IMPACT ASSESSMENT OF CHANGES IN LOW SALINE WATER QUALITY AND SOIL SEDIMENTATION FOR COMMERCIAL BLACK TIGER SHRIMP CULTURE

NAHATAI VIJITROTAI

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE PROGRAM IN APPLIED CHEMISTRY

SCHOOL OF GRADUATE STUDIES
KING MUNGKUT 'S INSTITUTE OF TECHNOLOGY LADKRABANG

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หัวข้อวิทยานิพนธ์	**การประเมินผลกระทบของการเปลี่ยนแปลงคุณภาพของน้ำความเค็มต่ำและดินตะกอนต่อการเพาะเลี้ยงกุ้งกุลาดำเป็นการค้า**
นักศึกษา	**นางณหทัย วิจิตโรทัย**
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บทคัดย่อ

การประเมินผลกระทบการเปลี่ยนแปลงคุณภาพน้ำและดินตะกอนของการเลี้ยงกุ้งกุลาดำ (จำนวน 4 บ่อ) ตั้งแต่เริ่มต้นเลี้ยงด้วยอาหารสำเร็จรูป จนถึงช่วงที่สามารถวัดอัตราการเจริญเติบโต โดยอาศัยการเก็บตัวอย่างน้ำ ดินตะกอน และวัดการเจริญเติบโต (ความถี่ 2 ครั้งต่อสัปดาห์) จำนวน 23 ครั้ง พบว่า การเจริญเติบโตของกุ้งแบ่งออกได้เป็น 2 ลักษณะ ดังนี้

1. กุ้งเจริญเติบโตดี ได้แก่

บ่อที่ 2 : พบว่า ดินตะกอนและน้ำมีค่า pH ที่เหมาะสม (7.02 และ 7.85) มีค่า alkalinity 94 mg/l ปริมาณอินทรียสารและปริมาณซัลเฟต (273_s , 494_w mg/l) และปริมาณเหล็ก (137_s, 1.46_w mg/l.) ในดินและน้ำซึ่งต่ำกว่าในบ่อที่ 1 และ 3

บ่อที่ 4 : พบว่า ดินตะกอนและน้ำมีค่า pH ที่เหมาะสม (7.10 และ 7.50) มีค่า alkalinity 69 mg/l และมีปริมาณอินทรีย์สารในดินและน้ำ รวมทั้งมีปริมาณซัลเฟต (274_s, 624_w mg/l) และปริมาณเหล็ก (138_s, 0.95_w mg/l) ซึ่งต่ำกว่าในบ่อที่ 1 และ 3

2. กุ้งตาย ได้แก่

บ่อที่ 1 : พบว่า ดินตะกอนและน้ำมีค่า pH ตลอดการเลี้ยง 6.35 และ 7.85 ค่าความเค็มและalkalinity ต่ำ 55.3 mg/l มีปริมาณอินทรีย์สารในดินและน้ำสูงรวมถึงมีปริมาณซัลเฟต (391_s , 800_w mg/l) และปริมาณเหล็ก (197_s , 1.14_w mg/l)

บ่อที่ 3 : พบว่าดินตะกอนมีค่า pH 7.32 และในน้ำ 8.07 (pH เป็นด่างสูง 8.74 ตอนกุ้งตาย) นอกจากนี้ยังพบว่ามีปริมาณอินทรีย์ในโตรเจน และปริมาณออกซิเจนสูง ประกอบกับมีปริมาณซัลเฟต (368_s , 674_w mg/l) และปริมาณเหล็ก (185_s , 1.45_w mg/l) ในดินและน้ำสูงทำให้เกิดการออกซิเดชั่นในสภาวะที่เป็นด่างและส่งเสริมให้เกิดตะกอนเจลของ Ferric oxides และ Ferric hydroxides

จากการศึกษาความสัมพันธ์ของ Pearson Correlation **ของความยาวและน้ำหนักของกุ้งเลี้ยงในบ่อที่ 1, 2 และ 4 พบว่ามีความสัมพันธ์ทางบวก** (p<0.05) **และไม่พบความสัมพันธ์ดังกล่าวในบ่อที่ 3** (p>0.05)

จากการศึกษาสมการถดถอยร่วมเชิงเส้นของอัตราการเจริญเติบโตของกุ้งเลี้ยงแต่ละบ่อกับคุณภาพของดินและน้ำ พบว่า

1. บ่อกุ้งที่เจริญเติบโตดี ได้แก่

บ่อที่ 2 ปริมาณ pH ในดิน และ organic matter ปริมาณ chloride sulfate และ total phosphorus ในน้ำ ควบคุมความยาวกุ้งทางบวก โดยค่า pH และ soluble salts ในน้ำมีผลทางลบ นอกจากนี้ยังพบว่าค่า pH ปริมาณ soluble salts organic matter ในดิน และ suspend solids chloride ในน้ำ ควบคุมน้ำหนักของกุ้งทางบวก โดยค่า ซัลเฟตในดินและ organic nitrogen ในน้ำมีผลทางลบต่ออัตราการเจริญเติบโตของกุ้ง

บ่อที่ 4 ปริมาณ organic matter ในดิน และ alkalinity ในน้ำมีผลต่อการควบคุมความยาวกุ้งในทางบวก โดยค่า solule salts ปริมาณ suspended solids และ sulfate ในน้ำมีผลทางลบ และพบว่า ปริมาณ organic matter และ total nitrogen ในดิน ควบคุมน้ำหนักของกุ้งทางบวก โดยค่า soluble salts ในดินและค่า suspended solids chloride รวมถึงปริมาณ total nitrogen ในน้ำมีผลในทางลบต่ออัตราการเจริญเติบโตของกุ้ง

2. บ่อกุ้งที่ตาย ได้แก่

บ่อที่ 1ระดับอุณหภูมิและปริมาณออกซิเจนในน้ำควบคุมความยาวของกุ้งในทางบวก

บ่อที่ 3 ปริมาณอินทรีย์สารในดินควบคุมความยาวกุ้งในทางบวก

นอกจากนี้สามารถสร้างความสัมพันธ์ร่วมกันของข้อมูลพื้นฐานที่เกี่ยวข้องกับคุณสมบัติของน้ำและดินตะกอนบางประการกับอัตราการเจริญเติบโตได้ในส่วนของการเสริมความยาวและน้ำหนักของกุ้งออกมา ได้แต่ละรูปแบบดังนี้

บ่อที่ 1 : ความยาว $= -21.24+0.24Temp+2.22DO$

น้ำหนัก $= 22.32+0.39Temp+1.54DO$

บ่อที่ 2 : ความยาว $= -162.97+21.93pH_s+1.71OM_s-0.18pH-0.09EC+0.39Cl^-+0.002SO_4^{2-}+0.20TP$

น้ำหนัก $= -201.04+27.24pH_s+0.08EC_s+1.29OM_s-0.01SO_4^{2-}{}_s+4.27SS+0.81Cl^--1.02ORN$

บ่อที่ 3 : ความยาว $= -89.11+8.23OM_s$

น้ำหนัก $= -119.76+10.91OM_s$

บ่อที่ 4 : ความยาว $= 8.48+0.19OM_s-0.82EC-68.0SS+0.07ALK-0.002SO_4^{2-}$

น้ำหนัก $= -53.12-3.67EC_s+6.24OM_s-53.61SS-2.72Cl^-+2.40TN$

หมายเหตุ: s = ดินตะกอน , w = น้ำ

Thesis Title	Impact Assessment of Changes in Low Saline Water Quality and Soil Sedimentation for Commercial Black Tiger Shrimp Culture
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Student ID.	36064163
Degree	Master of Science
Programme	Applied Chemistry
Year	2000
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Thesis Co - advisor	Asst. Prof. Dr. Suntorn Poolpipatana

ABSTRACT

Impact assessment of changes in water quality and soil sediment for black tiger shrimp culture (4 ponds) used commercial shrimp feed, until can measure growth rate of shrimp, frequency sampling water, soil sediment and measure length and weight of shrimp (every two weeks) total 23 times, found that the growth rate of shrimp divides to 2 categories such as :

1. Shrimp production is good.

The second pond : The soil sediment and water, pH is suitable (7.02 and 7.85), have alkalinity 94 mg/l, organic matter and sulfate (273_s , 494_w mg/l), and have iron (137_s , 1.46_w mg/l) less than the first pond and the third pond.

The fourth pond : The soil sediment and water, pH is suitable (7.10 and 7.50), have alkalinity 69 mg/l, and have organic matter in both contain sulfate (274_s , 624_w mg/l), and iron (138_s , 0.95_w mg/l) have value less than the first pond and the third pond.

2. Dead shrimp.

The first pond : The soil sediment and water, pH is 6.35 and 7.85, have low value of soluble salts and alkalinity but have high value of organic matter in both, contain sulfate (391_s, 800_w mg/l) and iron (197_s , 1.14_w mg/l)

The third pond : The pH of soil sediment is 7.32 and 8.07 in water (The shrimp die, pH is high = 8.74), and have high value of organic nitrogen and oxygen involved sulfate (368_s , 674_w mg/l), and iron (185_s , 145_w mg/l) in soil and water, reduce to oxidation state in alkaline condition and support to gel precipitate of Ferric oxides and Ferric hydroxides.

Study correlation analysis : Pearson Correlation between length and weight of shrimp in the first pond, second pond and fouth pond, found that they have positive correlation ($p<0.05$) and no have correlation in the third pond ($p>0.05$).

The regression equation of growth rate with soil sediment and water quality in each shrimp pond, could be described as:

1. Shrimp production is good.

The second pond :

- Factors that give positive result to increase shrimp length depend on pH, organic matter in soil and chloride sulfate and total phosphorus in water, but pH and soluble
salts in water have negative to decreased length of shrimp.

- Factors that give positive result to increase shrimp weight depend on pH, soluble salts, organic matter in soil, but sulfate in soil and organic nitrogen in water have negative to decreased weight of shrimp.

The fourth pond :

- Factors that give positive result to increase shrimp length depend on organic matter in soil and alkalinity in water, but soluble salts, suspended solids and sulfate in water have negative to decreased length of shrimp.

- Factors that give positive result to increase shrimp weight depend on organic matter, total nitrogen in soil, but soluble salts in soil and suspended solids chloride and total nitrogen in water have negative to decreased weight of shrimp

1. Dead shrimp.

The first pond : The level of temperature and oxygen value in water is positive factor to increase length of shrimp.

The third pond : The organic matter in soil is positive factor to increase length of shrimp.

Study from regression equation of basic soil sediment and water quality with growing rate to support increase length and weight of shrimp, show the relation of information as below:

Pond no.1 : Length = $-21.24+0.24Temp+2.22DO$

Weight = $22.32+0.39Temp+1.54DO$

Pond no.2 : Length = $-162.97+21.93pH_s+1.71OM_s-0.18pH-0.09EC$ $+0.39Cl^-+0.0002SO_4^{2-}+0.20TP$

Weight = $-201.04+27.24pH_s+0.08EC_s+1.29OM_s-0.01SO_4^{2-}{}_s$ $+4.27SS+0.81Cl^--1.02ORN$

Pond no.3 : Length = $-89.11+8.23OM_s$

Weight = $-119.76+10.91OM_s$

Pond no.4 : Length = $8.48+0.19OM_s-0.82EC-68.0SS+0.07ALK-0.002SO_4^{2-}$

Weight = $-53.12-3.67EC_s+6.24OM_s-53.61SS-2.72Cl^-+2.40TN$

Remark : s = soil sediment , w = water

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Nahatai vijitrotai

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CHAPTER 1
INTRODUCTION

1.1 General

The business of black tiger shrimp Penaeus monodon, culture seems to be a highly productive income and affects to the whole economic views of country both at the present and in the future. Shrimp farming in brackish water increases rapidly in Thailand. P. monodon is fairly large, body length of 20 centimeters in minimum, dark brown body color with horizontal blackstripes on the dorsal side of the abdomen, and walking legs in bluish brown (Surin, 1989). It is one of the most suitable species for intensive cultivation because of its outstanding, omnivorous feeding habit, eurhyaline native, grows rapidly, high tolerance against handling stress, and it can reach marketable size within 4 months and gives high profit return to shrimp farmer.

1.1.1 Shrimp Culture Systems

Shrimp culture systems in Thailand can be catagoried into three levels: extensive, semi - intensive, and intensive. The main characteristics farms of these systems are summarized in Table 1.1

Extensive culture. Penaeid shrimp could be formed extensively at a productive produces yields of 24 kg rai^{-1} $year^{-1}$ or less. The productive reliance is placed on natural food within the pond, the mangrove is also a suitable source of food and income for near - shore communities, which may be enhanced by fertilization with animal manure or chemical fertilizers. The pond are stocked with naturally occurring juveniles but with little prospect of controlling density. There is usually some tidal water exchange of up 5 - 10 cm per day. The tidal pattern, range and wetted areas are particularly important for constructing extensive pond. Pond sizes are ranged from 31.25 - 62.5 rais. In Thailand, which have a maximum tidal range of - 0.4 m mean sea level (MSL) to + 2.0 m MSL, the most ideal elevation for the pond is between 0.0 m and + 1.4 m MSL.

Semi - intensive culture. In 1980, the semi - intensive system was introduced into Thailand. The crustaceans farmed at higher densities are predominately penaeid shrimp. Cultures and productivities could be yield from 96 - 288 kg rai^{-1} $year^{-1}$. and are frequently found from 2 - 2.5 crops per year. Mainly compounded foods are used occasionally in conjunction with fertilization to enhance natural production. Productive performance depends on controlled stocking density / or hatchery reared post-larvae. Good yields are likely with carefully manage tidal or pumped water exchange, and provision of supplementary aeration towards the end of the culture period. Generally, pond sizes are ranged from 6.25 - 12.5 rais and modern farms may have square or rectangular purpose -

built earthen ponds with separate inlet and outlet channels to assist water management. In some locations the ponds are lined with clay, concrete or butyl linings. Productivity of many semi - intensive ponds is limited to a maximum of 3000 kg ha^{-1} per harvest by low and fluctuating oxygen levels, poor phytoplankton management and irregular water exchange.

Intensive culture. This category of cultivation is dominated by penaeid shrimp which can provide yields of over 960 kg rai^{-1} $year^{-1}$ taking 4 months per crop, with two crops per year. Intensive culture demands almost total reliance on compounded feeds, precisely controlled feeding rates, and the use of hatchery - reared, nursed juveniles stocked at specific densities. Continuous exchange of new water, generally over 50 – 200% perday, as well as aeration, is necessary. The type of culture system does not require high volume water exchange. In this regard, the pond bottom needs to be at a higher elevetion, preferably + 2.0 MSL. These areas are behind the mangrove zone. Some farms also recycle a proportion of the culture water. Because of the high densities and the use of supplement feeding, there is a large organic accumulation at the pond bottom after period which requires complete drying to facilitates sanitation and removal of waste. Pond construction in the mangrove area is unsuitable, the soil is high in organic content; therefore, it is acidic in nature and inapropriate for shrimp growth. Shrimp ponds are ranging in size from 6.25 rais or less.

Table 1.1 Characteristics of shrimp culture at the three levels of intensity.

Characteristics	Level of Intensity		
	Extensive culture	Semi - intensive	intensive
Land elevation (m)	0 - +1.4 MSL	0 - + 1.4 MSL	> + 2.0 MSL
Pond size (rai)	> 31.25	6.25 - 12.5	6.25 or less
Aeration	Natural	Water exchange or more mechanical	Continual mechanical and flushing
Stocking rate (PL m^{-2} $crop^{-1}$)	< 5	5 - 15	20 or more
Feed	Natural (No supplement)	Natural + supplement	Formulated
Production level (kg rai^{-1} yr^{-1})	16 - 48	96 - 288	> 960

Remark : MSL = mean sea level ; PL = Postlarvae

Source : Menasveta, 1996

1.2 Problem identification

At present Thailand is still to be the world's leading shrimp producer and the top shrimp exporting country as reported in 1994. The production was 260,000 metric tons, export value 49,057 million baths and in 1998 was 220,000 metric tons had export value 58,343 million baths (Table 1.2). The shrimp culture industry with its great potential to generate high export earnings has developed rapidly in countries during the past decade. The explosive growth of the industry has been towards the intensification of shrimp farming using high stocking densities. The development has created various problems in pond and water management. (C. P. Shrimp News, 1993)

Table 1.2 Production capacity and value export of frozen shrimp in Thailand.

Year	Shrimp production (1000tons)	Frozen shrimp (1000tons)	Value (million bahts)
1993	220	148.86	37,988
1994	260	199.08	49,057
1995	256	174.99	50,386
1996	220	161.30	43,362
1997	198	137.08	47,182
1998	220	150.01	58,343
1999	200		

Source : Krung thai economic report, 2000.

Since 1987, many shrimp farms, especially the intensive ones, of various countries have experienced in decreased production, disease outbreaks and often bankruptcy. In Taiwan during 1991 - 1993, due to multifactorial effects of sub-optimal environment and disease, production dropped from 30,000 metric tons to 25,000 metric tons per year. Also in Indonesia and Philippines, many intensive farms are crowded along small estuaries farming so - called "shrimp slums". These often choke with disastrous results, including decreased growth and disease outbreak. In China the suffered substantial loses are due to an acute mass mortality problem. This disease problem was first found plaguing the shrimp farming area in the southern province of Fugal around June / July 1993, then moved further up to province of Zhejiang and Jaingsu, and eventually reaching, the Gulf of Bohai. No concrete identification has been made as to what was the exact cause of this problem which took only two to three days from onset to 100% mortality. Production dropped from 145,000 metric tons in 1991 to 50,000 metric tons in 1993 (Table 1.3). In case of Thailand shrimp culture did not succeed in all areas. There have been several problems and impediments which are yet to be resolved. These problems are interrelated and seem to be associated with improper farm management, environmental problems, mangrove destroy, diseases and low quality seed (Menasveta and Jarayabhand, 1995).

Table 1.3 Production capacity of shrimp in the world.

	Unit : 1000 tons				
	Year				
Source	1991	1992	1993	1994	1995
China	145.0	140.0	50.0	35.0	35.0
Thailand	102.0	184.0	225.0	250.0	253.0
Taiwan	30.0	30.0	25.0	25.0	25.0
Indonesia	100.0	125.0	80.0	100.0	101.
Ecuador	100.0	95.0	70.0	100.0	101.0
Bangladesh	25.0	25.0	30.0	35.0	35.0
India	35.0	44.0	50.0	70.0	70.0
Philippines	30.0	24.0	25.0	30.0	30.0
Vietnam	30.0	32.0	40.0	50.0	50.0
Peru	3.0	3.0	30.	3.0	3.0
Japan	2.0	2.0	2.0	2.0	2.0
Panama	4.0	4.0	4.0	4.0	4.0
Others	24.0	13.0	5.0	29.0	29.0
Total	690.0	721.0	610.0	733.0	738.0

Source : C.P. SHRIMP NEWS, 1994.
Remark : 1995 Trend.

The main factors affecting the success of this enterprise are related directly with high water qualities and lands that used as shrimp culture ponds. However, there is a lack of data base or information on how much variation a specific database in an environmental parameter can cause in survival or growth of shrimp in ponds. The most widely recognized factors are pH, temperature, salinity, nutrient concentrations, total solids, organic matter, soil acidity and condition of soil at beginning of each crop. In close culture system shrimp population can be kept healthy in a limited volume of water and It must be relied on the balance of quality wastes produced by shrimps.

Now, the shrimp culture in Thailand causes many problems to surrounding environment in coastal area. The intensive system being used in Thailand will not be sustained. Understanding on various aspects of environmental impact caused by shrimp culture is essential for problem solving. Shrimp culture has been developed rapidly in coastal areas of Thailand, and it also has expected that this activity will take as important role in Thai economics. There are many attempts to sustain this activity. Shrimp business are concerned with many people around 15,000 families (Deangsakul, 1994). The culture areas of shrimp farm are increased from 229,943 rais in 1984 to 531,250 rais in 1993 and covering coastal areas of the Gulf of Thailand and Andaman Sea. Mangrove forest destruction is one problem that could be received much attention. How serious the impact is remained in question. The mangrove destruction, both the extensive and semi - intensive shrimp culture causes the higher rates of mangrove devastation as shown in Table 1.4 It should be noted that the intensive culture system was introduced in 1986 and since then the shrimp production increased shrarply, while mangrove destruction and the total shrimp farming area leveled off. The majorities of shrimp farmers in Thailand are serious about their livelihood and have made sustainability their goals, which are in compatible with mangrove utilization. In the present, European Union (EU) will dismiss a Generalized System of Preferences (GSP) for Thailand which will make shrimp farming in Thailand hardly competitive with other countries. This is turn would encourage more extensive - type culture operations in the country, and for this reason, more mangroves worldwide may be potentially destroyed.

Table 1.4 Shrimp culture modernization* and mangrove destruction in Thailand.

Before modernization		During modernization
1961 - 1986		1987 - 1993
26 years	Time span	7 years
Extensive & Semi - intensive	Shrimp culture system	Intensive
Rather primitive	Culture technology	More advanced
283,548 (1986)	Shrimp culture area (rai)	449,292 (1993)
17,886 (1986)	Annual shrimp production (MT)	225,514 (1993)
63 (1986)	Productivity (kg/rai/Year)	502 (1993)
1,100,076	Destroy mangrove area (rai)	173,458
42,311	Mangrove destroyed rate (rai/Year)	24,780
47.26	% Mangrove detroy in the period**	7.45
Summary 1986 Destroy area=1,100,076 rais Remaining area=1,227,724 rais		Summary 1993 Destroy area=1,273,543 rais Remaining area=1,054,266 rais

Remark : * Moderization of shrimp culture technology started in 1987.

** Based on mangrove area of 2,327,800 rais in 1961 as 100%.

MT = Metric Ton

Source : Menasveta, 1996.

1.3 Objectives of the study

The study aims to:

1.3.1 Analyze physical and chemical properties of soil sediment and low saline water during culture period of P. monodon.

1.3.2 Correlate the regression model about the basis properties of soil sediment and low saline water with shrimp growth.

1.3.3 Preliminary assessment effect of physical and chemical parameters changes for the culture shrimp.

1.3.4 Applied simulation (computer model) for expect and trend about suitable condition (environmental factors) for commercial black tiger shrimp in the future.

