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ORIGINAL ARTICLE

Functionalization of GNP with sulphur containing molecules and its catalytic application

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ABSTRACT

In this work, we have synthesized GNP by adopting a green method. Aqueous extract of *Andrographis Paniculata* was used for reduction and stabilization of GNPs and funtionalization of GNPs were done with two biologically relevant molecules containing sulphur such as cysteine and 3-mercaptopropanoic acid (MPA). The GNPs interacted with cysteine and MPA through sulphur atom to produce assembly of nanoparticles of GNPs. The assemblies of the nanoparticles were established using UV-Visible spectra and transmission electron microscopy. The functionalized GNPs have been also utilized to verify the catalytic activity of it by reducing o-nitrophenol to o-aminophenol. The reduction of o-nitrophenol to o-aminophenol is evidenced by a decrease in absorbance at 400 nm and simultaneous growing of a new peak at 296 nm associated with formation of o-aminophenol. The plot of natural log of the absorbance at 400 nm ($\ln A_{400nm}$) versus time produced almost straight line. As the reduction reaction is pseudo-first-order in the presence of excess $NaBH_4$ and catalyst, the slope of the plot mentioned above, yields the apparent reaction rate (k_{app}) 1.5×10^{-3} (s^{-1}) and 5.6×10^{-3} (s^{-1}) for cysteine and MPA functionalized GNP respectively for this trial.

INTRODUCTION

Gold nanoparticles (GNP) are extensively used in various applications including electronics, bio-sensing and surface enhanced Raman spectroscopy. GNPs have found to receive great attention in the progress of optical sensing schemes [1-5]. The SPR band is sensitive to the size and shape of the particles [6]. GNPs smaller than 60 nm in diameter display an intense red color due to SPR absorption when their conducting electrons are confined to dimensions smaller than electron mean free path [7].

Self assembly of nanoparticles is an essential aspect in nanoscience and nanotechnology [8]. A number of chemical strategies have been employed to formulate assemblies of nanoparticles [9,10]. Gold nanorods have been assembled using DNA, surfactants and various linker molecules [11-17]. Development of chains and necklaces of self assembled gold nanopaticles using organic linker molecules would involve two processes: one of them is the interaction of the linker molecules with the gold nanoparticles and the other is the formation of the extended chains or necklaces. When the assembly of GNPs takes place, the color turns blue or purple because of the coupling of the Plasmon absorbance which could results as the nanoparticles come close. Assemblies of nanoparticles are reported as GNPs-based colorimetric recognition of DNA [18,19], proteins [20] and metal ions [21].

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Catalysis at the nanoscale level has gained significant attention in the past two decades due to the unique properties of materials at that level [22]. Metal nanocatalysts have found a wide range of applications in various field like carbon nanotube nucleation [23], alcohol dehydrogenation [24], oxidation of aromatic alcohol [25], formation of hydrogen peroxide from H_2 and O_2 [26], formic acid electro-oxidation [27], reduction of oxygen [28] etc. Gold, in particular, has become the basis for novel catalysts due to its special activity at the nanoscale [29].

In this work, we have synthesized GNP by adopting a green method. Aqueous extract of *Andrographis Paniculata* was used for reduction and stabilization of GNPs and funtionalization of GNPs were done with two biologically relevant molecules containing sulphur such as cysteine and 3-mercaptopropanoic acid (MPA). The GNPs interacted with cysteine and MPA through sulphur atom to produce assembly of nanoparticles of GNPs. The assemblies of the nanoparticles were established using UV-Visible spectra and transmission electron microscopy. The functionalized GNPs have been utilized to verify the catalytic activity of it by reducing o-nitrophenol to o-aminophenol.

MATERIALS AND METHODS

Chloroauric acid, mercaptopropanoic acid and cysteine, all of A R grade, were purchased from Sigma-Aldrich Chemical Ltd. Sodium hydroxide, was purchased from Merck. Double distilled de-ionized water was used in all experiments.

Andrographis Paniculata was collected from local forest, washed with water and dried under sunlight for one week. It was then crushed into small pieces using mortar pestle. 5 gm of these were taken in a beaker and 100 ml double distilled de-ionized water was poured into it. Then it was kept standing for 6 hours and was filtered to get aqueous extract of *Andrographis Paniculata*. From this extract we prepared diluted extract having different compositions like

Catalytic application of GNP

5:4 (5 ml extract and 4 ml water), 5:3 (5 ml extract and 3 ml water) and 5:1 (5 ml extract and 1 ml water).

Green synthesis of Gold Nanoparticles by *Andrographis Paniculata* extract

GNP was produced by reduction of chloroauric acid solution using aqueous extract of *Andrographis Paniculata*. 10 ml of aqueous *Andrographis Paniculata* extract of 5:1 composition was cooled in ice cold water and 5 ml of 0.005M aqueous chloroauric acid was added drop wise with continuous stirring. The mixture was then cooled further for 10 minutes and finally it was heated for 30 minutes at 80^0C. The colour of the solution gradually changed from yellow to reddish violet. The reddish violet colour indicated the formation of gold nanoparticles (GNPs).

Functionlization of GNP with Cysteine

10 ml of as prepared GNP was added to 2 ml of alkaline cysteine solution having different concentrations (0.001 to 0.005 M). The mixture was heated at 85^0C for 10 minutes and the color of the sol became reddish violet to violet and finally with increased concentration of cysteine the sol color change to light blue.

Functionlization of GNP with 3-mercaptopropanoic acid (MPA)

10 ml of as prepared GNP was added to 5 ml volume of MPA solution containing different concentrations (0.001 to 0.01 M). The mixture was heated at 85^0C for 5 minutes and the color of the sol became reddish violet to deep blue with increased concentration of MPA.

Functionalized GNP catalyzed reduction of o-nitrophenol

The catalytic reduction of o-nitrophenol to o-aminophenol was carried out in presence of functionalized GNP. A freshly prepared aqueous solution of sodium borohydride (2 ml of 0.005 M) was added in the reaction mixture containing 3 ml functionalized GNPs and 1ml of 0.001 M o-nitrophenol. The colour of the solution changed gradually from yellowish to colourless as the reduction proceeded using either cysteine or MPA functionalized GNP.

The absorbance spectra of the GNPs were analyzed by using a 'SHIMADZU' UV 1800 spectrophotometer and TEM images were taken using JEOL-JEM 2100 high resolution transmission electron microscope (HR-TEM). Samples for the TEM studies were prepared by placing a drop of the aqueous suspension of particles on carbon-coated copper grids followed by solvent evaporation under vacuum. The crystalline nature of the GNPs was examined using X' Pert Pro X-ray diffractometer operated at a voltage of 40 kV and a current of 30 mA with Cu Kα radiation.

RESULTS AND DISCUSSION

The Bio-synthesis of gold nanoparticles using plant extracts are in vogue now-a-days. The use of varied biological systems for the synthesis of gold nanoparticles is evolving different kind of important branches of nanotechnology. The present study deals with the synthesis of gold nanoparticles using a green technique using aqueous extract of *Andrographis Paniculata*.

The GNP produced exhibits reddish violet color in water. The color appears due to the excitation of the Localized Surface Plasmon vibrations of the metal nanoparticles. A smooth and narrow absorption band was observed at 519 nm for the 5:4 extract composition of *Andrographis Paniculata.* The Plasmon band shifted to higher values and becomes broad with the increase of concentration of *Andrographis Paniculata* in the extracts and finally it reaches at 530 nm for 5:1 composition (Fig. 1A). *Andrographis Paniculata* is a strong reducing agent but not a good capping agent. So, this induces rapid nucleation and can't restrict the growth of gold nanoparticles. Hence polydispersed gold nanoparticles are observed. The polydispersity and the colloidal instability (agglomeration tendency of gold nanoparticle) may by the reason of having broad spectrum of gold sol along with a shift in the peak position (Fig. 1A, 5:1 composition). GNP synthesized from *Andrographis Paniculata* extract of 5:1 composition has been used throughout the experiment for colorimetric sensor properties study.

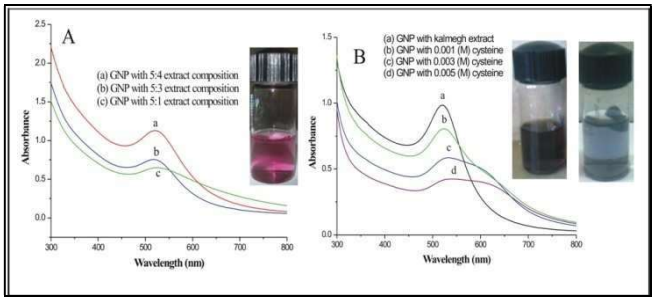


Fig. 1. UV-Vis spectra of (A) GNP at different extract composition, (B) functionalization of GNP with different concentration of cysteine and corresponding digital photographic images of color change (inset).

Functionalization of GNP with cysteine

From the UV-Visible spectra it is observed that the GNP peak becomes broader due to functionalization with cysteine. As the concentration of cysteine increased, the corresponding GNP peak gradually broadened (Fig. 1B). This broadening may be due to the linking of gold particles [30].

Andrographis Paniculata is strong reducing agent but not so good capping agent. So, it induces rapid nucleation and can't restrict the growth of gold nanoparticles. Hence polydispersed gold nanoparticles are observed in TEM micrographs having size in between 10 to 22 nm (Fig. 2A).

Being a strong capping agent, cysteine stabilizes the gold nanoparticles as soon as nucleation happens and there by restricted the nanoparticles to a finite size of 5 to 13 nm (Fig. 2B-D). The presence of linker atom sulphur in cysteine facilitates the binding of the molecules to gold nanoparticles [31]. Due to the electrostatic interaction, assembling processes occur and hence chain or necklace formation of GNP happened through the formation of zwitterions (Scheme 1). The assemblies of nanoparticles are evidenced in transmission electron microscopic images (Fig. 2B-D).
The morphology and the orientation of gold nanoparticles are clearly observed in the TEM images in presence of cysteine (0.005 M). Different geometrical structures like triangular sheets or hexagonal sheets along with chain structures are visible (Fig. 3). The crystalline natures of gold nanoparticles are shown in SAED images (Fig. 3 inset).

Functionalization of GNP with MPA

In presence of MPA the UV-Visible peak of GNP also becomes broader with the increase of the concentration of MPA (Fig. 4). The broadening of the peak may be due to the linking of gold nanoparticles.

3-mercaptopropanoic acid is strong capping agent stabilizes the gold nanoparticles as soon as nucleation happens and there by restricts the nanoparticles to a finite size of 10 to 17 nm were obtained in TEM micrograph (Fig. 5 A and 5B). Simultaneously the linking of molecules facilitates the assembling processes by hydrogen bonding between the carboxylic groups and thereby formation of chains or necklaces occurs (Fig. 5 C and 5D) through the formation of six-member dimeric hydrogen bonded ring (Scheme 1). Formation of such chains or necklaces using organic linker molecules like MPA and cysteine would involve two processes: (i) interaction of the linker molecules with the gold nanoparticles and (ii) formation of the extended chains or necklaces. The attractive chain or necklaces formation occurred in case of MPA functionalized GNP due to the better binding property of MPA molecules with compare to cysteine molecules.

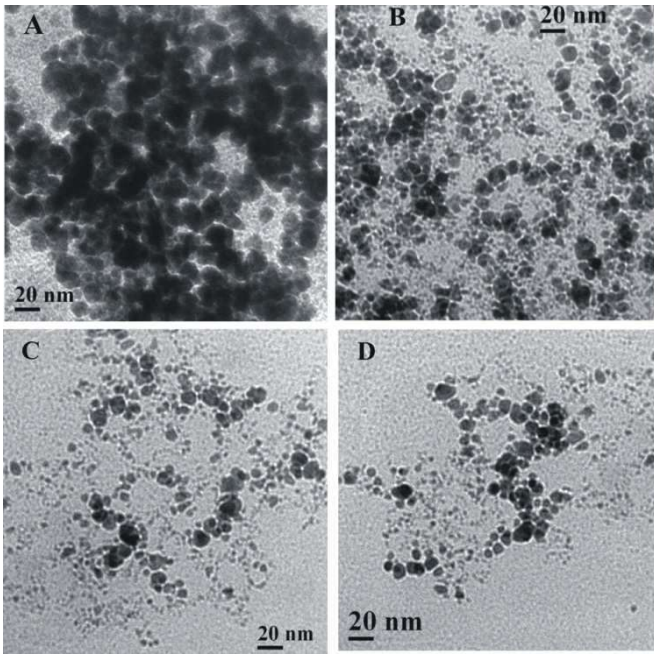
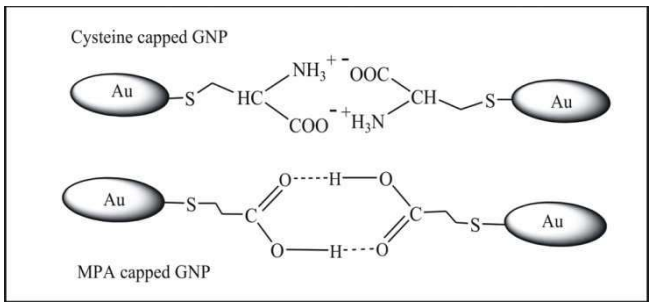


Fig. 2. TEM micrographs of (A) GNP and (B-D) cysteine functionalized GNP synthesized by *Andrographis Paniculata* extract.



