO refractometer respectively. Number of fishing boats, active fishers population and number of fishing days in a year were used for computation of catch per unit effort (CPUE). Experiencing the problem of multi-species and multi-gear fishery in Chilika lake, the catch per unit effort (CPUE) was computed as catch per boat-day. As suggested by Jhingram and Natarajan (1969) prawn catches were separately monitored for judicious yield study. For fish transported to out-stations, data from booking counters of railway stations and packed fish assembling centers for transport by lorries were collected. Fish catch statistics prior to hydrological intervention, were collected by the DoF. For the purpose of evaluating the impact of hydrological intervention on the fisheries of Chilika lake, four years catch data before (1996-97 to 1999-00) and after (2000-01 to 2003-04) the intervention were used.

RESULTS AND DISCUSSION

Production trend before intervention

Commercial landings of fish, prawn and crab in Chilika lake during 1986-87 were recorded at 7283 t, 1589 t and 54 t respectively, which dropped to 1556.3 t, 180.4 t and 9.0 t respectively in 1999-2000 (Table 1). The total catch (fisheries output) continued to decline during the period, registering the lowest catch of 1274 t in 1995-96 and maintained almost the same level of yield with negligible fluctuations till opening of the new mouth. Fish and shellfish landings for four years (1996-97 to 1999-2000) ranged between 1352.2 t -1556.3 t (Table 2) and from 146.6 t -293.2 t (Table 3) respectively. Declining trend in fisheries output could be attributed to poor recruitment of fish and shellfish seed (Table 4) and continued eco-degradation process and rapid expansion of '*prawn gheries'* (typical pen aquaculture). The average landings of fish and shellfish components for the last four years before opening of the new mouth were 1489.1 t and 197.3 t respectively (Table 2 and 3). Mohanty *et. al.,* (2003) reported that the central sector registered the highest catch (45%) followed by northern sector (32%) before intervention. Southern and outer channel sectors contributed 14% and 9% respectively to the total catch from the lake. Analysis of commercial catch statistics before intervention indicated that the average fisheries output (1686.2 t), productivity (1.8 t km^{-2}), CPUE (1.1kg boat-day^{-1}) and the value of average landing of fish and shell fish (Rs. 49.9 million) were quite dismal.

Production trend after intervention

Table 2 and 3 show the annual landings of fish and shellfish during 2000-01 to 2003-04 and Table 5 shows average landings (relative catch composition) of fish and shellfish for the said period. During the first four years after opening of the new mouth, fish and shellfish landings ranged from 3592.9 t -10286.3 t (average 7918.6 t) and 1389.8 t -3766.9 t (average 2561.0 t) respectively. The post-intervention average landings (relative catch composition) of fish and shellfish registered 431.8%

Table 1 : Landings (in t) of fish, prawn and crab from Chilika lake during 1985-86 to 2003-04

Year	Fish	Prawn(A)	Crab(B)	Shell fishComponent(A+B)	AGR(Fish)%	AGR(Shell fish)%
1985-86	7446.0	1144.0	79.0	1223.0	-	-
1986-87	7283.0	1589.0	54.0	1643.0	-2.2	34.3
1987-88	6863.0	1241.0	39.0	1280.0	-5.8	-22.1
1988-89	5211.0	917.0	44.0	961.0	-24.0	-24.9
1989-90	5493.0	1177.0	36.0	1213.0	5.4	26.2
1990-91	3792.0	481.0	24.0	505.0	-31.0	-58.4
1991-92	3680.0	876.0	30.0	906.0	-2.9	79.4
1992-93	3207.0	951.0	15.0	966.0	-12.8	6.6
1993-94	2799.0	686.0	11.0	697.0	-12.7	-27.8
1994-95	1239.0	176.0	03.0	179.0	-55.7	-74.3
1995-96	1056.0	213.0	05.0	218.0	-14.8	21.8
1996-97	1352.0	281.2	12.0	293.2	28.0	34.5
1997-98	1492.0	149.5	10.4	159.9	10.3	-45.5
1998-99	1555.7	136.9	9.7	146.6	4.3	-87.8
1999-00	1556.3	180.4	9.0	189.4	0.0	29.2
2000-01	3592.9	1296.3	93.5	1389.8	130.9	633.7
2001-02	9530.0	2347.8	111.0	2458.8	165.2	76.9
2002-03	8265.2	2478.8	149.8	2628.6	-13.3	6.9
2003-04	10286.3	3611.4	155.5	3766.9	24.4	43.3

