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ORGANIC MANURING IN FRESHWATER AQUACULTURE AND ITS IMPACT ON POND ECOSYSTEM AND FISH HEALTH: AN OVERVIEW

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The use of organic manure in aquaculture had been practiced since centuries in India, China and other Far East countries. Sustainability of aquaculture farming depends upon eco-friendly, economically and socially viable culture systems. The recycling of organic wastes for fish culture serves the dual purpose of cleaning the environment by avoiding the problem of waste disposal and providing economic benefits. The recycling of animal dung/wastes in fish ponds for natural fish production is important to sustainable aquaculture and to reduce expenditure on costly feeds and fertilizers which form more than 60% of the total input cost. Integrating aquaculture with animal husbandry results in the most rational utilization of organic manures. However, the indiscriminate use of these manures in fish ponds, instead of improving the pond productivity, may also lead to pollution causing negative impact on the dissolved oxygen regime of the fish ponds and may cause problems to fish health. Therefore, it is necessary to understand the standard doses of these wastes which would keep the physico-chemical parameters of pond water in a favorable range required for the survival and growth of fish. When organic manure is applied in aquaculture ponds, best results are obtained with its frequent applications. Judicious organic manuring of fish ponds can eliminate the need for supplementary feeding. Although a lot of work has been done on the utilization in fish culture ponds, of animal manures, particularly farmyard manure, poultry droppings, cow dung and biogas slurry which are suitable substitutes for costly feeds and fertilizers. In the present review, an attempt has been made to elucidate the present status of organic manuring in fish culture systems and its impact on pond ecology and fish health.

INTRODUCTION

The organic manures have a long history of its use as sources of soluble P, N, and C for algal growth and natural food production, and as sources of particulate organic matter for rotifer production (Wohlfarth and Schroeder, 1979; Colman and Edwards, 1987). Organic manures of animal origin like cow dung and poultry manure have been used as principal organic inputs in oriental aquaculture system for centuries. In China manuring of fish ponds dates back to over 2000 years (Hepher, 1953) and fecal fertilization in Israel is an integral component of intensive and culture system particularly poultry manure (Bejerano *et at.,*1979).

Fish pond manuring is a management protocol to enhance biological productivity using both organic manure and inorganic chemical fertilizers. Evaluation of fertilizer value of different organic manure has been a subject of research in aquaculture ever since (Sharma, 1988; Sharma and Das, 1988; Dhawan and Toor, 1989; Schroeder *et al.,* 1990; Milstein *et al.,* 1995; Morissens *et al.,* 1996; Egna and Boyd, 1997, Dhawan and Kaur, 2002). The first and foremost criteria in pond fertilization is to determine, how do each fertilizers release soluble P, N, and C for enhancing pond productivity and development of fish food organisms. Most of the nutrient release occurs within a few days of manure application to the pond, primarily through leaching and the breakdown of soluble organic molecules (Nath and Lannan, 1993). A certain percentage of manure P, N, and C remain bounded in particulate matter, and eventually buried in pond sediments.

Organic Manures

Organic manures have been widely used for improving the productivity of fish culture ponds. Cow dung is the most widely used organic manure in many areas and is typically applied at a rate of 5,000-15,000 kg/ha in one installment well in advance of stocking with spawn, preferably at least a fortnight prior. The amount is reduced to 5,000 kg/ha when mahua oil cake is used as a fish toxicant in shallow nursery ponds. Sometimes, to hasten the process of decomposition of added manures, nurseries are limed ($CaCO_3$) at a rate of 250-350 kg /ha after the application of manure. Sometimes spaced manuring with cow dung at a rate of 10,000kg/ha 15 days prior to stocking followed by subsequent application of 5,000 kg/ha seven days after stocking has been practiced for sustainable production of zooplankton in nurseries. When more than one crop is raised, nurseries may be manured with cow dung at 5,500 kg/ha immediately after the removal of the first crop. Besides the cow dung, a combination of mustard oil cake, cow dung and poultry manure in the ratio of 6:3:1 at 1,100 ppm have been successfully used for the culture of zooplankton for carp spawn.

