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Flow of chemical energy in Alwar jheel of Yamuna basin near Allahabad

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Abstract: *The water quality, rate of energy transformation, chemical composition of producers and flow of chemical energy were studied in both feeding river Yamuna and Alwar jheel near Allahabad. As the river Yamuna had high value of alkalinity (210.0 mgl^{-1}), conductance (518.0 μmhos), dissolved solids (260.0 mgl^{-1}), hardness (162.0 mgl^{-1}) and chloride (54.6 mgl^{-1}) jheel also showed high values of these parameters. The rate of energy transformation from kinetic radiant energy to chemical energy was very high in the jheel 32,315 Cal m^{-2} day^{-1} of which 25,620 Cal m^{-2}day^{-1} was contributed by aquatic plants. Out of 11,764 x 10^{4} Kcal ha^{-1} yr^{-1} total energy fixed in the system, producers stored 7,154 x 10^{4} Kcal ha^{-1} yr^{-1} and the rest was lost as heat of respiration. The pattern of storage of energy was different in two groups of producers and thus most of the energy fixed by phytoplankton was stored as protein (56.2%) and less as carbohydrate (11.7%) while aquatic plants stored more energy as carbohydrate (40.8%) than protein (23.2%). The chemical energy obtained from the system was 1,85,000 Kcal ha^{-1} yr^{-1} and thus only 0.260% of the chemical energy stored by producers was harvested. The potential chemical energy resource in the jheel was 81.4 x 10^{4} Kcal ha^{-1} yr^{-1} of which only 22.6% was harvested in the jheel and there is enough scope for further enhancement.*

Key words: *Environmental degradation, Chemical composition, Energy transformation, Photosynthetic efficiency.*

Introduction

The energy source of all organisms on the earth is Sun, which releases energy, as pulsating field of electromagnetic waves by nuclear transmutation of hydrogen to helium. A small fraction of this kinetic radiant energy is captured by chlorophyll bearing organisms and transformed into potential chemical energy through photosynthetic redox reactions. The redox process, in which water is oxidized to oxygen and carbon dioxide is reduced to carbohydrate, is endergonic in nature requiring chemical energy and consequently plants can store large amount of energy through this process. In the presence of nutrients, the carbohydrate synthesized by producers, during photosynthesis, is transformed into other energy rich organic compounds mainly proteins. In fact, the chemical energy stored by one group of organisms forms the energy source for the other organisms which consume them as food. When organic compounds are taken by animals from producers or predators they are broken into simple compounds (basic units) and the liberated energy is used for various metabolic activities. Some amount of energy is again stored by the animal as the basic organic compounds of the tissue. Thus, the flow of energy through an ecosystem is nothing but transfer of stored chemical energy (as protein, fat and carbohydrate) from one compartment to the other. The flow of energy in different aquatic systems has been studied by many workers (Ganapati and Sreenivasan, 1970; Haniffa and Pandian, 1978; Natrajan and Pathak, 1980; Pathak *et al.*, 1985; Pathak, 1990; Pathak *et al.,* 2001; Sreenivasan, 1972). Several workers have attempted to draw energy flow models in lakes and reservoirs (Lindeman, 1942; Clark, 1946; Juday, 1940; Odum, 1957; Odem, 1962; Teal, 1962). The present communication is an attempt to throw light on the water quality, rate of transformation of solar radiant energy into chemical energy, chemical composition of chlorophyll bearing organisms and patterns of utilization of chemical energy in a jheel connected with Yamuna river near Allahabad, Uttar Pradesh.

Materials and Methods

Water samples were collected from both feeding river Yamuna and Alwar jheel near Allahabad four times in a year on seasonal basis (January-March, April-June, July-September and October-December). The samples were analyzed by following standard methods (APHA, 1989; Strickland and Parson 1960). Rate of carbon synthesis by phytoplankton was studied by using dark and light bottle technique, that by macrophytes from diel oxygen curve and the rate of energy fixation was calculated by multiplying carbon values with a factor 9.82, the calories of energy require to fix one milligram of carbon through photosynthesis (Natarajan and Pathak, 1987). Protein was estimated by Folch's biuret method (Raghuramulu *et al.,* 1983). The absorbance of violet complex develop with copper salt in alkaline solution was measured spectrophotometrically at 540 - 550 nm. Carbohydrate estimation was based on the absorbance of green colour complex developed by anthrone in sulphuric acid at 625 nm (Strickland and Parson, 1968). Total lipid content was measured by taking absorbance of the coloured complexes developed with hydroxyl amine and ferric salts (Stern and Shapiro, 1953). Ash content or mineral matter was determined by igniting a known weight of the dried material at high temperature in a silica crucible. The calorific values of plant and fish samples were determined with bomb calorimeter. Wet oxidation with potassium dichromate and concentrated sulphuric acid was also used for energy estimations. Fish catch was collected from various landing centres. Energy harvest from the jheel was calculated by taking the calorific value of 1kg of fish as 1200Kcal. This factor is based on the fact that fish on

Table – 1: Chemical characteristics of feeding river Yamuna and Alwar jheel near Allahabad.