Scheme 1. Strategy of the assembly process and resulting the formation of chain or necklaces type GNP strucrure.

GNP Catalyzed reduction of o-nitrophenol

We have employed the cysteine and MPA functionalized GNP to verify the catalytic activity of it by reducing the o-nitrophenol (Fig. 6). The reduction of o-nitrophenol in the presence of $NaBH_4$ and functionalized GNP is fast. From literature it is confirmed that the role of the metallic catalyst is to bind the o-nitrophenol molecule through the two oxygen atom of the nitro group [32-34].

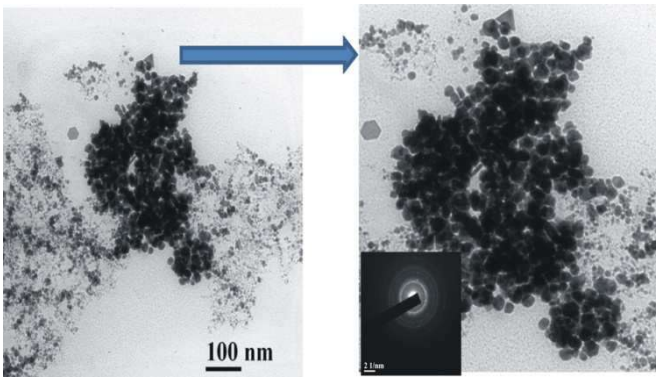


Fig. 3. TEM micrograph of different morphology of cysteine functionalized GNP and the corresponding SAED pattern (inset).

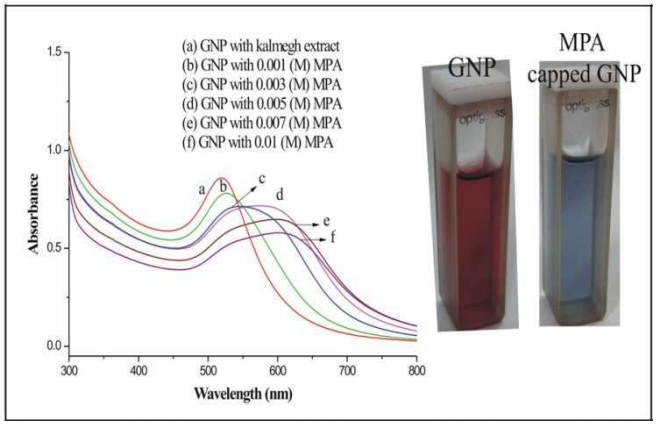


Fig. 4. UV-Vis spectra of MPA functionalized GNP at different concentration of it and corresponding digital photographic images of color change (inset).

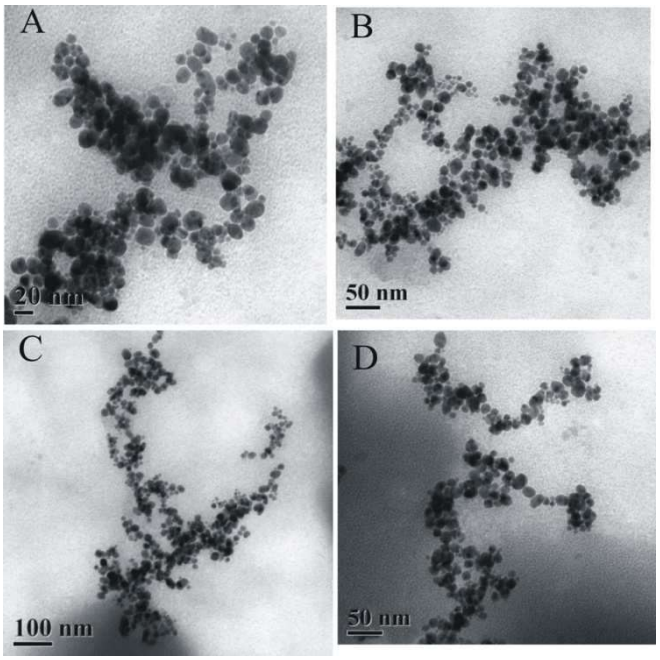


Fig. 5. TEM micrographs of (A-D) MPA functionalized GNP synthesized by *Andrographis Paniculata* extract.

o-nitrophenol absorbs strongly in the visible range with a maximum absorbance at 400 nm. The reduction of o-nitrophenol to o-aminophenol is evidenced by a decrease in absorbance at 400 nm and simultaneous growing of a new peak at 296 nm associated with formation of o-aminophenol. The reduction progress was observed for a period of 480 S (Fig. 6).

Catalytic application of GNP

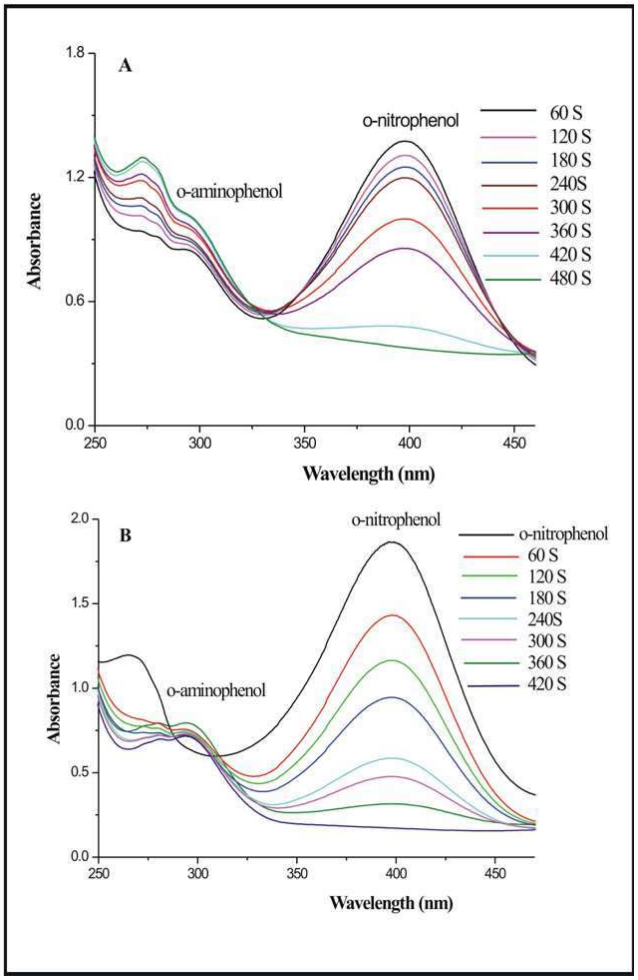


Fig. 6. UV–Visible spectra (A and B) show the reduction progress of o-nitrophenolate using cysteine and MPA functionalized GNP respectively, with time interval of 60 S.

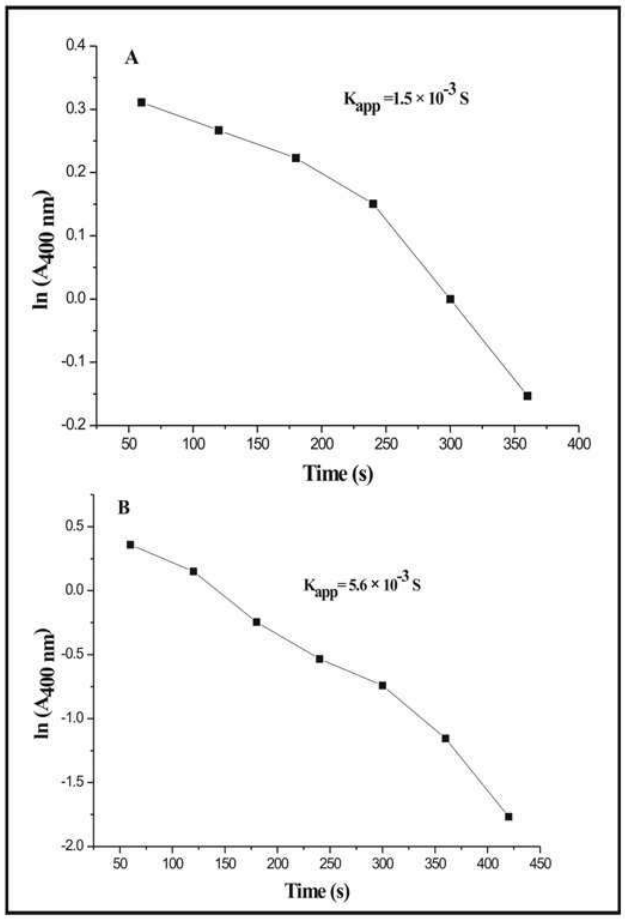


Fig. 7. The plot of the natural log of the absorbance at 400 nm versus time; data points are separated by 60 s intervals. The slope yields the apparent rate constant k_{app} = 1.5 ×10^{-3} (s^{-1}) and 5.6×10^{-3} (s^{-1}) for cysteine and MPA functionalized GNP respectively for this trial.

The plot of natural log of the absorbance at 400 nm (ln A400nm) versus time produced straight lines. As the reduction reaction is pseudo-first-order in the presence of excess NaBH4 and catalyst, the slope of the plot mentioned above, yields the apparent reaction rate, kapp for both the cysteine and MPA functionalized GNP (Fig. 7). Thus, this is found to be an easy method for determining reaction rate by ultraviolet–visible (UV–Vis) spectroscopy [35].

The XRD analysis was performed to confirm the crystalline nature of cysteine functionalized GNP. Various Braggs' diffractions pattern were clearly visible (Fig. 8A). The face centered cubic (fcc) structure of the bulk gold having peaks at 38.24o, 44.42o, 64.64o, 77.78o and 87.73o indicated the presence of corresponding (111), (200), (220), (311) and (222) planes, respectively. The XRD spectrum of the MPA functionalized GNP is shown in Fig. 8B and it is seen that the spectrum shows the same four peaks. On the basis of these Braggs' diffractions, we can say that the functionalized GNP are fcc and essentially crystalline in nature. The (200), (220) and (311) set of lattice planes were observed to be weak and broadened compared to (111) Bragg's diffraction, which indicated that the cysteine and MPA functionalized GNP were (111) oriented.

CONCLUSIONS

The assembly of the GNPs was established using the biologically relevant molecules containing sulphur such as cysteine and MPA. Due to the presence of linker atom sulphur in cysteine which facilitates the binding of the molecules to gold nanoparticles and hence assembling process by electrostatic interaction, resulting the formation of zwitterions. Chains or necklaces formation of GNP occurs through the formation of zwitterions between cysteine molecules. When we have employed 3-mercaptopropanoic acid as the linker molecules wherein the linkage occurs through the formation of six-membered dimeric hydrogen bonded ring between the carboxylic groups which facilitates assembling process of GNP and hence the formation of chains or necklaces occurs. The reduction of o-nitrophenol to o-aminophenol is evidenced by a decrease in absorbance at 400 nm and simultaneous growing of a new peak at 296 nm associated with formation of o-aminophenol. The reduction progress was observed for a period of 480 S. The plot of natural log of the absorbance at 400 nm (ln A_{400nm}) versus time produced almost straight lines. As the reduction reaction is pseudo-first-order in the presence of excess $NaBH_4$ and catalyst, the slope of the plot mentioned above, yields the apparent reaction rate (k_{app}) 1.5 ×10^{-3} (s^{-1}) and 5.6×10^{-3} (s^{-1}) for cysteine and MPA functionalized GNP respectively for this trial.

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We are thankful to Central Research Facility of IIT Kharagpur, India for HR-TEM and XRD measurements.

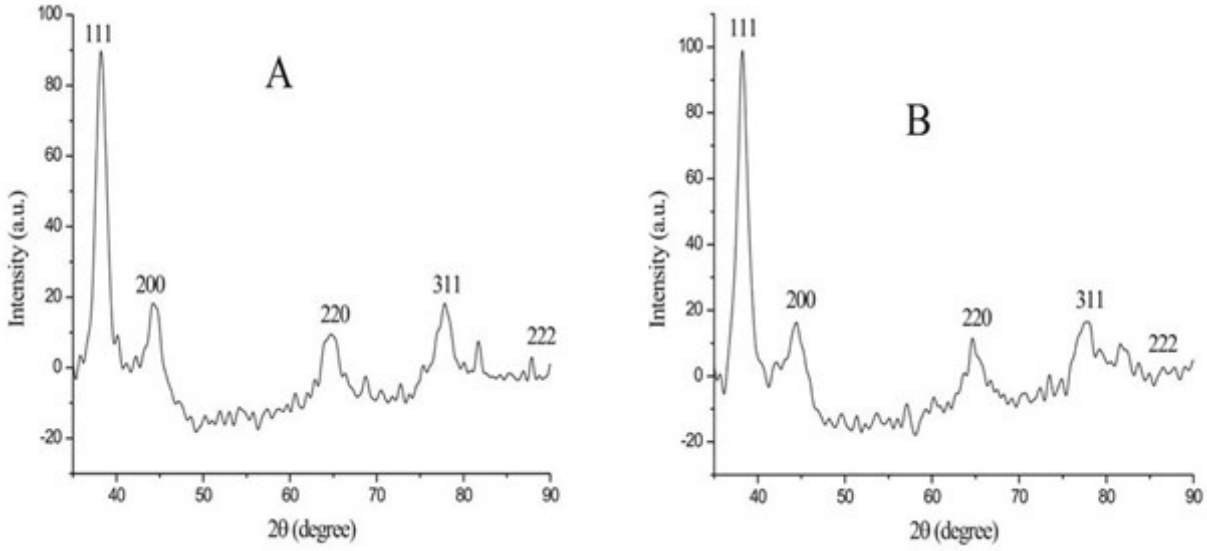

Fig. 8. XRD of (A) cysteine functionalized GNP and (B) MPA functionalized GNP prepared from *Andrographis Paniculata* extract.