1.4 Scope

The scope of this study is localized in shrimp farm at Klong Dacho, Ampher Bang Nam Priew, Chacherngsao province, Thailand.

All details are monitored at selected sites. The monitory includes the sample from water and soil sediment in selected ponds. The data are concerning with physical and chemical parameters changed during the culture period and then, have tremendous impacted direct of soil and water quality for culture shrimp. Let's the data to predict the effect of soil sediment and low saline water quality for growth rate and production of black tiger shrimp.

CHAPTER 2

REVIEW OF LITERATURE

2.1 PHYSICAL AND CHEMICAL PARAMETERS

2.1.1 WATER PROPERTIES (SHRIMP PONDS)

Temperature

Temperature is both a limit factor, setting high and low temperature lethal limits, and a determinant of growth rate though its impact on molecular activity. In ponds, temperature is strongly affected parameter. James and Josefa (1992) reviewed the research finding that the tolerance to variation in temperature and salinity often differs among closely related species due to genetic differences. Motoh (1981) studied on three age groups of P. monodon. All groups could tolerate a low temperature of 10°C for short period of time. Survival rates was 98% at 39°C for all groups and heavy mortality. Fast and James (1992) reviewed the research finding that the temperatures as low as 11°C in ponds but no experimental studies of mortality of P. monodon. Besides, the aquarium studies of 1 of 5 g P. monodon over 18°C to 33°C showed the highest growth at 27°C to 33°C. Pond growth rate increased with temperature in the range 21 - 27°C. Water temperature has a greater effect on aquatic in vertebrates than any other environmental variable. Water temperature has significant effects on respiration, food consumption, digestion, assimilation, growth, and behavior (Schmidt-Nielsen, 1979). Black tiger shrimp grows well at temperatures 25 - 32°C. Lower water temperatures are often halted or reduced in production (Boyd, 1982).

pH of water

The ponds constructed in or near the parent materials of acid - sulfate soil, pH monitoring of pond water is necessary to assure that excessively acidic condition do not develop. Blackish water normally has a high alkalinity, pH near 8, and is well - buffer against drastic pH changes. Nevertheless, in ponds with heavy plankton blooms, pH can fluctuate between 7.5 and 9.5 over a 24 - hour period with the lowest pH occurring near down and vertical pH patterns results from the influence of light on photosynthesis and from the effects of community respiration. The pH of natural waters is greatly influenced by the concentration of carbon dioxide, and an acidic substance (Strum and Morgan, 1970). Phytoplankton and other aquatic vegetation remove carbon dioxide from the water during photosynthesis, then the pH of a body of water rise during the day and deceases at night. Water with a low alkalinity often have pH values of 5 - 7.5 before the day break, but when phytoplankton photosynthesis is great, the afternoon pH values may exceed 10 (Swingle, 1961). Fluctuations in pH are not as great in water with higher total alkalinity; in these waters, pH values normally range from 7.5 or 8 at the day break to 9 or 10 during the afternoon. In some water with high total alkalinity and very low total hardness, the pH may rise to above 11 during period of rapid photosynthesis (Boyd, 1982). Sea water is generally alkaline, with pH in the region of 8.2 with slight variations (0.1 - 0.2 pH units) limited by the buffering capacity of weak acids; carbonates, bicarbonates, borate, which affect the equilibrium as described below:

$$H_2O + CO_2 \longrightarrow H_2CO_3 \longrightarrow HCO_3^- + H^+ \longrightarrow CO_3^{2-} + 2H^+$$

Carbon dioxide   carbonic acid   bicarbonates   carbonates

This leads to the formation of carbonate ions by the addition of acids, and carbon dioxide gas by the addition of a basis solution. Grande and Andersen (1981) studied the pH values for 40 days that led to the mortality of 50% of batch of Atlantic salmon alevins varied between 4.5 and 10.2 and toxic compounds is not increased. High Fe^{2+} concentrations could be occurred in anaerobic interstitial water, and the mineral siderrite ($FeCO_3$) controls the solubility of Fe^{2+} according to the equilibrium:

$$FeCO_3(s) + H^+ = Fe^{2+} + HCO_3^- \qquad K = 10^{-0.3}$$

Assuming that HCO_3^- and Fe^{2+} concentrations in the interstitial water of an aquaculture pond are 60 mg/l and 20 mg/l, respectively, we may calculate the pH of the interstitial water by substituting Fe^{2+} and HCO_3^- concentrations into the mass - action form of Equation as:

$$\frac{[Fe^{2+}][HCO_3^-]}{[H^+]} = 10^{-0.3}$$

The result is $[H^+] = 10^{-6.44}$ M or pH = 6.44. At the ranges of Fe^{2+} and HCO_3^- found in interstitial water of pond sediment, pH is between 6 and 7. Of course, in the oxidized surface layer of sediment, the pH is controlled by exchangeable acidity or iron pyrite oxidation, and the range of pH values in the oxidized surface layer can be much wider than that of anaerobic soils.

Suspended solids

Suspended solids are small pieces of particulate matter, larger than 0.45 mm, found in the water column. Particles smaller than the indicated size are considered to be dissolved in the water. The amounts 96 suspended solids are made up of sediment particles (fine sand, silt, clay), organic material (detritus composed of plant and animal remains), waste feed particles, as well as bacteria, fungi, phytoplankton, and other microorganisms. Each of these materials contributes to water turbidity. The higher the concentration of suspended solids in the water, the more turbid the water becomes. Sediment particles composed largely of silt clay may become suspended in the water column as a result of currents or wind mixing, or they may be washed into the water system from land runoff. Inorganic particles can have detrimental effects on aquatic organisms (Cairns, 1967). The mechanical action of such particles can lead to clogging of the gills or the irritation of gill filaments and other membranes. If great deal of suspended particulate matter is introduced into an pond, subsequent setting of the material may lead to the burial of eggs, larvae, fry, and even juveniles of benthic organisms. Wallen (1951) examined the effects of turbidity on 16 species of fish, including channel catfish and common carp, and observed no adverse effects until turbidity exceeded 20,000 mg/l. Most species were able to withstand turbidity up to 100,000 mg/l for a week or more. Turbidity increased make interfere with the ability of a fish to identify food items, it also reduces light transmittance, which further compounds the problem.

Suspended solids is the degree of produce in water by suspended particulate matter. The concentration of particulate matter determines the transparency of the water by limiting the light transmission. The suspended solids can create thickened gill lamellae on the cultured species this impedes oxygen uptake and, in turn, decreases growth rate. Certain species of invertebrates that naturally live in turbid waters have sufficient interlamellar spaces to minimize the contact of suspended solids with gill tissue (Schmidt-Nielsen, 1979). The suspended solids restrict light penetration and limit the growth of plants. Water turbidity is caused by the presence of solids in suspension. These solids comprise mineral and organic particles from the detritus, as well as phytoplankton and zooplankton. They are known as suspended solids (SS). Turbidity has a quantity and qualitative effect on the penetration of light into water. It can reduce the level of photosynthesis, and phytoplankton production.

Salinity

Salinity is a measure of the total concentration of all dissolved ions in water expressed in grams per liter or parts per thousand (ppt). The major dissolved ions are sodium (Na^+), chloride (Cl^-), magnesium (Mg^{2+}), calcium (Ca^{2+}), potassium (K^+), sulfate (SO_4^{2-}) and bicarbonates (HCO_3^-). The osmotic pressure of watch increases with increasing salinity. The optimum salinity for acquaculture depends on the species. Salinity tolerances of Black tiger shrimp is 15 - 25 g/l (Boyd, 1989). The salinity increases the ability of water to conduct electrical current (conductivity) also rise. Salinity may be also estimated from chloride concentration. (Wooster *et. al.* 1969): salinity (ppt) = 1.80655 x [Cl] (ppt).

Dissolved salts presented in sea water are defined by Sverdrup (1942) as salinity (S^0%) which is the weight in grams of solids contained in a kilogram of sea water, when bromide and iodide ions are replaced by their chloride equivalents, all carbonates converted to oxides, and all organic matter oxidized. Chlorinity ($Cl^0\%$) is described as the weigh in grams of chlorine equivalent to the total quantify of halogens in a kilograms of sea water. Salinity and chlorinity are linked by the equation: $S^0\% = 1.805\ Cl^0\% + 0.03\%$ or Salinity = 0.03 + 1.805 x Chlorinity (Stickney, 1994). Salinity may be determined indirectly from chlorinity estimates by silvernitrate titration. In general, salinity has an effect on reproduction, nutrition and growth of aquatic organisms. Growth may be optimal at a restricted salinity range depending on the species. The chloride concentration can be estimate by refractometer or by titration of water sample with standard silver nitrate, using a potassium chromate indicator. Salinity seems lesser effect than temperature on survival of shrimp. The effect of salinity on growth is unclear. The osmoreguration and ion transport require energy expenditure which could have supported growth. Crustaceans and other invertebrates have blood salts concentrations isotonic with the surrounding water, or very nearly, so osmoregulation is still required. Invertebrate blood ionic composition is not identical with seawater. Lockwood (1967) reported that physiological processes must occur to control and maintain that blood chemistry. Osmoregulation involves the selective absorption of ions, and in some cases the selective removal of salts through the gills. In marine telecasts, the kidney is responsible for the excretion of salt. Because osmoregulation is a metabolic process, it requires energy. The more salt the body of an aquatic animal must take in or remove in order for it to maintain its internal salt concentration, the more energy is required. Energy used for osmoregulation may be used at the expense of growth. Motoh (1981) showed the tolerance of P. monodon culture in very low salinity. Survival rate was 64% at 0 ppt. Survival remained high at salinity > 0 ppt until 38 ppt, which mortality began to increase. In 20 - day culture period under controlled conditions, P. monodon PL16 1 cm has a higher survival rate at 15 ppt (82%) than at 20 ppt (74%) and 0 ppt (64%). Rajyalakshmi and Chandra (1987) seems survival rate decreased when the rearing time was extended. James and Josefa (1992) reported that P. monodon could survive very low salinity, even freshwater, but only for short period. P. monodon juveniles are the greatest tolerance. Motoh (1981) reported with a survival rate of 100% at 0 ppt. At 52 ppt, there was mortality. Deshimaru et al. 1985 reported that survival and growth were lower when P. monodon (0.65g) were reared at higher salinity (34 to 35 ppt) than at lower salinity (19 - 21 ppt). Rajyalakshmi and Chandra (1987) Studied in laboratory with the growth rate of P. monodon is ranked as follows: 15 ppt >20 ppt >0 ppt and the temperature condition was 28°C to 30°C.

Alkalinity and the carbonate buffer system

Alkalinity and hardness as water increasing show an increased capacity to buffer pH and ionic changes. Calcium carbonate chemical reactions use up in fluxes of acidic ions, and sufficient concentrations of calcium carbonate can prevent major changes in pH (Meade, 1989). The bicarbonate - carbonate character of a water can be analyzed by slowly adding a strong acid solution to a sample of water and reading resultant changes in pH. The process called titration is used to measure the alkalinity of a water.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

$$\rightleftharpoons H^+ + HCO_3^-;\ pH\ \ 4.5$$

$$\rightleftharpoons H^+ + CO_3^{2-};\ pH\ \ 8.3$$

When the water pH is grater than 4.5, carbonic acid ionizes to form bicarbonate which, in turn, is transformed to the carbonate radical if the pH is above approximately 8.3. Total alkalinity in aquaculture systems should generally be between 30 and 200 mg/l in fresh water, though water of higher and lower alkalinity has often been utilized successfully by culturists. Water of very low alkalinity has little capacity to resist pH changes and should be avoided under most circumstances. Low alkalinity water may be suitable for intensive closed culture systems because a buffering agent is routinely recommended for inclusion in the design. Boyd and Hollerman (1981) found that finely pulverized agricultural limestone was more effective than coarse limestone for increasing alkalinity, undoubtedly because of the increased surface area that would allow the final material to dissolved more rapidly and more completely. The pH of water affects the percentage of alkalinity contributed by carbonic acid, bicarbonates, and carbonates. Temperature and salinity also affect these relationships. Spotte (1979) indicated that in seawater of pH 8.0 and 24°C temperature, slightly more than 8% of alkalinity is the form of carbonates, where as in fresh water at the same pH and temperature, less than 0.5% of the alkalinity is represented by carbonate ions. Most of fresh water and low salinity estuarine waters may be attributed to bicarbonates.

Total alkalinity refer to the total concentration of titratable bases in water expressed as mg per liter of equivalent calcium carbonate ($CaCO_3$). In most waters these bases are principally bicarbonates (HCO_3^-) and carbonate (CO_3^{2-}) ions. Bicarbonates represent the major from of alkalinity illustrated for two alkaline earth carbonates, calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) as:

$$CO_2 + CaCO_3 + H_2O \longrightarrow Ca^{2+} + 2HCO_3^-$$

$$CaMg(CO_3)_2 + 2CO_2 + 2H_2O \longrightarrow Ca^{2+} + Mg^{2+} + 4HCO_3^-$$

The alkalinity is resisted to pH change. The volume of acid required to cause a specified change in pH increases as a function of total alkalinity of the water. In general, early morning pH is greater in water with moderate or high total alkalinity than in waters with low total alkalinity.

The carbonate buffer system

The carbonate buffer system involves a series of reversible chemical reactions. Carbon dioxide is one source of carbon for the system. Carbon dioxide is dissolved in water through diffusion from the atmosphere and as a result of respiration as follows:

$$H_2O + CO_2 \longrightarrow H_2CO_3^- \qquad \text{equation 1}$$

Carbonic acid ($H_2CO_3^-$) dissociates in water to from bicarbonate ion (HCO_3^-) and hydrogen ion (H^+):

$$H_2CO_3^- \longrightarrow HCO_3^- + H^+ \qquad \text{equation 2}$$

Bicarbonate ion can further dissociate to produce another hydrogen ion and carbonate ion (CO_3^{2-}):

$$HCO_3^- \longrightarrow H^+ + CO_3^{2-} \qquad \text{equation 3}$$

The carbonate buffer system resists changes in pH by releasing or absorbing hydrogen ions as necessary to maintain a steady state. In most cases fresh water has a pH of between 6.5 and 8.5, while sea water has a pH above 7.0. The level of calcium carbonate and other buffering agents present in the system helps establish the equilibrium pH.

If a hydrogen ion (from respiration or the dissolution of atmospheric carbon dioxide) is added to buffered water system, it will be captured by carbonate to from bicarbonate (moving equation 3 to the left). Thus, there will be addition of free hydrogen ions to the system, and the pH will not be reduced. If, on the other hand, hydrogen ion is removed when the system is in equilibrium, such as when it combines with hydroxide (OH^-) to from water (H_2O), bicarbonate or carbonic acid can dissociate to replace the lost hydrogen ion (moving equation 2 or 3 to the right). Photosynthesis removes carbon dioxide from the system, thereby forcing equation 1 to the left and taking hydrogen ions from bicarbonate or carbonic acid, the pH of the system will not rise.

$$CaCO_3 \longrightarrow Ca^{2+} + CO_3^{2-} \qquad \text{equation 4}$$

The reaction in equation 4 may not keep up with demand in some instances, or the pool of calcium carbonate may be insufficient to meet the demand. In such instances, the pH may fall dramatically as hydrogen ions are added to the system. Similar, if carbon dioxide is removed to the extent that the bicarbonate pool is exhausted, the pH may rise dramatically. In pond with high level of primary productivity, pH may actually increase significantly during the daytime as a result of photosynthesis. Conversely, at night when photosynthesis ceases, respiration by both plants and animals adds carbon dioxide to the system and the pH falls. In poorly buffered systems, the dial change can actually amount to several pH units (less than 6.0 to over 10.0). Such changes can be detrimental or lethal to aquatic animals, but they can be avoided if the system is well buffered. This can be accomplished by maintaining sufficiently high alkalinity. Bicarbonate ion appears to be an important element in the evolution of oxygen during photosynthesis (Stemler and Govindjee, 1973) and sometimes can be substituted carbon dioxide in the photosynthesis process. Bicarbonate usually serves as the carbon source in photosynthesis only when its concentration is at least 10 times that of free carbon dioxide (Wetzel, 1975). This occurs frequently, at least in the marine environment. Stemann (1975) indicated that about 1% of the total inorganic carbon in seawater is in the form of carbon dioxide, while 90% is bicarbonate and the remainder carbonate. When bicarbonate is utilized in photosynthesis, it is exchanged for hydrogen ions:

$$HCO_3^- \longrightarrow CO_2 + OH^-$$

At sufficiently high pH, calcium carbonate crystals will form on the leaves of aquatic macrophytes:

$$OH^- + HCO_3^- \longrightarrow H_2O + CO_3^{2-}$$

and

$$CO_3^{2-} + Ca^{2+} \longrightarrow CaCO_3$$

In alkaline fresh water, it is often possible to create a white cloud of calcium carbonate by disturbing rooted macrophytes that have been photosynthesizing in this manner. The utilization of bicarbonate ions in photosynthesis may be more advantageous to macrophytes is usually discouraged.

Dissolved Oxygen

Biological decomposition of organic mater is based on the utilization of dissolved oxygen. Dissolved oxygen in water is an important substance for growth of various organisms. It is also considered as the key substance for the existence of lived animals in water. Level significantly below saturation values, often occur in polluted surface waters. Most fishes and aquatic life are not survivied a lack of oxygen, hence dissolved oxygen determination is a principle measurement in pollution surveys. The rate of air supply to aerobic treatment process is monitored by dissolved oxygen testing to maintain aerobic conditions, and to prevent waste of power by excessive aeration (Stickney, 1994). The level of DO available to the animals in an aquaculture system is perhaps the most critical among the water quality variables that are routinely monitored. If a sufficient level of DO is not constantly maintained, animals will become stressed, after which they may not eat well for some period of time and their susceptibility to disease can increase dramatically. In the worst instance the animals may be killed outright. Even slight reductions in DO below the minimum desirable levels can lead to reduced growth rates and sub optimal food conversion efficiencies

(FCE). DO depletion can actually be exacerbated when the culturist provides food to animals that do not eat properly since waste feed will decompose and increase the oxygen demand on the system (Wheaton, 1977). As a general rule, if the DO concentration is equal to, or in excess of 5 mg/l, conditions relative to this parameter should be acceptable for aquatic organisms (Piper *et. al.* 1982). Fish some species may suffer severe stress or die if exposed to such low level, though most will perform well at 4 mg/l and may survive for extended periods 3 mg/l. While most fish species can tolerate 1 to 2 mg/l for brief periods, death is common if exposure to those levels exceeds a few hours.

Dissolved oxygen present in the water results from exchange taking place between the air above the surface of the water and the photosynthetic activity of phytoplankton and other plants. Oxygen solubility is limited, and reaches a level known as saturation which correlates inversely with temperature and salinity

Dissolved Oxygen (DO) is probably the most critical water quality variable in aquaculture. The solubility of oxygen in water decreases as water temperature and salinity increases (Banabe, 1990). Dissolved oxygen will diffuse into water, the rate of diffusion is very slow. Thus, photosynthesis by phytophankton is the primary source of dissolved oxygen in most aquaculture systems (Boyd, 1973). The primary loses of dissolved oxygen from ponds are caused by respiration by plankton, respiration by benthic organisms, and diffusion of oxygen into the air (Boyd *et. al.* 1978). The ranges of expected gains and losses of dissolved oxygen caused by different processes in culture ponds is given in Table 2.1 It is apparent that the major losses of dissolved oxygen are caused by plankton and fish and that photosynthesis is the major source.

Table 2.1 Ranges of expected gain and losses of Dissolved oxygen caused by different processes in fish ponds, of 1.0 - 1.5 meters average depth.

Process	Range (mg/l)
Grains Photosynthesis by phytoplankton	5 - 10
Diffusion	1 - 5
Losses Plankton respiration	5 - 15
Fish respiration	2 - 6
Respiration by organism in mud	1 - 3
Diffusion	1 - 5

Dissolved oxygen is related to plankton density. Photosynthesis decreases with decreasing light intensity, and as plankton becomes more abundant, the rate for oxygen consumption by the plankton increases. There is a marked dial fluctuation in DO concentration in ponds and natural waters. Concentrations of dissolved oxygen are lowest at sunrise, increase during daylight hours to a maximum in late afternoon, and then decline the night. The only really effective procedure for preventing fish mortality during periods of extremely low dissolved oxygen involves the mechanical devices (Boyd and Tucker, 1979). The aeration devices may because to introduce oxygen into waters with low DO. Shrimp farms can afford to maintain and operate emergency aeration equipment, when faced with dissolved oxygen problems. Problems with dissolved oxygen seldom occur except in ponds where fish are fed at high rates.

Chemical Oxygen Demand (COD)

COD is widely used to characterize the organic strength of wastewater and pollution of natural waters. The test measures the amount of oxygen required for chemical oxidation of organic matter in the sample to carbon dioxide and water.

