Editorial

The Network of Tropical Aquaculture Scientists (NTAS) and the *Aquabyte* section of *Naga* have come under a new management. The outgoing NTAS Coordinator and Editor of *Aquabyte* Dr. R.S.V. Pullin and Secretary Ms. Maan P. Bimbao have done a great job, who, in this issue, trace the history of the network since its inception.

With ever increasing demand for fish, all eyes are focused on increasing fish production through aquaculture. Much aquaculture research has been and is being done in developing and developed countries and the results of these studies are not easily available to researchers in developing countries who lack access to good libraries. *Naga*, with its wide circulation, could communicate research results to a large section of the research community. NTAS encourages young scientists to publish their research results in *Aquabyte* along with those of the Specialists.

M.V. Gupta

Aspects of Phosphorus Pollution from Aquaculture

Golam Kibria, Dayanthi Nugegoda, Paul Lam and Robert Fairclough

Introduction

Phosphorus is an essential element for living organisms and exists in waterbodies as dissolved and particulate forms. Phosphorus is required for optimum growth, feed efficiency, bone development and maintenance of acid-base regulation in fish (Lall 1989; Ketola and Richmond 1994). The presence of high concentration of phosphates in water may indicate presence of pollution as it may accelerate plant growth (Beveridge 1987) and disrupt the aquatic ecosystem thereby benefiting certain species and altering species diversity in affected areas (Anon. 1987; OCE 1988). Eutrophication of waterbodies is often correlated with the phosphorus loading into the environment (Kaushik 1992) and aquaculture has been identified as one of the sources of phosphorus pollution (EPA 1995). Details of the impacts of eutrophication is given in Bernhardt (1981). Phosphorus must be provided in fish feed because of its low concentration in water (Lall 1991). Studies made in Europe and Northern America have revealed a phosphorus surplus in most commercial feeds which is above actual requirements (Tacon and de Silva 1983; Beveridge 1987); or is supplied in a form which is unavailable to the fish (Beveridge 1987). Surplus phosphorus is excreted, while unavailable phosphorus is passed out in the feces (Beveridge 1987). Discharge of phosphorus from fish farms and hatchery effluents have caused phosphorus pollution in Nordic countries, North America and Europe (Bernhardt 1981; Alabaster 1982; Beveridge 1984; Enell 1987; Folke and Kautsky 1989; Ketola 1990; Bratten 1991; Foy and Rosell 1991a; Lall 1991). This article examines the path of phosphorus pollution, quantification/ prediction of phosphorus load from aquaculture and remedial measures.

Path of Phosphorus Loss

Feed is the main source of phosphorus loadings from aquaculture to the environment (Ketola 1990; Seymour and Bergheim 1991). There are a number of ways in which phosphorus can be lost during aquaculture operation such as feed fines, uneaten food, feces, dead fish and excretion (Fig. 1). However, the main loading of phosphorus to the environment was reported to be via fecal pellets (Pillay 1992; Kibria et al. 1995). Fish excrete phosphorus in soluble and particulate forms (Lall 1979). The particulate form (feces) settles to the bottom of the tank or accumulates in the sediment and soluble form is lost through urine in the form of phosphate (Lall 1991; Pillay 1992). The soluble fraction is referred to as either dissolved inorganic phosphorus or orthophosphate or soluble reactive phosphate. It is the dissolved fraction that is most available for plant growth (Bostrom et al. 1988).