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Small indigenous freshwater fish faunal diversity of Belda and its surroundings

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ABSTRACT

Small indigenous freshwater fish are often an important ingredient in the diet of village people who live in the proximity of freshwater bodies. Word 'Indigenous' means the originating in and characteristic of a particular region or country & native area. Paschim Medinipur is a districts having 29 blocks, among which Belda is located in Narayangarh block. This block is about 70 km North from Bay of Bengal. Therefore, it represents only it's freshwater indigenous fish resources. In the present study, different rivers and water bodies of Belda and its surroundings have been surveyed thoroughly for natural small indigenous fish diversity. A total number of 44 indigenous freshwater fish species belonging to 33 genera, 18 families and 7 order were collected and identified according to the existing literature, during the survey period. Among all the collected specimens family Cyprinidae shows maximum number of species followed by Ambassidae, Channidae, Mastacembelidae, Bagridae and Gobiidae etc. At the order level Perciformes shows the maximum diversity in the study area. Present study shows the IUCN status of icthyofauna of the study region. A good number of indigenous fishes of the study area are under threat due to eco - destruction of aquasystem and need to be restored by appropriate strategy of conservation.

INTRODUCTION

Belda and it's surroundings is an Agro industrial zone of Paschim Medinipur district**.** Located at 22°05′N 87°21′E22.08°N 87.35°E. It has an average elevation of 12 metres (42 feet). The *gram panchayat*s Belda–I and Belda–II are located in the Narayangarh community development (CD) block in the Kharagpur subdivision of Paschim Medinipur district. Belda is the headquarters of the Narayangarh CD block. Narayangarh block is surrounded by 7 blocks, namely in north Kharagpur I and Kharagpur II block, in south Dantan I and Dantan II, in east Pingla and Sabong and in west Keshiary.

In West Bengal 171 freshwater fish species was reported by Sen, 1992. After few years there were a wide change in number of fish species has been reported fom this region. Mishra et al., 2003 studied on the freshwater fishes of Midnapur, Bankura and Hooghly districts. Barman, R.P. 2007 recorded 239 freshwater species belonging to 147 genera, 49 families and 15 order. 70 indigenous ornamental fish species belonging to 45 genera, 30 families and 9 orders were reported by Basu et al. (2012).Till there were a few works on freshwater fishes has been reported from West Bengal . All of these works are mostly based on indigenous ornamental freshwater fishes. But works on small indigenous freshwater fishes of West Bengal are very poor. So, the record of freshwater fish fauna of Paschim Medinipur is very poor. From this region only the work of Bhakta, J. N. and Bandyopadhyay, P. K. 2008 was reported, but their study area was restricted to Ramnagar, Purba Medinipur. Therefore, present work is the major attempt towards the recording of small indigenous freshwater fish fauna of Belda and its surroundings.

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MATERIALS

Present study is mainly based on the specimen collected from the study area. Specimen were collected from different river, pond, bill by different traditional fishing methods throughout the study area during May 2013 to August 2015.

METHODS:

Collection of fish fauna was done at early morning and specimens were immediately preserved in 2-4% formaldehyde and were brought to laboratory in preserved condition. Then fish specimen were washed and finally preserved in 4-6% formaldehyde. Body parts of the specimen have been dissected and studied for identification. List of species, genera, family and order name and also their distribution, threatened status have been furnished. In addition to this an attempt has been made to include a comprehensive coverage of references in the end of this article.

MEASUREMENT:

All Measurement of fish were made in metric system as followed by Talwar-Jhingran,1991; Jayaram, K.C,1999; Jayaram, K.C. 2010 and www.fishbase.org.ver 08/2015.

RESULTS:

Total number of 44 indigenous fish species belonging to 33 genera, 18 families and 7 order were identified during the survey period (May 2013 to August 2015) from different area of Belda and its surroundings (table-1).

DISCUSSION:

Very less attention has been focused on the freshwater small indigenous fishes and their role in aquaculture, nutritional value, biological significance, breeding status, and conservation. Present study reveals that out of 44 small indigenous freshwater fishes of the study area 4 species namely *Oreochromis mossambicus* (Peters,1852), *Parambassis lala* (Hamilton,1822), *Ompok pabo*

(Hamilton,1822) and *Wallago attu* (Bloch & Schneider, 1801) are Near Threatened.

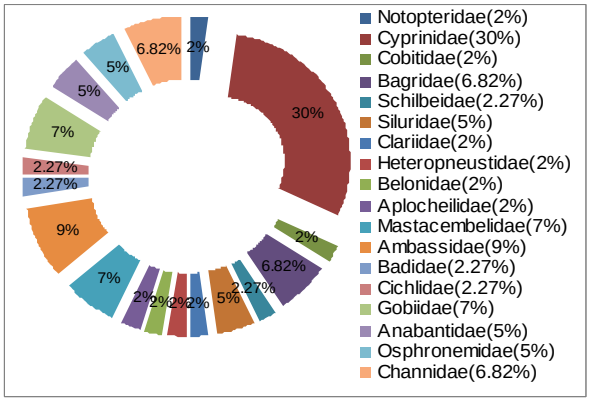

Fig. 1 Family level diversity assessment of fish fauna in Belda and its surroundings, found during the study

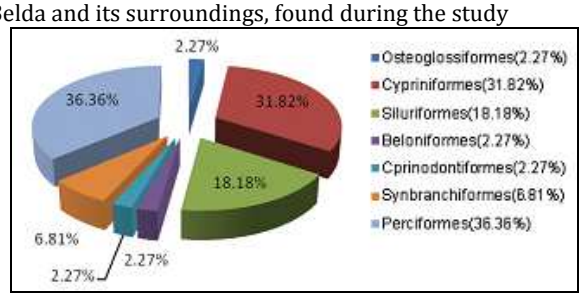

Fig. 2 Order level diversity assessment of fish fauna in Belda and its surroundings, during the study.

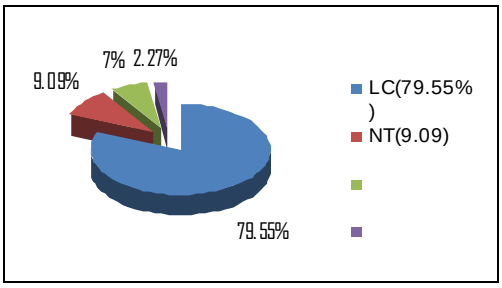

Fig.3 Conservational status assessment of fish Species during the study in Belda and its surroundings (Acc. to IUCN ver.08/2015)

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Table-1: Distribution of Fish fauna and their IUCN category from Belda and its surroundings

Name of the order	Name of the family	Name of the species	Registration No.	IUCNVersion 8/2015 & NBFGR (2010)	Distribution in Belda and its Surroundings (blockwise)
Osteoglossiformes	Notopteridae	*Notopterus notopterus* (Pallas,1769)	RNLK-16	LC	All blocks
Cypriniformes	Cyprinidae	*Amblypharyngodon mola* (Hamilton,1822)	RNLK-1	LC	All blocks
		Cabdio morar (Hamilton,1822)	RNLK-32	LC	Keshiary, Sabong
		Danio rerio (Hamilton,1822)	RNLK-22	LC	Keshiary, Dantan I, Dantan II
		Esomus danricus (Hamilton,1822)	RNLK-18	LC	All blocks
		Laubuca laubuca (Hamilton,1822)	RNLK-33	LC	Keshiary, Dantan I
		Osteobrama cotio cotio (Hamilton,1822)	RNLK-27	LC	Keshiary
		Puntius chola (Hamilton,1822)	RNLK-15	LC & VU	Pingla, Sabong, Dantan II
		Pethia ticto (Hamilton,1822)	RNLK-21	LC	Pingla, Sabong, Dantan II, Dantan I, KGP I
		Puntius sophore (Hamilton,1822)	RNLK-2	LC	All blocks
		Rasbora daniconius (Hamilton,1822)	RNLK-54	LC	Narayangarh
		Salmophasia bacaila (Hamilton,1822)	RNLK-17	LC	Narayangarh
		Salmophasia phulo (Hamilton,1822)	RNLK-28	LC	Pingla
		Salmophasia sardinella (Valenciennes, 1844)	RNLK-41	LC	Narayangarh, Sabong

	Cobitidae	*Lepidocephalichthys guntea* (Hamilton,1822)	RNLK-3	LC	All blocks
Siluriformes	Bagridae	*Mystus bleekeri* (Day,1877)	RNLK-26	LC	Pingla, Dantan I
		Mystus cavasius (Hamilton,1822)	RNLK-34	LC	Pingla, Sabong
		Mystus tengara (Hamilton,1822)	RNLK-4	LC	Narayangarh, Sabong, Pingla, KGP I
	Schilbeidae	*Neotropius atherinoides (Bloch,1794)*	RNLK-40	LC	Dantan I, Dantan II
	Siluridae	*Wallago attu* (Bloch & Schneider, 1801)	RNLK-5	NT	Pingla, Sabong
		Ompok pabo (Hamilton,1822)	RNLK-38	NT & EN	Narayangarh
	Clariidae	*Clarias batrachus* (Linnaeus,1758)	RNLK-6	LC & VU	Sabong, Pingla
	Heteropneustidae	*Heteropneustes fossils (Bloch,1794)*	RNLK-23	LC & VU	Pingla , Sabong, Dantan II
Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton,1822)	RNLK-36	LC	Sabong , Keshiary, Narayangarh
Cyprinodontiformes	Aplocheilidae	*Aplocheilus panchax* (Hamilton,1822)	RNLK-7	LC	Keshiary, Sabong, Dantan I, KGP I, KGP II
Synbranchiformes	Mastacembelidae	*Macrognathus aral* (Bloch &Schneider,1801)	RNLK-24	LC	Keshiary
		Macrognathus pancalus (Hamilton,1822)	RNLK-13	LC	All blocks
		Mastacembelus armatus (Lacepède, 1800)	RNLK-31	LC	Keshiary
Perciformes	Ambassidae	*Chanda nama* (Hamilton,1822)	RNLK-8	LC	All blocks
		Parambassis baculis (Hamilton,1822)	RNLK-39	LC	Sabong
		Parambassis lala (Hamilton,1822)	RNLK-25	NT	Keshiary, Sabong , Dantan II, Narayangarh, Dantan I
		Parambassis ranga (Hamilton, 1822)	RNLK-19	LC	Pingla
	Badidae	*Badis badis* (Hamilton,1822)	RNLK-35	LC & VU	Narayangarh, Pingla , Sabong,
	Cichlidae	*Oreochromis mossambicus* (Peters,1852)	RNLK-12	NT	Sabong, Pingla , Dantan I
	Gobiidae	*Glossogobius giuris* (Hamilton,1822)	RNLK-9	LC	Narayangarh, Pingla,
		Apocryptes bato (Hamilton, 1822)	RNLK-55	NE	Pingla , Sabong
		Brachyamblyopus brachysoma (Bleeker, 1854)	RNLK-56	NE	Sabong
	Anabantidae	*Anabas testudineus* (Bloch,1792)	RNLK-37	DD &VU	Pingla,
		Anabas cobojius (Hamilton,1822)	RNLK-10	DD	All blocks
	Osphronemidae	*Trichogaster fasciata* (Bloch & Schneider,1801)	RNLK-14	LC	All blocks
		Trichogaster lalius (Hamilton,1822)	RNLK-30	LC	Pingla, Keshiary
	Channidae	*Channa punctata* (Bloch, 1793)	RNLK-20	LC	Keshiary , Dantan I
		Channa gachua (Hamilton, 1822)	RNLK-11	LC	All blocks
		Channa orientalis (Bloch & Schneider,1801)	RNLK-29	NE & VU	Narayangarh

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ORIGINAL ARTICLE

Effect of fungicide on cellulase activity of epigeic earthworm *Eisenia fetida* (Oligochaeta)

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ABSTRACT

In the present study, the epigeic earthworm, *Eisenia fetida*, selected as the test specimen were exposed to two fungicides, carbendazim and captan, in natural garden soil. The 96 hour LC_{50} values of the two selected fungicides were determined. According to the LC_{50} value of the two fungicides more toxic carbendazim used for the cellulase enzyme activity assessment. Feeding preference experiment was carried out and they showed maximum preference for *Anacardium oxidentale* (cashew) leaves. The test specimen was exposed to sub lethal doses of carbendazim, i.e. 25% of LC_{50} value and 50% of LC_{50} value, along with the control set. The enzyme activity measured on the 3rd, 7th, 15th and 30th day from the experiment .The values of the control set and two sub lethal doses, i.e. 25% of LC_{50} value and 50% of LC_{50} for 3rd, 7th, 15th and 30th day were 1.09 ± 0.40, 1.59 ± 0.50, 1.25 ± 0.45; 1.29 ± 0.48, 1.50 ± 0.50, 1.75 ± 0.55; 2.25 ± 0.85, 1.58 ± 0.50, 1.83 ± 0.60 and 2.75 ± 1.15, 3.05 ± 1.35, 3.05 ± 1.30 mg of glucose/minute/mg protein respectively. The enzyme activity was suppressed a little in between 7th and 15th day of the experiment. From the activities of the enzyme we can use as a potential biomarker to detect pesticide pollution in soil in agro ecosystem and can be further used in genotoxicity studies.