The Nitrogen behavior in shrimp ponds

The compounds of nitrogen are of great interest for aquatic systems because of the importance of nitrogen compounds in the chemistry and in the life processes of all plants and animals. The chemistry of nitrogen is complex because of the severe oxidation state that nitrogen can assume. Sawyer and McCartry (1978). The relationships that exist between the various forms of nitrogen compounds and the changes that can occur in nature are best illustrated by a diagram of nitrogen cycle shown in Figure 2.1 Nitrates are also produced by direct oxidation of nitrogen or of ammonia in the production of commercial fertilizers. The nitrates serve to fertilize plan life and are converted to proteins.

$$NO_3^- + CO_2 + \text{green plants} + \text{sunlight} \longrightarrow \text{protein}$$

Atmospheric nitrogen is also converted to proteins by nitrogen- "fixing" bacteria and certain algae.

$$N_2 + \text{special bacteria or certain algae} \longrightarrow \text{protein}$$

In addition, ammonia and ammonium compounds are applied to soils to supply plants with ammonia for further production of proteins. Urea is one of the popular ammonium compounds because it releases ammonia gradually.

$$NH_3 + CO_2 + \text{green plants} + \text{sunlight} \longrightarrow \text{protein}$$

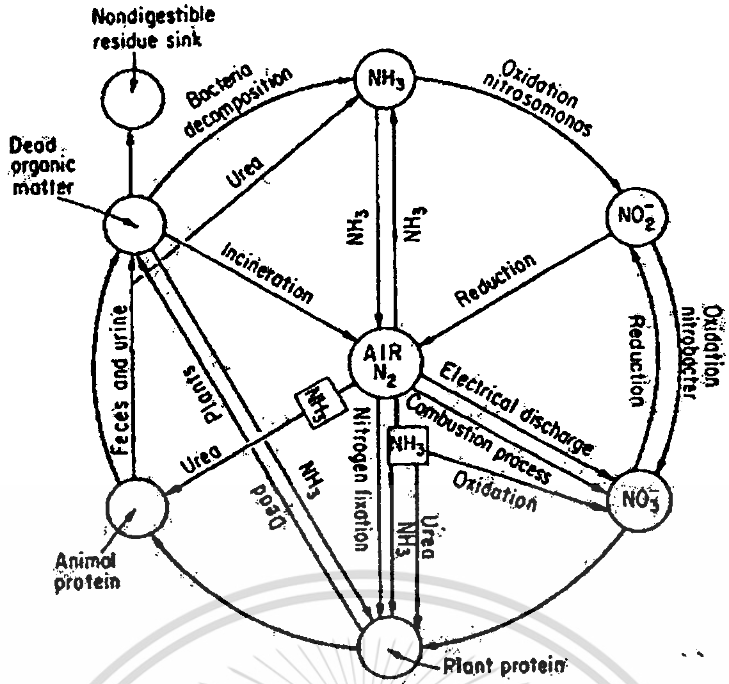


Figure 2.1 The nitrogen cycle in shrimp ponds. (Source: Sawyer and McCartry, 1978)

The feces of animals contain appreciable protein matter remaining in the bodies of bead animals and plants are converted in large measure to ammonia by the action of saprophytic bacteria, under aerobic or anaerobic condition:

$$\text{protein (organic N) + bacteria} \longrightarrow NH_3$$

- Ammonia

Ammonia in water has become an important consideration in the design and operation of pond. In some states limitations have been imposed because of suspect toxic effects upon aquatic life. Ammonia reaches ponds water principally as a product of fish metabolism and decomposition of organic matter by bacteria in water. It is well known that molecular ammonia is toxic but that the ammonium ion is not. The ammonia released into the environment establishes the following equilibrium in equation as below:

$$NH_3 + H_2O \rightleftharpoons NH^+_4 + OH^-$$

The proportion of unionized and ionized ammonia varies with pH (Trussell . 1972). Ammonia gas in water is ammonium hydroxide forms in turn can dissociate into ammonium and hydroxyl ions. The non - ionized form of ammonia is toxic to fish, but the toxicity is complicated depends on pH and temperature of the water. Increasing the pH or temperature increases the toxicity because more of the ammonia change rapidly during the day so ammonia toxicity becomes difficult to predict. In addition, the gill surface of fish will have a much higher carbon dioxide concentration than the surrounding water and the carbonic anhydrase in mucus will catalyze the formation of carbonic acid from that carbon dioxide. The resulting pH decrease at the surface will then affect the ammonia toxicity The toxicity of ammonia is enhanced as DO concentration is reduced (Boyd, 1992). Long – term exposure of aquatic animals to elevated ammonia levels can results in reduced growth, impaired stamina, gill abnormalities, and ultimately death (Burrows, 1964).

– Organic Nitrogen

Most of the nitrogen in organic matter exists as amino groups in protein. Protein are dominated through biological activity. The results from large organic matter decomposition gets ammonia and gives a condition of abnormally low dissolved oxygen occures.

Sulfate

The sulfate ion is one of the major anions occurring in natural waters. It is of importance in public water supplies because of its cathartic effect upon humans when it is present in excessive amounts. For this reason the recommended upper limit 250 mg/l in waters intended for human consumption. Sulfates are also important in both public and industrial water supplies because of the tendency of waters containing appreciable amounts to form hard scales in boilers and heat exchangers. Sulfate are indirectly responsible for two serious problems often associated with the handling and treatment of wastewater. These are odor and sewer – corrosion problems resulting from the reduction of sulfates to hydrogen sulfide anaerobic conditions, as shown in the following equations:

$$SO_4^{2-} + \text{organic matter} \longrightarrow S^{2-} + H_2O + CO_2$$

$$S^{2-} + 2H^+ \rightleftharpoons H_2S$$

Hydrogen sulfide is toxic to fish at concentration less than 1 mg/l (Smith *et. al.* 1976). The level of hydrogen sulfide assumed to be safe for most aquatic species is 0.002 mg/l (Boyd, 1979). The percentages of un – ionized hydrogen sulfide in water at different pH values are given in Table D-6 Hutchinson (1957) 's report. As pH decreases, concentrations of H_2S increase while those of HS and S^{2-} decrease.

A knowledge of the sulfur cycle, as represented in Figure 2.3 is essential to an understanding of the transformations that occur. The sulfate (SO_4^{2-}) ion is one of the major ions occurring in natural waters (Hem, 1970). Concentrations in ponds vary with the nature of the geological materials in the watershed. In regions with water of low salinity, concentrations of sulfate often range from 1 to 5 mg/l as sulfur. However, in regions with waters of higher salinity, and particularly in arid regions, sulfate concentrations are much greater. Peter (1993) Reported that the nitrate concentration is much lower than sulfate concentration under marine conditions and the nitrate is soon depleted, allowing the sulfate - reducing micro - organisms to become dominant.

The formation of hydrogen sulphide (H_2S) is a characteristic feature of anaerobic marine sediment due to the high levels of sulfate, as compared with nitrate, in sea water. Examples include; (a) marine muds, in which the sulfate has already been converted to sulphide; (b) fresh waters, in which sulfate is naturally at a low level (c) sewage sludge, in which both nitrate and sulfate are at low levels.

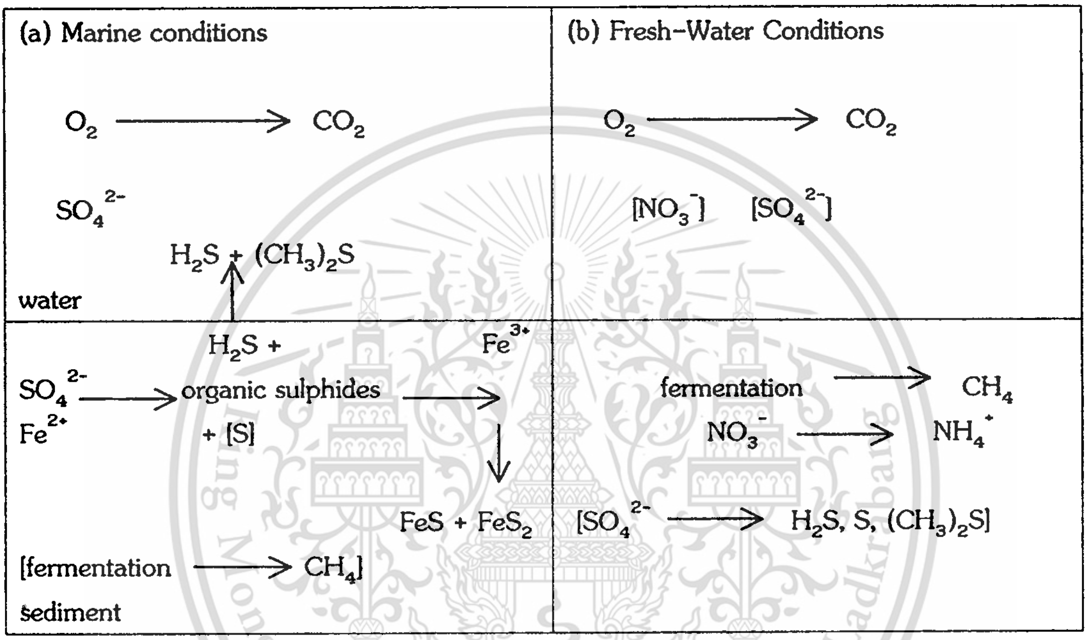


Figure 2.2 Electron acceptors found under different natural environmental condition. (Souce: Peter, 1993)

For marine and fresh - water systems, the surface water are generally aerobic with a plentiful supply of dioxygen, but at depth or in sediments conditions become anaerobic

(c) Soils

$O_2 \longrightarrow CO_2$

$NO_3^- \longrightarrow NH_4^+$

fermentation $\longrightarrow CH_4$

anaerobic conditions result when the soil is saturated with water or an impermeable layer forms preventing access by dioxygen - fermentation reactions are particularly common in buried refuse tips.

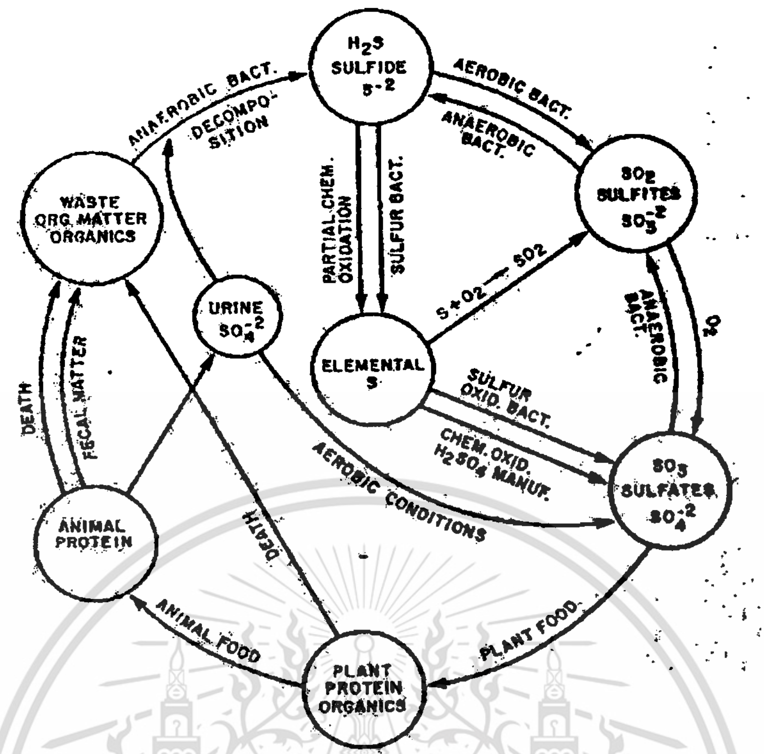


Figure 2.3 The sulfur cycle in shrimp ponds. (Source: Sawyer and McCartry, 1978)

Phosphorus

The common compounds are orthophosphates ($H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}), polyphosphate such as $Na(PO_3)_6$ used in synthetic detergent formulation, and organic phosphorus. All polyphosphates gradually hydrolyze in water to the stable ortho form, while decaying organic matter decomposes biologically to release phosphate. Orthophosphates are, in turn, synthesized back into living animal or plant tissue. In phosphorus pollution control, the primary concern is over fertilization on surface waters, resulting in nuisance growths of algae and aquatic weeds.

Phosphorus is a constituent element of all living tissues. It is part of many large molecules which are essential to life: adenosine triphosphate (ATP) which is associated with the internal transport of energy, nucleic acids, proteins and phospholipids. Phytoplankton obtain their essential phosphorus in the from of salts of orthophosphoric acid (PO_4^{3-}). Phosphate in sea water comes from the minerlization of decaying cells and organisms as well as from human activities, an important source being the polyphosphates used in domestic detergents.

Phosphorus is a required nutrient for both plants and animals. It is often present in only minute concentrations in natural water (Wetzel, 1975). The report can range from 0.01 to 200 mg/l. Phosphorus is normally the first limiting factor to plant growth in natural freshwaters system, while nitrogen may be the first limiting nutrient in the marine environment. Ponds and recirculating systems are excellent reservoirs for nutrient accumulations. The carbon/nitrogen/phosphorus ratio required by most phytoplankton species is near 106:16:1. Toxicity from high levels of phosphorus have not been reported by aquaculturists, the level of phosphorus as about 5 mg/l, and the pond apparently became nitrogen - limited as a bloom of blue - green algae occurred that was readily consumed by the tilapia in the pond.

Phosphorus is a key nutrient for plant growth. In aquatic systems, phosphorus is usually the most important single factor regulating phytoplankton productivity. Large in fluxes of phosphorus can depending an the latitude cause the rapid eutrophication of natural water.

Iron

The oxidation of insoluble pyrite (FeS_2), leading to anaerobic conditions and the formation of soluble iron sulfate.

$$2FeS_2 + 7O_2 + 2H_2O \longrightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

The summery, the evidence seems clear that development of anaerobic conditions is essential for appreciable amounts of iron to gain entrance to a water supply. Only under anaerobic conditions are the soluble forms of ions, Fe(II) thermodynamic stable. A sulfur mineral:

$$2FeS_2 + 7\ 1/2O_2 + 7H_2O \longrightarrow 4SO_4^{2-} + 8H^+ + 2Fe(OH)_3$$

This reaction produces eight protons and contributes toward decreasing soil acidity. The process is of special importance in soils derived from mine spoils and in drained areas affected by the tide.

2.1.2 SOIL PROPERTIES (SHRIMP PONDS)

pH values of soil

Although soil pH ranges from <2 in active acid sulfate soil to >9 in alkali soils, most highly leached mineral soils do not have pH <4. Calcareous and alkaline soils have pH <8.5, and even saline - alkaline soils seldom have pH >8.5. Alkali soils have a pH range of 8.5 - 10. Some highly organic soils may have pH values as low as 3, and others may have pH of 8 or more. A wide range in pH was found in soils of aquaculture ponds. The pH of 358 freshwater pond soils ranged from 3.9 to 8.0 and from 1.2 to 9.8 for 346 brackish - water pond soils. Average pH was 6.69 for freshwater pond soils and 6.5 for brackish - water pond soils and then they had an average pH of 7.23. The pH of waterlogged agricultural soils usually is near neutral, and the pH of freshly collected, water - saturated samples of soil from the bottom of ponds is consistently between 6.0 and 7.0. The pH in such samples reflects the pH of the pore water. In water - saturated soil the pore water at a depth of 1-2 cm below the soil - air or soil - water interfaces usually is anaerobic. The solubility of soil iron compounds is enhanced by anaerobic conditions, but the solubility of soil aluminum compounds is not increased. High Fe^{2+} concentrations occur in anaerobic in terstitial water, and the mineral siderite ($FeCO_3$) controls.

Organic Soils

Organic soils usually contain mineral matter, but there is a much greater proportion of organic matter in organic soils than in mineral soils. Soil not saturated with water for long periods each year is considered to be organic soil if the organic carbon concentration is above 20%. Soil saturated with water most of the time is classified as organic soil at organic carbon concentrations of 12 - 18%. Organic matter in soil contains 48 - 58% carbon. A factor of 2 times organic carbon concentration often is used to estimate organic matter concentration from organic carbon concentration in surface soils of terrestrial ecosystems. A mineral soil is contrasted with an organic soil in. There are three basic types of organic soil material. Fibric materials consist largely of plant fibers. A fiber is a fragment of plant tissue, excluding live roots, large enough to be retained on a 0.15 - mm sieve. Fibric soil materials have a fiber content, after hand rubbing, of 75% or more of the soil volume. Coarse fragments of wood and mineral layers are excluded when determining the volume of fiber. Peat is a fibric soil material. Sapric materials contain highly decomposed organic matter. After rubbing, the fiber content is less than 18 - 20% of the soil volume. Sapric soil materials are dark gray to black and relatively stable when drained and exposed to the air. Colloquially, these materials are called muck soils. Soil materials with fiber contents between sapric and fibric are called hemic soil materials. Lack of drainage is the usual reason for formation of organic soils. Microorganisms cannot decompose organic matter efficiently where soils are saturated and anaerobic conditions exist. Additionally, decomposition products that accumulate in poorly drained organic soils are acidic, and low pH also retards microbial activity. If an organic soil is drained, its decomposition rate increases and there may be a noticeable decrease in the soil's bulk volume. Construction of ponds on organic soils should be avoided when possible. Organic soils will not form stable embankments, because, when exposed to the air and dried, a large part of the organic matter decomposes. A noticeable decrease in the height and width of embankments made from organic soils usually can be detected within one to two years. Organic soils do not provide good bottom habitats for plants and animals, are highly acidic, have a high oxygen demand, and do not form firm substrates. As indicated, organic matter tends to accumulate in mineral soils of pond bottoms. However, bottom soil seldom contains more than 5 - 6% organic carbon, and it should not be concluded that mineral soils in aquaculture ponds tend to be transformed into organic soils.

Cation exchange capacity (CEC)

The cation exchange capacity of soils is defined as the capacity of soil to adsorb the exchangeable cations. The term cation exchange is preferred over the term base exchange, since the reaction also involves H^+. The hydrogen ion is a cation but not a base. The adsorbed cation can be exchanged by other cations, hence the cations are also called cations. The process of replacement is called cation exchange. Cation exchange capacity, generally expressed as milliequivalents (meq.) per 100 g of soil, refers to the sum of the exchangeable cations of soil. Peter (1993) considered these process as a neutralization and precipitation type of cation exchange reaction. such as:

$$CaCO_3 + H_2CO_3 \longrightarrow Ca(HCO_3)_2$$

The calcium bicarbonate formed is soluble in water. Calcium that is dissociated off can then be adsorbed by the soil exchange for Al^{3+} as:

$$3/2\ Ca(HCO_3) + Al\text{-soil} \longrightarrow Ca3/2 - soil + Al(HO_3) + 3CO_2$$

The various methods have been proposed for determining CEC. Most investigators at present employ methods based on saturating the exchange complex with a given cation, and then determining the total of the adsorbed cations by appropriate means. It must be noted that the method of determining cation exchange capacity of one soil may not prove as accurate on another. The values depend on the kind of base and salt solution used, exchange materials involved and degree of solubility of some soil materials such as $CaCO_3$ and $CaSO_4$. Two methods are described as: 1) The ammonium acetate method (pH 7.0), and 2) the sodium acetate method (pH 8.2). For distinctly acid soils, the summation method is suggested. When reporting CEC of soil, it is important to indicate the method employed. In the ammonium acetate saturation method for CEC, soil is leached with an excess of neutral, 1N ammonium acetate solution to remove the exchangeable cations and saturate the exchange material with ammonium. After removal of the excess of ammonium present in the soil as the acetate, the exchangeable ammonium is determined by distillation. For the purpose of measuring the CEC of soil, ammonium acetate has two particular valuable qualities. First, it is highly buffered. As a result when a neutral, 1N solution of ammonium acetate is used to saturate a soil with second, ammonium is easily determined. In addition to the foregoing advantages, ammonium acetate has special advantages in connection with measurement of the cations displaced from soils.

Contrary to the foregoing advantages, ammonium acetate has some disadvantages. With soils of high organic matter content, and with soils containing appreciable kaolin, halloysite or other 1:1 type clay minerals, will often give somewhat lower values for exchange capacity than the barium acetate or barium chloride triethanolamine methods. Also with soils which contain vermiculite clay, interlayer cations such as Ca^{+2},

Mg^{+2}, Na^{+} or H^{+} can be replaced by ammonium, but the ammonium so fixed is nor then replaceable by the usual method employed, e.g., aeration with Na_2CO_3 or replacement with acidified NaCl. Calcareous soils present a problem with the ammonium acetate method because of the solubility of the $CaCO_3$ in the ammonium acetate solution. Values for CEC are too low in the presence of $CaCO_3$ because the dissolved calcium present in the ammonium acetate solution prevents complete saturation of exchange positions with ammonium. The cation-exchange capacity is calculated as CEC milliequivalents of NH_4^{+} absorbed by 100g soil (dry weight basis)

Table 2.2 The CEC of soils depends on the quality of colloids in the soil and on the type of colloids.

Type of soils	CEC (meq. $100g^{-1}$)
Humus	> 200
Clay	150
Vermiculite	150
Smectite	100
Chlorite	30
Kaolinite	8
Gibbsite and geothite	4
30% Smectite clay 5% organic matter	35-40
10% Kaolinite, 20% iron and aluminium oxide clay and 1% organic matter	3-4

The lowest values are <1 meq $100g^{-1}$, and highest values are >100 meq $100g^{-1}$. Bottom soils from 28 public fishing impoundments in Alabama had CEC values of 0.5 - 26 meq $100g^{-1}$. The CEC of pond soils also varies with location in the pond and with depth the soil surface.

Exchangeable aluminum

A knowledge of the amount of exchangeable aluminum in soils is important from the viewpoint of soil fertility and chemistry. Exchangeable aluminum is considered to be adsorbed from the soil exchange complex like any other cation but the degree of adsorption is relatively stronger. It is active only under relatively acid conditions and its level in the soil may indicate the need for the addition of lime to acid soils.

The exchangeable aluminum in soils could be measured either by titration method. A neutral 1N potassium chloride solution is used to leach a soil sample of exchangeable hydrogen and aluminum ions. The leachate which is acidic can be titrated with a standard solution of an alkali, the amount of alkali used being equivalent to the sum of the hydrogen and aluminum ions, as:

$$H^{+} + OH^{-} \longrightarrow H_2O$$
$$Al^{3+} + 3OH^{-} \longrightarrow Al(OH)_3$$

When aluminum is complexed with sodium fluoride, an equivalent quantity of alkali is released, as:

$$Al(OH)_3 + 6NaF \longrightarrow Na_3AlF_6 + 3NaOH$$

The exchangeable aluminum may then be measured by titration the released alkali with standard acid.

The presence of aluminum species appears to play a part in controling the pH of acid soil and waters. The soluble aluminum is moderately toxic to most plants and the effects of acidification of soils are to reduce the concentration of some essential elements and increase the concentration of toxic elements. Peter (1993) report that Aluminum is less toxic to humans at low concentrations and the quantities of dissolved Aluminum in water are normally very low (50 $\mu g\ dm^{-3}$). Al-Zheimer's disease have been found to have higher than normal amounts of aluminum in their brains, and the resulting higher intake aluminum can eventually cause death.

Phosphorus

Soil phosphorus is presented in minerals and organic matter, and there is an equilibrium between the concentration of phosphorus in the soil solution and phosphorus contained on soil solids. The equilibrium concentration of phosphorus in the soil solution or in water bodies is a major factor affecting productivity of natural ecosystems, but in agricultural ecosystems natural concentrations of phosphorus generally are too low for optimal rates of plant productivity. Phosphate fertilizers are applied to overcome phosphorus limitations. Phosphorus not removed in the crop is largely bound in the soil in forms unavailable to plants. Phosphorus must be applied on a regular basis to maintain adequate concentrations of available phosphorus for optimal plant productivity.