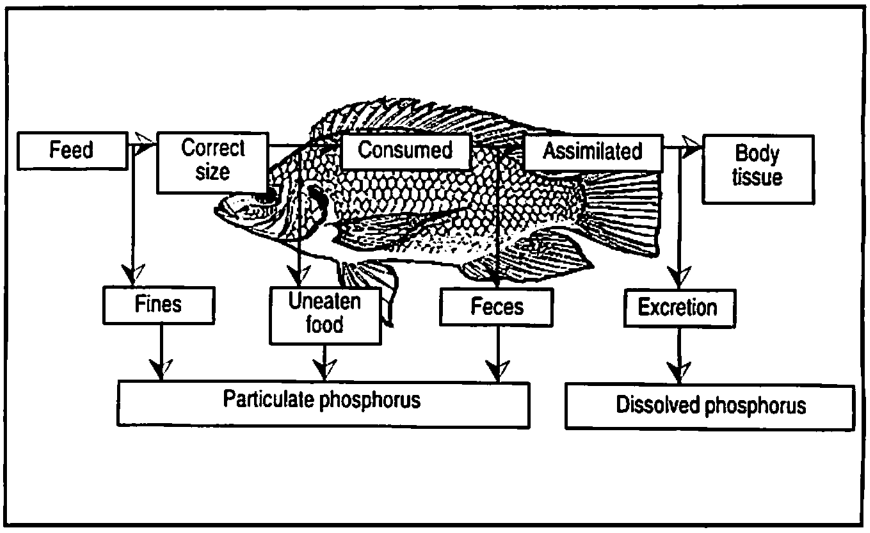

Fig. 1. Flowchart of origin of phosphorus in aquaculture from feeding.

Table 1. Comparision of phosphorus loss rates (kg fish produced) in aquaculture.

Country	Phosphorus loss (kg/t)	Species	Culture method	Reference
Denmark	11.0	Rainbow trout	Ponds	Warren-Hansen (1982)
Finland	18.3	Rainbow trout	Ponds	Sumari (1982)
UK	15.7	Rainbow trout	Ponds	Solbe (1982)
N. Ireland	25.6	Rainbow trout	Tanks	Foy and Rosell (1991b)
Norway	9.0	Atlantic salmon	Ponds	Ibrekk (1989)
USA	10-15	Rainbow trout	Jars	Ketola (1991)
Poland	23	Rainbow trout	Cages	Penczak et al. (1982)
Norway	13.5	Rainbow trout	Cages	Enell and Lof (1983)
UK	27	Rainbow trout	Cages	Phillips (1985)
Spain	39.2	Rainbow trout	Ponds	Tarazona et al. (1993)
Canada	6.0	Brown trout	Tanks	Cho et al. (1991)

Data on Phosphorus Pollution from Aquaculture

Phillips et al. (1990) estimated that 85% of phosphorus fed to fish was lost to the environment. In a study made with native Australian silver perch (*Bidyanus bidyanus*), Kibria et al. (1995) demonstrated that phosphorus loss from aquaculture can vary with temperature, being higher at a lower temperature (95% lost at 20°C) versus (80% lost at 25°C). The phosphorus loss rates of different commercial aquaculture species is reported to be mostly between 9 and 40 kg of fish production (Table 1). The feed type could also determine the level of phosphorus loss since a much higher phosphorus loss could result if trash feed is supplied to fish compared to dry and moist feed (Warren-Hansen 1982).

Quantification of Phosphorus Loss from Aquaculture

The phosphorus loss/pollution load to the environment can be estimated from data on retention in fish carcass using feed/gain data (Ketola 1990). It is equal to the difference between what is added by the feed and what is utilized for fish production (Foy and Rosell 1991b). In order to determine the phosphorus retention in carcass growth, survival and feed conversion data are needed to be determined initially. Next, phosphorus concentration is to be analyzed in feed, fish carcass, uneaten food and solid wastes (feces). Then the amount of soluble and suspended phosphorus (P) discharged in water could be determined using the following phosphorus balance equation:

P discharged in water = P supplied as feed - (P deposited in body tissues + P in uneaten food + P in solid wastes)

The food conversion ratio (FCR) can play a significant role in determining the level of phosphorus pollution expected since an increase in FCR value from 1.0 to 1.5 may increase pollution load to about 86% for total phosphorus (Storebakken and Austreng 1987a, 1987b). Therefore, improvement of FCR is vital for reducing phosphorus pollution from aquaculture. A strong correlation was found between the phosphorus loss rates and the FCR with silver perch: the better the FCR, the lower the rates of phosphorus loss (Fig. 2).