AGR: Annual Growth Rate

Table 2 : Fish catch scenario in Chilika lake before and after hydrological intervention

Fish group of commercial importance	1996-97	Before Interventions (quantity in t) 1997-98	1998-99	1999-00	Average
Mullets	130.9 (9.7)	152.3 (10.2)	152.8 (9.8)	168.9 (10.8)	151.2 (10.2)
Clupeoids	325.3 (24.1)	342.1 (22.9)	404.0 (25.9)	350.1 (22.5)	355.4 (23.9)
Perches	90.5 (6.7)	152.0 (10.2)	166.4 (10.7)	122.7 (7.9)	132.9 (8.9)
Threadfins	67.5 (5.0)	61.7 (4.1)	72.3 (4.6)	69.1 (4.4)	67.6 (4.5)
Sciaenids	79.8 (5.9)	108.0 (7.2)	110.9 (7.1)	107.9 (6.9)	101.6 (6.8)
Beloniformes	53.8 (3.9)	55.1 (3.7)	76.0 (4.9)	82.3 (5.3)	66.8 (4.5)
Catfishes	141.3 (10.4)	212.1 (14.2)	170.9 (11.0)	178.6 (11.5)	175.7 (11.8)
Tripod fishes	45.2 (3.3)	45.3 (3.0)	41.9 (2.7)	55.6 (3.6)	47.0 (3.1)
Cichlids	106.9 (7.9)	78.1 (5.2)	98.0 (6.3)	112.1 (7.2)	98.8 (6.6)
Murrels	53.9 (4.0)	51.6 (3.5)	47.7 (3.1)	68.6 (4.4)	55.5 (3.7)
Feather backs	76.4 (5.6)	86.7 (5.8)	80.6 (5.2)	103.5 (6.6)	86.8 (5.8)
Others	180.7 (13.4)	146.8 (9.8)	134.2 (8.6)	136.8 (8.8)	149.6 (10.0)
Total	1352.2	1492.0	1555.7	1556.3	
Fish group of commercial importance	**2000-01**	**After Interventions (quantity in t) 2001-02**	**2002-03**	**2003-04**	**Average**
Mullets	327.2 (9.1)	589.5 (6.2)	1004.5 (12.1)	1126.7 (10.9)	762.0 (9.6)
Clupeoids	893.9 (24.9)	2508.1 (26.3)	2702.5 (30.4)	2911.9 (28.3)	2254.1 (28.5)
Perches	168.5 (4.7)	429.6 (4.5)	295.5 (3.6)	939.3 (9.1)	458.2 (5.8)
Threadfins	72.4 (2.0)	415.2 (4.4)	472.1 (5.7)	386.6 (3.7)	336.6 (4.2)
Sciaenids	209.8 (5.8)	1037.6 (10.9)	893.9 (10.8)	823.4 (8.0)	741.2 (9.4)
Beloniformes	132.3 (3.7)	271.6 (2.8)	331.0 (4.0)	683.2 (6.6)	354.5 (4.5)
Catfishes	534.9 (14.9)	1766.3 (16.9)	1338.1 (15.8)	2176.2 (21.2)	1453.9 (18.4)
Tripod fishes	241.7 (6.7)	525.3 (5.5)	524.3 (6.3)	318.5 (3.1)	402.5 (5.1)
Cichlids	333.3 (9.3)	580.3 (6.1)	146.9 (1.8)	123.6 (1.2)	296.0 (3.7)
Murrels	156.6 (4.4)	339.1 (3.6)	79.9 (0.9)	173.8 (1.7)	187.4 (2.4)
Feather backs	197.3 (5.5)	630.9 (6.6)	153.7 (1.9)	198.3 (1.9)	295.1 (3.7)
Others	324.7 (9.0)	436.3 (4.6)	322.5 (3.9)	424.6 (4.1)	377.0 (4.8)
Total	3592.9	9530.0	8265.2	10286.3	