The organic manures are mainly of animal origin, except green manure which is of plant origin. Hence, organic manures are also referred as animal manures. The animal manures are further categorized as either of poultry (e.g., chickens, ducks and goose) or mammalian origin. Manures from mammals are either from ruminants (e.g., cows and buffaloes) or non-ruminants (e.g., pigs and rabbits). In the case of manures of animal origin, the nutrient concentrations, and the percentage of manure -P, -N, and -C which becomes available for the development of fish food organisms, depend primarily on the animal's diet, whether the manure is liquid or solid, and the age and storage conditions of the manure (Muck and Steenhuis, 1982). First, the source-animal's diet is important because what comes out of an animal is directly influenced by what it consumed (Little and Muir, 1987). In other words, organic manures contain whatever is present in the materials from which these are derived. For example, the composition of animal feed determines the composition of dung which in turn determines the composition of organic manures (Tandon, 2017). Animals fed on high protein diets typically have manures richer in N and P than manure from similar animals that rely on scavenging for their sustenance.

Green Manure

Green manure is a type of organic manure which is of plant origin. Plants utilized as green manures include both terrestrial grasses and nitrogen-fixing legumes, as well as rooted aquatic macrophytes. The best plants are low in fiber (e.g., aquatic macrophytes) so decomposition is faster and high in soluble algal nutrients (e.g., nitrogen-rich legumes) (Biddlestone and Gray, 1987). Composted plant materials provide a pond with decomposed particulate matter, and release soluble algal nutrients and dissolved organic matter during decomposition (Biddlestone and Gray, 1987). Several green manure crops provide sufficient organic matter and nitrogen for growing crops. *Dhaincha* and *Sunhemp* are two most common green manure crops normally used as a source of nutrients and organic matter. They have potential to supply 60-90 kg nitrogen within a period ranging between 45-60 days. Green manuring also helps in providing large amount of easily decomposable organic matter to the soil which accelerate the nutrient cycling processes and make available nutrients to the crops.

Farmyard Manure (FYM)

India has vast resource of livestock and poultry, which play a vital role in improving the socio-economic conditions of rural masses. Livestock wastes including animal manure and poultry byproducts which are a nuisance to the environment are sources of wealth creation in fish farming (Adewumi *et al.,* 2011). The livestock wastes such as cow-dung, poultry and pig excreta, goat and sheep pellets in fish culture are useful in enhancing the production of fish food organisms as well as in cutting down the expenditure on costly feeds and fertilizers (Kaur *et al.,* 2015). A number of studies have established that fish yields could be greatly enhanced by the addition of manures to ponds containing a mixed assemblage of fish species (Li, 1956, 1987; Schroeder and Hepher, 1979; Sharma and Olah, 1986), and that formulated feeds for fishes can be partially replaced by manures (Barash and Schroeder, 1984) without sacrificing fish yields. It has been estimated that 100 kg organic manure (cow dung, duck and chicken droppings) contain 8 kg carbon which can produce 15-16 kg algae and 3-4 kg fish (Kausar, 1983). Table 1 compares nutrient concentrations of some typical animal manure.

Table 1: Representative availabilities of nitrogen (N) and phosphorus (P) in various organic manures

Animal manures	% Moisture	% N	% P
Poultry litter	28	2.8	1.2
Chicken (bagged)	38	2.0	3.0
Duck (fresh)	82	3.7	1.7
Buffalo (fresh)	77	1.7	0.1
Dairy cattle (fresh)	86	0.5	0.1
Swine (fresh)	89	0.6	0.2
Sheep (fresh)	77	1.4	0.2
Biogas slurry	91.12	1.36	0.88

Source: Kean and Preston, 2001.