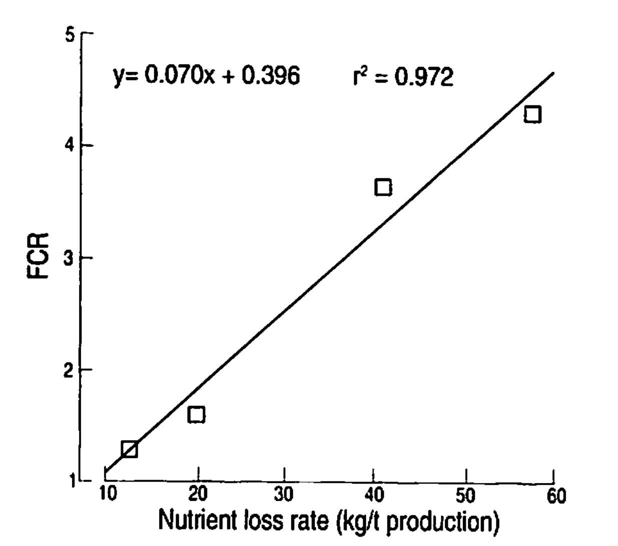

Fig. 2. Relationship between the food conversion ratio (FCR) and average phosphorus loss rate per tonne of silver perch (Bidyanus bidyanus) production. The lower FCR value obtained at 25°C when good growth is achieved and FCR at 20°C when comparatively poorer growth resulted (Kibria et al. 1995).

Simple Calculation of Phosphorus Retention

If a commercial diet contains 1.7% phosphorus and retention of phosphorus is estimated to be 21%, then phosphorus wasted per ton of feed supplied can be calculated as follows:

The amount of P present per ton of feed			=	1 000 kg x 0.017 kg= 17.0 kg
If P retention is 21%, the amount of P retained			=	17 kg x 0.21= 3.57 kg
The amount of P discharged (as solid and dissolved) to environment			=	17-3.57 = 13.43 kg/t of feed fed
<u>Values at different FCR</u>				
At FCR 1.0:1, the amount of P present per ton of feed			=	1 000 kg x 0.017 kg =17.0 kg P
At FCR 1.5:1, the amount of P present per ton of feed			=	1 500 kg x 0.017 kg = 25.5 kgP
At FCR 2.0:1, the amount of P present per ton of feed			=	2 000 kg x 0.017 kg = 34.0 kg P
<u>P losses to environment</u>				
at FCR 1.0:1 →	(17.0-3.57)	→	=	13.43 kg P/t feed fed
at FCR 1.5:1 →	(25.5-5.35)	→	=	20.14 kg P/t feed fed
at FCR 2.0:1 →	(34.0-7.14)	→	=	26.86 kg P/t feed fed

Phosphorus as an Indicator of Water Quality

The phosphorus concentration at any given time may be used to assess the quality of freshwater aquatic environment (Table 2). Based on this, it appears that effluents from fish farms and hatcheries will be of degraded quality since the discharge from fish farms and hatcheries are reported to contain 0.15 mg/l total phosphorus (Warren-Hansen 1982) and 0.1 mg/l dissolved phosphate (Alabaster 1982), which leads to the possibility of eutrophication in waterbodies which receive direct fish farm effluents.

Identification of the "Right Phosphorus"

As mentioned above, feed is the main source of phosphorus pollution in aquaculture. In plants, two-thirds of phosphorus is bound in phytin that trout and salmon cannot digest (Ketola 1990). It has been demonstrated that phosphorus requirements are species-specific and surplus phosphorus provided through feed is either excreted. Most of the animal and inorganic sources of phosphorus are readily available to fish (Ketola 1990). Ketola (1982) reported that the source of the phosphorus significantly influenced the retention as well as loss rate, e.g., defluorinated rock phosphate (DRP) resulted in good growth of rainbow trout with a reduction of 46% in phosphorus discharge (Ketola 1985) in comparison to dicalcium phosphate (Ketola 1991). Additionally, the bioavailability of dietary phosphorus is influenced by the digestibility of diet, particle size, interaction with other nutrients, feed processing and water chemistry (Lall 1991). Salmonids utilize phosphorus from fish meal more efficiently than do carp (Yone and Toshima 1979) whereas availability to tilapia is low.

Phosphorus Release from Food and Feces

The majority of phosphorus loss is in particulate form such as feces and uneaten food. However, release to the environment of phosphorus from food and feces depends on physico-chemical characteristics of the environment such as pH, temperature, oxygen, turbulence and microbial activity (Persson 1988). Phosphorus release from fish food was observed to be accelerated in acidic rather than in neutral or alkaline medium (Fig. 3).