Parameters	River Yamuna		Alwar jheel	
	Range of variation	Mean value	Range of variation	Mean value
Temperature	18.5 – 31.5	25.8	13.0 – 30.5	24.6
Dissolved oxygen	6.8 – 9.0	8.0	6.3 – 8.4	7.6
pH	7.95 – 8.35	8.2	8.2 – 8.4	8.3
Free CO_2 (mgl^{-1})	0.0 – 5.8	2.8	0.0 – 2.0	0.58
Total alkalinity	153.7 – 266.3	210.0	126.0 – 414.0	228.4
Conductance	390.0 – 682.0	518.0	363.0 – 883.0	542.0
Total dissolved solids	195.0 – 341.0	260.0	181.0 – 445.0	272.0
Hardness as $CaCO_3$	137.0 – 202.5	162.0	95.0 – 341.0	180.0
Chloride	48.2 – 58.8	54.6	32.0 – 45.0	38.6
Dissolved organic	0.86 – 2.80	2.12	2.92 – 4.51	3.85
Nitrate	0.032 – 0.22	0.12	0.18 – 0.5	0.32
Phosphate	0.05 – 0.12	0.082	0.15 – 0.231	0.18

All the parameters are in mgl^{-1} except Temp. (°C) and conductance (μmhos).

Table – 2: Seasonal variation in the rate of energy fixation as carbohydrates by producers in alwar jheel.

Seasons	Phytoplankton (Cal $m^{-2}day^{-1}$)		Aquatic plants (Cal $m^{-2}day^{-1}$)		Total (Cal $m^{-2}day^{-1}$)	
	Gross energy	Net energy stored	Gross energy	Net energy stored	Gross energy	Net energy stored
January to March	7,954	5,011	34,842	20,900	42,796	25,911
April to June	9,594	5,564	26,270	20,900	35,864	20,537
July to September	2,980	1,848	11,120	6,894	14,100	8,742
October to December	5,920	3,352	30,246	19,660	36,166	23,012
Average	6,612	3,994	25,620	15,607	32,232	19,601
Annual energy fixed in the system Kcal $ha^{-1}yr^{-1}x\ 10^4$	2,413	1,458	9,351	5,696	11,764	7,154

average contain 18% protein and 2% fat. The same factor has been used by several workers for energy calculations (Sreenivasan, 1972; Natarajan and Pathak, 1987).

Results and Discussion

Water quality: The range and mean values of water quality parameters of feeding river Yamuna and Alwar jheel near Allahabad has been presented in Table 1. Water was invariably alkaline in nature (pH 7.95 to 8.4) with rich oxygen (6.3 – 9.0 mgl^{-1}) in both the systems. The average value of chemical parameters such as alkalinity, conductance, dissolved solids, hardness and chloride were 210.0mgl^{-1}, 518μmhos, 260mgl^{-1}, 162mgl^{-1} and 54.6mgl^{-1} in Yamuna and 228.4mgl^{-1}, 542μmhos, 272.0mgl^{-1}, 180.0mgl^{-1} and 38.6mgl^{-1} in Alwar jheel respectively. The values of above parameters in both the systems were quite comparable. The nutrients, nitrate and phosphate, were comparatively higher in jheel than feeding river. These findings are supported by a comparative study of water quality of a number of jheels in Uttar Pradesh and impact of their feeding rivers (Pathak *et al.,* 2004). The water quality parameters observed in Alwar jheel were found to be much higher than many other jheels of the state clearly indicating thereby, that alkalinity, conductance, dissolved solids, hardness and chloride were all high in the feeding river Yamuna than other feeding rivers. It can thus be concluded that the annual water quality cycle of the jheel was regulated by feeding the river. Waters with rich oxygen (above 5mgl^{-1}) and alkalinity more than 90mgl^{-1}, conductance above 200μmhos, dissolved solids and hardness above 100mgl^{-1} are considered to be good productive (Moyle, 1949; Northcote and Larkin, 1956). As all the above parameters were found to be within much higher range in Alwar jheel it can very well be put under high productive class.