Unlike inorganic fertilizers, organic manures can vary considerably in their moisture content and their chemical composition from one lot to other. Secondary nutrient, micronutrient and heavy metal content of some common organic manures is given in Table 2 (Tandon, 2017).

Table 2: Secondary nutrients, micronutrients and heavy/ other metal contents fund in some organic manures

Elements	Poultry Manure		Pig Manure	Farmyard Manure
	Fresh	Rotted		
Calcium, %	2.80	4.48	1.65	0.91
Magnesium, %	0.50	0.60	0.62	0.19
Sulphur, %	0.74	0.99	0.56	0.49
Zinc, ppm	36.0	50.0	198.5	14.5
Copper, ppm	4.4	6.9	12.8	2.8
Iron, ppm	1,010	1,075	1,600	1,465
Manganese, ppm	187.0	190.0	168.0	69.0
Boron, ppm	12.0	15.0	8.0	5.0
Molybdenum, ppm	41.5	65.0	34.0	21.0
Cobalt, ppm	5.0	8.0	11.0	11.0
Aluminum, ppm	1,450	1,475	2,313	2,830
Strontium, ppm	100.0	160.0	65.0	48.5
Chromium, ppm	10.0	11.0	13.5	11.5
Lead, ppm	90.0	122.5	168.0	120.0

Source: Arora *et al.* (1975)

There are many benefits of using organic manures for pond fertilization. Manure can be a good source of CO_2, which may be needed in rain-fed or other ponds with low alkalinities. Although manures do not increase alkalinity unless lime was added during storage, the CO_2 released during decomposition will be available for algal uptake. Manure can supply soluble N and P for algal utilization, and provide a substrate for zooplankton production (Wohlfarth and Schroeder, 1979; Colman and Edwards, 1987). Manure additions may also help to clarify clay turbidity in pond water. Furthermore, a layer of organic matter on the pond bottom can help reduce the rate of P adsorption to pond sediments (Borggaard *et al.,* 1990) and may reduce seepage of pond water (Teichert-Coddington *et al.,* 1989). The final benefit of manure may be its availability and easy production on the farm. It may be argued that manure can be consumed directly, thus providing an additional benefit for culture organisms (Noriega-Curtis, 1979; Oláh *et al.,* 1986; Colman and Edwards, 1987; Green *et* *al.,* 1989). In fact, Knud-Hansen *et al.,* (1991) demonstrated utilization of particulate chicken manure by Nile tilapia in ponds fertilized only with chicken manure. In highly productive ponds receiving primarily chemical fertilizers, however, there was no significant benefit to tilapia when the fertilization regime was supplemented with chicken manure (Schroeder *et al.,* 1990; Knud-Hansen *et al.,* 1993). This latter conclusion is not surprising, since there is no reason to believe that the direct consumption of manures is more advantageous for filter-feeding organisms than feeding on natural foods produced in the pond. The use of animal manures to fertilize fish ponds have been reported in many parts of the world (Woynarovich, 1979; Hopkins et al., 1980; Oladosu and Ayinla, 1992; Njoku, 1997). Cattle manure has been used extensively in India as the major source of organic manure in carp polyculture (Lakshmanan *et al.,* 1971; Sinha *et al.,* 1973) stated that organic manure is normally applied at 5000-10,000 kg/ha/yr, in low productive ponds but can be used as high as 25 tonnes/ha/yr. Hopkins and Cruz (1982) showed that increase in fish yield attributable to pig or chicken manure was about twofold compared to inorganic fertilizer. Evaluation of swine, cattle and poultry wastes as manure in fish ponds was made in Israel and USA (Buck *et al.,* 1978 a,b; Rappaport and Sarig, 1978).