The maximum availability of phosphorus in mineral soil occurs between pH 6 and 7. In this pH range there is less Fe^{3+} and Al^{3+} to react with phosphorus and a smaller tendency of iron and aluminum oxides to adsorb phosphorus than at lower pH. Also, at a pH of 6 - 7 the activity of Ca^{2+} is normally lower than at higher pH. Nevertheless, even in the pH range of 6 - 7, most of the phosphorus added to soils normally is rendered insoluble through adsorption by soil colloids or precipitation as insoluble compounds.

Phosphorus contained in organic matter is released by microbial activity. A portion of the phosphorus released in decomposition is absorbed by plants, but the remainder reacts with Fe^{3+}, Al^{3+}, Ca^{2+} and soil colloids and is fixed in the soil. In a soil with a high concentration of organic matter, there is less mineral matter to react with phosphorus. Fe^{3+}, Al^{3+} and Ca^{2+} ions in soil solution are complexed by organic compounds and less available to react with phosphorus.

Sulfate

Sulfur is present in soil with various minerals. It is also presented in atmospheric gases and organic matter. The inorganic forms are highly soluble, and it can be transformed from one valence state to another by biochemical and chemical processes. The sulfur cycle in an ecosystem is similar to that of nitrogen, but sulfur is less abundant than nitrogen in organic matter.

Atmospheric sulfur originates from volcanic activity, and in the parent much sulfur has been added to the atmosphere through combustion of sulfur – containing fossil fuels. Sulfur can be absorbed directly from the atmosphere by plants and incorporated into organic matter. It also can be oxidized to sulfuric acid in the atmosphere and reach the land surface by rain. Sulfuric acid in rainfall is the major cause of acid rain.

Organic matter in soil decomposes and sulfur is released (mineralized) as sulfide, which in the presence of oxygen is oxidized to sulfate. The oxidation of sulfide to sulfate can occur through simple chemical reactions, but it occurs faster when mediated by soil microorganisms. Sulfate in soil is highly soluble. It is absorbed by plants or microorganisms, and it may be leached from the soil, but there usually is measurable sulfate in the soil solution.

In anaerobic soils, sulfate may be used instead of oxygen as a hydrogen acceptor in microbial metabolism. Some representative reactions can be described as follow:

$$SO_4^{2-} + 8H^+ \longrightarrow S^{2-} + 4H_2O$$

$$SO_3^{2-} + 6H^+ \longrightarrow S^{2-} + 3H_2O$$

$$S_2O_3^{2-} + 8H^+ \longrightarrow 2SH^- + 3H_2O$$

The following equations provide a pathway for the microbial production of hydrogen sulfide, which contains the following steps:

$$H_2SO_4 + 2H^+ \longrightarrow H_2SO_3 + H_2O$$
(sulfite)

$$H_2SO_3 + 2H^+ \longrightarrow H_2SO_2 + H_2O$$
(sulfoxylate)

$$H_2SO_2 + 2H^+ \longrightarrow H_4SO_2$$
(sulfur hydrate)

$$H_4SO_2 + 2H^+ \longrightarrow H_2S + 2H_2O$$

Except for the special case of potential acid – sulfate soils that contain iron pyrite (FeS_2), most of the sulfur in soils usually is contained in organic matter. The ratio of C:N:S is normally around 13:10:0.13. A soil containing 5% organic carbon would have about 0.05% total sulfur. Potential acid – sulfate soils may contain up to 5% total sulfur (Boyd, 1995).

Iron in soil

High Fe^{2+} concentrations occur in anaerobic interstitial water, and the mineral siderite ($FeCO_3$) controls the solubility of Fe^{2+} according to the equilibium.

$$FeCO_3 (s) + H^+ = Fe^{2+} + HCO_3^- ; K = 10^{-0.3}$$

Assuming that HCO_3^- and Fe^{2+} concentration in the interstitial water of an aquaculture pond are 60 mg/l (10^{-3}M) and 20 mg/l ($10^{-3.74}$M), respectively, we may calculate the pH of the interstitial water by substituting Fe^{2+} and HCO_3^- concentrations into the mass - action from of Equation.

$$\frac{[Fe^{2+}]\ [HCO_3^-]}{[H^+]} = 10^{-0.3}$$

The result is $(H^+) = 10^{-6.44}$ M or pH = 6.44. At the ranges of Fe^{2+} and HCO_3^- found in interstitial water of pond sediment, pH is between 6 and 7 of course, in the oxidized surface layer of sediment, pH is controlled by exchangeable acidity or iron pyrite oxidation, and the range of pH values in the oxidized surface layer can be much wider than of anaerobic soils. Iron soils contain pyrite (FeS_2) or closely related sulfide compounds. Iron pyrite accumulation is especially common in soils of coast all areas. Sulfide comeform in sediment in coastal wetlands. Brackish water in coast al wetland has a high sulfate concentration, and under anaerobic concentrations microbial activity produces sulfides and elemental S. Iron, sulfides, and sulfur can react by several pathway to form iron pyrite (FeS_2) which precipitate in to the sediment.

A summary equation for pyrite formation is :

$$Fe_2O_3 + 4\ SO_4^{2-} + 8\ CH_2O + 1/2\ O_2 \longrightarrow 2\ FeS_2 + 8\ HCO_3^- + 4\ H_2O$$

Iron III oxide Sulfate Organic matter

Iron pyrite is stable as long as it is in an anaerobic environment. It is not uncommon for some coastal soils to contain up to 5% total sulfur that is mostly in sulfide form. I have seam 0.5- to 1-cm-diameter by 3- to 5-cm-long cylindrical, rust colored particles of iron oxides and hydroxides on level surfaces where soils were highly sulfuric. Generally, actual acid sulfate soils are used mostly for Agricultural, rice, horticultural crops, tropical friuttree, shrimp culture and fish culture. The acidity is directly caused by H_2SO_4 formed by the oxidation of pyrite (FeS_2), or other reduced compounds. Potential acid sulfate soils are poorly drained and highly pyritic with a nearly neutral pH under in site conditions (Van Breeman,1982). The latter become actual acid sulfate soils if pyrite oxidizes after drainage. The acid conditions favour the dissolution of Fe^{2+} and Al^{3+}.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

The site of study is in shrimp farm at Klong Dacho, Ampher Bangnampriew Chacherngsao province, Thailand.

This experiment is carried out in 4 shrimp ponds, approximately area about 4-6 rais. The area is used to be culture of fish, and surrounding sites are used for various agriculture purpose as: rice fields, fish and shrimp culture. Water used for shrimp ponds are coming from Decho canal (fresh water storage reservoir enable them effectively control water quality and salinity). Soil type is clay with yellow spot (jarosite) and strong acidity. Before culture, the pond bottoms are dried and tractor clears the surface area. The ponds are prepared for couple weeks before stocking by lightly discing the bottom to aerate the soil. Using a fertilizer spreader, limestone is applied to the bottom and dikes. After filling of the fresh water reservoir, the canal water must be transferred about 30 centimeters to fill the ponds (Shown in Figure 3.5a). In this farm is generally used low saline water technique for culture shrimp, initial salinity is less than 7 ppt. (add water has 100 ppt. salinity), and then adjust salinity by fresh water for dilute salinity during culture until the condition is near the fresh water in final period.

In nursery period (1 month) in plastic strip, the level of water is about 30 centimeters (Shown in Figure 3.5a) after that the PL15 can be stocked. The PL15 stocked in ponds no. 1-4 is the density of 31, 31, 31 and 29 PL/m^2 respectively. Over 4-6 weeks, fresh water is gradually added until the dept is coming to 150 centimeters (Figure 3.5b). The nutritional feed is provided follow the feeding program from the company (Table 3.3). The paddlewheels are used for the circulation and aeration during culture period.

3.2 Site of shrimp farming

Pond in the experiment

Figure 3.1 Pond No.1 with an area of 4 rai (6400 m^2; 0.64 ha; 1.58 acres). First crop and grade surface area. Initial culture in 25/02/1997.

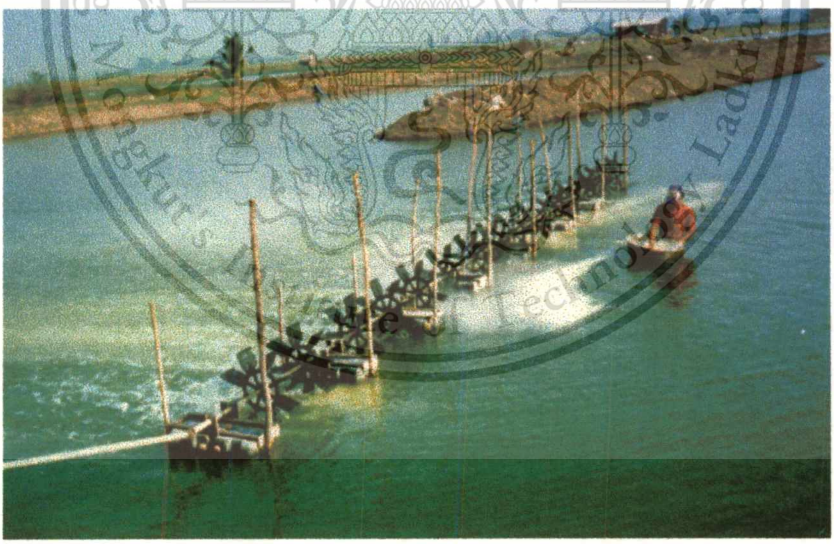


Figure 3.2 Pond No.2 with an area of 4 rai (6400 m^2; 0.64 ha; 1.58 acres). Areas are used for shrimp culture. Initial culture in 08/03/1997.

Figure 3.3 Pond No.3 with an area of 6 rai (9600 m^2 ; 0.96 ha; 2.37 acres). Grade surface area. Initial culture in 27/03/1997.

Figure 3.4 Pond No.4 with an area of 5 rai (8600 m^2; 0.86 ha; 2.12 acres). Initial culture in 19/04/1997.

3.3 Description of experimental ponds.

Step1 Culture Black tiger shrimp 200,000 - 300,000 PL/pond. (Shows in Table 3.1). Stocking water have level 30 - 70 centimeters about 45 days. (Shows in Figure 3.5a and 3.5b).

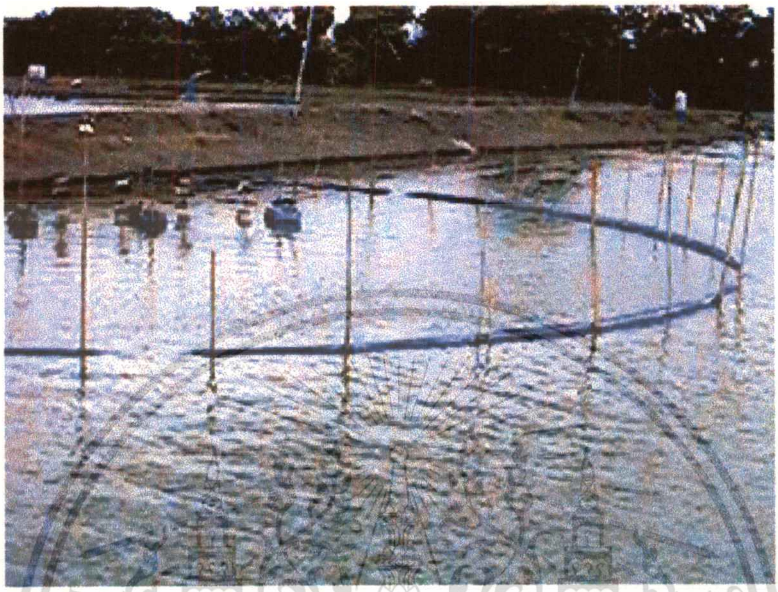


Figure 3.5a The level of water at first culture.

Step 2 Add water until level 1.5 meters (shows in Figure 3.5b) and culture Black tiger shrimp until final period.

Figure 3.5b The level of water at during culture period.

The techniques used for selecting and positions for taking water and soil sample from pond is random position. Method of collection is Integrated sample at mid - depth for representative water sample and at bottom for soil sedimentation.

Table 3.1 The detail of the study ponds.

Pond	Pond area (m^2)	Number of stocking density (PL/m^2)
1	6400	200,000
2	6400	200,000
3	9600	300,000
4	8000	250,000

Remark: PL = Postlarvae

3.4 Data collection

3.4.1 Water sampling

Water samples for the measurement of these quality parameters were collected from the mid - dept water in the daytime; every two weeks for the whole period of culture.

3.4.2 Soil sediment sampling

Soil sediment for the measurement of these quality parameters were collected from bottom in the same time of water sampling until end of culture period. A variety of water quality indices were measured every two weeks. Both water and soil samples were analysed in Nutrition Laboratory of Animal Production Department, Faculty of Agricultural and Chemical Laboratory of Chemistry Department, Faculty of Science, KMITL, Ladkrabang, Bangkok 10520.

3.4.3 Growth rate

This experiment was conducted for four months. E very two weeks . Black tiger shrimp were collected from four ponds for the measurement of length and weight. Measured the total shrimp length from the tip of telson to the tip of rostrum. After the end of culture, all black tiger shrimp were harvested. The numbers of surviving and the total production were recorded.

3.5 Statistical analysis

- Descriptive statistics were used to determine: mean, minimum, maximum, average and standard diviation of analysis data, growth rate of shrimp, measured length and weight of shrimp.
- Sample quality of soil sediment, water quality and growth rate in each shrimp pond.
- Compare the average sample quality of soil sediment, water and growth rate in shrimp pond No.1-4.
- Pearson Correlation Coefficient in soil sediment water and growth rate in each shrimp pond.
- Multiple linear regression of soil sediment, water quality in shrimp pond and growth rate in each shrimp pond.
- Linear regression of growth rate in all of shrimp ponds.

3.6 Shrimp Feed and Feeding

During culture period, shrimp were fed with commercial shrimp feed. (see Table 3.2).

Table 3.2 Feed types and commercial specifications of feed used during culture period.

Feed type No.	size of feed (mm)	Protein (%)
1	0.2 × 0.4	37
2	1.0 × 1.5	37
3	2.0 × 2.5	36
4	2.3 × 3.5	36
5	2.3 × 6.5	35
6	2.3 × 8.0	35

Feed was distributed 4 to 6 times par day depend on the size of shrimp. Feeding programs for cultured shrimp are according to the schedule in the Table 3.3.

Table 3.3 Recommended feeding program for commercial shrimp feed.

Shrimp (g)	%Feed(body wt)	Feed type	Checking time(hr)	Meals / day
P15-0.1	40-20	#1	2.5	4
0.1-0.5	20-15	#2	2.5	4
0.5-3.0	15-8	#3	2.5*	4
3-10	8-4	#4	2.0*	5
10-20	4-3	#5	1.5-2.0*	5
20-40	3-2.5	#6	1.0-1.5*	5-6

Source: C.P. manual for culture shrimp.
*C.P. Shrimp News, 1993
Remark P = Postlavae

3.7 Physical and chemical analysis of water

The pond water was analyzed for the following parameters and methods.

PARAMETER	ANALYTICAL METHOD (see Appendix E.1 for details)
Temperature	Thermometer
pH	pH meter
Soluble salts (EC)	Electrical conductivity method
Total solids	Gravimetric
Suspended solids	Gravimetric
Dissolved solids	Gravimetric
Dissolved oxygen (DO)	Azide modification , Oxi meter
Chemical oxygen Demand (COD)	Dichromate reflux
Alkalinity	Titrimetric method
Chloride	Titrimetric method
Total Nitrogen	Kjeldahl method
Organic-Nitrogen	Kjeldahl method
Ammonia (NH_3)	Distillation
Sulfate	Turbidity method
Phosphorus (PO_4^{3-})	Colorimetric method
Iron	AAS

Source : AOAC (1995), APHA (1980, 1989, 1992), Standard methods (1980)

3.8 Physical and chemical analysis of soil sediment

The soil sediment were analyzed for the following parameters and methods.

PARAMETER	ANALYTICAL METHOD (see Appendix E.2 for details)
pH	1:5 soil to water ratio[2]
Soluble salts (EC)	Electrical Conductivity method[2]
Cation exchange capacity (CEC)	Ammonium acetate method[1,3]
Exchangeable H^{+}, Al^{3+}	Titration method[2,3]
Total nitrogen	Kjeldahl method[1,2,3]
Organic matter	Drying method
Sulfate (SO_4^{2-})	Turbidity[1,2,3]
Phosphorus (PO_4^{3-})	Colorimetric method[1,2,3]
Iron (Fe^{2+})	DTPA method[2]

Source : [1] = AOAC (1995), [2] = Horneck et al. (1990), [3] = Standard methods (1980)

3.9 Equipments in experiment

Chemical for Water and soil analysis
DO meter (Microprocessor Oxi-meter Oxi196, WTW Oxygen-electrode EO196-1.5)
pH meter (Metrolm 654 pH-meter)
Conductivity meter (Shot model cg 654)
Mercury thermometer
Atomic Absorption Spectrophotometer (AAS)
UV - Visible Spectrophotometer
Analytical balance
Heating block, Hot plate
Sampling bottles
Compound stereo microscope
Incubator
Distillation set
Water sampling set and soil sampling set

CHAPTER 4

RESULTS AND DISCUSSION

The changes of chemical and physical quality in shrimp ponds at Chacherngsao, divided to three parts.

- The study of change in soil sediment quality with period of cultivation.
- The study of change in low saline water quality with period of cultivation.
- The study of growth rate of shrimp with period of cultivation.

4.1 The quality of soil sediment in shrimp pond with period of cultivation.

4.1.1 pH effect (Figure 4.1)

Pond no.1, pH ranged was 6.19–6.41, average 6.35. The pH in culture system was acid condition in during culture.

Pond no.2, pH ranged was 6.63–7.43, average 7.02. However pH in culture system was slightly changed in during culture.

Pond no.3, pH ranged was 7.25–7.36, average 7.32. However pH in culture system was slightly changed in during culture.

Pond no.4, pH ranged was 6.99–7.25, average 7.10. However pH in culture system was slightly changed in during culture.

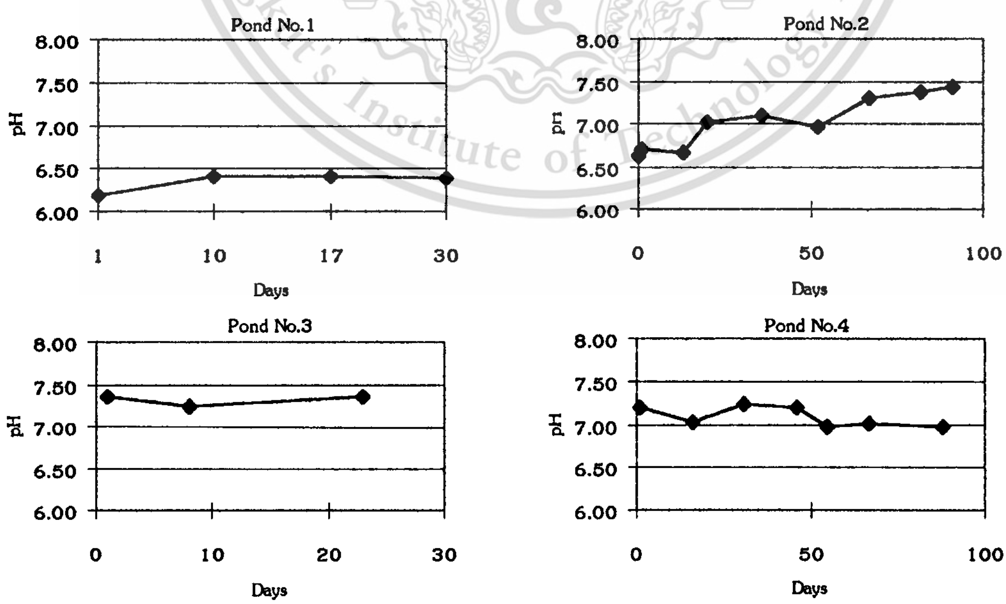


Figure 4.1 The pH of soil sediment changed during culture period in pond no.1–4.

4.1.2 Soluble salts EC (mS/cm) (Figure 4.2)

Pond no.1, Soluble salts ranged was1.67–2.84 mS/cm, average 2.22 mS/cm. Soluble salts was fluctuation during culture period. However soluble salts in culture system was slightly changed in final culture period.

Pond no.2, Soluble salts ranged was 0.32–3.82 mS/cm, average 1.40 mS/cm. Soluble salts was fluctuation during culture period. However soluble salts in culture system was slightly changed in final culture period.

Pond no.3, Soluble salts ranged was 1.41–2.00 mS/cm, average 1.69 mS/cm. Soluble salts in culture system was slightly changed in during culture.

Pond no.4, Soluble salts ranged was 0.57–2.10 mS/cm, average 1.02 mS/cm. Soluble salts decreased hardly after 3 weeks of culture and slightly changed in final culture period.

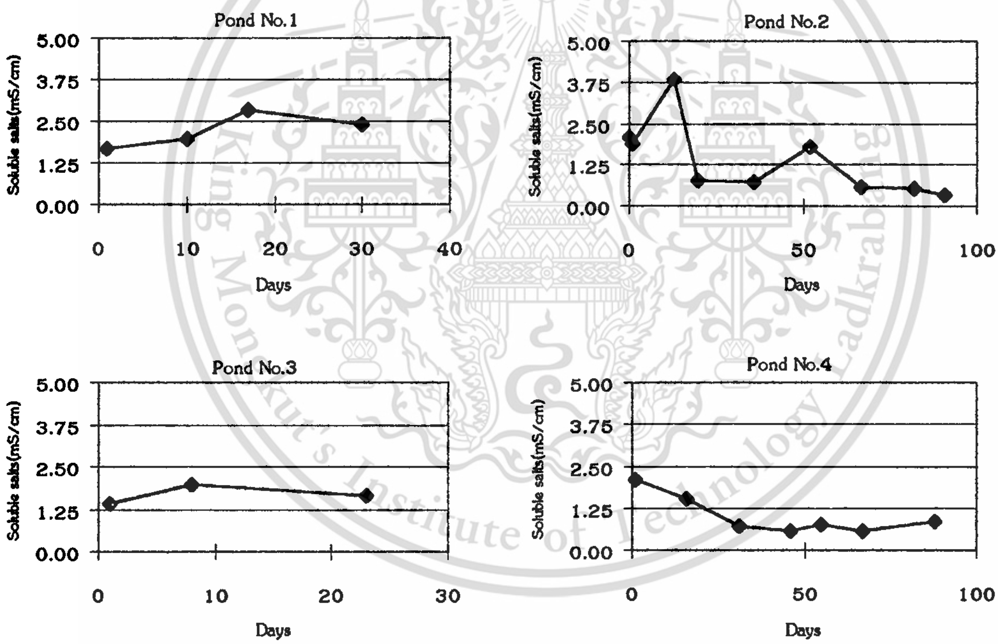


Figure 4.2 The Soluble salts of soil sediment changed during culture period in pond no.1–4.