INTRODUCTION

Present day agricultural practices largely depend on agro-chemicals for enhancing productivity. There are 60,000 varieties of chemicals in use with several thousand being added annually (Maugh, 1978). Besides seeds, nutrients, water etc, use of pesticides including fungicides is indispensable. Alarming population growth throughout the globe necessitates more food and cash crops production results rapid growth of pesticide market (Ecobichon, 2001). Inspite of their benefits, increasing trend of fungicide application has deleterious effect on human environment and agro-ecosystem.

The Bordeaux mixture was the first fungicide to be used on a large scale world-wide (Schneiderhan 1933). Regular use of fungicides can potentially pose a risk to the environment, particularly if residues persist in the soil or migrate off-site and enter waterways (e.g. due to spray drift, run-off) (Kookana et al., 1998;Wightwick & Allinson, 2007; Kibria et al., 2010; Komarek et al., 2010). If this occurs it could lead to adverse impacts to the health of terrestrial and aquatic ecosystems. For instance, concerns have been raised over the long term use of copper-based fungicides, which can result in an accumulation of copper in the soil (Wightwick et al., 2008; Komarek et al., 2010).This in turn can have adverse effects on soil organisms (e.g. earthworms, microorganisms) and potentially pose a risk to the long-term fertility of the soil (Wightwick et al., 2008; Komarek et al., 2010)

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A greater proportion (80%) of biomass of terrestrial invertebrates is represented by earthworms which play an important role in structuring and increasing the nutrient content of the soil. Therefore, they can be suitable bioindicators of chemical contamination of the soil in terrestrial ecosystems providing an early warning of deterioration in soil quality (Culy and Bolger ,1995; Sorour and Larink, 2001; Bustos-Obregón, and Goicochea, 2002). This is important for protecting the health of natural environments and is of increasing interest in the context of protecting human health (Beeby, 2001) as well as other terrestrial vertebrates which prey upon earthworms (Dell'Omo et al., 1999). The suitability of earthworms as bioindicators in soil toxicity is largely due to the fact that they ingest large quantity of the decomposed litter, manure, and other organic matter deposited on soil, helping to convert it into rich topsoil (Reinecke et al.,1999; Sandoval et al., 2001). Moreover, studies have shown that earthworm skin is a significant route of contaminant uptake (Lord et al.,1980) and thus investigation of earthworm biomarkers in the ecological risk assessment (ERA) can be helpful (Sanchez-Hernandez, 2006)

In the present study, two fungicides carbendazim and captam were used for acute toxicity test but only carbendazim used to evaluate the toxic effects of the sub-lethal doses on the cellulase enzyme activity, of the epigeic earthworm *Eisenia fetida* (Table-1).

SOIL ORGANISMS

Soil organisms can be defined as organisms which spend at least a part of their life cycle in or on the soil (Hendrix et al., 1990). Morphologically, soil organisms range from less than 1 micrometer in diameter to several centimeters in diameter (Lee, 1985). In general soil fauna act as catalysts of microbial activity. Soil fauna can be subdivided on the basis of their size into microfauna, mesofauna and macrofauna

(Wallwark, 1970). The large and conspicuous soil animals are the macrofauna, which include amphipods, isopods, centipedes, millipeds, adult as well as larval insects, mollusks and earthworms. Microfauna include protozoa, Nematoda etc. and mesofauna like Acarids, Collembolans and Enchytraedes etc.

Among these the ecological importance of earthworms in the organic breakdown and soil formation processes is well established (Wallwork, 1970). These animals are very sensitive to environmental characteristics like pH, moisture, temperature etc. and their ecological importance depends upon the prevailing edaphic and climatic parameters.

Table.1 The fungicides used in the study with their respective RADs.

Chemical Name	Trade Name	RAD*(mg/kg)
Carbendazim	BAVISTIN	0.96
Captan	CAPTAF	4.80

*RAD- Recommended Agricultural Dose

Ecological Importance of Earthworms:

Aristotle was one of the first who pointed out the role of earthworms in turning over the soil and called them "The Intestines of the Earth". However, earthworms were considered as pests until the publication of Charles Darwin's book "The Formation of Vegetable Mould through the Action of Worms", in 1881, where he convincingly documented in great detail the importance of earthworms in the breakdown of organic matter and the formation and maintenance of soil structure. Since then, a vast amount of studies have documented that earthworms play an essential role in improving soil structure and fertility. The main contributions of earthworms in this respect as highlighted in these studies are**:**

i. Physical participation by feeding, fragmentation of leaf litter, aeration turnover and dispersion (Lee and Foster, 1991; Lavelle et al., 1997).
ii. Chemical participation by digestion of organic substances and by contributing nutrients to the soil through metabolic by-product and dead tissue.
iii. Grazing over microflora and altering soil micro floral composition (Brown, 1995; Scheu, 2003).

In recent years it has been stressed that the role of the earthworms does not stop below ground, they also affect the above ground subsystem, especially plant performance including growth, development and plant community composition (Scheu et al., 1999; Schimidt and Curry, 1999; Zeller and Arnune, 1999; Wurst et al., 2003).

In forest ecosystems earthworms, especially litter feeders such as *L. terrestris*, can consume all the litter deposited on the soil surface within a period of several weeks (Knollenberg et al., 1985) or months (Satchell, 1967). Incorporation of litter by earthworms in apple orchards can be an important mechanism for preventing outbreaks of scab fungus, spores of which are transmitted from litter to new foliage by spring rains. Raw (1962) found a high correlation between *L. terrestris* biomass and apple leaf litter incorporation, with over 90 percent of litter incorporated during the winter when this species was abundant. Incorporation of surface litter may be an important function of earthworms in no-tillage agro-ecosystems.

Introduction of earthworms to areas not previously populated has led to improvement of soil quality and productivity in New Zealand grassland, on drained Dutch polders (Van Rhee, 1977) in heath land in Ireland (Curry and Bolger, 1984), and in mining spoils in the U.S. (Vimmerstedt and Finney, 1973). Lumbricids in a pasture soil produced casts that contained 73 percent of the nitrogen found in the ingested litter, indicating importance of earthworms in incorporating litter nitrogen into the soil as well as the inefficiency of earthworm in digestion of nitrogen (Syers et al., 1979). Earthworms increase the amount of nitrogen mineralized from organic matter in soil. Because nitrification is enhanced in earthworm casts, the ratio of nitrate-N to ammonium-N tends to increase when earthworms are present (Ruz Jerez et al., 1988). Nitrogen-fixing bacteria are found in the gut of earthworms and in earthworm casts, and higher nitrogenise activity, meaning greater rates of N-fixation, are found in casts when compared with soil (Simek and Pizl, 1989).

Earthworms increase level of metabolic activity in soils, but often reduce nematode abundance and microbial biomass (Yeates, 1981; Ruz Jerez et al., 1988) because they reduce the amount of substrate available to other decomposers and they also ingest other decomposer organisms as they feed. This process would tend to accelerate nutrient cycling.

Earthworms as model test organisms in ecological risk assessment

Extensive use of insecticides in agricultural field produces several deleterious effects on soil ecosystems. Insecticides produce inhibitory effect on the macrofaunal, mesofaunal and microfaunal population of the soil and disturb the equilibrium of soil organisms. Since earthworms constitute about 92 % of the invertebrate biomass of the soil, researchers around the world have used earthworms as model organisms for soil toxicity testing. The inception, testing and standardization of the acute earthworm toxicity test by OECD (1984) and EPA (1996) (URL 1) have been the catalysts for the emergence of earthworms as one of the key organisms in environmental toxicology. Therefore, it is not surprising that a number of recommendations have focused on laboratory testing methods on ecotoxicology using earthworms as the test organisms. The first two International Workshops on Earthworm Eco- toxicology (IWEE) supported a role for the artificial soil acute toxicity test in screening chemical toxicity. This included not only classical toxicity studies (e.g. Callahan et al., 1994; Edwards & Bohlen, 1992), but also field soil assessment (Bierkens et al., 1998; Charrois et al., 2001; Dorn et al., 1998), remediation evaluation (Ducrocq et al., 1999) and evaluations of bioavailability (Amorim et al., 2002). However the third international workshop on earthworm eco toxicology (IWEE III) held in Denmark in 2001was less supportive of the role of acute toxicity tests and suggested reproductive tests with sub lethal doses instead.

Laboratory experiments also give little idea about the consequences of the toxicant on behaviour of the soil organisms for exposure and effects in the field. Various physical and chemical aspects of the soil that are not included in laboratory tests may have a direct or indirect impact on the degradation, persistence, bioavailability and exposure of the different chemicals applied to the soil. Posthuma (1998) concluded that factors such as temperature and soil moisture content explain only a small part of the difference in response observed in their laboratory and field studies. This also emphasizes the

importance of developing models to predict exposure and bioavailability under field conditions.

Systematic position of the selected specimen:

Phylum: Annelida
Class: Oligochaeta
Family: Lumbricidae
Order: Haplotaxide
Suborder : Lumbricina
Genus: *Eisenia*
Species: *Eisenia fetida*
Eisenia fetida (Savigny, 1826)

Distribution:

Eisenia fetida is also an epigeic earthworm and is known as the red wiggler worm. The worm is native to the palearctic and are also found in Europe, North and South America, some parts of Asia, Africa, Iceland and Australasia (Reynolds, 1997). They are commonly found under the bark of tree trunks or animal dung accumulation or decaying plant material throughout the European countries and have become successfully established throughout the world for vermicomposting (Kale et al., 1982; Reinecke et al., 1992; Yasmin and DSouza, 2010). This species is exotic to India. But it is extensively cultured in this country as a most favourite worm species in composting and organic gardening (Garg et al., 2006). The species has acclimatized well in Indian climatic condition and is now readily available from any composting pit in the country.

MATERIALS AND METHODS

Biology:

Total length, diameter and number of segments of the body of *Eisenia fetida* ranges from 35 to 130mm (generally >70mm), 3 to 5mm and 80 to120 segments respectively. The life span of the species is about 450 days. The life cycle of *Eisenia fetida* has been studied by several researchers including cocoon production (Hartenstein et al., 1979), effect of temperature on the reproduction (Reinecke and Kriel, 1981), incubation time and hatching rate (Tsukamato and Watanabe, 1977). T**he life span of *Eisenia fetida* is reported to range from 4 to 5 years (Bouche, 1977). The worms become clitellate and began to produce cocoons by 4-6 weeks and after about 27 weeks the rate of cocoon production declines (Hartenstein et al., 1979). Cocoons** of *E. fetida* are even smaller than a grain of rice, shaped like lemon and yellow-coloured. The incubation period of the cocoon is about 23 days. The cocoons gradually change its color from golden yellow to deep red; much like maroon as 4 to 6 embryonic red wiggler worms develop inside. Cocoons hatch at a temperature of 68° to 77° F (20° to 25° C). The juveniles emerge from the cocoons at about 3-4 weeks. Juveniles are about $^1/_2$ inch in thickness and do not have any genital markings or the clitellum. Once they hatch they readily become organic waste eating machines. About 40-60 days are required for the juveniles to develop into an adult. It develops the genital markings and clitellum. The clitellum contains their reproductive organ and can only be seen when *E. fetida* is ready to reproduce and the clitellums are orange in color (Bouche, 1977).

Eisenia fetida can be easily bred in the laboratory using variety of organic medium and has a short generation time. Therefore, the species is very appropriate for toxicity studies (OECD, 1984; 2004).

Collection and Culture of test specimens:

Specimens of *Eisenia fetida* were collected from the vermicompost unit, from Tamluk (West Bengal, India), that has never been used for any agricultural purpose and pest control. The specimens were brought to the laboratory and were cultured in large earthen pots. Finely grinded soil (collected from the same grasslands) and farmyard manure mixed in the ratio of 1:1 was used as the culture medium (Ismail, 1997). The culture pots were covered with fine meshed iron nets and kept inside BOD incubators at 28 ± 0.5ºC. An approximate level of 50% moisture was maintained by adding distilled water into the medium. Farmyard manure was added as feed every week during the entire period of culture(OECD 1984, 2004).