The fish yield in experimental pond receiving only cattle manure showed production over 10950 Kg/ha/yr which was more than twice the national average for Israel ponds receiving costly conversion feeds (Schroeder, 1977). According to Hepher and Schroeder (1974), liquid cow manure has an effect on the food chain beginning with bacteria and protozoa. The result of Schroeder (1980) and Moav *et al.,* (1977) showed that feeding on liquid cow manure or on slurry in ponds had a better effect on *Sarotherodon* (tilapia) than on carp. In Israel, maximum fish yield was about 20, 30 and 40 kg ha-1 day-1 with chicken, cattle and duck manure, respectively. Varghese and Shankar (1981) showed that Indian major carp catla (*Catla catla*) and rohu (*Labeo rohita*) gained maximal weight when reared with poultry manure, while mrigal (*Cirrhinus mrigala*) with cattle manure, pig manure and sheep manure, however, no proper explanations have been provided. Fang *et al.*, (1986) found poultry manure especially suitable for the growth of common carp, silver carp and bighead carp in China.

In carp culture ponds, the recommended dose of poultry manure was 2000 kg ha^{-1} $year^{-1}$ and urea 100 kg ha^{-1} $year^{-1}$ (Dinesh *et al.,* 1986) or maximum loading with cow manure was 10,000 kg ha^{-1} $year^{-1}$ (Kapur and Lal, 1986 a, b). While working on four rates of application of fertilizers (1600–6400 kg ha^{-1} $year^{-1}$), Azim *et al.*, (2001a, b) observed the optimum dose of cow manure, urea and TSP at rates of 4500, 150 and 150 kg ha^{-1} respectively. A 2 to 3 week interval between two fertilization dates has been recommended (Zhu *et al.,* 1990; Garg and Bhatnagar, 2000), whereas a weekly interval has been found to be better than biweekly or monthly intervals in case of rock phosphate fertilizer (Sahu and Jana, 1994).

The use of animal wastes to fertilize pond farms as practiced in many countries is considered superior to inorganic fertilizers in producing and maintaining desirable species of planktonic and benthic organisms (Pillay, 1992) and to enhance fish production (Edwards, 1980; Yadava and Garg, 1992; Garg and Bhatnagar, 1999). Hepher and Schroeder (1974) reported 70% higher yield of fish from organically manured ponds while Dutta and Goswami (1988) demonstrated three times greater yields from manured ponds over the control ponds. Of the organic wastes, manuring with cow dung, compost and urine as manure have been recommended by Alikunhi (1957), Banerjee *et al.,* (1975; 1977). The manuring of fish pond is considered an important scientific discipline for increasing fish production (Doria and Leonhardt, 1993). Cow manure treatment in major carps nursery ponds yield 50-60 percent more fish than untreated ponds (Saha *et al.,* 1980). Cow manure adds to fish pond at the daily rate of 3-4% of fish yielded fish 20-30 kg/ha/day (Pullin and Schedadeh, 1980).

Poultry Manure

Poultry droppings, though richer than cow dung in manurial constituents, are less utilized as pond manure. Ray and David (1969) considered poultry manure as potential plankton producer, while Banerjee *et al.,* (1969) suggested its regular application in low doses in order to maintain required concentrations of nitrogen and phosphorus and significantly rich concentration of plankton. Poultry manures are nutrient-rich, but there is great variability in their quality at the time of use as fish production inputs. Burns and Stickney (1980) showed that the growth of *Tilapia aurea* was highest in ponds receiving digested poultry waste; *T. aurea* averaged only 46 g in pond receiving no organic fertilizers, but reached an average of 304 g in the pond fertilized by the waste from 4000 hens/ha. Nugent (1978) reported a yield of 2500 Kg/ha/yr of tilapia using poultry waste.