Rate of energy transformation by producers: The rate of energy transformation from solar electromagnetic waves to chemical energy, as carbohydrates, has been presented in Table 2. Out of a total of 32,315Cal$m^{-2}day^{-1}$ fixed by producers, the aquatic plants contributed 25,620Cal$m^{-2}day^{-1}$ and the rest 6,612Cal$m^{-2}day^{-1}$ by phytoplankton. Thus, almost 80% of the total energy fixed was contributed by aquatic plants and 20% only by algae. Poor rate of energy transformation by phytoplankton was because of their low concentration as most of the available nutrients were used and locked by aquatic plants in such waters and phytoplanktons do not get enough nutrients for their growth. Considerable seasonal variations were

Table – 3: Bio-chemical composition of two groups of producers (percentage in dry matter).

Composition	Phytoplankton		Aquatic plants	
	Range of variation	**Mean value**	**Range of variation**	**Mean value**
Protein	45.0 – 66.0	56.2	17.0 – 29.0	23.2
Carbohydrate	4.5 – 17.0	11.7	30.0 – 48.0	40.8
Fat	5.0 – 12.0	9.6	3.0 – 10.0	6.1
Ash (Mineral matter)	17.5 – 25.8	22.5	11.1 – 35.0	29.9

observed in the rate of energy transformation being, maximum during January-March and minimum during July-September. The high rate of energy transformation clearly reveals, that the system has very high potential of energy resource. Similar observations were made in beels of Assam and West Bengal (Pathak, 1990). Studies have shown that out of a total of 32,315Calm^{-2}day^{-1} gross energy fixed by the two groups of producers almost 12,714Calm^{-2}day^{-1} was used for their own metabolic activities and the rest 19,601Calm^{-2}day^{-1} was stored by them as energy rich organic compounds. The annual average of energy fixed and stored by producers in the jheel was 11,764 x 10^{4} and 7,154 x 10^{4} Kcalha^{-1}yr^{-1} respectively.

.**Biochemical composition of producers:** The biochemical composition of two groups of producers has been shown in Table 3. The average protein, fat and carbohydrate were 56.2%, 9.6% and 11.7%, respectively in phytoplankton and 23.21%, 6.11% and 40.8%, respectively in aquatic plants. The mineral matter or ash content was comparatively higher in aquatic plants (29.5%) than phytoplankton (22.5%). These studies clearly show that the storage or assimilation of energy in two types of producers followed separate pathways. Phytoplankton stored most of the energy fixed through photosynthesis as protein and less as carbohydrate while, aquatic plants stored energy more in the form of carbohydrate and less as protein. The assimilation of energy as fat was only 6.1% in macrophytes and 9% in phytoplankton. Studies of photosynthetic products using ^{14}C isotope showed, that approximately 50% of ^{14}C atom fixed by phytoplankton was found in protein after four hours which was not the case with aquatic plants (Bidwell 1957). Observations under present study confirm these findings.

Flow of chemical energy in Alwar jheel: Basically there are two main routes through which the potential chemical energy flows to consumers in the system; one in which the energy is directly used (grazing chain) and the other in which the unused energy is deposited as detritus and detritus energy is used by consumers. The pathway of flow of chemical energy in Alwar jheel has been shown in Fig. 1. The energy value of the total