The bioavailability of phosphorus from fish food and feces depends on proportion of labile phosphorus there. The fish food having the highest total phosphorus content has been found to have the highest concentration of labile phosphorus (Kibria et al. 1995).

Overcoming Phosphorus Pollution from Aquaculture

To reduce phosphorus pollution, the following are important:

1. estimation of phosphorus balance of species under aquaculture (Ketola 1991);
2. feed composition and type (e.g., extruded feeds are more digestible and generate less dust and solid waste and also result in better FCR (Warren-Hansen 1982; Matty 1990);
3. feeding techniques (e.g., avoiding overfeeding and adjusting feed amount and frequency to the temperature (Seymour and Bergheim 1991);
4. formulation of diets to meet nutrient requirements and proper choice of dietary ingredients (Kaushik 1992); and
5. reduction of phosphorus levels in feeds without affecting growth, feed efficiency, health and reproduction (Kendra 1991; Lall 1991).

Table 2. Criteria for assessing water quality of freshwater based on phosphorus level (OCE 1988).

	Total phosphorus (mg/l)	Dissolved phosphorus (mg/l)
Excellent	<0.010	<0.008
Good	<0.025	<0.020
Moderate	<0.050	<0.040
Poor	<0.100	<0.080
Degraded	<0.100	<0.080

Fish farm effluents can increase phosphorus levels and consequently cause eutrophication in receiving waters. As a result, further use of such waterbodies for recreational or domestic or industrial purpose will be seriously affected. In Asia, where aquaculture is a booming industry and demand to use water for agriculture and domestic purposes is high, it is essential that more research on phosphorus pollution is conducted. As phosphorus requirements are species-specific, it is vital that phosphorus be provided in feed at a level that maximizes growth of fish but minimizes pollution of the environment. In this context, research on the development of "low pollution diets" are of utmost importance. The nutrient from aquaculture can be minimized by retaining wastewater (effluents) in holding ponds and by reusing wastewater on lands for growing crops in integrated aquaculture-agriculture system. The other alternative would be to develop high energy diets which reduce phosphorus discharge to the environment compared to normal feed (Bohl et al. 1992). Though aquaculture has been identified as one of the point sources of phosphorus pollution, phosphorus loadings to the environment from fish farms is minimal compared to other sources such as agriculture (Table 3).

Table 3. Typical nutrient concentration for various point source discharges (EPA 1995).

Source	Total phosphorus (mg/l)
Fish farms	0.07
Dairy shed effluent	340
Feedlot effluent	150

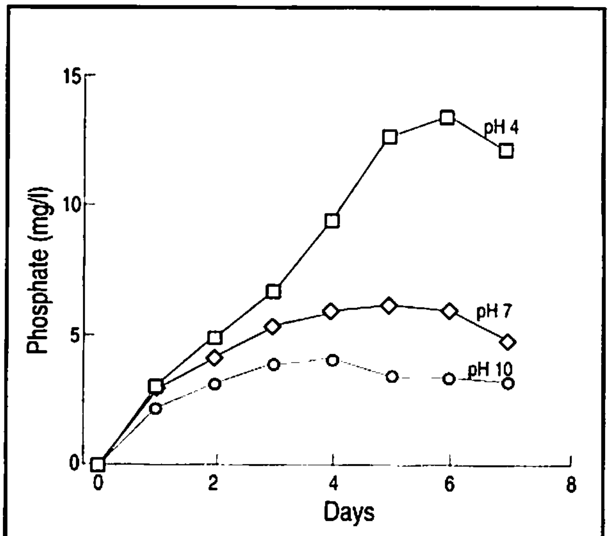

Fig. 3. The release of phosphate from fish food at different pH levels. The food was incubated at 20°C for seven days.

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***G. Kibria** and **D. Nugegoda** are from the Department of Environmental Management, Victoria University of Technology, PO Box 14428, MCMC, Melbourne 8001, Australia; **P. Lam** is from the Biology and Chemistry Department, City University of Hong Kong, Tatt Chee Av, Kowloon, Hong Kong; and **R. Fairclough** is from the Centre for Bioprocessing and Food Technology, Victoria University of Technology.*