The use of fowl excreta in fish ponds by fish farmers in Nigeria in order to increase output is an old practice (Miller, 1976; Woynarovich, 1979). Results indicated high mortalities in fish ponds (Oladosu and Ayinla, 1992) recommended 112-224 kg ha^{-1} per week. Schroeder (1978) recommended 70–140 kg ha^{-1} per day (organic matter) and 100–200 kg ha^{-1} per day (dry weight) of poultry droppings in fish ponds. Many studies have been conducted on the development of fish culture technology and the use of organic fertilizers in stillwater ponds in India and abroad (Chaudhury *et al.,* 1975; Moav *et al.,* 1977; Maddox *et al.,* 1978; Hopkins *et al.,* 1980; Hopkins and Cruz, 1982; Van and Shilo, 1989; Pekar and Olah, 1990; Saha *et al.,* 1990; Yadava and Garg, 1992; Garg and Bhatnagar, 1999). Earlier studies revealed that with high doses of organic fertilizers (24,000 kg ha^{-1} $year^{-1}$), cost of inorganic fertilizers and supplementary feed were reduced by about 50% (Yadava and Garg, 1992). Javed *et al.,* (1992) reported a net yield of 2928.54 kg/ha/year of major carps under polyculture conditions with adding cow dung at the rate of 0.10 g nitrogen (from cowdung) per 100 g of wet fish weight daily. The effect of treatment on fish weight, fork length and total length was highly significant. Gosh *et al.,* (1994) reported that the growth of the fish species Java punti (*Puntius javanicus*) when reared alone and *Catla catla, Cirrhinus mrigala* and Java punti reared together in the rice field was superior when organic fertilizer was applied either alone or in combination with an inorganic fertilizer. Garg and Bhatnagar (1999) reported that the effects of five (5000, 10,000, 15000, 20000, 24000 kg/ha/year) different doses of organic fertilizer (cow dung) were studied on the pond productivity in term of plankton production and fish biomass in fresh water fish ponds. The grow out period was of 60 days. Highest plankton population, zooplankton, fish biomass and specific growth rate (2.36% body weight/d) were observed in ponds which were treated with fertilizer at the rate of 15000 kg/ha/year.

Biogas slurry

Early research conducted at the College of Fisheries, Mangalore demonstrated the benefits of biogas slurry in carp culture. With the application of 3,000 kg /ha, in a short-term study, extrapolated values showed that a production of 2,900 kg / ha/year of fish could be obtained. Further research carried out at the ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar in Odisha using cow dung and water hyacinth as the basis for the production of slurry have demonstrated the benefit of using the digested components in fish culture. Application of biogas slurry at 15 to 30 tons/ ha/ year has given fish yields which are more than 60% higher as compared to the application of undigested cow dung. Experimental results have also shown the possibility of incorporating biogas slurry in the feed mixture of rice bran – oil cake to the extent of 50%, by taking advantage of the existence of coprophagy in carps. In another study conducted at the Madurai Kamaraj University, results have shown that growth of carps was nearly ten times higher in biogas slurry treated ponds as compared to those treated with conventional methods of chemical fertilizers applications. *Spirulina*, which is now considered as an important health food not only for fish, but also for people, has been successfully, produced using biogas slurry by the Center of Science for Villages located in Datapur of Wardha, Maharashtra. The yield obtained using the biogas slurry was comparable to the one obtained using chemical fertilizers.

Balasubramanian and Bai (1996) reported that effluent collected from a biogas plant fed on cattle dung was utilized in monosex (all male), monoculture of the fish *Oreochromis mossambicus* at field level in 0.002 ha ponds. Biogas-plant effluent was supplied at 0.15% (W/V) concentration level at 3-days interval. No supplementary feed was given to the fishes grown in biogas plant effluent. *O. mossambicus* attained a maximum weight gain of 0.67 g/fish/day. Total fish production was 4826 kg/ha in 125 days. In Vietnam, Chau (1998 a, b) showed that the effluent from bio-digesters charged with cattle or pig manure was superior to the fresh manure when applied to plots growing forage cassava and ponds growing duckweed. In both cases biomass yield and protein content were increased by the effluent compared with the fresh manure. Increased productivity in polyculture fish ponds when bio-digester effluent, rather than manure, was used as fertilizer was reported by Jieyi and Yujin (1984). Yields of fish were increased by 26% when the effluent was applied compared with the original manure.