4.1.3 **Organic matter (%)** (Figure 4.3)

Pond no.1, Organic matter ranged was 10.22–11.43%, average 10.90 %. The concentration of organic matter was increased until final culture period.

Pond no.2, Organic matter ranged was 9.05–12.81%, average 10.28%. The concentration of organic matter was fluctuation during culture period.

Pond no.3, Organic matter ranged was 10.95–11.80%, average 11.27%. The concentration of organic matter was increased until final culture period.

Pond no.4, Organic matter ranged was 9.78–10.76%, average 10.35%. The concentration of organic matter was fluctuation during culture period.

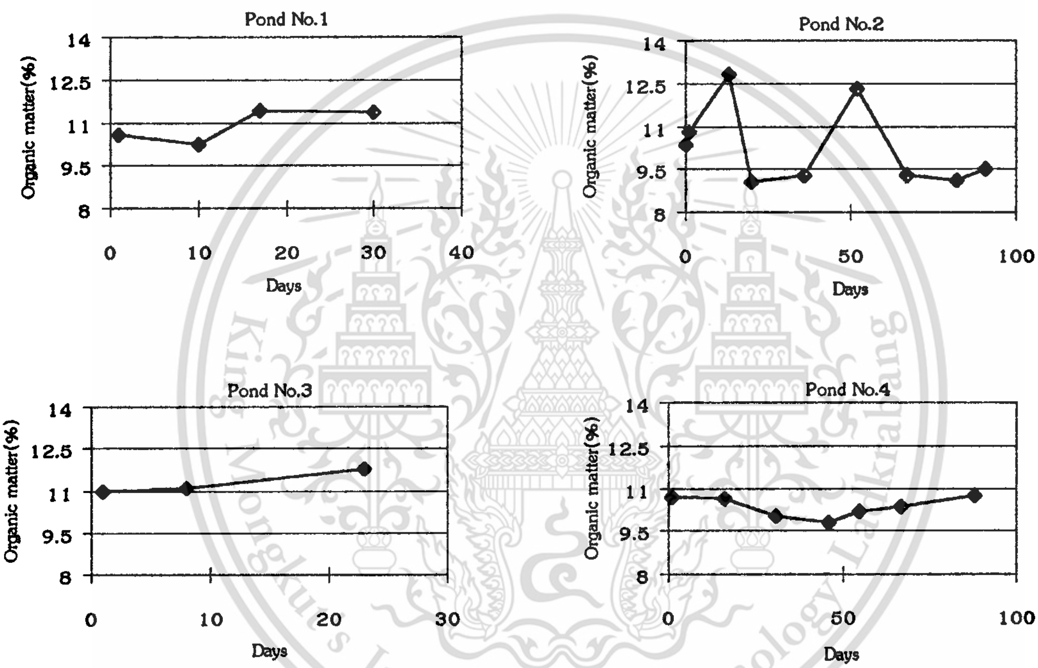


Figure 4.3 The concentration of organic matter in soil sediment changed during culture period in pond no.1-4.

4.1.4 **Total nitrogen (%)** (Figure 4.4)

Pond no.1, The concentration of total nitrogen ranged was 0.87-2.00 percent, average 1.51 percent. The concentration of total nitrogen was increased until final culture period.

Pond no.2, The concentration of total nitrogen ranged was 0.56-2.54 percent, average 1.38 percent. The concentration of total nitrogen was fluctuation during culture period.

Pond no.3, The concentration of total nitrogen ranged was 1.29-2.03 percent, average 1.59 percent. The concentration of total nitrogen was increased until final culture period.

Pond no.4, The concentration of total nitrogen ranged was 1.08-1.75 percent, average 1.34 percent. The concentration of total nitrogen was fluctuation during culture period.

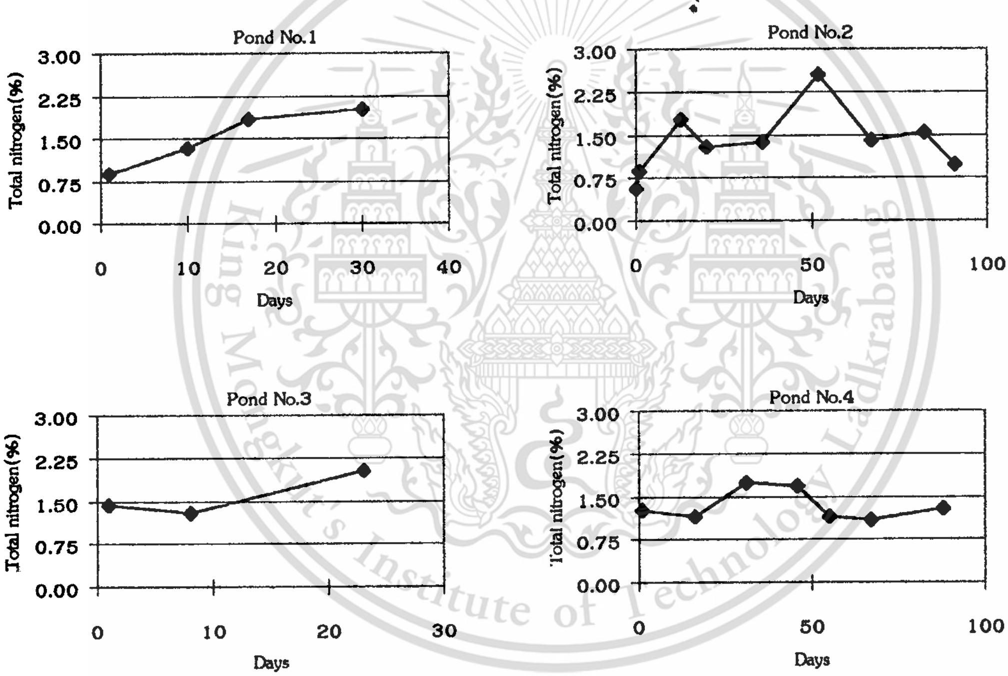


Figure 4.4 The concentration of total nitrogen in soil sediment changed during culture period in pond no.1-4.

4.1.5 Cation exchange capacity CEC (meq./100g soil) (Figure 4.5)

Pond no.1, Cation exchange capacity ranged was 37.05-49.67 meq./100g soil, average 42.25 meq./100g soil.

Pond no.2, Cation exchange capacity ranged was 24.53-50.72 meq./100g soil, average 36.78 meq./100g soil.

Pond no.3, Cation exchange capacity ranged was 32.21-37.04 meq./100g soil, average 35.08 meq./100g soil.

Pond no.4, Cation exchange capacity ranged was 29.13-48.82 meq./100g soil, average 33.96 meq./100g soil.

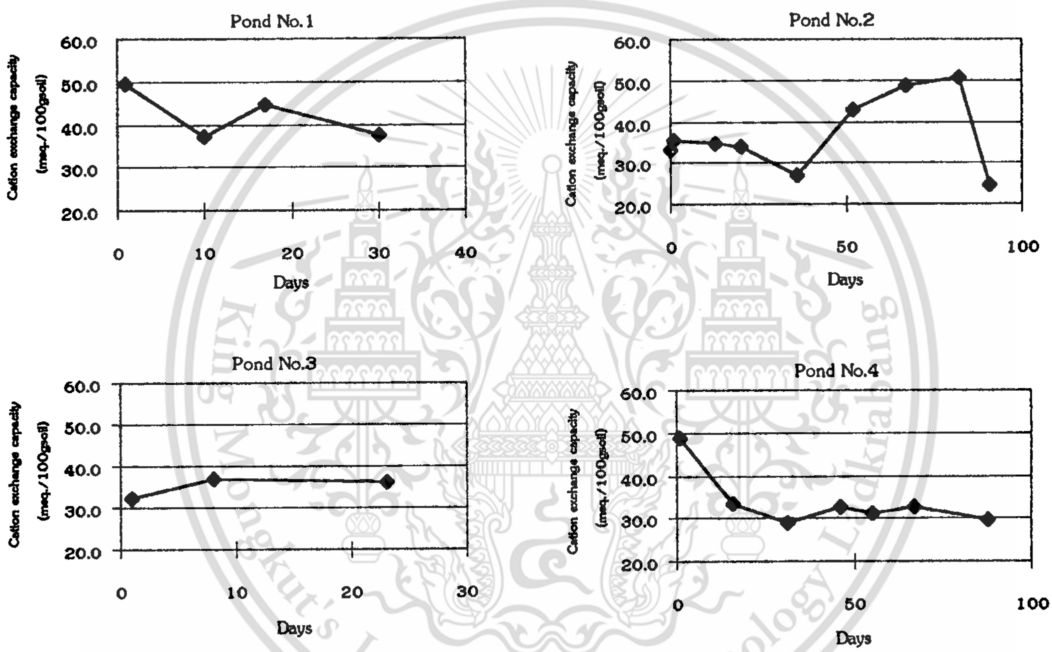


Figure 4.5 The cation exchange capacity of soil sediment changed during culture period in pond no.1-4.

4.1.6 Exchangeable Al^{3+} (meq./100g soil) (Figure 4.6)

Pond no.1, Exchangeable Al^{3+} ranged was 0.0197-0.0199meq./100g soil average 0.0198 meq./100g soil.

Pond no.2, Exchangeable Al^{3+} ranged was 0.0195-0.20 meq./100g soil average 0.0197 meq./100g soil.

Pond no.3, Exchangeable Al^{3+} ranged was 0.0196-0.0197 meq./100g soil average 0.0197 meq./100g soil.

Pond no.4, Exchangeable Al^{3+}ranged was 0.0195-0.0199 meq./100g soil average 0.0197 meq./100g soil.

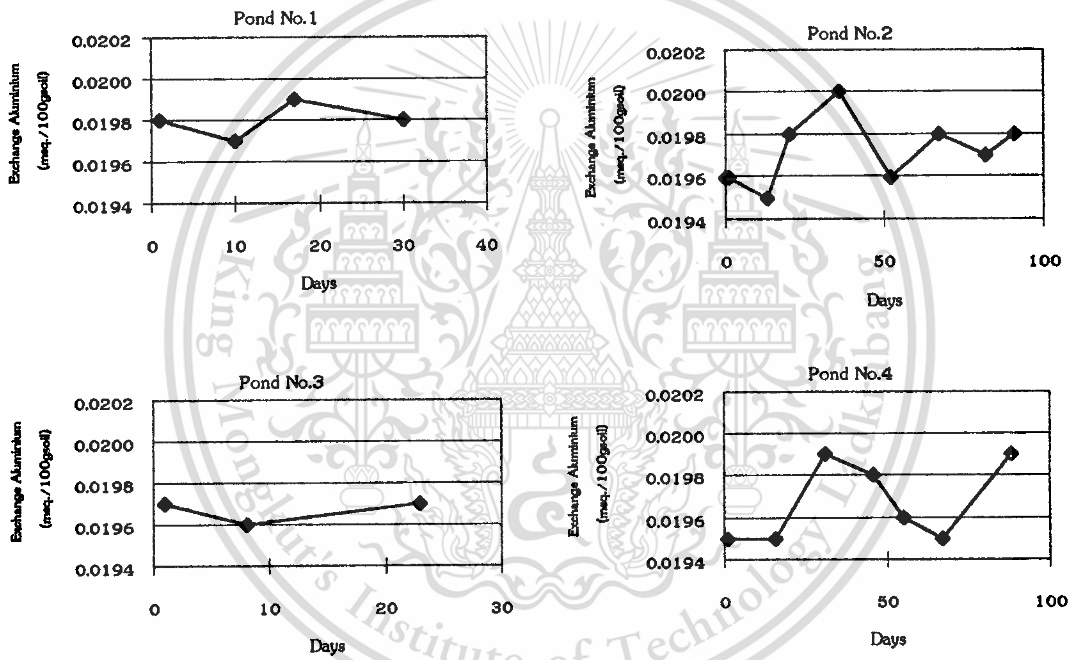


Figure 4.6 The exchangeable aluminum of soil sediment changed during culture period in pond no.1-4.

4.1.7 **Exchange H^+ (meq./100g soil)** (Figure 4.7)

Pond no.1, Exchange H^+ ranged was 0.03–0.06 meq./100g soil, average 0.05 meq./100g soil.

Pond no.2, Exchange H^+ ranged was 0.01-0.09 meq./100g soil, average 0.07 meq./100g soil.

Pond no.3, Exchange H^+ ranged was 0.01-0.10 meq./100g soil, average 0.06 meq./100g soil.

Pond no.4, Exchange H^+ ranged was 0.06-0.10 meq./100g soil, average 0.08 meq./100g soil.

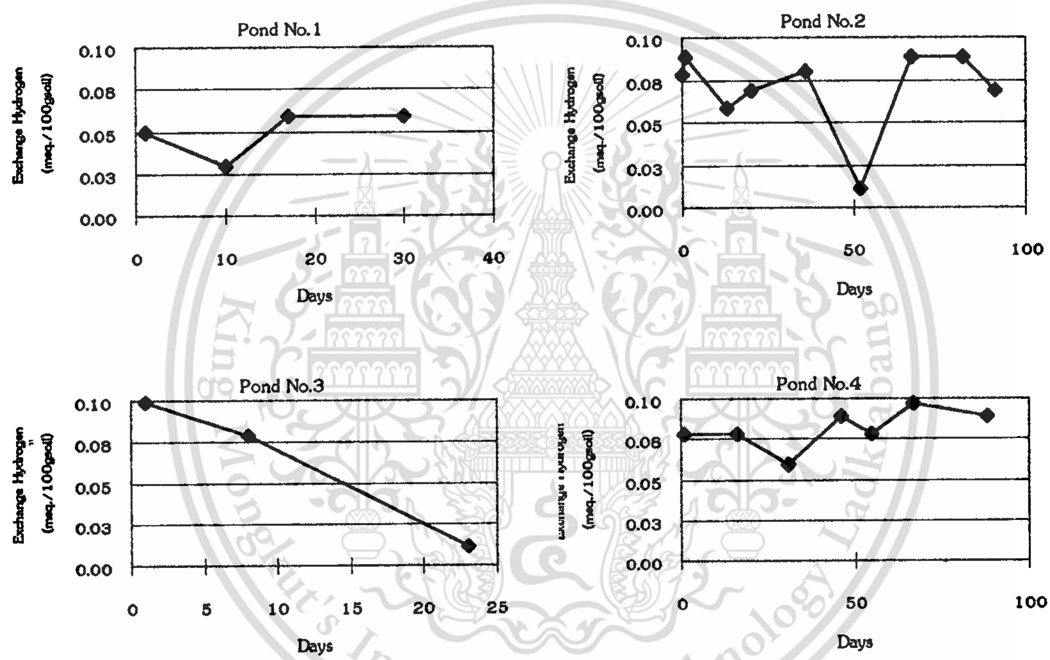


Figure 4.7 The exchange hydrogen of soil sediment changed during culture period in pond no.1-4.

4.1.8 Total phosphorus TP (mg/kg) (Figure 4.8)

Pond no.1, The total phosphorus ranged was 0.05-0.18 mg/kg, average 0.11 mg/kg during culture period.

Pond no.2, The total phosphorus ranged was 0.06-0.36 mg/kg, average 0.14 mg/kg during culture period.

Pond no.3, The total phosphorus ranged was 0.02-0.09 mg/kg, average 0.06 mg/kg during culture period.

Pond no.4, The total phosphorus ranged was 0.02-0.28 mg/kg, average 0.09 mg/kg during culture period.

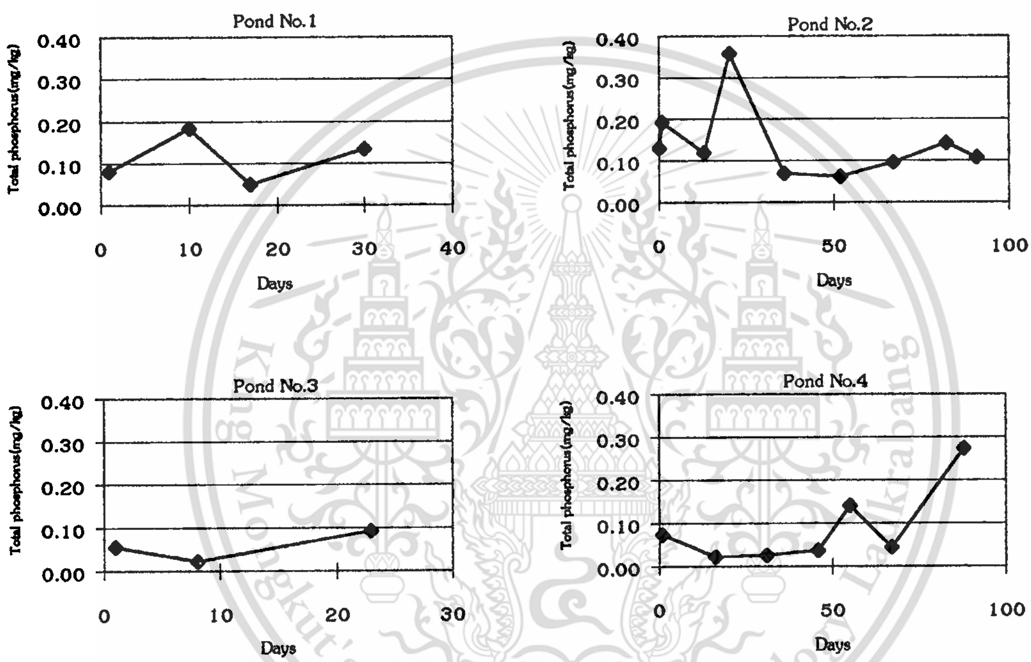


Figure 4.8 The concentration of total phosphorus of soil sediment changed during culture period in pond no.1-4.

4.1.9 Sulfate SO_4^{2-} (mg/kg) (Figure 4.9)

Pond no.1, The sulfate ranged was 256.41–513.93 mg/kg, average 390.82 mg/kg during culture period. The concentration of sulfate was high and increase until final culture period.

Pond no.2, The sulfate ranged was 117.65-535.57 mg/kg, average 272.47 mg/kg during culture period. The concentration of sulfate was fluctuation during culture period. However concentration of sulfate in culture system was decrease in final culture period.

Pond no.3, The sulfate ranged was 352.08–384.56 mg/kg, average 368.62 mg/kg during culture period. The concentration of sulfate was high and slightly change until final culture period.

Pond no.4, The sulfate ranged was 221.21–361.81 mg/kg, average 273.89 mg/kg during culture period. The concentration of sulfate was fluctuation during culture period.

However concentration of sulfate in culture system was slightly changed in during culture.

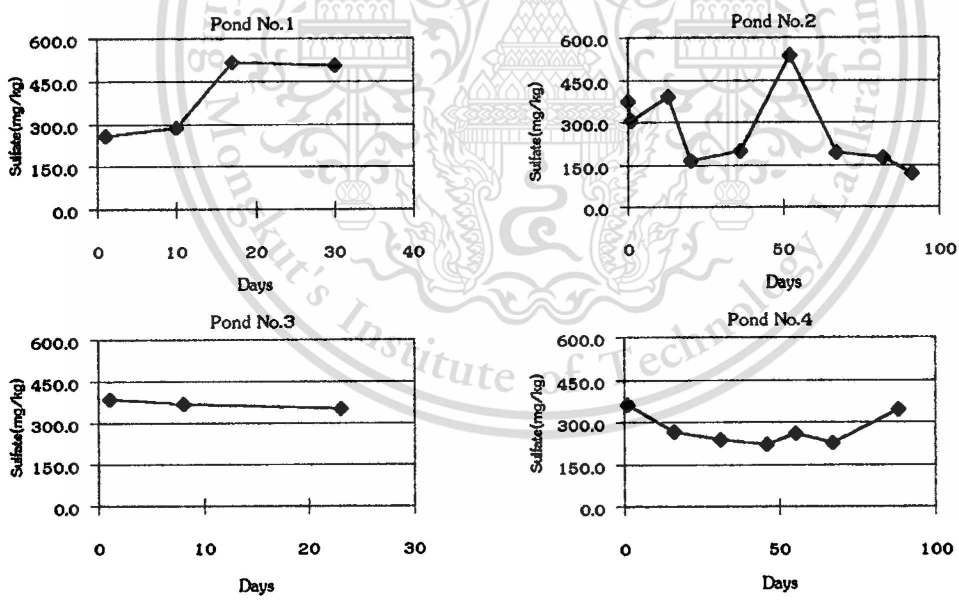


Figure 4.9 The concentration of sulfate in soil sediment changed during culture period in pond no.1-4.

4.1.10 Iron (mg/kg) (Figure 4.10)

Pond no.1, The iron ranged was 129.36-259.37 mg/kg, average 197.23 mg/kg during culture period. The concentration of iron was high and increase until final culture period.

Pond no.2, The iron ranged was 59.24-270.26 mg/kg, average 137.48 mg/kg during culture period. The concentration of iron was fluctuation during culture period. However concentration of iron in culture system was decrease in final culture period.

Pond no.3, The iron ranged was 176.75-193.63 mg/kg, average 185.61 mg/kg during culture period. The concentration of iron was high and slightly change until final culture period.

Pond no.4, The iron ranged was 111.66-182.35 mg/kg, average 138.16 mg/kg during culture period. The concentration of iron was fluctuation during culture period.

However concentration of iron in culture system was slightly changed in during culture.