Figures in parenthesis refer to percentage composition

Table 3 : Shellfish catch scenario (in t) in Chilika lake before and after hydrological intervention

Shellfish of commercial importance	Before Hydrological Intervention				
	1996-97	1997-98	1998-99	1999-00	Average
Penaeus monodon	26.3 (9.0)	15.1 (9.5)	11.8 (8.1)	19.1 (10.1)	20.5 (10.4)
Fenneropenaeus indicus	36.1 (12.3)	19.2 (12.0)	18.2 (12.4)	25.8 (13.6)	27.9 (13.9)
Metapenaeus monoceros	104.9 (35.8)	56.5 (35.3)	58.1 (39.7)	61.1 (32.3)	67.7 (34.3)
Metapenaeus dobsoni	113.8 (38.8)	58.7 (36.7)	48.7 (33.2)	74.3 (39.2)	71.4 (36.2)
(*Macrobrachium* Sp.)	NA	NA	NA	NA	NA
Mud crabs (*Scylla* Sp.)	12.0 (4.1)	10.4 (6.5)	9.7 (6.6)	9.0 (4.8)	10.3 (5.2)
Total landing	293.2	159.9	146.6	189.4	
	After Hydrological Intervention				
	2000-01	**2001-02**	**2002-03**	**2003-04**	**Average**
Penaeus monodon	190.1 (13.7)	265.7 (10.8)	337.2 (12.8)	359.1(9.5)	288.0 (11.2)
Fenneropenaeus indicus	200.4 (14.4)	343.3 (13.9)	317.9 (12.1)	823.4 (21.8)	421.2 (16.4)
Metapenaeus monoceros	52.3 (3.8)	706.7 (28.7)	1286.8 (48.9)	1163.5 (30.9)	802.3 (31.3)
Metapenaeus dobsoni	628.7 (45.2)	865.5 (35.2)	399.1 (15.2)	1050.3 (27.9)	735.9 (28.7)
(*Macrobrachium* Sp.)	224.8 (16.2)	166.6 (6.8)	137.8 (5.2)	215.1 (5.7)	186.1 (7.3)
Mud crabs (*Scylla* Sp.)	93.5 (6.7)	111.1 (4.5)	149.8 (5.7)	155.5 (4.1)	127.5 (5.1)
Total landing	1389.8	2458.8	2628.6	3766.9	

NA – Not Available

and 1198.1% increase respectively (Table 2 and 3), as compared to the pre-intervention data. Prawn catch after the intervention indicated maximum increase of 13 fold in comparison to pre-intervention prawn landings. Although fish catch showed slight drop during 2003-04, prawn and crab catches continued to rise during 2000-01 to 2003-04 (Table 3), which indicated that the recruitment was more successful (Table 4) and the environmental conditions were more conducive particularly the increased salinity (Table 5) for prawn and crab fisheries after opening of the new mouth. During 2000-01 to 2003-04 the average fisheries output was 10479.7 t, catch per unit effort was 6.2 kg boat-day^{-1}, per capita income of active fishers was Rs 17665, valuation of landing was Rs 543.2 million and the productivity was 11.3 t km^{-2} which registered spectacular increase of more than 6, 5, 9, 10 and 6 folds respectively, as compared to the pre-intervention data. The 4 years average CPUE (6.2 kg boat-day^{-1}) after hydrological intervention was 5.6 times of the pre-intervention CPUE (Table 6), which showed positive impact on the lake fisheries.