Sehgal *et al.*, (1992) observed that biogas slurry applied at 52.1 litres /ha / day (6.4% dry matter) resulted in a significant increase in total zooplankton over the control. The application of biogas slurry, however, did not change the community structure of zooplankton. Highest production of total zooplankton in biogas slurry plus supplementary feed treated tanks resulted in maximum fish yield in these tests. Yongabi *et al.,* (2003) while studying the microbial profile of biogas slurry showed that anaerobic digestion eliminates *E. coli* and significantly decimates *Coliform* and other aerobic mesophilic bacteria (Theresa *et al.,* 1993). With digestion, manure is made safer for application to the fields, as feeds in fish production, and as feed supplement for animals. These observations tally with the findings of Jones and Mathews (1975), Dahiya and Vasudevan (1986), Gadre *et al.* (1986) and Kunte *et al.* (1998) who observed that anaerobic digestion is a good option in the treatment of cattle dung.

According to Yongabi *et al.* (2003), microscopic analysis results revealed the presence of a few ova of helminthes in the raw slurry but there were no ova in the digested slurry. The absence of the helminthic ova in the digested slurry suggests that the digestion of manure is an effective way of breaking the cycle of infection in animals and the re-infection of man through his activities in agro-aquaculture. Addition of biogas slurry results in better growth of plankton and higher carp production than raw cow dung alone (Kalyani and Shetty, 1987). The use of biogas technology also gives a much higher nutrient recovery than the conventional manure application (Gaur *et al.,* 1990).

Impact of organic manuring on pond ecosystem

Although manures may represent a readily available source of nutrients in pond ecosystem, they contain other elements which can have serious and undesirable impacts on pond ecology. First, manures contain organic matter. Other than the possibility that culture organisms may in fact consume particles of manure, the main problem with introducing organic matter to a pond is the depletion of dissolved oxygen (DO) required for its utilization and decomposition (Wohlfarth and Schroeder, 1979; Shevgoor *et al.,* 1994). As more manure is added to a pond, pre-dawn DO levels can reach 0 mg l^{-1}, causing severe stress or even mass mortality of the culture organisms. The mixing of anoxic bottom water back into the water column can potentially increase ammonia and hydrogen sulfide concentrations to toxic levels (Ram *et al.,* 1981). Pond filling is an additional consideration associated with fertilizing with particulate manures. The depth of accumulated organic solids increases over time, thus reducing the effective volume of water available for culture organisms. Organic accumulation is less of a problem in warm water aquaculture ponds where water temperatures remain relatively warm all year, and when bottom sediments are resuspended into oxygenated waters above. Nevertheless, heavily manured ponds may periodically require the costly shoveling-out of bottom sediments. Manures produced by ruminants, such as cows and buffaloes, release dissolved organic compounds which can also degrade the pond environment. The plant material consumed by these animals contains complex organic molecules, which are passed into the manure. These soluble organic molecules impart a dark color to the water, thereby reducing the amount of light available for algal photosynthesis. The excessive load of organic manuring may lower the potential net pond productivity resulting in lower net fish yields. Shevgoor *et al.* (1994) reported increasing water color and decreasing dissolved oxygen with increasing rates of buffalo manure fertilization. Nath and Lannan (1993) found 60 to 80% of the total N and P in chicken manure was available.

Researchers have conducted a number of systematic studies on the use of manure in polyculture fish farming systems, including the effects of manure application upon the propagation of phytoplankton (Li, 1956; Hepher, 1962), and its effect on water quality (Schroeder, 1974; 1975a, b). Garg and Bhatnagar (2000) have shown that with continuous use of high levels of organic manures, an accumulation of toxic metabolites in the water column and pond sediment occur which not only reduces fish production but also deteriorates the pond environment. Most recommendations in aquaculture are empirical. In fact, very few studies have been carried out to determine the fertilizer dosage required in fish ponds for optimum pond productivity and fish production without adversely affecting pond ecology (Hopkins and Cruz, 1982; Wohlfarth and Hulata, 1987; Garg and Bhatnagar, 1999).