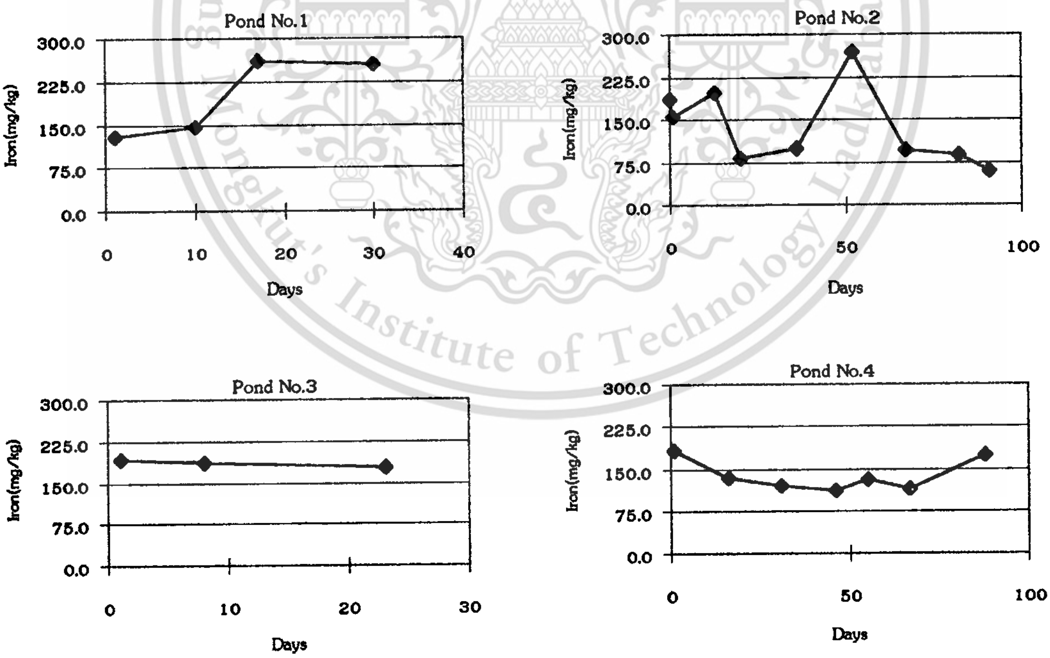


Figure 4.10 The concentration of iron in soil sediment changed during culture period in pond no.1-4.

4.2 The quality of water in shrimp pond with period of cultivation.

4.2.1 Temperature ($^{\circ}$c) (Figure 4.11)

Temperature in shrimp pond had similar pattern of change throughout the culture period.

Pond no.1, Temperature ranged was 28.1–31.6°c, average 30.43°c.

Pond no.2, Temperature ranged was 29.0-32.0°c, average 30.79°c.

Pond no.3, Temperature ranged was 31.0–31.6°c, average 31.37°c.

Pond no.4, Temperature ranged was 29.0–32.0°c, average 31.14°c.

However, there were not much different temperature in the ponds.

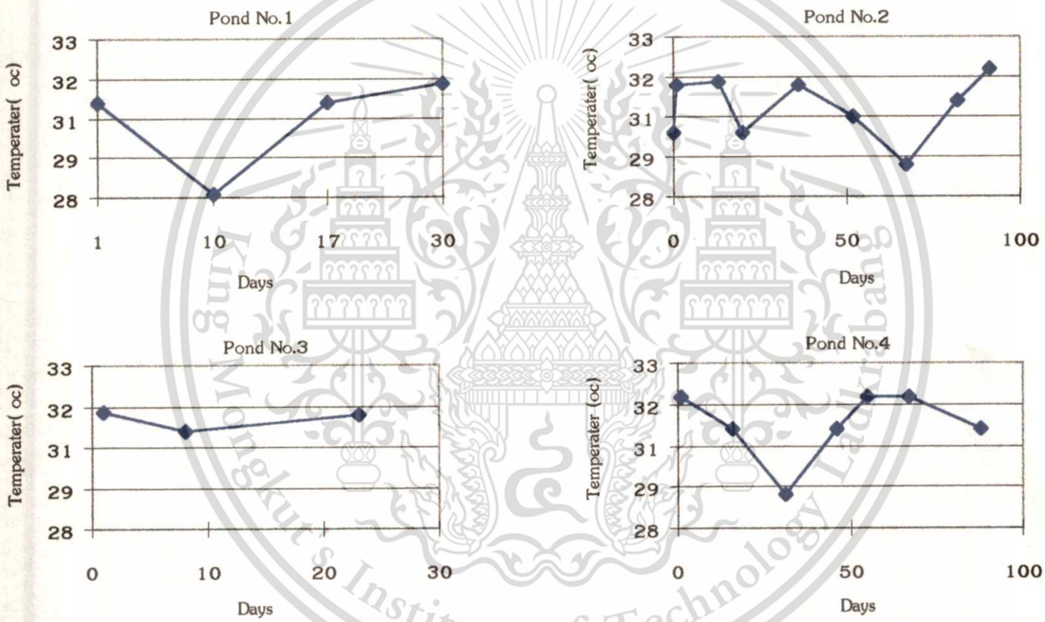


Figure 4.11 The temperature of water changed during culture period in pond no.1–4.

4.2.2 **pH effect** (Figure 4.12)

Pond no.1, pH ranged was 6.77-8.75, average 7.82. However pH in culture system was flactuation changed . It has basic condition in final period.

Pond no.2, pH ranged was 7.05–8.69, average 7.85

Pond no.3, pH ranged was 7.23–8.74, average 8.07. However pH in culture system was flactuation changed . It has alkaline condition in final period.

Pond no.4, pH ranged was 6.49-8.32, average 7.50. However pH in culture system was slightly changed in during culture.

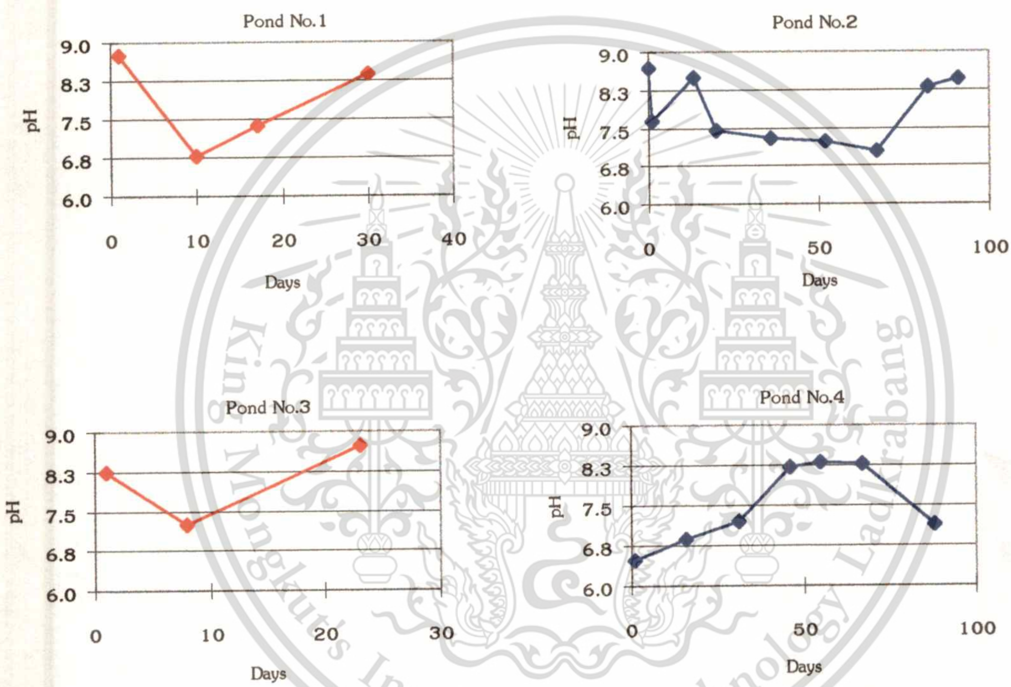


Figure 4.12 The pH of water changed during culture period in pond no.1-4.

4.2.3 **Soluble salts EC (mS/cm)** (Figure 4.13)

Pond no.1, Soluble salts ranged was 8.47–10.46 mS/cm, average 9.14 mS/cm. Soluble salts decreased hardly after 3 weeks of culture period.

Pond no.2, Soluble salts ranged was 1.83–13.13 mS/cm, average 5.09 mS/cm. Soluble salts decreased hardly after 3 weeks of culture period.

Pond no.3, Soluble salts ranged was 4.70-17.32 mS/cm, average 9.72 mS/cm. Soluble salts decreased hardly after 3 weeks of culture period.

Pond no.4, Soluble salts ranged was 2.90–13.25 mS/cm, average 5.66 mS/cm. Soluble salts decreased hardly after 3 weeks of culture period.

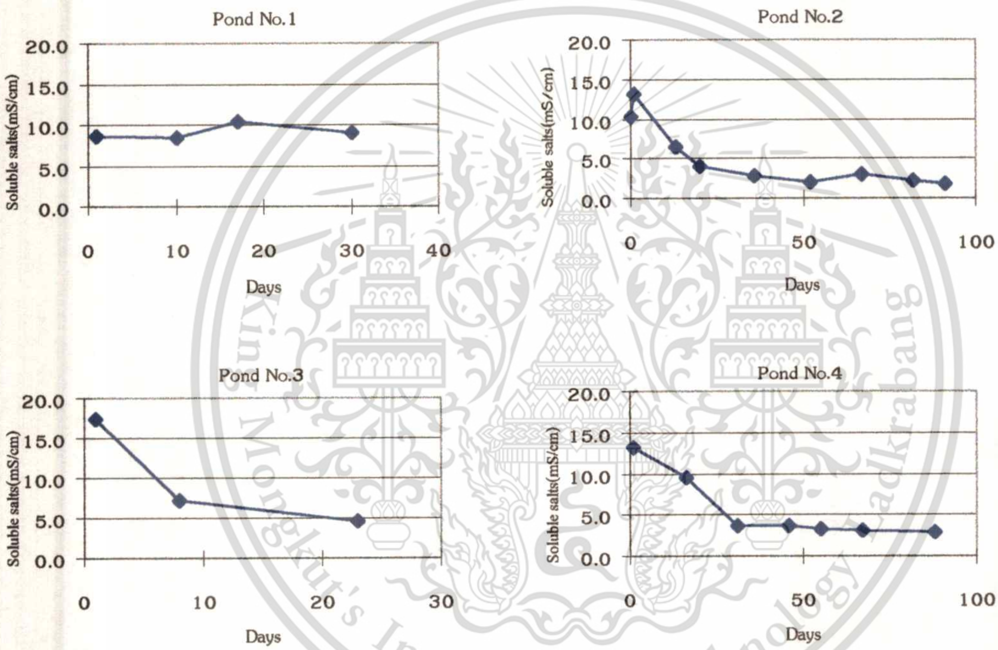


Figure 4.13 The soluble salts of water changed during culture period in pond no.1-4.

4.2.4 Total solids TS (mg/l) (Figure 4.14)

Pond no.1, The total solids range was 4.71-6.40 mg/l, average 5.52 mg/l.

Pond no.2, The total solids range was 1.05–7.11 mg/l, average 2.90 mg/l.

Pond no.3, The total solids range was 1.90-9.58 mg/l, average 4.48 mg/l. The total solids was high in the first weeks and decreased to 1.97 mg/l in ten days.

Pond no.4, The total solids range was 0.85-7.04 mg/l, average 2.33 mg/l.

The total solids was in similar pattern change. The concentration decreased when time was increased.

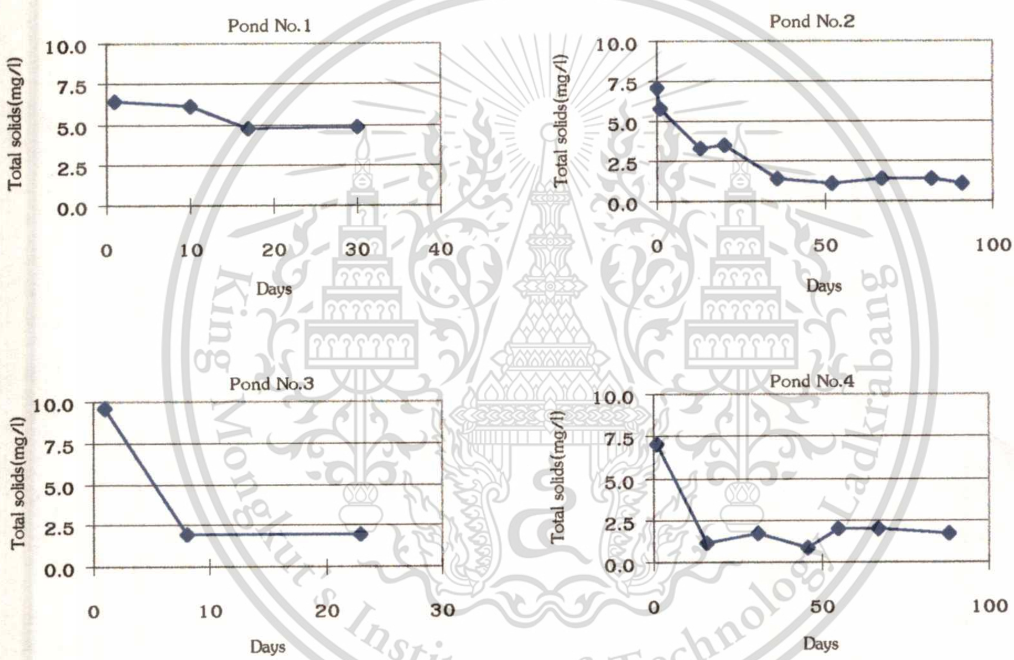


Figure 4.14 The total solids of water changed during culture period in pond no.1-4.

4.2.5 Suspended solids SS (mg/l) (Figure 4.15)

Pond no.1, The suspended solids range was 0.04-0.07 mg/l, average 0.06 mg/l.

Pond no.2, The suspended solids range was 0.00-0.22 mg/l, average 0.06 mg/l.

Pond no.3, The suspended solids range was 0.02-0.13 mg/l, average 0.07 mg/l.

Pond no.4, The suspended solids range was 0.01-0.05 mg/l, average 0.03 mg/l.

There were slightly different throughout the culture period.

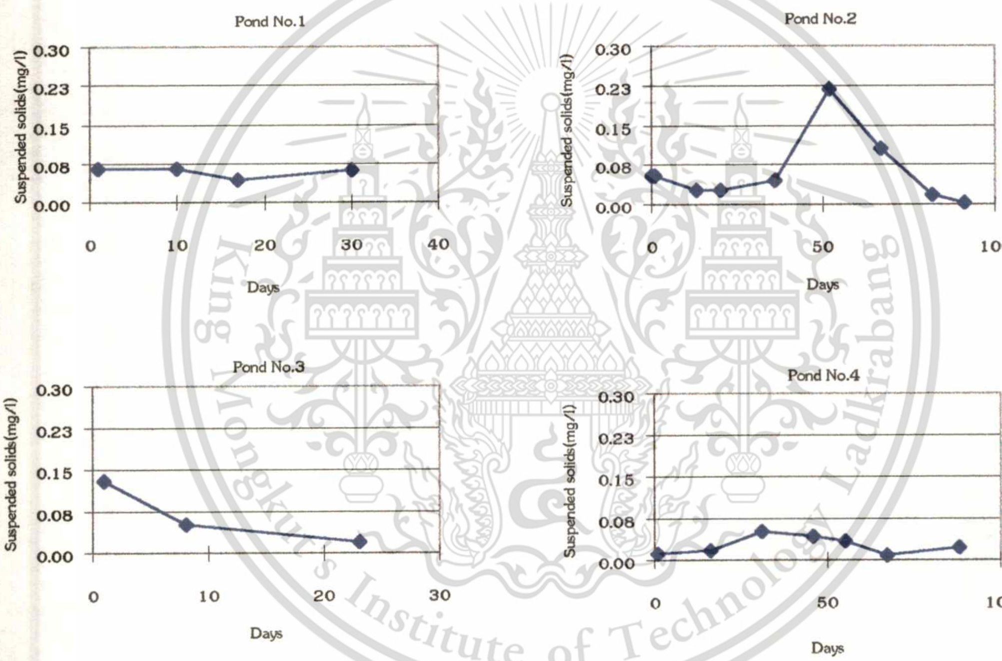


Figure 4.15 The suspended solids of water changed during culture period in pond no.1-4.

4.2.6 **Total dissolved solids TDS (mg/l)** (Figure 4.16)

Pond no.1, Total dissolved solids ranged was 4.67-6.34 mg/l, average 5.45 mg/l during culture period.

Pond no.2, Total dissolved solids ranged was 0.92-7.06 mg/l, average 2.84 mg/l during culture period.

Pond no.3, Total dissolved solids ranged was 1.88-9.45 mg/l, average 4.42 mg/l during culture period.

Pond no.4, Total dissolved solids ranged was 0.81-7.03 mg/l, average 2.31 mg/l during culture period.

The total dissolved solids has decrease pattern as similar the total dissolved solids.

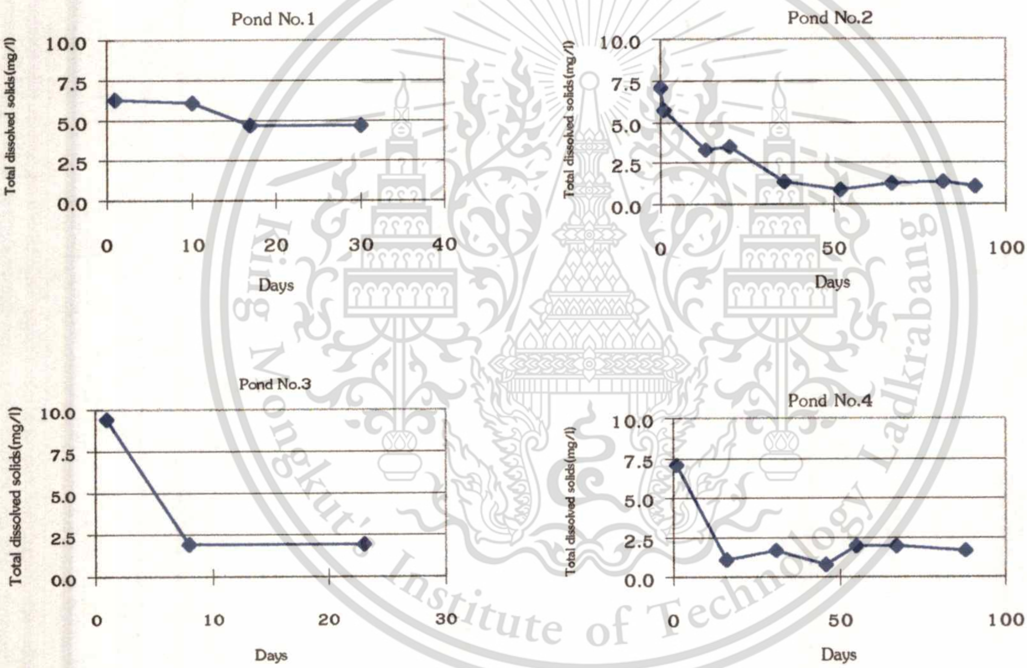


Figure 4.16 The total dissolved solids of water changed during culture period in pond no.1-4.

4.2.7 Chloride Cl^- (mg/l) (Figure 4.17)

Pond no.1, Chloride was high in the first weeks and slightly decreased to 3.42 mg/l in final culture. Chloride ranged was 3.14–4.79 mg/l, average 3.89 mg/l.

Pond no.2, Chloride was high in the first weeks and decreased to 0.46 mg/l as fresh water in final culture. Chloride ranged was 0.46–5.21 mg/l, average 1.63 mg/l.

Pond no.3, Chloride was high in the first weeks and decreased to 1.29 mg/l as fresh water in final culture. Chloride ranged was 1.29-7.88 mg/l, average 3.92 mg/l.

Pond no.4, Chloride was high in the first weeks and decreased to 0.48 mg/l as fresh water in final culture. Chloride ranged was 0.48–4.75 mg/l, average 1.68 mg/l.

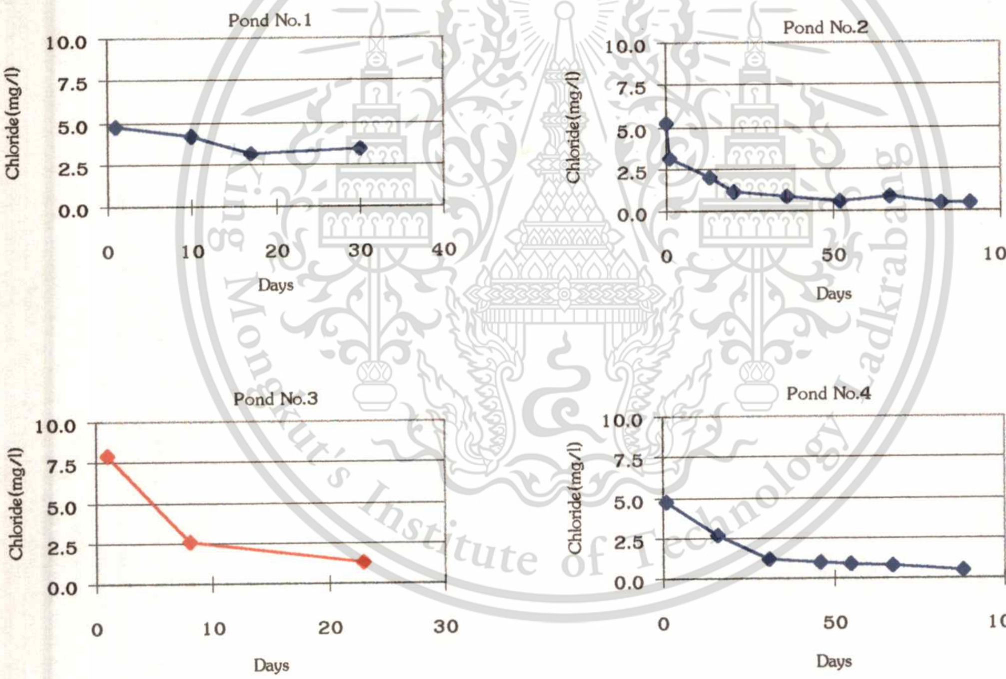


Figure 4.17 The cholride of water changed during culture period in pond no.1-4.

