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Study of C Dynamics between Mud and Water by the Influence of Physical Raking and Biological Condition Using Radioactive ^{14}C

J. N. Bhakta*, J. K. Biswas and B. B. Jana
Aquaculture and Applied Limnology Research Unit,
Department of Zoology, University of Kalyani,
Kalyani-741 235, West Bengal, India

Abstract : Experiment was performed in the laboratory using radioactive ^{14}C for ascertaining the dynamics and quantifying the exchangeable amount of carbon between sediment and water phase by the influence of physical and biological condition. Collected sediment (100 g) was dispensed in a glass beaker and filled with 250 ml tap water and after one hour each beaker treated with radioactive ^{14}C. Four treatments : physical raking once (RO), repeated raking (RR), bacteria (*Bacillus*, 167×10^2 ml^{-1}) inoculum (BI) and bacteria inoculum (*Bacillus*, 167×10^2 ml^{-1}) plus repeated raking (BI + RR) were used in the study. Water samples were collected and tested for specific activity of radioactive ^{14}C and examined for heterotrophic bacterial (HB) population. The ^{14}C value of BI+RR treatment was 5, 12, 28 and 37% higher than BI, RR, RO and control, respectively. In BI+RR, the concentration of ^{14}C of water also showed minimal decrease (31%) than other treatments. Synergistic effect of bacteria inoculum plus repeated raking (BI + RR) released maximum amount of carbon than that of the rest three treatments.

Critical appraisal of data clearly revealed five dynamic states of ^{14}C between water and sediment : ^{14}C moves to sediment causing rapid fall of ^{14}C level in water from day 0 to 20 - rapid absorption period (RAP) and slow decrease from day >20 to 28 - slow absorption period (SAP), ^{14}C move to water from day >28 to 55 resulting in the slow increase of ^{14}C level in water - desorption period (DP), again the ^{14}C level of water decreased from day >55 to 90 - absorption period (AP) and from day >90 to 124 the ^{14}C concentration became equilibrium in the water and sediment phase possibly due to no movement of ^{14}C - steady period (SP).

Keywords : Radioactive ^{14}C, raking, bacteria inoculum, absorption and desorption, mud-water exchange

Introduction :

Carbon is the critical element regulating the production and dynamics of aquatic ecosystem. Sediment can act as sink of this nutrient in the unfertilized ponds, but it acts as a source of nutrients in the fertilized ponds. An equilibrium exists between the concentration of a substance in the soil and its concentration in the water. As a result, if the concentration in water increases, the soil adsorbs the substance until equilibrium is reestablished. Conversely, if the concentration in water decreases the soil desorbs the substance until the aqueous concentration is again at equilibrium. This equilibrium concentration of nutrient may be too low for optimal phytoplankton growth. It is concluded that more phosphate would be released from the sediment to the overlaying water if the equilibrium is disturbed between the sediment and water (Boyd, 1995). In ponds, the soil involves

* **Corresponding author :** J. N. Bhakta, Aquaculture and Applied Limnology Research Unit, Department of Zoology, University of Kalyani, Kalyani-741 235, West Bengal, India
E-mail : *lsnjbhakta@rediffmail.com*, Tel: 91-033-2580-9212

inputs and losses of substances. There are movement of substances within pond water and soil, transfer of substances across the soil water interface, and uptake or release of substances by the soil through ion exchange, dissolution and decomposition. Adsorption is a three step process whereby the dissolved substance (1) moved by mass movement of water (advection) to the soil surface, (2) diffuses to the layer of water next to soil particles, and (3) attaches to or is adsorbed by the soil surface (Tchobanoglous and Schroeder, 1987). The adsorbed substance is readily desorbed when concentration of the surrounding solution decreases. Pekar and Olah (1998) proposed that radioisotopic tracer methods have been employed in the measurement of different production pathways in manured fish ponds. Several complex ecological processes are investigated by the radioisotopes tracer technique, both to study the pathways and to estimate the levels of exchangeable nutrients between media.

Metabolic activities of microorganisms are critical factors in pond dynamics. Microorganisms use molecular oxygen in oxidizing organic matter to carbon dioxide and ammonia and other mineral nutrients are released. Substances that enter the soil may be stored permanently, or they may be transformed to other substances by physical, chemical or biological means and lost from the pond ecosystem.

Consecutive application of fertilizer in aquaculture ponds has been a major problem of high production cost and may become a source of pollution later due to accumulation of nutrients in sediment. Although several studies have been made to delineate the strategy to increase the mud water exchange of carbon in fish ponds, the same has not been done by physical shearing or raking and biological process. It is, therefore, important to ascertain the level of carbon released from sediment to overlying water. The present investigation is aimed at ascertaining the dynamics and quantifying the exchangeable amount of carbon between sediment and water phase by the influence of physical and biological condition.