Experimental Procedures:

Studies were performed with age synchronized specimens (150-250 mg). Experiments were conducted in small inert polythene boxes (16 X 12 X 1 cm; total area, 192 cm2) containing soil, collected from grasslands, as the test medium. Soil samples were dried, grinded and sieved to get a particle size of 0.25 mm before filling in the experimental boxes. The moisture content of the soil was measured by Infrared Torsion balance moisture meter [Adair Dutt, Kolkata] (Joy and Chakravorty, 1991). Finally the experimental boxes were kept in an Environmental Chamber at a constant temperature of 28 ± 0.5°C and 60-65% relative humidity.

The physiochemical parameters of both the soil media, viz, pH and Organic carbon Content were measured and the temperature and moisture content were kept constant (Table 2).

Table.2 Physiochemical parameters of the natural soil used as medium in both the Acute toxicity test and Enzyme activity estimation.

Natural soil parameters	Values
P^H	6.90
Organic Carbon Content	1.18%
Moisture	61.2%

a. Acute Toxicity Test:

Different levels of the carbendazim and captan based on their recommended agricultural doses (RAD) (viz RAD, 1/2X-RAD,2X-RAD and 3X-RAD) were administered into the test boxes with a micropipette (Lofs-Holmin, 1983). The amount of a fungicide required was determined from the total area of the experimental box and was converted into mg per kg soil taking into consideration the total amount of soil (200 g) contained in one box. The experiment was setup with three replicates for each level of the fungicide and control. The boxes were then left undisturbed for about 30 min for uniform spreading of the chemical in the soil medium. Five numbers of age synchronized specimens of *Eisenia fetida* were then transferred into the boxes. Observations were made every 24 h. Those individuals, who showed no apparent sign of life, even when poked with a needle, were considered dead and were removed. The total mortality obtained after 96 h of exposure were subjected to probit analysis by EPA probit analysis program, version 1.5(US EPA 2006) to determine LC_{50} value (Table 3) and 95% confidence limit of each insecticide. The entire experiment was repeated three times (Dasgupta *et al.,* 2010).

Table.3 LC_{50} values of the two fungicides used in the Acute Toxicity study.

Chemical Name	Trade Name	LC_{50} Values
Carbendazim	Bavistin	5.38 mg/kg
Captan	Captaf	10.41 mg/kg

b. Determination of Feeding Preference of test organisms:

Open choice experiment was done on epigeic earthworm *Eisenia fetida* with five common tree species leaf litters viz., *Anacardium occidentale* (cashew), *Mangifera indica* (mango), *Shorea robusta* (shal), *Acacia auriculiformis* (Acacia) and *Eucalyptus citridora* (Eucalyptus), to study their food preference. The experiment was conducted in plastic trays containing five different randomly distributed leaf litter in pits in petri dishes inserted into a uniform layer sand bed (Maity and Joy, 1999a; 1999b). Fifty adult specimens of same size and age group were released in the centre of the plastic tray and they were to migrate among the litter types. Known amount of litter cuttings were used. Optimum moisture and temperature were maintained throughout the experimental period. The rate of migration and colonization of specimens were recorded by counting their number in each litter type at 15 days interval up to 90 days. Thus, cashew was selected as the source of food to be provided to the earthworms during the entire period of digestive enzyme estimation.

c. Estimation of Digestive Enzyme:

A very important aspect of the laboratory study was the quantitative estimation of the digestive enzyme cellulase (Sadasivam and Manickam, 2010) determined under laboratory conditions in natural garden soil (pH-6.90, organic carbon-1.18% moisture content-61.2%) by exposing the earthworms to sub-lethal dose of the fungicide, carbendazim, i.e., 25% and 50% of LC_{50} value. The specimen earthworms were kept inside inert polyethylene boxes of 192 cm^2 area each containing 250g of sieved garden soil along with 15 worms. Distilled water was added to maintain 60-70% moisture. The earthworms were provided with finely cut cashew leaf litter as food during the entire experimental period on a small petri-dish inside each box into a uniform layer of soil. The experiment was set following the procedure of open choice experiment as described by Maity and Joy, 1999a; 1999b. The food was contaminated with fungicide in the treatment boxes. The whole set up was kept inside an Environmental chamber and the temperature (28±0.5°C) and humidity (67%) was maintained. The determination of cellulase activity was performed on 3rd, 7th, 15th and 30th day from the setting of the experiment. The test specimens were kept in starvation before setting of the experiment.

RESULTS

The 96 hrs acute toxicity tests showed that Carbendazim with an LC_{50} value of 5.38 mg/kg soil was more toxic than Captan, LC_{50} value 10.41 mg/kg soil. The LC_{50} value of carbendazim is about five times higher than its RAD and in case of captan it is about two times higher than its RAD.

In the feeding preference experiment the earthworms showed maximum preference for *Anacardium occidentale* (cashew) leaves followed by *Mangifera indica* (mango), *Shorea robusta* (shal), *Acacia auriculiformis* (Acacia) and *Eucalyptus citridora* (Eucalyptus) (Fig A).

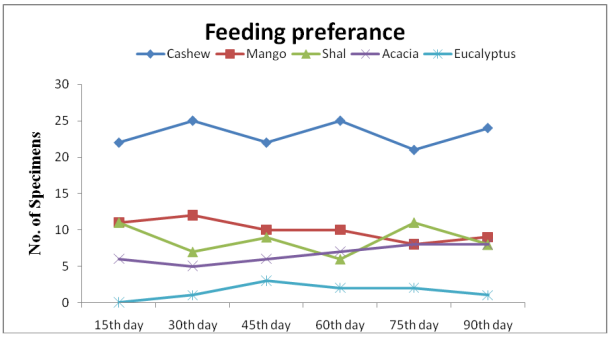

Figure: A Feeding preference of *Eisenia fetida* in the leaf litter of five tree species.

Due to more toxic LC_{50} value of carbendazim determined by the acute toxicity test, the chronic toxicity test was carry forword with only carbendazim.

In this experiment the cellulase enzyme activity in response to the carbendazim, of the test specimen was higher in both the sub lethal doses, 25% LC_{50} and 50% LC_{50} viz, 1.59 ± 0.50 mg of glucose/min./mg protein and 1.25 ± 0.45 mg of glucose/min./mg protein respectively and 1.50 ± 0.50 mg of glucose/min./mg of protein and 1.75 ± 0.55 mg of glucose/min./mg protein respectively than that of the control values viz, 1.09 ± 0.40 mg of glucose/min./mg protein and 1.29 ± 0.48 mg of glucose/min./mg protein on the 3rd and 7th day respectively after setting of the experiment. The activity of the enzyme diminished significantly than the control value (2.25 ± 0.85 mg of glucose/min./mg protein) on the 15th day of the experiment viz, 1.58 ± 0.60 mg of glucose/min./mg protein in both the sub lethal doses i.e. 25% of LC_{50} and 50% of LC_{50} value respectively. But on the 30th day of the experiment the activity of the enzyme increased to 3.05 ± 1.30 mg of glucose/min./mg protein and 3.05 ± 1.35 mg of glucose/min./mg protein in both the sublethal doses i.e. 25% of LC_{50} and 50% of LC_{50} respectively which are slightly higher than the control value i.e. 2.75 ± 1.15 mg of glucose /min./mg protein (Fig B).

One way ANOVA has been done using SPSS ver.16.0

DISCUSSION:

The LC_{50} value of carbendazim is higher than its RAD which indicates that this fungicide is ecologically safe in respect of short term (96 hours) acute toxicity. Studies of acute risk on *Eisenia fetida* after application of carbendazim in vineyards shows a LC_{50} value of 5.7 mg/kg. (URL 2).

Maximum colonization in Cashew and Mango with higher rates of degradation of these leaf litters can again be related to their lower antinutrient contents, viz polyphenol and tannin leading to higher palatability. (Hendriksen, 1990; Hobbie *et al*., 2006; Patricio, 2012; Johansson, 1995).

On the 3rd and 7th day of the experiment, cellulase activity of the earthworms somewhat significantly increased in both the sub lethal doses as compared to the control. This is probably because of the test specimen were unable to sense the fungicide contamination in the food and consumed it, as a result of keeping them in starvation before setting of the experiment. On the 15th day there was a little increase in the cellulase activity. This is because of that the earthworms were little bit affected by the fungicide but the enzyme activity didn't increase in the same rate as observed between 3rd and 7th day in sub lethal doses but in control the enzyme activity increased. On the 30th day the enzyme activity increased further in sub lethal doses and also in control compared to the 15th day's result of the experiment.

Probable cause of this increase in cellulase activity is that the fungicide is been degraded in food or the earthworms after sensing the fungicide become resistant to it. As the enzyme activity increased it can be said that the earthworms are not avoiding the food and restoring their enzyme activity to normal value.

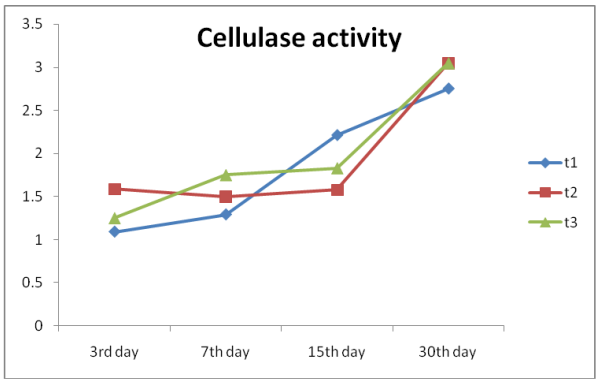

Figure: B Cellulase activity of *Eisenia fetida*, T1(Control), T2 (25% of LC_{50}) and T3 (50% of LC_{50}) Values of the enzyme are expressed in least significant difference, $p<0.05$ probability value.

Studies on the effect of carbendazim on the cellulase activity of *Eisenia fetida* has not been reported so far.

CONCLUSION:

From the above study it can be concluded that carbendazim shows less toxicity upon the earthworm after a certain period from the initial date of exposure, it does not have harmful effect when long term exposure is performed. In this regard carbendazim can be treated as an ecologically safe fungicide.

Last of all, it can be concluded that the enzyme cellulase can be used as a potential biomarker to detect pesticide pollution in agro ecosystem.

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CONFLICT OF INTEREST: None

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Raja N.L. Khan Women's College

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ORIGINAL ARTICLE

Sustainable development and environmental sustainability: With special reference to science and technology

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ABSTRACT

For the past one decade much effort was expended in the global label to achieve sustainable development. At present the World summits towards the protection of environment. The World is environmentally less sustainable than in the previous days. Directly or indirectly science and technology is an important role to play for sustainable development. Science and technology can offer economically viable solutions for small to large environmental problems. Science and technology are exclusively concerned to environmental sustainability, it is impossible to achieve sustainable development.

INTRODUCTION

At present, there is no unique operational definition for sustainable development. The reason is that there is no signal indicator for comparing the relative progress made by different countries or regions towards sustainable development at a given time or for measuring progress made by a given country or region over time. This lack has been impeding progress towards global sustainable development.

GOAL OF SUSTAINABLE DEVELOPMENT

1. Protection of regional cultures, diversity, regional knowledge and age-old time, tested eco-friendly practices.
2. Creation of conditions that ensure the future survival of human beings and other living species.
3. Creation of the sustainable system that helps preservation and protection of environment and ecosystem.
4. Creation of environment that sustains biological and natural productivity systems.
5. Creation of environment that provides and satisfies at least elementary basic requirements.

PRINCIPLE OF SUSTAINABLE DEVELOPMENT

1. The business and industrialist community has specific role to manage environmental impacts of the goods and services it provides.
2. Unsustainable consumption pattern is more visible in physical infrastructures.
3. Rectification in chain of production-consumption and final disposal government must provide incentive measures, infrastructural facilities.
4. Participation of the people in the decision making process.
5. The development process must be balanced and conductive with nature.
6. Equal distribution and social justice should be taken care of.
7. The development process must be participatory from all section of people.
8. All development process must be intrigrated and co-ordinated.

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ENVIRONMENTAL SUSTAINABILITY:

The only hope is that if we reduce or stop further CFC emission, so that the environmental sustainability control of the future generation. At first CFC emission, in due course the problem would probably or possibly be solved by nature's own capacity for regeneration. And second, while science and technology can offer economically viable solutions to small-scale environmental problems, such as those for treating municipal waste water or restoring relatively small areas of contaminated land, they cannot be applied to solve large-scale or global manmade problem, or to alleviate their achieve global environmental sustainability.

SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL SUSTAINABILITY

Unfortunately, experience shows that in the environmental community there are many who do not understand the true meaning of sustainable development. In addition, the environmental community must discharge its collective professional responsibility in ways that are consistent with the core requirements of sustainable development and global environmental sustainability.

ROLE OF SCIENCE AND TECHNOLOGY IN DELIVERING ENVIRONMENTAL SUSTAINABILITY

There is a strong belief in the international scientific community that the environmental problems can be solved and sustainable development and global environmental sustainability achieved only with the application of science

and technology alone. But the progress towards sustainable development is dependent upon a fundamental change in society's attitude to nature and the environment. It is only with such enlightenment that the affluent would be willing to adopt less consumptive life styles commensurate with the Earth's ecological capacity. Science and technology, however advanced cannot help in their matter. Hence, what is needed to bring about their change of altitude is education in moral and ethical philosophy. In the young minds, it is essential to reinforce the environment-respecting moral values.