Organic manures and inorganic fertilizers have been extensively used, either alone or in combination, as nutrient sources in pond fertilization (Sinha and Saha, 1980). The doses and frequencies of fertilizer use influence water quality parameters significantly, often reaching 'critical limits' exerting considerable stress on the rearing species. Further, the large quantity of proteinaceous feed used in culture systems also contributes to accumulation of considerable amount of the metabolites in the pond (Avnimelech and Lacher, 1979; Chiba, 1986). Water quality, a major factor determining the production of fish, is considerably influenced by the pond soil and pond management practices such as stocking density, fertilization strategy and supplemental feeding. Both fertilizer and feed, upon mineralization, together influence the water quality of fish pond.

Cow dung and poultry manures are the most commonly used organic manures in fish culture ponds, often used in combination with urea and super phosphate as inorganic nitrogen and phosphorus sources. The conventional dosage followed in carp culture practice in India usually includes 10-20 t ha^{-1} $year^{-1}$ cow dung or 3-4 t $ha^{-1}year^{-1}$ poultry manure alone or in combination with urea ~ 100 kg N ha^{-1} and super phosphate ~ 50 kg P ha^{-1}. For obtaining higher fish production the fish farmers often add more inputs into the culture systems, which is certain to cause serious environmental problems in the long run. Therefore, knowledge of the maximum permissible limit of the critical inputs such as manures, fertilizers and feed, and, further, the intermittent time required for mineralization of organic inputs and hydrolysis of inorganic fertilizers ultimately reflecting the water quality parameters is of paramount importance.

It has been shown that during long culture periods, continuous fertilization and use of supplementary feeds leads to accumulation of more waste matter and metabolites in the ponds, leading to the cessation of fish growth through deteriorating production conditions (Moav *et al.,* 1977; Lazard, 1980; Edwards *et al.,* 1981, 1994). Hopkins and Cruz (1982) in their comprehensive studies on the use of pig, duck and poultry manure in fish ponds reported that an increase in the dosage of manures enhanced nutrient release, production of fish food organisms and fish yield. However, a further increase in the manure load beyond the optimum dose (optimum dose for pig 101-110 kg ha^{-1} d^{-1}, duck 82 kg ha^{-1} d^{-1}, and chicken 100 kg ha^{-1} d^{-1}) resulted in lower fish growth and production, probably due to decrease in DO concentration. Several studies (Boyd, 1982; Chakrabarty and Jana, 1998; Datta and Jana, 1998) have emphasized the role of water and sediment quality as well as plankton abundance in regulating the fish growth as observed in the present investigation. Banerjee *et al.* (1979) detailed the studies under low temperatures (19-23^{0}C) on the diurnal variations of dissolved oxygen concentration under different doses of manures indicated that introduction of either of the manures above 1000 kg /ha in a single dose may adversely affect the diurnal oxygen budget of the ecosystem and therefore a proportionate reduction of organic doses with the rise of temperature should be followed. The daily average consumption of dissolved oxygen is found to be more in case if the treatment with poultry droppings compared to cow dung and this is a positive index of high biodegradability of the former. The increase in phytoplankton abundance did not contribute to higher DO level rather led to more organic production and greater respiration rate in manured ponds where BOD level also increased (Dutta and Goswami, 1988). Hepher (1962) observed high rate of photosynthesis near surface of pond containing abundant plankton, but total oxygen production of entire euphotic zone was less. Singh et al. (1993) observed that the oxygen content of water affected the feeding, absorption and growth of rohu. Adlerman and Smith (1970) recorded a gradual decrease in growth and food conversion of northern pike when the dissolved oxygen level was reduced to 3 or 4 ppm and then a fast decrease (about 50%) below that level. The common carp shows hypoxic effects when oxygen in ambient water is highly reduced.