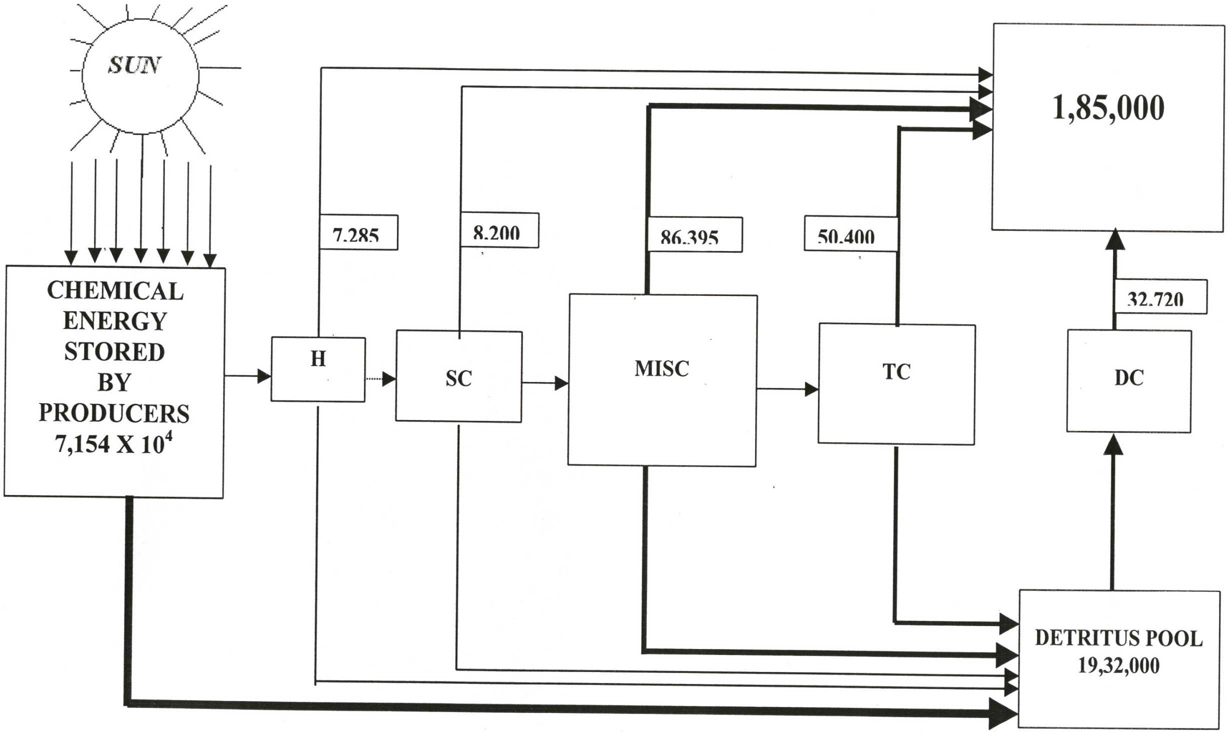

Fig. 1: Flow of energy (K cal ha^{-1} yr^{-1}) in Alwar jheel.
H- Herbivores, SC- Secondary consumers, MISC- Miscellaneous sp., TC- Tertiary consumers, DC- Detritivores

fish harvested form alwar jheel was found to be 1,85,000 Kcalha^{-1}yr^{-1} by taking the calorific value of 1kg of fish as 1200 Kcal (Sreenivasan, 1972; Natarajan and Pathak, 1987). The contribution of fishes, feeding at various trophic levels was 7,285Kcal, 8,200Kcal, 50,400Kcal, 32,720Kcal and 86395Kcal from herbivores, secondary consumers, tertiary consumers, detritus feeders and miscellaneous or uneconomical fishes respectively. The annual potential chemical energy stored by producers was 7,154 x 10^4 Kcal ha^{-1}yr^{-1} (Sreenivasan, 1972; Natarajan and Pathak, 1987) Thus, the conversion from producer energy to energy harvest was 0.26% only. The conversion efficiencies at the above mentioned trophic levels were 0.01%, 0.01%, 0.07%, 0.05% and 0.12% respectively. Thus, almost 73% of the energy harvest was contributed by uneconomical miscellaneous species and tertiary consumer fishes whereas, the plant and detritus feeders fishes in the jheel contributed only 23%.

The production efficiency at any level is the ratio of chemical energy available at that level (λn) and the energy available at the previous level (λm) that is $\lambda n/\lambda m$ X 100. Thus, during the flow of energy the maximum efficiency obtained in a number of aquatic systems was found to be around 10% and in the flow from one level to the other almost 90% of the available chemical energy is lost (Hutchinson, 1957; Slobodkin, 1962; Mann, 1965). This is in accordance with the second law of thermodynamics. The above formula has been used to calculate the fish production potential or the potential energy resource of the aquatic systems having wide spectrum of fishes (Odem, 1975). The potential energy resource of Alwar jheel, estimated by taking 0.5% of chemical energy fixed by producers as energy available at fish level (Natrajan and Pathak 1987), was 81.4 X 10^4 Kcalha^{-1}yr^{-1}. In jheels where the maximum energy stored was contributed by macrophytes, the single channel of energy flow is through detritus (Odem and Smalley, 1959).

The average protein content of a wide spectrum of fishes has been taken as 18% and the calorific value of 1g of protein as 5.6Kcal has been used by many workers (Sreenivasan, 1972; Natarajan and Pathak, 1987; Ganapati and Sreenivasan 1972) for the energy calculation. On this basis the potential energy resource of Alwar jheel in the form of protein comes to 608384 Kcalha^{-1}yr^{-1} and the actual energy harvest to 137267Kcalha^{-1}yr^{-1}. Thus, the conversion efficiency from energy harvest to the potential or protein-to-protein was only 22.6%. The poor conversion efficiency from energy stored by producers to energy harvest (0.26%) or potential to actual (22.6%) clearly reflects that the energy is not properly utilized in the jheel. The dominance of uneconomical fishes or tertiary consumers clearly shows that most of the available energy is going waste and there is enough scope of minimizing the energy loss by building the desired stock and bridging the gap between potential resources and actual harvest. All the energy transformation and utilization processes are dependent on the hydrological status of the jheel. The role of feeding river in regulating the water quality cycle can therefore, not be ignored.

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