CONTRIBUTION OF SCIENCE AND TECHNOLOGY

An analysis would show that the main contribution of science and technology to environmental protection has been in two distinct areas. First alerting us to potential or manifest environmental problems. For example it is through science that the global impacts of some of our polluting activities have been discovered mainly in terms of qualitative Couse effect relationships. Typically, it was though science that CFC emissions were found to be the cause of stratospheric ozone depletion. Once a scientifically sound cause-effect relationship in established, appropriate measures (such as the Montreal protocol in the case of ozone depletion) may be taken up by the international community to modify our lifestyle environmental degradation. However, neither science nor technology can be applied to repair the damage already caused. For example, neither can offer an economically viable method of stratospheric ozone layer to its pristine state.

SUSTAINABLE DEVELOPMENT THOUGH SCIENCE AND TECHNOLOGY

It is very hard to find any aspect of modern life untouched by science and technology. Directly or indirectly they have brought immense benefits to human societies, and it has given us the means to understand how the physical world around us works. The impacts of science and technology are determined by how they are applied, why they are applied, and whether or not we choose to apply them in the first place. As for the natural environment is concerned, whether they turn out to be good or bad is determined by their environmental impacts.

Following the industrial revolution economic development though industrialisation based on science and technology become the norm. But in the international organisations such as World Bank and international monetary fund, environmental degradation is considered as the norm.

Science and technology have brought immense benefits. However we are paying a high 'price' for it terms of environmental degradation and the 'price' is escalating to thwart the achievement of even a modest degree of globally sustainable development. And this has serious implications for future generations.

SOLVE THE LIMITS OF SUSTAINABILITY

Compelled to conclude that although science and technology can help the process of sustainable development and global environmental sustainability in a limited way, they cannot deliver them. Science and technology are exclusively concerned with treating the effluent and not the cause. Hence, this conventional approach, which focuses only on symptoms, cannot bring meaningful progress towards global sustainable development.

CONCLUSION

If the science and technology can deliver sustainable development, then the rich developed countries should be the most sustainable on the country, they are the biggest consumer and polluters. For example, USA with 4.5% of World's population, it consumers an estimated 25% of the World's resources and produces an estimated 26% of global pollution. Such a nation cannot be said to be sustainable. So, it is clear that sustainable development is economic development that exclusively relies upon and is firmly rooted in the integrity and sustainability of the natural environment.

CONFLICT OF INTEREST: None

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ORIGINAL ARTICLE

Role of Roof – top Water Harvesting to Manage Drought in Bankura District of West Bengal

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ABSTRACT

In the present work, draught prone region of Bankura district is selected for the analysis of feasibility and sustainability in developing participatory and coordinated systems of roof-top water harvesting. In the present study area, subsurface sources of water are not equally accessible to all. Withdrawal of subsurface water requires huge investment and technology to get access to deeper aquifers. Dug wells at shallow aquifers become dry in lean season and most of them have to experience the hardship of collecting water. A detailed survey with structured questionnaire is made for analyzing the extent of problem and to estimate the demand for water per household per day through the assessment of adult and minor constituents of population, family composition etc. The feasibility of roof top water collection is assessed through examining construction-materials of roofs and calculating the daily yield of water-discharge from roof top of average size (calculated from sample survey) in relation to daily rainfall as an average of past 35 years (1969-1991; 1995-1996; 2006-2011). Survey shows that as much as 83% of surveyed houses have either tin, tiles, asbestos or cement roof, having a yielding capacity of more than 90%. The daily amount of water yield from roof top and that of daily demand are plotted in a graph to construct Mass Curve for calculating the reservoir size for a family of four members to meet average demand in dry period Mass curves are constructed by plotting cumulative demand of domestic water for drinking and cooking (60 L/Household/Day) and cumulative supply from the average roof top of 10mx5m size from average daily rain. Considering the possibility of climatic fluctuation, the effective reservoir sizes are designed to meet the demand of worst drought in certain recurrence interval. Log probability analysis shows that the reservoir size of 4025, 5130, 6445 and 7835 L may serve the demand that may recur at recurrence interval of 2, 5, 20, 50 and 100 years.

INTRODUCTION

In the context of global climatic change, irregularities and concentration of rainfall seem to be spectacular and important in controlling regional hydrology in general and water availability in particular. Intergovernmental Panel on Climate Change (IPCC) predicts that by 2025, 1800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions. In India per capita availability of freshwater was 1816 m^3 in 2001 and that has been reduced to 1588 m^3 in 2010 due increase in population and decline in freshwater availability. According to CWC (2010) total estimated utilisable water in India is 1123 BCM of which Surface water amounts to 690 BCM and Ground water is of 433 BCM. Projected water demand from different sectors shows that by 2050, India will come under absolutely water deficit condition. In these circumstances, it is essential to formulate strategy to be adopted by the communities for building resilience to cope with the situation. Rain water harvesting is the best among the alternative options to manage water scarcity in the potential water scarcity regions (Myres, 1967; Rao, (2007).

The term water harvesting refers to collection and storage of natural precipitation. It also involves other activities for prevention of losses through evaporation and seepage and incorporates all other hydrological studies and engineering interventions, aimed at conservation and efficient utilization of the limited water endowment of a physiographic unit, such as a watershed.

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The term Rain Water Harvesting refers to direct collection of precipitation falling on the roof or onto the ground within passing through the stage of surface runoff on land (Athavale, 1991, 2001 & 2003). To mitigate the hardship of residential population due to water crisis, the best and cost-effective method may be the roof-top water harvesting (Babu, R. A., 2007 and Muralidharan. D., 2007). In the hilly regions roof top water harvesting is carried out traditionally and it is a significant alternate source of water (Pandey, 2002; Moitra Maiti, 2008; Mishra et al 2007).

In the present work, attempt has been made to analyse the feasibility and effectiveness of roof-top water harvesting in an attempt to formulate a strategy for water management at domestic units through community participation in an area that presently suffers from acute water scarcity and may also experience intense crisis in future. Specific objective of the present work is to calculate the rational reservoir size for a standard family considering average roof size, average rain, amount of water demand and probability of drought.

STUDY AREA

Hirbandh, the western most block of Bankura district running along the border of Purulia district, is selected for the present study. On an average, the elevation of the region ranges from180 to 120 m with an average gradient of 1:100. Geographically the area is situated on the wide interfluve between the river Shilabati and Knagsabati. The concerned area represents the undulating topography and considerable gradient that favours easy drainage and soil erosion thus belongs to the soil and water source zone of the Shilaboti drainage basin. The hypsometric analysis shows the younger stage of erosion indicating huge potentiality of further

erosion. The concerned area falls in the drainage basin of an unnamed right hand tributary of the river Silabati and the drainage systems are mainly composed of first order seasonal streams. This region experiences sheet wash where rain drop impact and sheet flow is active for the displacement of matter.

The water divide between the mighty Silabati and Kangsabati suffers from water scarcity for the easy and immediate drainage of both surface and sub surface water down the steep slope just after the rainfall. The sharp increase of water demand due to faster growth of population and improved life style on one hand and no major water storage facility, on the other essentially created the acute crisis. The increased tendency of concentration of annual rainfall in the monsoon months and reduction in the storage of soil water by indiscriminate slope clearing intensify the problem. The crisis becomes acute during dry summer when maximum of the channels and the ponds become dry. The agriculture remains at the rudimentary level entirely depending on the natural supply and without having any irrigation facility. The traditionally practiced gender difference in work participation imposed the responsibility of maintenance of households and collection of water to women sector and thus they have to suffer more than their male counterpart. People, specially women have to cover longer distance to collect water from remote sources. The social and economic processes are disturbed as they have to spend a long time for water collection. During acute crisis period, almost all the villagers are gathered at one or two alive but almost dying ponds for bathing, sanitation and washing. Huge pollutant pools make the water non-suitable for use in the ponds.

MATERIALS AND METHODS

Primary data on the population composition, rate of increase, damand of water for domestic use specially cooking and drinking, roof size, roof composition etc. are collected by surveying 231 sample households with structured questionnaire from 16 villages. Samples are selected randomly from different social and economic strata. Secondary data on daily rainfall and temperature for duration of 35 years (1969-1991; 1995-1996; 2006-2011) is collected from IMD, Pune. Collected data are analysed by SPSS software.

The necessity of roof-top water harvesting is examined through

- The study of water demand of a family through intensive field survey with structured questionnaire,
- The source of water and distance during normal period and that in crisis period and the hardship involved in collection of water from distant sources are studied in details.

The scope of roof-top water harvesting is examined through

- The study of constituent materials of houses specially the roofs.
- Roof sizes of the houses are measured during field study to get the average roof size for calculating yield of water from a rain of certain intensity

The feasibility study is made through quantification of water yield and required reservoir size

- The yield of water for every rainy day from average roof top is calculated for a duration of last 35 years (1969-1991; 1995-1996; 2006-2011) considering a loss of 10% during conveyance.
- Mass curves for last 35 years (1969-1991; 1995-1996; 2006-2011) are constructed after Weiner and Matthews, 2007 for calculating the size of reservoir for each of these years sufficient to store water for a family with an average demand of 60 L per day.
- Considering the variability of rainfall, the reservoir sizes sufficient for the drought of a 5, 20 and 100 years' recurrence interval were calculated following log probability law after Chow (1954, 1964) & Schwab (2002).

RESULT

Month-wise Average Rainfall Distribution

The analyses of rainfall data confirm the concentric character of the monsoonal rain. Daily rainfall data of past 35 years available from IMD (1969-1991; 1995-1996; 2006-2011) shows that about 79% rain is received in the monsoon months during June to September. Some moderate amount of rain is received in May (92mm) and October (81mm) as pre and post-monsoon rain respectively. The dry period of six months (November - April) receives very meagre amount of rain (Fig. 1). This seasonal concentration is mainly responsible for water scarcity.

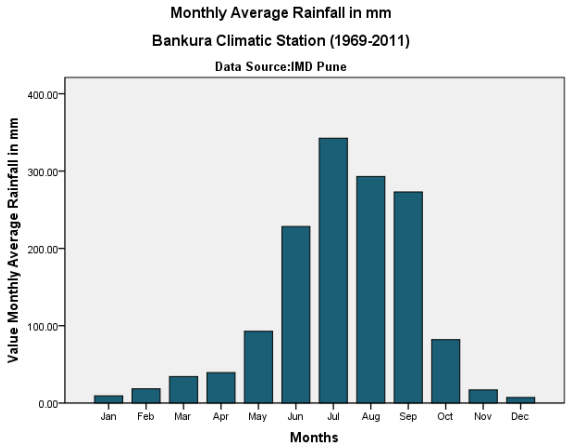

Fig. 1: Average monthly distribution of rain

Distribution of Rain in Dry and Wet Period

It is essential to understand the distribution of rain in wet and dry period (Linsey et al.1982). The period from June-October is considered as the wet period. Analysis shows that a major share (ranging from 70 to 91%) of annual rain is received in this period of five months. Again 16.44% of annual rain is concentrated to a single storm of average 7-8 days. Prolonged dry period of 7 months receives very meagre amount of rain that may be as low as 9% of the annual total (i.e. in 1984; Fig. 2). Rain in the dry period are so less that in maximum cases almost all the rain received are either evaporated or adsorbed by vegetation or soil and are dried down in the next day. So, the rain water in the wet season is the effective input that is to be retained in situ for availability in longer dry period.

Concentration of Rain in Few Intensive Storms

Concentrated Rain in storms of few days' duration is one of the main characters of rain in the area under study (Moitra Maiti, 2008). This tendency is increasing at present, may be due to global warming (Fig. 3). Rain is increasingly associated to such extreme events. This rain may amounts to even 643 mm being concentrated within eight days (August

27-30, 1987-88). Almost every year since 1969, experiences such concentration of rain in storm periods that receives on an average 239 mm of rain. Studies on the storm periods of 20 years show that, on an average, 16.44% of annual rain is received within a single storm of 7-8 days' duration. This concentrated rain causes high percentage of surface runoff in saturation condition and this huge immediate runoff causes extreme flood in the lower catchment of the mighty Silabati. Flood at the lower catchment in the Silabati is thus an annual event. This rain of concentrated duration is neither retained in the soil, nor infiltrated down to recharge ground water and so no water is available in prolonged dry period. Rather, it causes enormous soil erosion during this period of concentrated flow. The main challenge of water harvesting is to arrest this concentrated flow of surface runoff arising out of storm-rains of few days' duration (Moitra Maiti et al. 2012, Moitra Maiti, and Maiti, 2009).