Changes in the sectoral landings indicated increased contribution by central sector (47.1%) followed by northern sector (37.4%) and decreased landings in southern sector (5.9%). The outer channel sector registered 9.5% landing, which is almost same as pre-intervention landing. Such changing pattern in sectoral landings was due to enhancement in environmental condition in the northern and central sectors after spectacular decrease in weed area and increase in salinity regime (Table 5). These three sectors were observed to be the main impact area after hydrological intervention where fish and shellfish population increased resulting in higher catches. Decreased landing in the southern sector was attributable to poor recruitment through non-functional Palur canal, migration of fish stock from southern sector to central and northern sectors (improved habitats) and reduction in fishing efforts (as many fishers migrated to central sector to get better catch). Capturing of brood stock mullets and other fishes in the outer channel during their seaward breeding migration was reduced due to shorter distance of new mouth and stronger current in migration route. Effective recruitment of juveniles from the sea (Table 4) had probably the greater contribution to the increased population and catch during the post-intervention phase.

Table 4 : Incursion of fish and shellfish seed in the outer channel of Chilika lake during pre and post-hydrological intervention phases

Season	CPUE (average collection net-hour^{-1})			
	Prawn	Fish	Crab	Total
Summer (Mar.-June)	217 (126)	61 (23)	31 (13)	309 (162)
Monsoon (Jul.-Oct.)	131 (63)	98 (46)	13 (8)	242 (117)
Winter (Nov.-Feb.)	287 (106)	76 (31)	38 (21)	401 (158)
Average for the year	212 (98)	78 (33)	27 (14)	323 (149)

Figures within parenthesis represent pre-intervention (1999-00) data. Figures without parenthesis represent post-intervention (2003-04) data.

Table 5 : Average water quality parameters of Chilika lake during pre (1999-00) and post intervention (2000-01 to 2003-04) phases

Parameter	Northern sector	Central sector	Outer channel sector	Southern sector	Whole lake Average Value
Water depth (cm)					
Pre-intervention	1.2	1.5	2.9x	2.1	1.8
Post-intervention	1.1	1.8	1.8	2.1	1.8
Transparency (cm)					
Pre-intervention	54.8	82.9	69.2	101.6	77.0
Post-intervention	39.2	78.2	75.5	111.7	73.5
Temperature (°C)					
Pre-intervention	28.3	28.0	27.9	28.1	28.1
Post-intervention	28.7	28.2	28.8	28.8	28.8
Sub-surface salinity (%)					
Pre-intervention	3.7	8.8	13.6	9.5	8.5
Post-intervention	6.6	10.4	21.5	12.2	11.9

Table 6 : Total catch and CPUE during the pre and post-intervention phases

Year	Total catch (t)	Number of fishing boats	Number of fishing days	CPUE(kg boat-day^{-1})
1996-97	1645.4	5140	303	1.07
1997-98	1651.9	5245	310	1.02
1998-99	1702.4	5320	306	1.05
1999-00* 1	745.7	4500	301	1.3
2000-01	4982.7	4500	306	3.6
2001-02	11988.9	5000	345	6.9
2002-03	10893.8	5087	356	6.0
2003-04	14053.2	5059	336	8.3

*Several boats damaged in super cyclone

Composition of commercial catch

The commercial catch of fish and shellfish from Chilika lake can broadly be classified into twelve and six groups/species respectively (Table 2 and 3). Based on number of species, 89.9% and 95.2% of fish catch during pre and post intervention phases were contributed by 38 and 62 number of species respectively. Similarly, 86.4% and 90.1% of prawn catch during pre and post intervention phases were contributed by 7 species. Two mud crab species contributed to 100% crab landings during both pre and post intervention phases.