Materials and Methods :

Experiment was conducted in the laboratory of the Department of Nuclear Medicine, Indian Institute of Chemical Biology, Calcutta. The experiment used radioactive ^{14}C in the form of $Na_2{}^{14}CO_3$ was collected from the Board of Radiation and Isotope Technology, Department of Atomic Energy, Hydrabad, Government of India.

Fifteen 500 ml beakers were provided with 100 g nutrient rich sediment (pH 7.4) collected from natural fish pond. Each beaker was filled with 250 ml tap water. After one hour period of settlement, 2 ml of the radioactive ^{14}C in the form of $Na_2{}^{14}CO_3$ with specific activity 44 m Ci m mole^{-1} diluted to 100 ml and 10 ml of this solution was added to water column of each treatment. Of the fifteen beakers three were used as control. Rest of the beakers used as: physical raking once (RO) which raked once at the beginning of the experiment, repeated raking (RR), bacteria (*Bacillus,* 167×10^2 ml^{-1}) inoculum (BI) and bacteria inoculum (*Bacillus,* 167×10^2 ml^{-1}) plus repeated raking (BI+RR). Thus, there were altogether 15 beakers allotted to four treatments and one control in triplicate ($5 \times 3 = 15$). All the beakers were kept in the dark in the laboratory (30^o C) to avoid light induced algal growth. The loss of water due to sampling was compensated by adding the equal volume of same water.

The water samples were collected from each treatment at a fixed hour (12 hour) of the day at regular intervals. The specific activity of radioactive ^{14}C of the collected water samples were determined by liquid scintillation counter. The population density of heterotrophic bacteria (HB) was counted following the method described by Rodina (1972) during the period of study.

Adsorption and desorption efficiency of sediment was estimated. Assuming the substance of water column as S, then the substance absorption and desorption by the sediment was written as, SA and SD, respectively. C is designated for substance concentration in water column, then initial and final concentration was represented as C_i and C_f. Time was depicted as T, and final and initial time represented as T_f and T_i, respectively. The rate of adsorption and desorption of sediment can also be expressed in percent as :

$$S_A \text{ (Absorption) } = \frac{C_i - C_f}{T_f - T_i} \times 100 \ldots (1)$$

$$S_D \text{ (Desorption) } = \frac{C_f - C_i}{T_f - T_i} \times 100 \ldots (2)$$

All results obtained from the study were statistically evaluated. A one way ANOVA (Gomez and Gomez, 1984) was used to compared the treatment means. If the main effect was found significant, the ANOVA was followed by a LSD (least significance difference) test. All statistical tests were performed at 5% probability level using statistical package EASE and M-STAT.

Results :

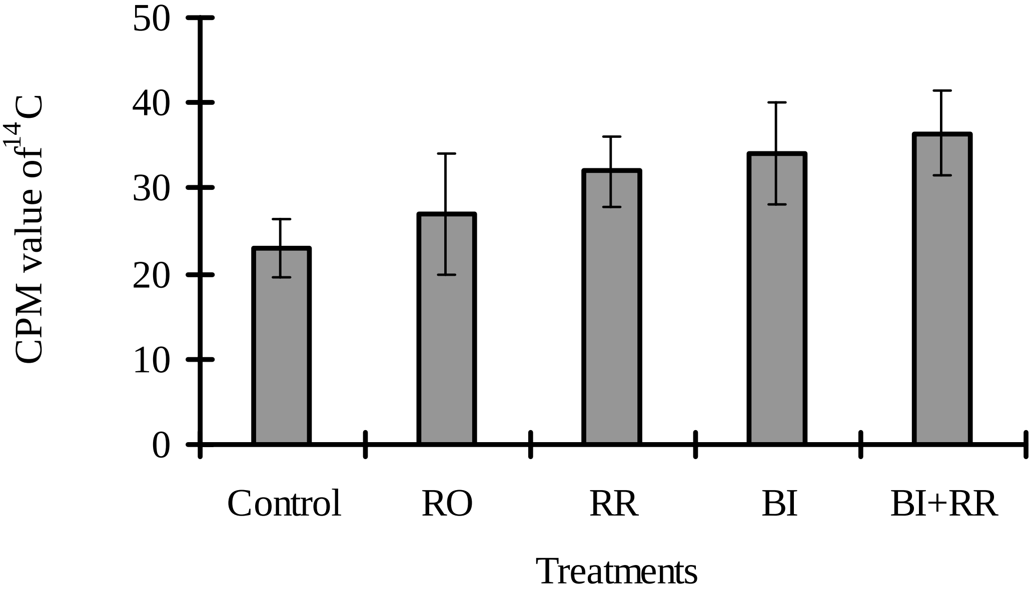
***Radioactive ^{14}C* :** There was a marked difference (ANOVA; $P < 0.05$) in the CPM values of ^{14}C in water ranging from 17.52 to 48.21 in all the treatments throughout the period of experimentation. The maximum mean value 34.60 was observed in BI + RR followed by BI, RR and RO (Fig. 1a). The values of radioactive ^{14}C in BI + RR showed 5, 12, 28 and 37% higher than that of BI, RR, RO and control, respectively.