4.2.8 Alkalinity (mg/l) (Figure 4.18)

Pond no.1, Alkalinity ranged was 51.67–64.17 mg/l, average 55.27 mg/l. The low Alkalinity is not suitable for shrimp culture. It about buffer capacity in water quality during day, It 's one source of pH fluctuation changed in culture period.

Pond no.2, Alkalinity ranged was 75.00–110.83 mg/l, average 94.26 mg/l.

Pond no.3, Alkalinity ranged was 104.17-135.00 mg/l, average 119.17 mg/l. It decreased until final period.

Pond no.4, Alkalinity ranged was 50-80 mg/l, average 68.81 mg/l. It increased after one month and then rather constant until final period.

This culture in low saline water has alkalinity lower than culture in saline water.

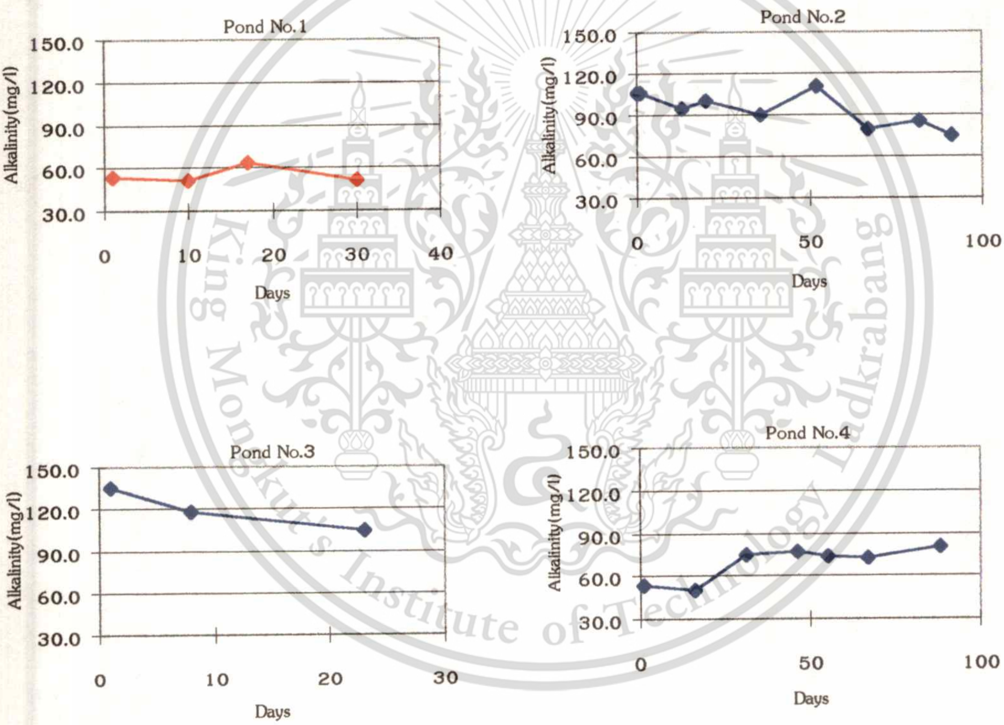


Figure 4.18 The alkalinity of water changed during culture period in pond no.1-4.

4.2.9 Chemical oxygen demand COD (mg/l) (Figure 4.19)

Pond no.1, Chemical oxygen demand ranged was 207–360 mg/l, average 269.75 mg/l. The average concentration was too high and not suitable for aquatic life.

Pond no.2, Chemical oxygen demand ranged was 48–300 mg/l, average 144.74 mg/l.

Pond no.3, Chemical oxygen demand ranged was 99.33-411.33 mg/l, average 236.44 mg/l. The concentration was high and then drop when culture one week and increased in final period (not suitable for aquatic life).

Pond no.4, Chemical oxygen demand ranged was 117.33–318 mg/l, average 207.62 mg/l.

The chemical oxygen demand concentration was rather high in all culture. The pond no.2 and no.4 were very similar patterns and they had lower concentration than pond no.1 and no.3 during culture.

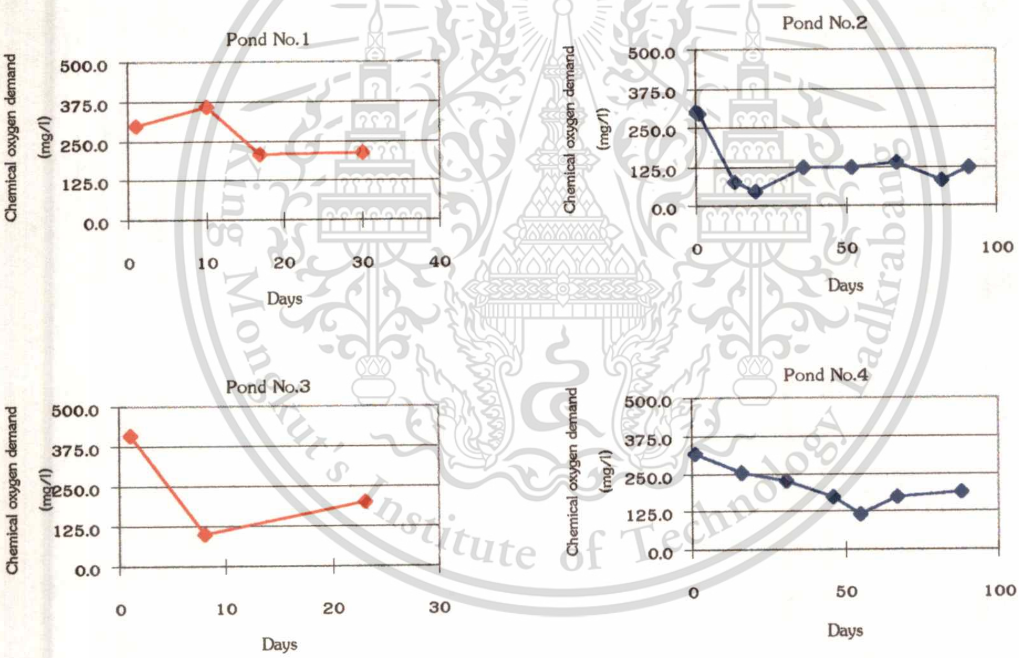


Figure 4.19 The chemical oxygen demand of water changed during culture period in pond no.1-4.

4.2.10 Dissolved oxygen DO (mg/l) (Figure 4.20)

Dissolved oxygen level in culture system had the same pattern change throughout the culture period with aeration supply.

Pond no.1, Dissolved oxygen ranged was 6.6-9.0 mg/l, average 7.80 mg/l. Dissolved oxygen level in this culture, increased during culture period.

Pond no.2, Dissolved oxygen ranged was 6.0-8.7 mg/l, average 7.74 mg/l.

Pond no.3, Dissolved oxygen ranged was 8.0-9.0 mg/l, average 8.57 mg/l. The concentration of Dissolved oxygen was higher than other ponds.

Pond no.4, Dissolved oxygen ranged was 5.9-7.0 mg/l, average 6.49 mg/l.

It was good condition for shrimp growth.

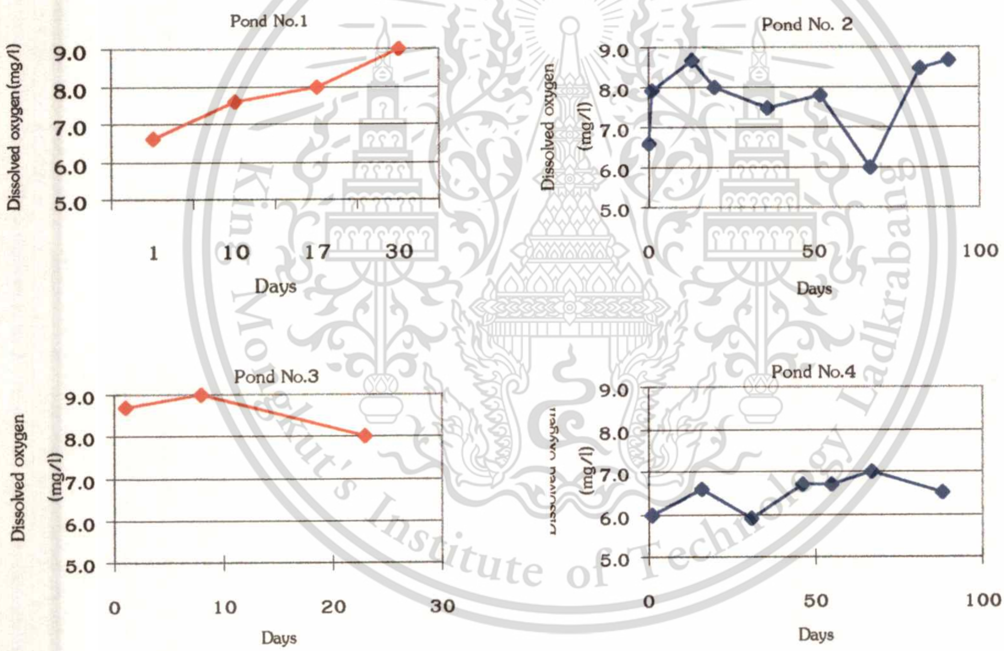


Figure 4.20 The dissolved oxygen of water changed during culture period in pond no.1-4.

4.2.11 Total nitrogen TN (mg/l) (Figure 4.21)

Pond no.1, The concentration of total nitrogen ranged was 1.56–3.61 mg/l, average 2.66 mg/l. The concentration of total nitrogen was higher than the others ponds.

Pond no.2, The concentration of total nitrogen ranged was 0.50–3.16 mg/l, average 1.51 mg/l.

Pond no.3, The concentration of total nitrogen ranged was 0.37–1.57 mg/l, average 1.14 mg/l.

Pond no.4, The concentration of total nitrogen ranged was 0.22–3.20 mg/l, average 1.09 mg/l. The concentration of total nitrogen was in similar pattern, and decreased until the final culture period.

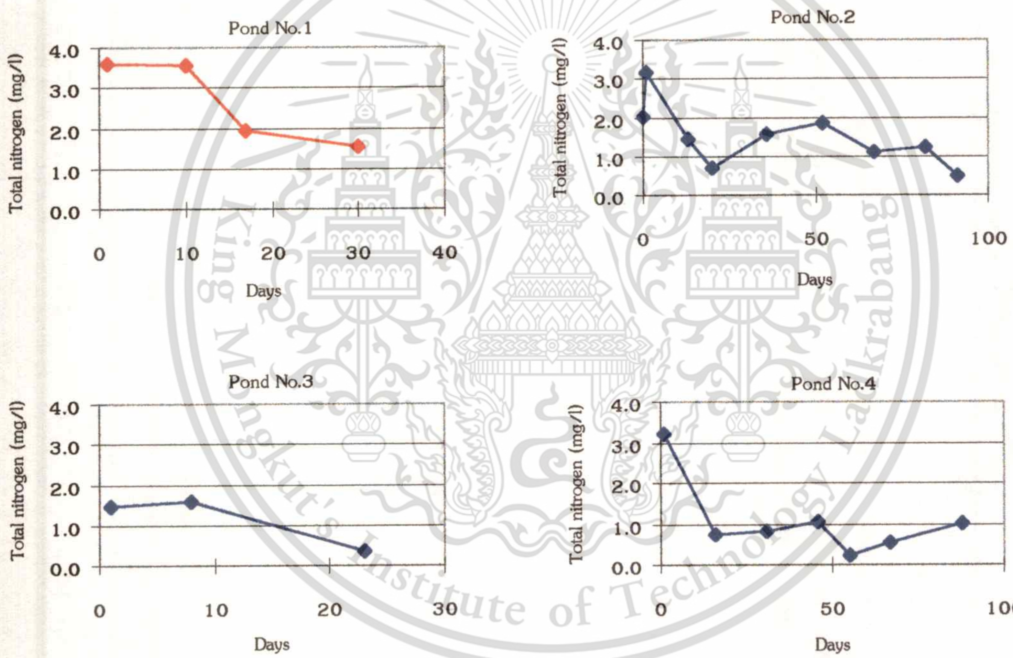


Figure 4.21 The concentration of total nitrogen in water changed during culture period in pond no.1-4.

4.2.12 Organic nitrogen Org-N (mg/l) (Figure 4.22)

Pond no.1, The Organic nitrogen ranged was 1.23–1.64 mg/l, average 1.42 mg/l during culture period.

Pond no.2, The Organic nitrogen ranged was 0.54–1.29 mg/l, average 0.87 mg/l during culture period.

Pond no.3, The Organic nitrogen ranged was 0.56–1.16 mg/l, average 0.91 mg/l during culture period.

Pond no.4, The Organic nitrogen ranged was 0.37–1.15 mg/l, average 0.75 mg/l during culture period.

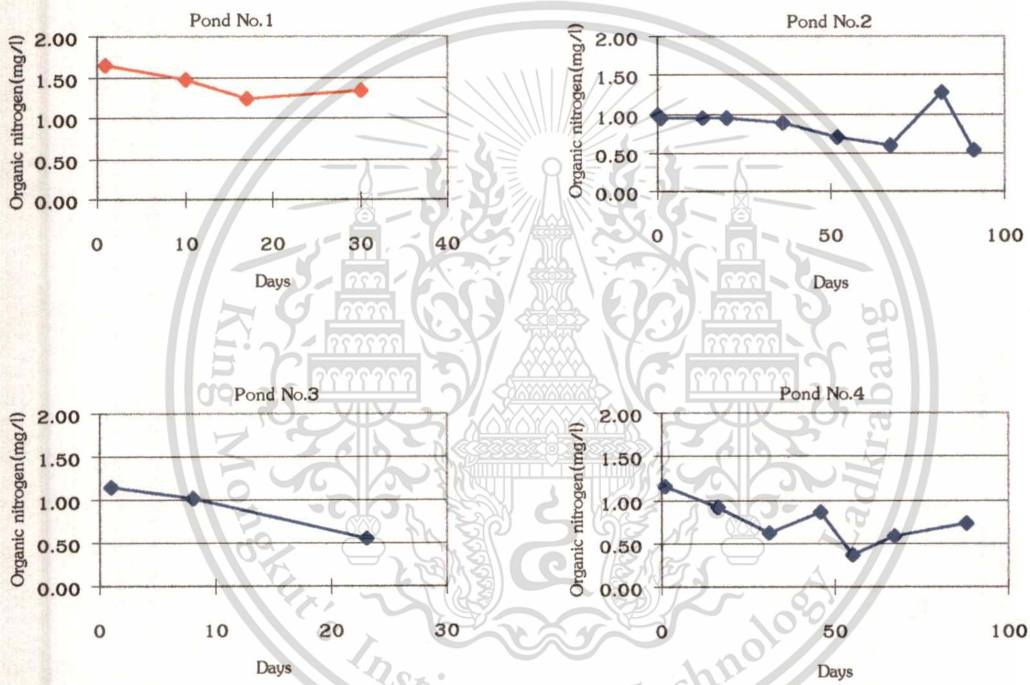


Figure 4.22 The concentration of organic nitrogen in water changed during culture period in pond no.1-4.

4.2.13 Ammonia NH_3-N (mg/l) (Figure 4.23)

Pond no.1, The ammonia ranged was 0.06–2.05 mg/l, average 0.87 mg/l. The concentration of Ammonia was high, and became one source of respiration problem in shrimp pond.

Pond no.2, The ammonia ranged was 0.06–1.72 mg/l, average 0.72 mg/l.

Pond no.3, The ammonia ranged was 0.04–0.32 mg/l, average 0.14 mg/l.

Pond no.4, The ammonia ranged was 0.02–1.42 mg/l, average 0.45 mg/l.

The previous conditions were not suitable for shrimp growth. The concentration was decrease during the culture period.

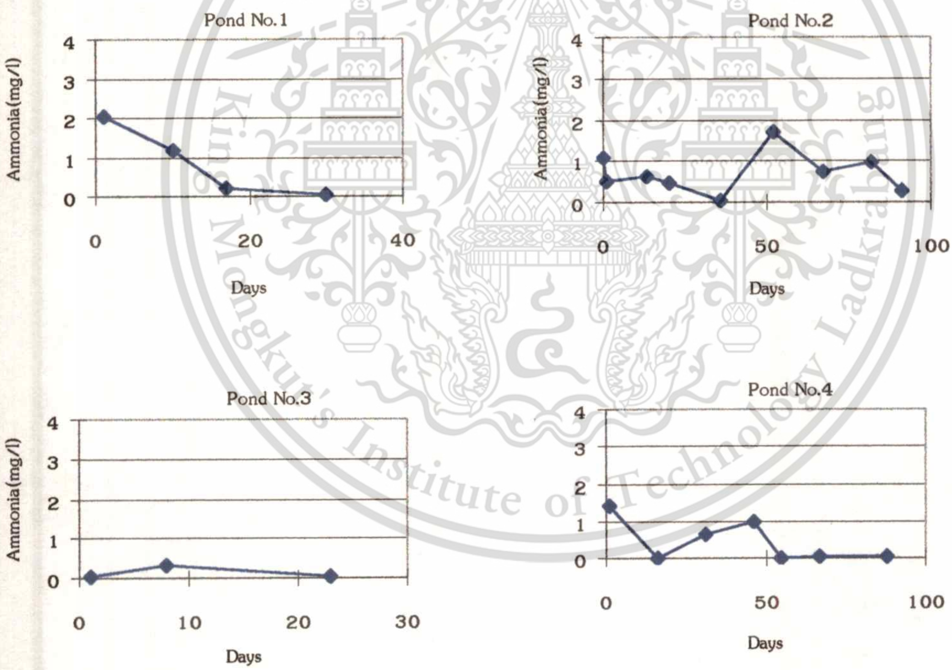


Figure 4.23 The concentration of ammonia in water changed during culture period in pond no.1-4.

4.2.14 Sulfate SO_4^{2-} (mg/l) (Figure 4.24)

Pond no.1, The sulfate ranged was 684.11–846.05 mg/l, average 800.85 mg/l during culture period.

Pond no.2, The sulfate ranged was 172.20–868.99 mg/l, average 493.53 mg/l during culture period.

Pond no.3, The sulfate ranged was 528.02–891.49 mg/l, average 674.07 mg/l during culture period. The average concentration of sulfate is very high. It 's not good for shrimp life.

Pond no.4, The sulfate ranged was 166.76–1545.55 mg/l, average 623.57 mg/l during culture period.

The sulfate concentration of marine water is higher concentration than fresh water (show in figure 2.2). The sulfate concentration is rather high in all cultures. The pond no.2 and no.4 were very similar pattern and they have lower concentration than pond no.1 and no.3 during culture period.

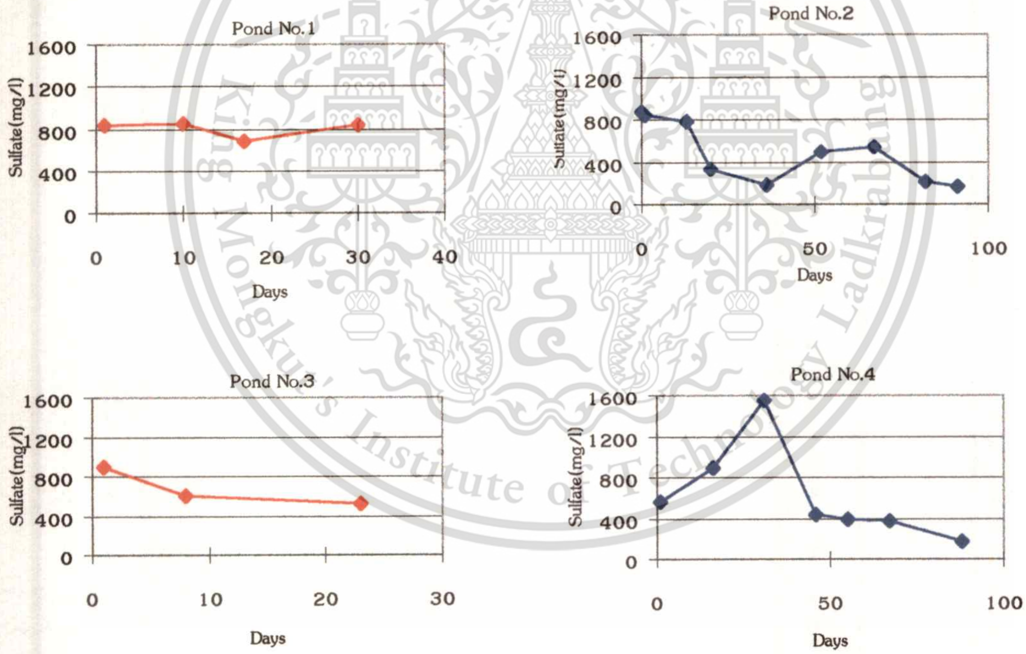


Figure 4.24 The concentration of sulfate in water changed during culture period in pond no.1-4.

4.2.15 Total phosphorus TP (mg/l) (Figure 4.25)

Pond no.1, The total phosphorus ranged was 0.20–1.06 mg/l, average 0.50 mg/l during culture period. The concentration were decreased during culture period.

Pond no.2, The total phosphorus ranged was 0.24–0.90 mg/l, average 0.58 mg/l during culture period.

Pond no.3, The total phosphorus ranged was 0.45–0.70 mg/l, average 0.59 mg/l during culture period. The concentration were slightly changed during culture period.

Pond no.4, The total phosphorus ranged was 0.20–1.11 mg/l, average 0.55 mg/l during culture period.

The pond no.2 and no.4 were very similar pattern and they have slightly fluctuation concentration of total phosphorus when comparison with pond no.1 and no.3 during culture period.