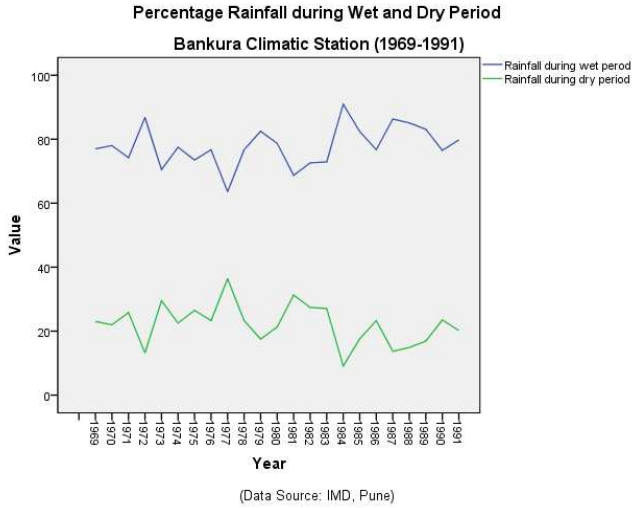

Fig. 2: Distribution of rain in dry and wet season

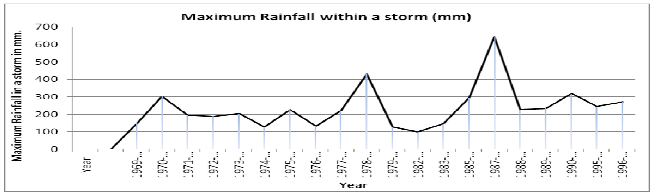

Fig. 3: Concentrated rain received in the storm periods.

Duration of Storm Period

The storm periods may last for 2 to even 18 days (Fig. 4). The contiguous days with some rain is considered as a storm generated mainly by low pressure situation. Almost all the rain of the study area is of cyclonic nature. Effective watershed management should adsorb the rain received in those days for making available in dry period.

Characters of Dry Periods

Analyses of the daily rainfall data reveals that the stretch of continuous duration of no rain i.e. the dry spell varies from 25 days to 88 days with an average of 62 days. That means any effective management should have the arrangements for water supply for at least 3 months in the area under study.

Probability of Rain in Dry Period

Probability of rain in dry period since 1969 was calculated (Table 2) and are arranged in descending order for calculating return period after Gumbel's law (1954). On an average, 323 mm of rain may be expected within this period of 7 months. This rain has a huge variability characterised by the value of standard deviation 102 mm. The rain of 513mm may occur at a recurrence of 24 years and that of 493mm may recur at every 12 years.

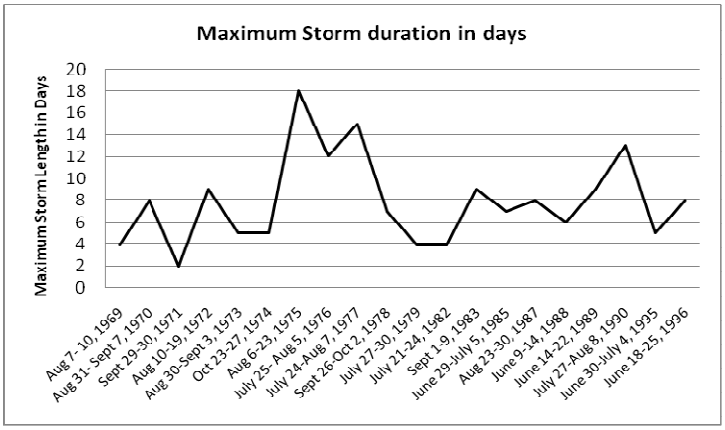

Fig 4: Storm duration in days since 1969

For the better understanding of the recurrence interval of such prolonged dry period and to propose long-term management plan, Log-Probability analysis seems to be important following Chow (1954) and Schwab et al. (2002). Analysis shows that a maximum drought length of 95 days may recur at 20 years' recurrence interval at 5% probability. This length may be 115 days at 100 years' recurrence interval (Table 1).

Table 1: Drought duration at certain recurrence intervals

Calculation of Magnitude of Droughts in Days			
P (%)	T (Years)	K (Frequency factor)	Xc (Magnitude of Drought Length in Days)
99	1.01	-1.633	31.43
50	2	-0.141	58.84
20	5	0.742	75.05
5	20	1.837	95.168
1	100	2.922	115.1

Roof-top Water Harvesting

Roof-Top water harvesting may be an efficient management of water scarcity in the area of concern. This area receives sufficient water as rain, but due to inefficient retention, water scarcity results. The feasibility of roof top water collection is assessed through examining construction-materials of roofs and calculating the daily yield of water-discharge from roof top of average size of 10m X 5m (calculated from sample survey) in relation to daily rainfall. The daily amount of water yield from roof top and that of daily demand are plotted in a graph to construct Mass Curve for calculating the reservoir size for a household. The average household demand in the study area is calculated from the data collected from field survey. The demand per day per household for drinking and cooking is 63.3L. It is considered to be 60L for the convenience of calculation. Considering the possibility of climatic fluctuation, the effective reservoir size has to be designed to meet the demand of worst drought in 20 years.

Roof size

It is essential to analyse the roof size as the discharge yield from a roof depends on its size. Survey shows a greater

variation in the size of the roofs. Among the results, the size of 10m X 5m seems to be the best representative of the study area. In all the calculations this size is considered. A loss of 10% discharge is considered during conveying from roof to reservoir.

Table 2: Rain during dry period

Year	Rainfall in dry period(mm) [Oct-May]	Calculation of Return period after Gumbel (1954)	
		Rank in descending order	Return periods in Year (T)
1969	262.1	18	1.333333333
1970	321.5	10	2.4
1971	493.7	2	12
1972	152.6	23	1.043478261
1973	449.6	5	4.8
1974	311	11	2.181818182
1975	303.7	12	2
1976	204.5	21	1.142857143
1977	513.4	1	24
1978	462.4	4	6
1979	208.14	20	1.2
1980	271	15	1.6
1981	393	7	3.428571429
1982	299	13	1.846153846
1983	367.8	8	3
1984	166.94	22	1.090909091
1985	262.6	17	1.411764706
1986	338.2	9	2.666666667
1987	267.4	16	1.5
1988	221.9	19	1.263157895
1989	296.17	14	1.714285714
1990	472.83	3	8
1991	409.6	6	4
Mean 323.8730435			
Standard deviation 102.9423203			
Variance 10597.12132			
Skewness 0.284470893			
Kurtosis -0.868472351			
(Coefficient of Variation) Cv 0.32			

Constituent materials of Roof

Intensive household survey shows that a considerable percentage of the roofs are constituted of tin, tiles, asbestos or cement. The percentage ranges from 83-25%. These materials yield sufficient discharge from rain and are suitable for roof-top water harvesting (Table 3).

Table 3: Constituent Materials of roof

Name of Villages	Roof (in percent)					Roof Suitable for Rain Water Harvesting
	Thatch	*Tin*	*Tiles*	*Asbestos*	*Cement*	
Elora	28.57	*21.43*	*35.72*	*7.14*	*7.14*	*71.43*
Sahardih	37.5	*37.5*	*25*	*0*	*0*	*62.5*
Palashboni	60	*20*	*0*	*20*	*0*	*40*
Deulbera	75	*0*	*25*	*0*	*0*	*25*
Bonsal (Nanda)	33.3	*0*	*33.3*	*0*	*33.3*	*66.6*
Kadia	20	*50*	*20*	*10*	*0*	*80*
Fatepur	37.5	*12.5*	*37.5*	*12.5*	*0*	*62.5*
Gopalpur	16.66	*25*	*25*	*0*	*33.34*	*83.34*
Lachipur	25	*37.5*	*18.75*	*0*	*18.75*	*75*
Batikara	50	*15*	*20*	*0*	*15*	*50*
Dhanalangi	28.13	*28.13*	*28.13*	*12.5*	*3.11*	*71.87*
Tilabaid	57.14	*28.57*	*14.29*	*0*	*0*	*42.86*
Dhaibari	66.66	*33.34*	*0*	*0*	*0*	*33.34*
Saluipahari	28.57	*14.29*	*0*	*14.29*	*42.86*	*71.44*
Bansa	33.33	*16.67*	*0*	*0*	*50*	*66.67*
Bhimpur	40	*40*	*0*	*20*	*0*	*60*

Water demand per household

Demand of water per household for drinking and cooking is estimated by survey with structured questionnaire. The demand varies from village to village. On an average, a household requires 63.3 L of water for the purpose of drinking and cooking. The demand for washing and bathing could not be estimated as they perform those activities in the ponds in a sharing basis. For the purpose of further calculations, the demand of 60 L per household per day is considered.

Estimation of Reservoir Size

Average Daily Rain since 1969

For further calculation of rain water harvesting, daily rainfall of 31years since 1969 has been considered. Daily rainfall recorded during this period has been made total and divided with the duration to get expected rain on the date concerned. This result has been used for calculating reservoir size.

Construction of Mass Curve

Mass curves are constructed by plotting cumulative demand of domestic water for drinking and cooking (60 L/Household/Day) and cumulative supply from the average roof top of 10mx5m size from average daily rain since 1969. As there is continuity in inflow and outflow of water in the reservoir system by supply from rooftop and use for domestic purpose respectively, cumulative of supply and demand is considered. One Mass Curve (Fig. 5) is drawn on the basis of the mean rainfall of 35 years. The graph shows deficit of water in dry period and surplus of it in rainy

period. The amount of deficit in each year is calculated in table 4. If the maximum deficit amount is stored, it can serve the purpose for rest of the period.

Table 4 Maximum deficit with their corresponding dates

Year	Date(MM/DD/YY)	Highest Deficit in L
1969	3/19/1969	2889
1970	05/08/1970	5446
1971	04/07/1971	2913
1972	06/12/1972	6244
1973	03/01/1973	3150
1974	3/24/1974	4606
1975	4/20/1975	3063
1976	05/07/1976	5740
1977	3/25/1977	3510
1978	03/11/1978	2980
1979	06/08/1979	5044
1980	05/11/1980	5053
1981	1/31/1981	1860
1982	03/01/1982	3222
1983	04/09/1983	3537
1984	04/04/1984	4496
1985	05/07/1985	2544
1986	6/15/1986	5890
1987	4/25/1987	5955
1988	05/12/1988	2980
1989	5/13/1989	7206
1990	2/18/1990	2940
1991	3/13/1991	3396
1995	05/07/1995	4360
1996	4/21/1996	2355
2006	4/13/2006	2594
2007	4/24/2007	4257
2008	05/02/2008	6079
2009	05/02/2009	5777
2010	4/27/2010	5385
2011	04/04/2011	4628
Mean		4196
SD		1229.69
Coefficient of Variation (C_v)		0.293

In hydrology the concept of average does not yield fruitful result. For that purpose analysis is made on available daily rainfall data of each year (Table 4). If the decision of reservoir size is taken based on the average deficit of the past years the value becomes 4196 L. This amount will not serve the purpose for more than half of the years. So Log Probability analysis is made to calculate the deficit amount that may arise at recurrence interval of 2, 5, 20, 50 and 100 years using the equation 1. The calculation shows that deficit may become 4025, 5130, 6445 and 7835 L at recurrence interval of 2, 5, 20, 50 and 100 years respectively (Table 5).

X_c= Mean (1+ C_v.K) ------- Eq. 1

(Chow, 1954 and Schwab et al. 2002)

Table 5 Rational Reservoir sizes for different recurrence interval.

Year (Recurrence Interval)	1.01	2	5	20	100
P (%)	99	50	20	5	1
K (After Chow, 1954)	-1.738	-0.139	0.76	1.83	2.96
Xc (Reservoir Size in L)	2059	4025	5130	6445	7835

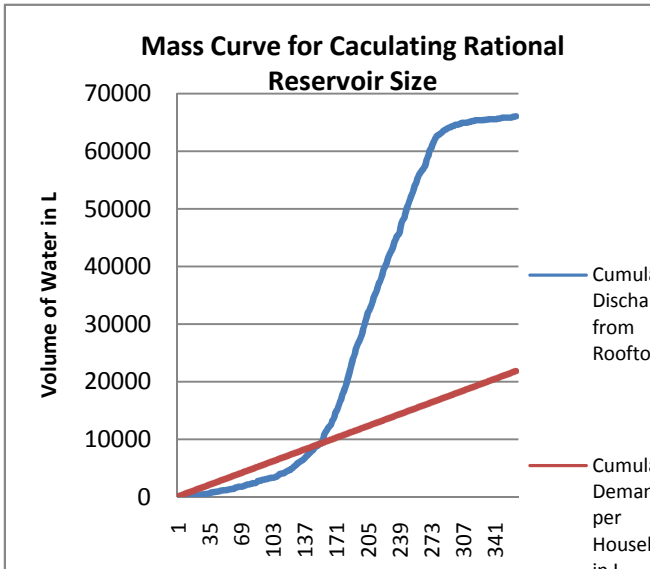

Fig. 5 Mass Curve on the Mean value of 35years Rainfall Data

CONCLUSION

The study reveals that in spite of receiving sufficient rainfall, the region suffers from water scarcity due to lack of proper initiative of retention. Based on decentralised participatory approach targeting at household units, roof top water harvesting may be effective in building resilience against irregular and concentrated rain and resulted water scarcity in the context of global climatic change. Only a reservoir at domestic unit storing a portion of discharge (90%) from the roof top may ensure the supply of total year-long domestic demand. Reservoir may be built either of polythene tank (Myres, 1967) or concrete. These may be set on the open courtyard available at each domestic unit in the area under study. Excess discharge from the reservoir may be directed to recharge underground water table and proper care must be taken to avoid contamination. A recharge pit of considerable size has to be constructed up to a depth of 6-8ft beyond lateritic hard pan. For constructing recharge pit, an elevated place must be chosen away from open toilet and a cemented dyke surrounding it has to be constructed to avoid surface and seepage flow of contaminated water from toilet or waste water drain.