***Heterotrophic Bacteria (HB)* :** The counts of HB varied between 109 and 259×10^4 ml^{-1} in different treatments. In BI+ RR treatment, the maximum number of HB (259×10^4 ml^{-1}) was 9, 22, 26 and 49% higher than that of BI, RR, RO and control, respectively (Fig. 1b). Temporal changes in count of HB exhibited a slight declining trend till day 8 followed by gradual increasing trend up to day 55 and steady afterwards.

Discussion :

From the present study it was observed that the treatment of bacteria inoculum and repeated raking (BI + RR) exhibited relatively higher concentration of radioactive ^{14}C. Synergistic effect of bacteria inoculum and repeated raking (BI + RR) showed 5, 12, 28 and 37% higher carbon over BI, RR, RO and control, respectively (Fig. 1a). Concentration of ^{14}C in water showed minimal absorption (31%) from initial level than other treatments indicating the bacteria inoculum and repeated raking action enhancing the C level in water. It was concluded that the nutrient release from the sediment increases by bioturbation activity (Jana *et al.*, 1992; Jana and Das, 1992a,b; Jana and Sahu, 1993,

A



B

Fig. 1 : Mean values of radioactive ^{14}C (a) and heterotrophic bacteria (b) in different treatments. [RO = physical ranking once; RR = repeated ranking once; Bl = bacteria inoculum; BI+RR = repeated ranking once bacteria inoculum.

1994) and by physical raking (Chakraborty *et al*., 2004) to over laying water. According to Petr (1977), bioturbation increases the influx of water to the sediment which much equals the volume of water containing solutes flushed from sediments. Higher concentration of ^{14}C in water make an inequilibrium condition in nutrient between sediment and water phase which resulting in movement of ^{14}C from sediment to overlying water and vice-versa for ^{14}C to reach a balance state.

Critical appraisal of data clearly revealed five states of dynamic of ^{14}C between sediment and overlying water (Fig. 2); because of higher concentration in water the ^{14}C moves to sediment causing rapid decrease of ^{14}C level in water from day 0 to 20 - rapid absorption period (RAP) and slow decrease from day >20 to 28 - slow absorption period (SAP), ^{14}C molecules move to water due to slightly higher concentration in sediment from day >28 to 55 resulting in the slow increase of ^{14}C level in water - desorption period (DP), again the ^{14}C level of water decreased from day >55 to 90 - absorption period (AP) and from day >90 to 124 the ^{14}C concentration became equilibrium in the water and sediment phase possibly due to no movement of ^{14}C - steady period (SP).

Sedimentation, adsorption or precipitation, chemical transformation and phosphorus uptake are some of the mechanism for phosphorus dynamics in natural water (Williams and Mayer, 1972;