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Pre-intervention scenario

Before the intervention, the average catch compositions (Table 2 and 3) indicates that clupeoids and catfishes dominated the catch with 23.9% and 11.8% respectively, followed by mullets (10.2%), perches (8.9%), sciaenids (6.8%), cichlids (6.6%), threadfins (4.5%), beloniformes (4.5%) and tripod fishes (3.1%). Featherbacks (5.8%) and murrells (3.7%) were caught mostly from northern sector where freshwater condition and weed area dominated throughout the year. Relative abundance of clupeids increased after hydrological intervention when the two antagonistic hydrological processes brought back the conducive estuarine character increasing the salinity regime. Similar observations were also made by Baran (2000) in African estuaries. Although cichlid group was represented in the past by the single species *Etroplus suratensis* (Bloch), later during late nineties, *Oreochromis*

mossambicus (Peters) occurred in Chilika lake as an invasive (non-native) species, probably being escaped from some island village ponds in Parikud area (central sector). This species proliferated its population quickly to constitute 25-30% of cichlid population during 1999-2000 due to low salinity regime and wider weed areas before the hydrological intervention

The average shellfish catches (Table 2 and 3) during four years before intervention were dominated by soft brown shrimp (*Metapenaeus dobsoni*), which formed 36.19%, followed by *Metapenaeus monoceros* (34.3%). Average composition of *Fenneropenaeus indicus* and *Penaeus monodon* were13.9% and 10.4% respectively. Mud crabs (*Scylla* sp.) constituted 5.2% in the shellfish catches.

Post-intervention scenario

After the intervention, both the dominant groups i.e., clupeoides and catfishes indicated higher relative abundance by registering average of 28.47% and 18.35% respectively, in the annual landings (Table 2 and 3). Sciaenids and tripod fishes also registered increased percentage composition of 9.4% and 5.1% respectively as compared to the pre-intervention data. Threadfins and beloniformes almost maintained their position with regard to relative abundance. In general, composition of cichlids, murrells, featherback and miscellaneous groups decreased during the post-intervention period most likely due to increased salinity regime (39.4% increase in mean salinity for the lake as compared to pre-intervention data) and decreased weed area. Mullet fishery did not improve, as compared to pre-mouth composition (Table 2 and 3), which was attributable to loss of mullet nursery grounds (traditional 'Janos' and 'Dians' fishery areas), which were utilized for illegal '*prawn gheries'* (pen culture). This human-induced activity resulted in habitat loss for mullet fishery in Chilika lake (Mohanty *et al.,* 2004).

In the shellfish component (Table 2 and 3), *Metapenaeus monoceros* was found to be the most dominant shrimp with average composition of 31.3%, followed by *Metapenaeus dobsoni* (28.7%). The relative abundance of *Penaeus monodon* (11.2%) and *Fenneropenaeus indicus* (16.4%) increased during post-hydrological intervention phase, as compared to the pre-intervention data. Maximum densities of mud crabs (*Scylla* Sp.) in the outer channel and lower part of central sector occurred during post–intervention period due to shorter recruitment route and prevalence of higher salinities for longer period, which agreed with the observation made by Lord and Associates (1998) in Dawesville channel of PHES in Australia. Mud crab catch in Chilika Lake after hydrological intervention was observed to be maximum (64.9%) in the outer channel, followed by central sector (32.5%). Northern sector contributed 2.6% to the total crab landing, whereas no crab catch was recorded in the southern sector. The situation is likely to improve as the existing Palur canal has already been renovated and may facilitate incursion of crab seed. Average landing of mud crabs after opening of the new mouth contributed 5% to the total average landing of shellfish.

Biodiversity Status

RamaRao (1995), Reddy (1995) and MayaDeb (1995) documented 217 fish species, 24 prawn and shrimp and 28 crab species respectively from Chilika lake. Bhatta *et al.,* (2001) recorded 8 fish species before opening of the new mouth, thus, totaling to the pre-mouth record of 225 fish species (149 genera 72 families and 16 orders), 24 prawn and shrimp species (13 genera, 9 families and 2 sub-orders) and 28 crab species (22 genera, 9 families and single suborder). The inventorisation survey for faunal diversity of fish and shell fish initiated by CDA after opening of the new mouth documented new records of 43 fish species (6 freshwater and 37 marine species), 4 prawn and shrimp species, 2 spiny lobsters (*Panulirus ornatus* Fabr. and *Panulirus polyphagus* Herbst as first time record from Chilika lake) and 7 crab species. Thus, in total, 187 fish species, 18 prawns, 2 lobsters and 14 brachyuran crab species were collected during the inventorisation survey, showing an overall recovery of 66.4%.