Over all, efficient water management in such drought-prone area must ensure community participation; only initiatives from government may not yield any success. The present

practice of state's responsibility of water management has to be changed and community participation in water management must be practiced. Roof-top water harvesting may be initiated as a pilot project at every government school and office buildings to make people aware of the benefits and necessity of it. Again financial assistance from government may be extended as an attempt to encourage local people in adopting rooftop water harvesting as an effective instrument for fighting climate change and water scarcity.

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ORIGINAL ARTICLE

Ichthyofaunal diversity of Keleghai river at Medinipur district in West Bengal

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ABSTRACT

During the study period we recorded 20 species of fish from 9 Order, 17 Families and 20 Genera. Among the collected species Order Perciformes is the most dominant group contributing 30%, Cypriniformes 15%, Siluriformes 25% and Clupeiformes, Cyprinidontiformes, Osteoglossiformes, Ophiocephaliformes, Mastacembeliformes and Synbranchiformes each with 5% of the total species. Order Siluriformes contributed 5 Families to the total species, followed by Perciformes 4, Cypriniformes 2 and Cyprinidondiformes, Clupeiformes, Osteoglossiformes, Mastacembeliformes and Synbranchiformes each with 1 Family. Among the Genera, 3 are from Cypriniformes, 6 are from Perciformes, 5 are from Siluriformes and 1 from Cyprinidontiformes, Clupeiformes, Osteoglossiformes, Mastacembeliformes, Ophiocephaliformes and Synbranchiformes.

INTRODUCTION

Fishes form the most diverse and protean group of vertebrates; fishes are a treasured source both in terms of utility as food and as material for scientific study. [1] Fish are often a key element in environmental planning [2] and they appear to be good indicators of the status of aquatic environments. [3] In addition to being an important, palatable food item for human consumption, they are part of aquatic food chain, nutrient cycling and ecosystem services. Fish also generate employment, function as a genetic library for possible future use in medicine and aquaculture, stimulate human interest in nature, and provide aesthetic and recreational values. Ichthyofaunal diversity refers to variety of fish species; depending on context and scale, it could refer to alleles or genotypes within piscian population, to species of life forms within a fish community, and to species of life forms across aquaregimes. Fish biodiversity of river essentially represents the fish faunal diversity and their abundance. River conserves a rich variety of fish species which support to the commercial fisheries.

There are many rivers in West Bengal, one of these is Keleghai. Keleghai River originates at Baminigram, near Dudhkundi, under Sankrail police station, in Jhargram subdivision of Paschim Medinipur district in the Indian state of West Bengal. It flows past Keshiari, Narayangarh, Sabang and Patashpur to join the Kasai at Tangrakhali under Mahisadal police station of Purba Medinipur district. Keleghai River is geographically coordinates are 22^0 12′ North & 87^0 66′ East. It is 121 kilometres (75 mi) long.

STUDY AREA

Table 1: Study site

Sl. No.	Name of the sampling site	Distance (Km)
1.	Kalidahachara	3.5
2.	Paschimbarh	
3	Shiulipur	4.0

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MATERIALS & METHOD

The periodical survey of the ichthyofauna of the Keleghai was conducted for a period of 5 months (from January 2015-May 2015). Data were collected from three regions of the Keleghai river namely Kalidahachara, Paschimbarh, Shiulipur. Information about the fishes were collected from the local fishermen also collected from local fish markets located on the banks of the river. Immediately photographs were taken for the identification of fishes. Fishes were preserved in the Dept. of Zoology, Raja N. L. Khan Women's College for future research.

RESULT

During the study period we recorded 20 species of fish from 9 orders, 17 Families and 20 Genera. Among the collected species Order Perciformes is the most dominant group contributing 30%, Cypriniformes 15%, Siluriformes 25% and Clupeiformes, Cyprinidontiformes, Osteoglossiformes, Ophiocephaliformes, Mastacembeliformes and Synbran-chiformes each with 5% , of the total species. Order Siluriformes contributed 5 Families to the total species, followed by Perciformes 4, Cypriniformes 2 and Cyprinidondiformes, Clupeiformes, Osteoglossiformes, Mastacembeliformes and Synbranchiformes each with 1 Family. Among the Genera, 3 are from Cypriniformes, 6 are from Perciformes, 5 are from Siluriformes and 1 from Cyprinidontiformes, Clupeiformes, Osteoglossiformes, Mastacembeliformes, Ophiocephaliformes and Synbranchiformes.

The results revealed that, 10 species are found abundant, 7 are moderately found, 3 are rarely found in the river. Among the fish recorded 18 species are food fish, 11 species are ornamental value and 2 species are use in aquaculture. According to the CAMP (Conservation Assessment and Management Plan) And IUCN Red List categories, 2 are Near Threatened (NT), 2 are Not Evaluated (NE), 2 are Data Deficient (DD) and 14 are Least Concern (LC) ,Vulnerable (VU) and Endangered (EN) species are absent.

CONCLUSION

The present investigation thus helps to understand the ichthyofaunal diversity in river Keleghai. The river is very rich in food fish than ornamental fish. The result of the

present study revealed that, river Keleghai is the resources of rich and diversified fish fauna. However, fish diversity of this river is in declining mode due to several anthropogenic threats. During the period of survey, different types of crafts and gears were observed. In order to conserve these valuable resources, a holistic approach, integrating the concept of sustainable development and conservation measures should be measured. Present study provides a comprehensive data on biodiversity, conservation status and the gene pool of unique ichthyofauna of this river.

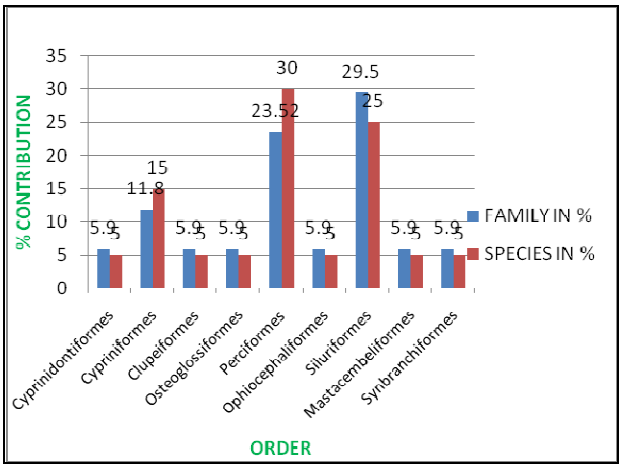

Fig 1: Percentage contribution of Family &Species under various Orders

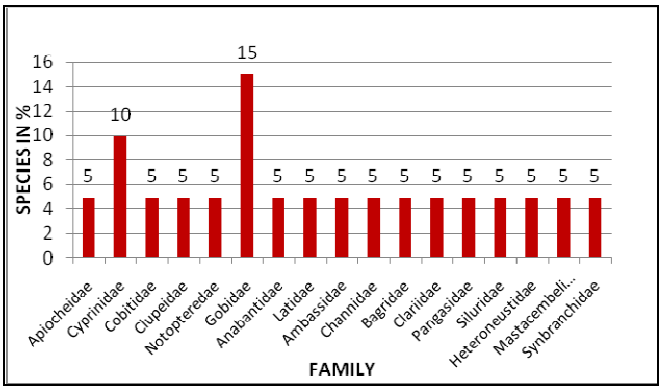

Fig 2: Percentage representation of a available species at Familly level in Keleghai river

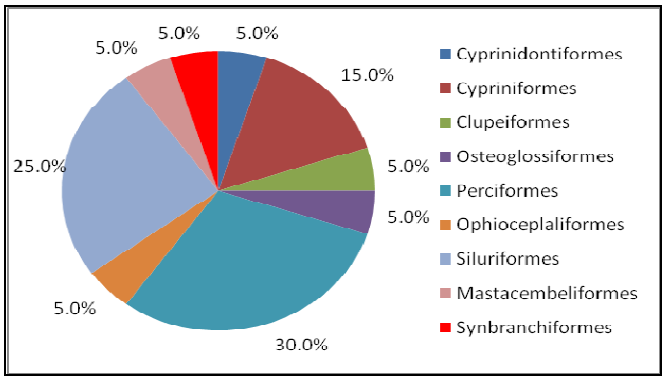

Fig 3 :Percentage representation of species at Order level in River Keleghai.

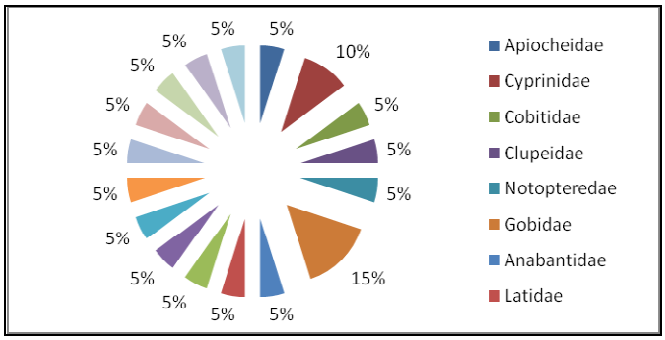

Fig 4: Percentage representation of species at family level in river Keleghai

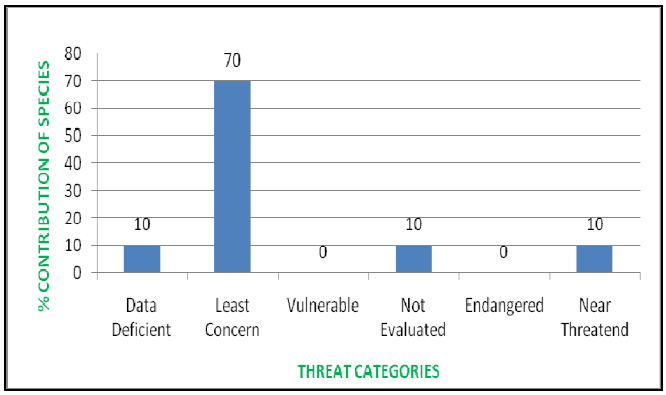

Fig 5: Percentage contribution of species under various Threat categories of CAMP & IUCN Red list.

Table 2: Fish species their Scientific name, Local name, Human use, Feeding habitat and Conservation status in Keleghai river.

Order	Familly	Sl. No.	*Scientific name*	Local name	IUCN	Human use	Feeding habitat
Cyprinidontiformes	Aplocheidae	1	*Aplocheilus panchax*	Kanapona	DD	Commercial	Herbivore
	Cyprinadae	2	*Salmostoma bacaila*	Chela	LC	Commercial	Herbivore
Cypriniformes		3	*Esomus danricus*	Darke	LC	Commercial	Herbivore
	Cobitidae	4	*Lepidosephalichthys guntea*	Guntey	LC	Commercial	Omnivore
Clupeiformes	Clupeidae	5	*Gudusia chapra*	Khaira	LC	Commercial	Herbivore
Osteoglossiformes	Notopteredae	6	*Nopterus notopterus*	Phulai	LC	Ornamental Aquaculture	Carnivore
		7	*Glossogobius giuris giuris*	Bele	LC	Ornamental Commercial	Omnivore
	Gobidae	8	*Pseudoapocryptes lanceolatus*	Chewa	LC	Commercial	Omnivore

Ichthyofaunal diversity of Keleghai river at Medinipur district in West Bengal

Order	Familly	Sl. No.	*Scientific name*	Local name	IUCN	Human use	Feeding habitat
Perciformes		9	*Odontamblyous rubicundus*	Lal cewa	LC	Commercial	Omnivore
	Anabantidae	10	*Anabus testudineus*	Koi	DD	Ornamental Commercial	Omnivore
	Latidae	11	*Lates calcarifer*	Bhetki	NE	Commercial	Carnivore
	Ambassidae	12	*Chanda ranga*	Chanda	NE	Ornamental Commercial	Omnivore
Ophiocephaliformes	Channidae	13	*Channa punctata*	Lata	LC	Ornamental Aquaculture	Carnivore
	Bagridae	14	*Mystus vittatus*	Tangra	LC	Ornamental Commercial	Carnivore
	Clariidae	15	*Clarias batracus*	Magur	LC	Ornamental Commercial	Carnivore
Siluriformes	Pangasidae	16	*Pangasius pangasius*	Pangus	LC	Ornamental Commercial	Carnivore
	Siluridae	17	*Wallago attu*	Boal	NT	Commercial	Carnivore
	Heteropneustidae	18	*Heteropneustes fossilis*	Singi	LC	Ornamental	Carnivore
		19	*Mastacembelus armatus armatus*	Pankal	NT	Commercial Ornamental	Omnivore
Mastacembeliformes	Mastacembelidae					Commercial	
Synbrachiformes	Synbranchidae	20	*Amphipnous cuchia*	Cuchia	LC	Commercial	Carnivore

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