For nursery pond, raw cow dung (RCD) is generally considered to be the best organic manure (Alikunhi, 1957). But a combination of cow dung and poultry manures has been found to be better than cow dung alone (Banerjee *et al.,* 1969). The water receiving poultry droppings alone also having the high pH values with wide fluctuations supported by the high alkalinity values show high plankton production (Banerjee *et al.,* 1979). Dutta and Goswami (1988) reported the increase in pH of all manured ponds in summer when phytoplankton were abundant, indicating that all free carbon dioxide were used for photosynthesis

Effect of organic manure on fish health

The disadvantage of using poultry litter lies in its richness of pathogens. Bejerano *et al.,* (1979) have shown mass mortalities in silver carp associated with *Proteus rettgeri* in pond fertilized with poultry wastes. But of poultry litter rid off all pathogens, since the feed is subjected to temperature of 120^0 C while passing through dyes in the pellet mill (Kumar and Singh, 1984).

Hubbert *et al.,* 1975 reported the occurrence of *Proteus* spp. and *Edwardsiella* spp. in group of carps which were fed on a slurry. It appeared that feeding carps on slurry may have caused a destabilizing effect on the gut ecosystem through the reduction of bacterial diversity. *Edwardsiella* spp. which have been shown to be pathogenic to eels (*Anguilla* spp.), (Wakabayashi and Egusa, 1973) and channel cat fish (*Ictalurus punctatus*), (Meyer and Bullock, 1973) and other carps. Organic matter in cow manure accelerates the development of large bacterial population as a result of decomposition (Buschiel, 1983).

As manuring causes organic enrichment, it may also hasten the deterioration of the water quality making the aquatic environment favorable for the growth and multiplication of human pathogenic bacteria (Garg and Bhatnagar, 1999). Pathogenic bacteria such as *Aeromonas, Citrobacter, Edwardsiella tarda, Enterobacter, Escherichia coli, Klebsiella* and *Serratia* may be introduced into the aquatic environment (Cuelin, 1962; Rao *et al.,* 1968; Cohen and Shuval, 1973; Allen *et al.,* 1983; Austin and Austin, 1993; Ringo *et al.,* 1995).

Bejerano *et al.,* (1979) reported mass mortalities in silver carp, *Hypophthalmichthys molitrix* (Val.) associated with bacterial infection following handling. These mass mortalities of silver carp were caused by *Proteus rettgeri,* a gram negative bacterium normally found in the gut of poultry. They concluded that since poultry manures were used extensively to fertilize carp ponds in Israel, so their infection came via poultry manure as proved by reproduction of the same disease by scarification and exposure to *P. rettgeri* (Bejerano *et al.,* 1979).

Toor *et al.* (1983) studied problems of fish diseases in tanks loaded with high levels of organic manures. They reported two acute fish diseases viz., hemorrhagic septicemia, caused by *Aeromonas punctata* and *Seprolegniasis* caused by *Seprolegnia parasitica* in *Labeo rohita* and *Cyprinus carpio*. The diseases were prevalent only in winter and in tanks with a high organic load.

Combining organic and inorganic fertilization

The combined use of both organic and inorganic fertilizers is another strategy for increased production of either fish food organisms or fry. The combination of mustard oil cake and 6:8:4: N:P:K inorganic fertilizer on equivalent nutrient basis (at 12 kg nitrogen/ha) is suitable as compared to either organic to inorganic for nutrient management of nurseries. However, on an equivalent nutrient basis (N:P:K) organic manure (cow dung) is the most suitable fertilization strategy for management of carp nurseries compared to either inorganic fertilizer or combined use of organic and inorganic fertilizer.

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