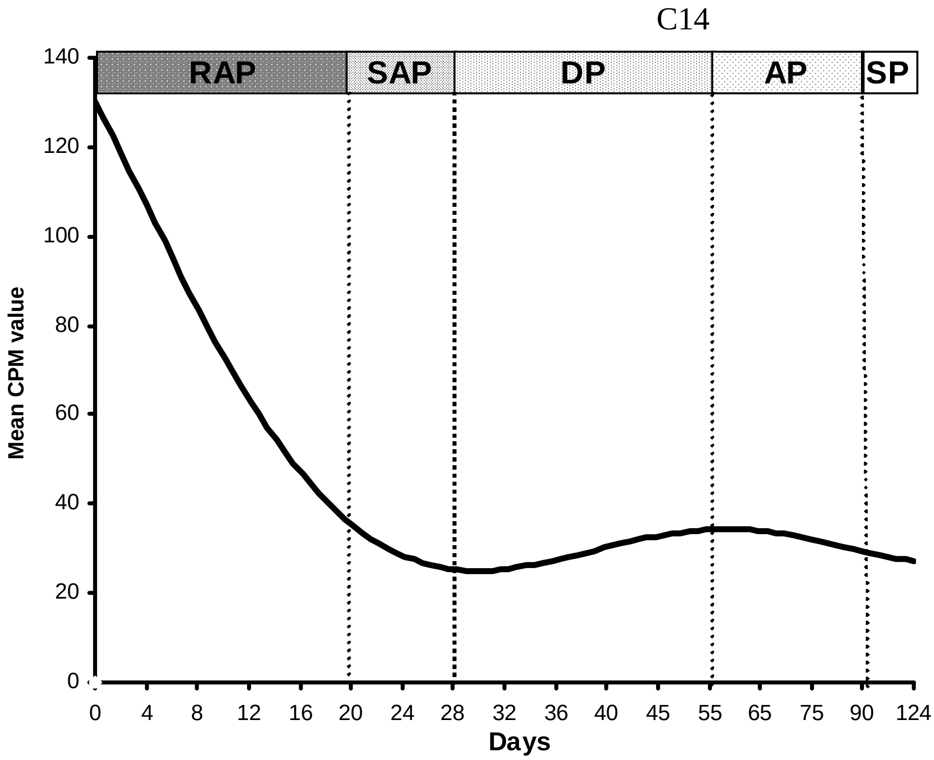


Fig. 2 : Dynamics of Radioactive ^{14}C between water and sediment through exchange process with time scale.

Bostrom *et al*., 1988; Wetzel, 2001). It has been proposed that the upper few millimeters of the sediment exchange is controlled by motions of molecular scales with correspondingly low diffusion rates (Wetzel, 2001). Phosphorus absorption by the sediment depends on the initial P content of the sediment (Shrestha, 1994).

Conclusion :

It implies from the study that (1) the bacteria inoculum and repeated raking (BI + RR) synergistically can be used as a management tool for releasing the maximum nutrient from sediment to overlying water and (2) time scale dynamics of carbon in the mud water exchange process.

References :

Bostrom B., Andersen J.M., Fleischer S. and Jansson M. (1988) : Exchange of phosphorus across the sediment-water interface. *Hydrobiologia.* **170,** 229-224.

Boyd C.E. (1995) : Bottom Soils, Sediment, and Pond Aquaculture (New York : Chapman and Hall).

Chakraborty P., Biswas J. K. and Jana B. B. (2004) : Sediment raking as a tool for enhencement of phosphate and productivity of water in tropical pond system. *Hydrobiologia.* **524,** 157 – 165.

Gomez K.A. and Gomez A.A. (1984) : Statistical Procedures for Agricultural Research. 2nd ed. (New York : John Wiley and Sons). 680 pp.

Jana B.B. and Sahu S.N. (1993) : Relative performance of three bottom grazing fishes (*Cyprinus carpio. Cirrhinus mrigala, Heteropneustes fossilis*) in increasing the fertilizer value of phosphate rock. *Aquaculture.* **115,** 19-29.

Jana B.B. and Sahu S.N. (1994) : Effect of frequency of rockphosphate application in carp culture. *Aquaculture.* **122,** 313-321.

Jana B.B. and Das S.K. (1992a) : Bioturbation-induced changes of fertilizer value of phosphate rock in relation to alkaline phosphatase activity. *Aquaculture.* **103,** 321-330.

Jana B.B. and Das S.K. (1992b) : The fertilizer value of phosphate rock in carp culture. *Bamidgeh.* **44,** 13-23.

Jana B.B., Das S.K. and Chakravorty D. (1992) : Use of common carp *(Cyprinus carpio* L.) in increasing the fertilizer value of phosphate rock. *J. of Appl. Ichthyol.* **8,** 222-227.

Pekar F. and Olah J. (1998) : Fish pond manuring studies in Hungary. In: Proceedings of a Workshop on Integrated Fish Farming. (Eds) J A Mathias, A T Charles and H Baotong (Wuxi, Jiangsu Province, Peoples's Republic of China : CRC Press LLC. Integrated Fish Farming) pp 163-177.

Petr T. (1977) : Bioturbation and exchange of chemicals in the mud water interface. In: Interactions between Sediments and Fresh water. (Eds) H L Golterman (The Hague) pp 216-226.

Rodina A.G. (1972) : Methods in Aquatic Microbiology. (Eds) R R Colwell and M S Zambruski (London : University Park Press. Baltimore) 461 pp.

Shrestha M.K. (1994) : Dynamics and recovery of phosphorus in mud of fertilizer fish pond. D. Technical Dessertation no. AE-94-2, Asian Institute of Technology, Bangkok, Thiland.

Tchobanoglous G. and Schroeder E.D. (1987) : Water Quality (MA : Addison-Wesley Publishing Company) 768 pp.

Wetzel R.G. (2001) : Limnology : Lake and River Ecosystem (California : Academic Press).

Williams J.D.H. and Mayer T. (1972) : Effects of sediment diagenesis and regenaration of phosphorus with special reference to lakes Eire and Ontario. In: Nutrients in Natural Waters. (Eds) H E Allen and J R Kramer (New York : John Wiley & Sons) pp 281-315.