Before hydrological intervention, six species, namely *Chanos chanos, Megalops cyprinoides, Elops machnata, Hilsa (Tenulosa) ilisha, Rhinomugil corsula and Acanthopagras berda* were almost absent in the commercial catches. However, all the six species re-appeared after opening of the new month and contributed to the commercial catches.

CONCLUSION

Hydrological intervention in Chilika lake demonstrated that a clear understanding of the coastal process and the river basin is essential for successful restoration of coastal wetlands with estuarine character. Fisheries monitoring before and after opening of the new mouth, showed spectacular fisheries enhancement, which was evident from more than six fold increase in fisheries output. Improvement in salinity regime (more than 39% increase) and effective incursion of shrimp post-larvae and mud crab juveniles through the new mouth resulted in thirteen and twelve fold increase in their yield respectively. Average productivity and catch per unit effort (CPUE) during post-intervention period increased by more than 6 and 5 folds respectively as compared to the pre-intervention data. Per capita income of active fishers increased ten folds indicating their livelihood enhancement. Dredging of recruitment routes and shorter distance of the new mouth from the lake proper facilitating lake-sea-lake migration of fish and shellfish were crucial factors for fisheries enhancement in Chilika lake. The increase in fisheries output after hydrological intervention may be of a transient in nature caused by sudden shake (trophic burst) in the ecosystem. The sustainability of the situation would largely depend on the effective functioning of the new mouth, outer channel and Palur canal.

Although spectacular enhancement in the fisheries of Chilika has been achieved after the hydrological intervention, its sustainability appears to be doubtful in the face of increasing destructive fishing in absence of any regulatory measures (legislation). Hence it is imperative that State Government should enforce rational fishing regulations along with making efforts to develop capacity building and create awareness among fishers and local communities.

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2.4. **Abstract**. Maximum 200 words convening the objectives, methodology and the most important results.

2.5. **Key words.** Maximum of 5-6 key words should be provided for subject indexing.

2.6. **Introduction**. It should be concise and include the scope of the work in relation to the state of art in the same field along with specific objectives.

2.7. **Materials and Methods.** A full technical description of the methods followed for the experiment(s) should be given, providing enough information. Detailed methodology should be given when the methods are new while for standard methods, only references may be cited.

2.8. **Results and Discussion.** In this section, only significant results of the experiment(s) should be reported. Along with the tables and figures, the discussion should deal with interpretation of results and relate the author's findings with the past work on the same subject. The conclusions drawn should be explicitly listed at the end of this section.

3. **References.** Refer the copy as sample for references. For ex.*:* Thankppan A, Das BK, Barman HK and Samal SK (2008) Genetic fingerprinting of *Aeromonas hydrophila* isolated from diseased fresh water fishes of eastern India; e-planet, 6(2): 01-06.Distinction for the same author and same year be done as e.g. 1969a, 1969b. Unpublished data, and personal communication are not acceptable as references but may be referred to parenthetically in the text.

4. **Tables.** Number the tables consecutively in Arabic numerals. Tables should have comprehensible legends. Conditions specific to a particular experiment should be stated. Zero results must be represented by 0 and not determined by n.d. The dash sign is ambiguous. For values <1, insert a zero before the decimal point.

5. **Illustrations.** All graphs, diagrams and half-tones should be referred to as Figure and should be numbered consecutively in Arabic numerals. The figures should either match with the column width (8.5 cm) or the printing area (17.8 x 22 cm). The legends should be brief and self-explanatory. All graphs, figures should be drawn by MS-EXCEL and submitted in editable format. Define in the footnote or legend any non-standard abbreviations or symbols used in a table or figure. Photographs, which must be kept to a minimum, should be good quality glossy prints.

6. **Reviews.** Review articles whether full or mini are invited. Very special review articles are also considered.