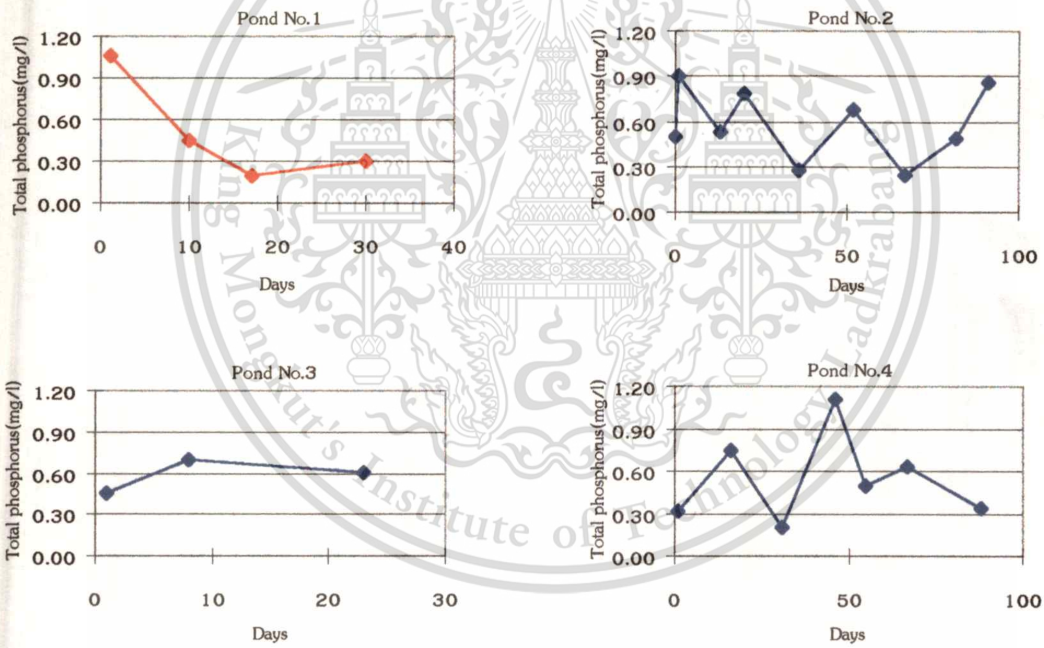


Figure 4.25 The concentration of total phosphorus in water changed during culture period in pond no.1-4.

4.2.16 Iron (mg/l) (Figure 4.26)

Pond no.1, The iron ranged was 0.57–1.79 mg/l, average 1.14 mg/l during culture period. The concentration were decreased during culture period.

Pond no.2, The iron ranged was 0.25–4.27 mg/l, average 1.46 mg/l during culture period.

Pond no.3, The iron ranged was 0.74–2.04 mg/l, average 1.45 mg/l during culture period. The concentration were decreased during culture period.

Pond no.4, The iron ranged was 0.67–1.44 mg/l, average 0.95 mg/l during culture period.

The pond no.2 and no.4 were very similar pattern and they have lower concentration than pond no.1 and no.3 during culture period.

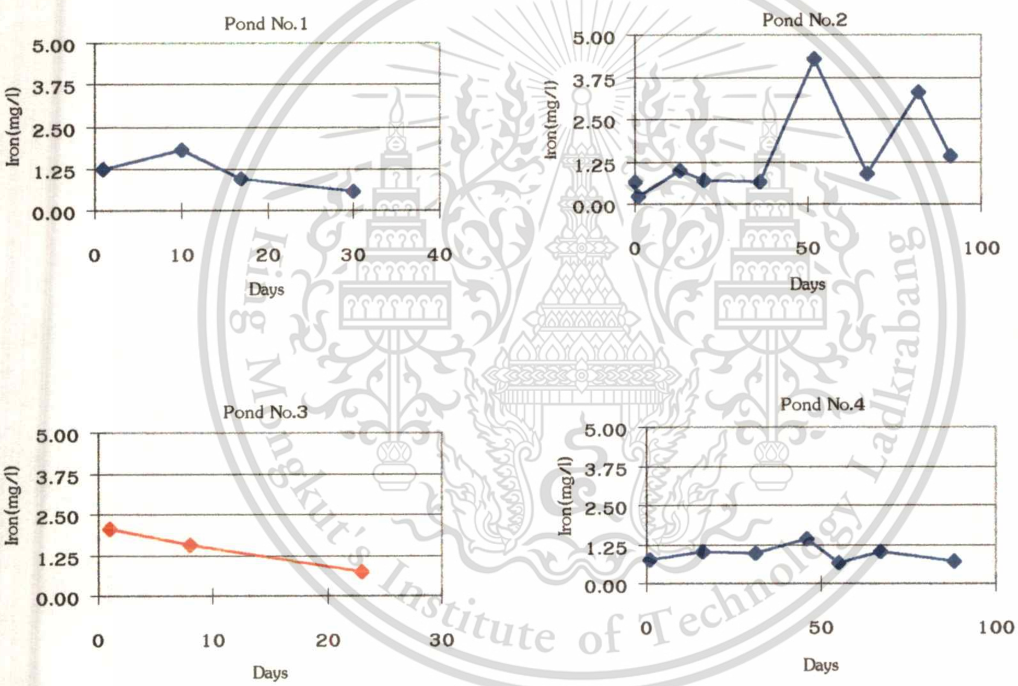


Figure 4.26 The concentration of iron in water changed during culture period in pond no.1-4.

4.3 Shrimp growth

4.3.1 **Length (cm)** of shrimp is shown in Figure 4.27.

Pond no.1, The length ranged was 1.00-6.50 centimeters, average 3.50 centimeters and had standard deviation 2.35 centimeters.

Pond no.2, The length ranged was 0.0-15.00 centimeters, average 7.63 centimeters and had standard deviation 5.29 centimeters.

Pond no.3, The length ranged was 1.0-8.00 centimeters, average 3.67 centimeters and had standard deviation 3.79 centimeters.

Pond no.4, The length ranged was 0.15-12.00 centimeters, average 7.57 centimeters and had standard deviation 4.15 centimeters.

The pond no.2 and no.4 were very similar pattern and the length of shrimp in pond no.2 was the longest.

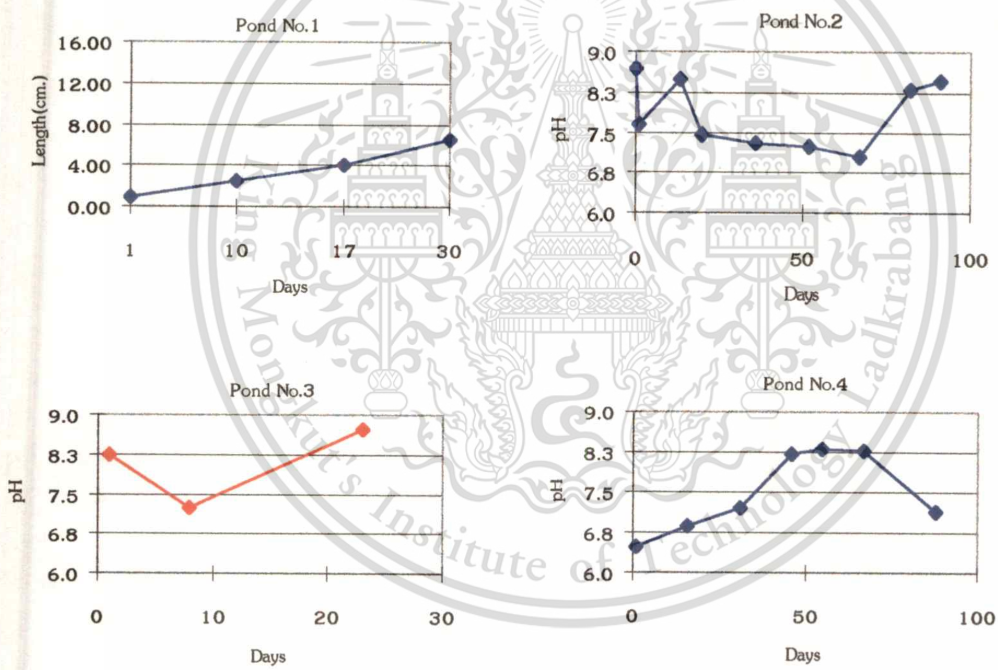


Figure 4.27 Length of shrimp changed during culture period in pond no.1-4.

4.3.2 Weight (g) of shrimp is shown in Figure 4.28.

Pond no.1, The weight ranged was 0.15-4.13 grams, average 1.70 grams and had standard deviation 1.81 grams.

Pond no.2, The weight ranged was 0.0-14.71 grams, average 6.61 grams and had standard deviation 5.60 grams.

Pond no.3, The weight ranged was 0.10-9.00 grams, average 3.18 grams and had standard deviation 5.04 grams.

Pond no.4, The weight ranged was 0.30-11.00 grams, average 4.38 grams and had standard deviation 3.81 grams.

The pond no.2 and no.4 were very similar pattern and the weight of shrimp pond no.2 was the best .

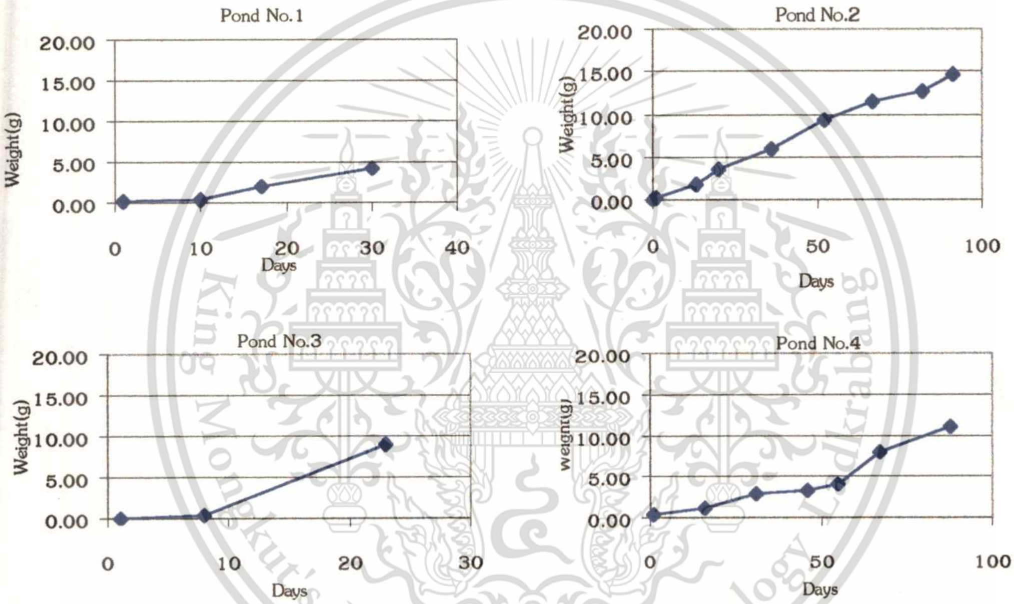


Figure 4. 28 Weight of shrimp changed during culture period in pond no.1-4.

The average comparison of chemical and physical quality of four shrimp ponds at Chacherngsao, could be divided into 3 parts as.

- Average changes in soil sediment quality.
- Average changes in low water quality.
- Average changes growth rate of shrimp.

4.4 Average quality of soil sediment in shrimp pond no.1-4. (Table A-13)

4.4.1 pH (Figure 4.29)

pH in shrimp pond o.1-4 have Mean±SD 6.35±0.11, 7.02±0.31, 7.32±0.06 and 7.10±0.12, respectively, and pH average of 6.95±0.42.

4.4.2 Soluble salts EC (mS/cm) (Figure 4.30)

Soluble salts in shrimp pond no.1-4 have Mean±SD 2.22±0.51, 1.40±1.13, 1.69±0.30 and 1.02±0, respectively, and EC average of 1.58±0.51.

4.4.3 Organic matter (%) (Figure 4.31)

Organic matter in shrimp pond no.1-4 have Mean±SD 10.90±0.58, 10.28±1.43, 11.27±0.46 and 10.35±0.38, respectively, and average of 10.70±0.47.

4.4.4 Total nitrogen (%) (Figure 4.32)

Total nitrogen in shrimp pond no.1-4 have Mean±SD 1.51±0.51, 1.36±0.57, 1.59±0.39 and 1.34±0, respectively, and average of 1.45±0.12.

4.4.5 Cation exchange capacity CEC (meq./100g soil) (Figure 4.33)

Cation exchange capacity in shrimp pond no.1-4 have Mean±SD 42.25±6.04, 36.78±8.99, 35.08±2.54 and 33.96±6.73, respectively, and average of 37.02±3.68.

4.4.6 Exchangeable Al^{3+} (meq./100g soil) (Figure 4.34)

Exchangeable Al^{3+} in shrimp pond no.1-4 have Mean±SD 0.0198 ±0.0001, 0.0197±0.0002, 0.0197±0.0001 and 0.0197±0.0002, respectively, and average of 0.0197±0.001.

4.4.7 Exchange H^{+} (meq./100g soil) (Figure 4.35)

Exchange H^{+} in shrimp pond no.1-4 have Mean±SD 0.05±0.01, 0.07±0.02, 0.06±0.05 and 0.08±0.01, respectively, and average of 0.07±0.01.

4.4.8 Total phosphorus TP (mg/kg) (Figure 4.36)

Total phosphorus in shrimp pond no.1-4 have Mean±SD 0.11±0.06, 0.14±0.09, 0.06±0.03 and 0.09±0.09, respectively, and average of 0.10±0.03.

4.4.9 Sulfate SO_4^{2-} (mg/kg) (Figure 4.37)

Sulfate in shrimp pond no.1-4 have Mean±SD 390.82±137.69, 272.47±137.71, 368.62±16.25 and 273.89±56.38, respectively, and average of 326.45±62.18.

4.4.10 Iron Fe (mg/kg) (Figure 4.38)

Iron in shrimp pond No.1-4 have Mean±SD 197.23±69.46, 137.48 ±69.53, 185.61±8.47 and 138.16±28.40, respectively, and average of 164.62 ±31.31.

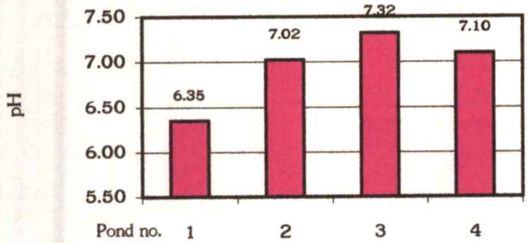


Figure 4.29 Average pH of soil sediment in pond no.1-4 during culture period.

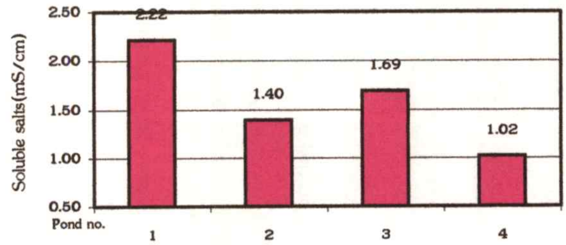


Figure 4.30 Average Soluble salts of soil sediment in pond no.1-4 during culture period.

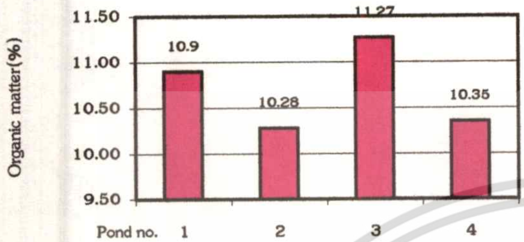


Figure 4.31 Average Organic matter of soil sediment in pond no.1-4 during culture period.

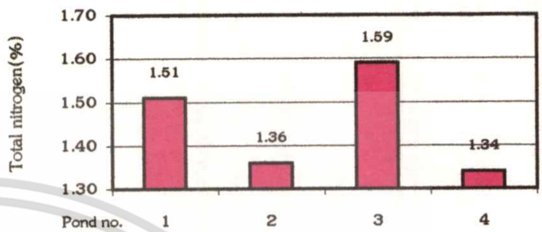


Figure 4.32 Average Total nitrogen of soil sediment in pond no.1-4 during culture period.

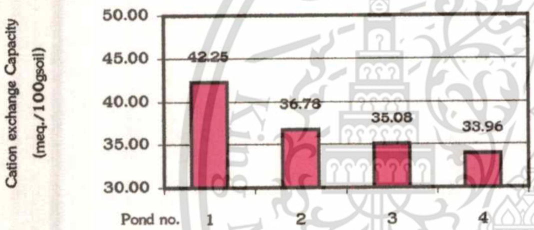


Figure 4.33 Average Cation Exchange Capacity of soil sediment in pond no.1-4 during culture period.

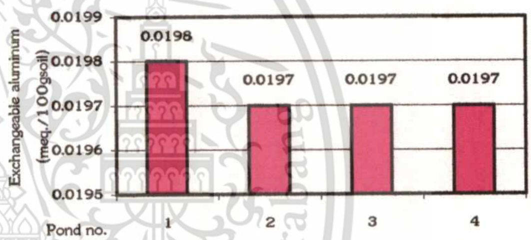


Figure 4.34 Average Exchangeable aluminum of soil sediment in pond no.1-4 during culture period.

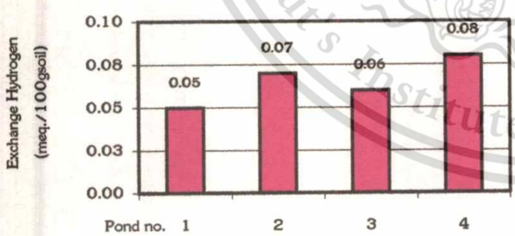


Figure 4.35 Average Exchange hydrogen of soil sediment in pond no.1-4 during culture period.

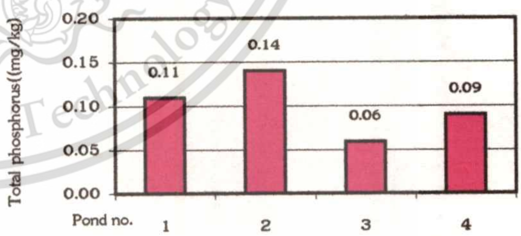


Figure 4.36 Average Total phosphorus of soil sediment in pond no.1-4 during culture period.

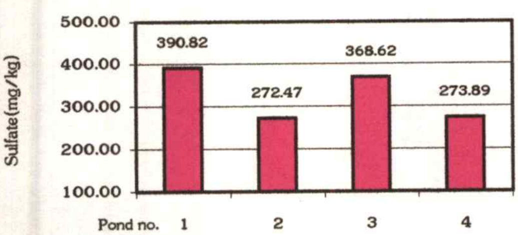


Figure 4.37 Average Sulfate of soil sediment in pond no.1-4 during culture period.

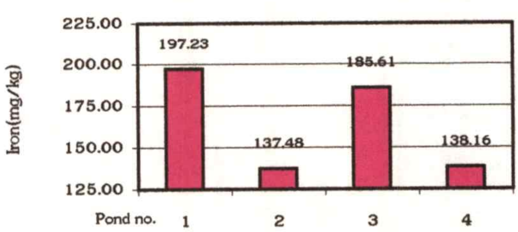


Figure 4.38 Average Iron of soil sediment in pond no.1-4 during culture period.

4.5 Average Quality of Water in shrimp pond No.1-4. (Table A-14)

4.5.1 Temperature (^{o}c) (Figure 4.39)

Temperature in shrimp pond no.1-4 have Mean$\pm$SD 30.43$\pm$1.58, 30.79$\pm$0.98, 31.37$\pm$0.32 and 31.14$\pm$1.07, respectively, and average of 30.93$\pm$0.41.

Temperature in shrimp pond had similar pattern of change throughout the culture period. A ranged Temperature was 28 - 32 °C and average of 31.03 °C. However, there were not much different in temperature in the ponds.

4.5.2 pH (Figure 4.40)

pH in shrimp pond no.1-4 have Mean$\pm$SD 7.82$\pm$0.91, 7.85$\pm$0.64, 8.07$\pm$0.77 and 7.50$\pm$0.75, respectively, and average of 7.81$\pm$0.23. However pH in culture system was slightly changed in during culture.

4.5.3 Soluble salts EC (mS/cm) (Figure 4.41)

Soluble salts in shrimp pond no.1-4 have Mean$\pm$SD 9.14$\pm$0.91, 5.09$\pm$4.07, 9.72$\pm$6.69 and 5.66$\pm$4.07, respectively, and average of 7.40$\pm$2.37.

4.5.4 Total solids TS (mg/l) (Figure 4.42)

Total solids in shrimp pond no.1-4 have Mean$\pm$SD 5.52$\pm$0.87, 2.90$\pm$2.24, 4.48$\pm$4.41 and 2.33$\pm$2.12, respectively, and average of 3.81$\pm$1.46.

4.5.5 Suspended solids SS (mg/l) (Figure 4.43)

Suspended solids in shrimp pond no.1-4 have Mean$\pm$SD 0.06$\pm$0.01, 0.06$\pm$0.07, 0.07$\pm$0.06 and 0.03$\pm$0.02, respectively, and average of 0.05$\pm$0.02.

4.5.6 Total dissolved solids TDS (mg/l) (Figure 4.44)

Total dissolved solids in shrimp pond no.1-4 have Mean$\pm$SD 5.45$\pm$0.88, 2.84$\pm$2.26, 4.42$\pm$4.36 and 2.31$\pm$2.12, respectively, and average of 3.75$\pm$1.44.

4.5.7 Chloride Cl^- (mg/l) (Figure 4.45)

Chloride in shrimp pond no.1-4 have Mean$\pm$SD 3.89$\pm$0.75, 1.63$\pm$1.60, 3.92$\pm$ 3.49 and 1.68$\pm$1.52, respectively, and average of 2.78$\pm$1.30.

4.5.8 Alkalinity (mg/l) (Figure 4.46)

Alkalinity in shrimp pond no.1-4 have Mean$\pm$SD 55.27$\pm$6.001, 94.26$\pm$12.67, 119.17$\pm$15.43 and 68.81$\pm$11.98, respectively, and average of 84.38$\pm$28.27.

4.5.9 Chemical oxygen demand COD (mg/l) (Figure 4.47)

Chemical oxygen demand in shrimp pond no.1-4 have Mean±SD 269.75±73.79, 144.74±91.23, 236.44±159.39 and 207.62±64.77, respectively, and average of 214.64±50.07.

4.5.10 Dissolved oxygen DO (mg/l) (Figure 4.48)

Dissolved oxygen in shrimp pond no.1-4 have Mean±SD 7.80±0.99, 7.74±0.93, 8.57±0.51 and 6.49±0.40, respectively, and average of 7.65±0.86.

4.5.11 Total nitrogen TN **(mg/l)** (Figure 4.49)

Total nitrogen in shrimp pond no.1-4 have Mean±SD 2.66±1.07, 1.51±0.80, 1.14±0.66 and 1.09±0.98, respectively, and average of 1.60±0.73.

4.5.12 Organic nitrogen Org-N (mg/l) (Figure 4.50)

Organic nitrogen in shrimp pond no.1-4 have Mean±SD 1.42±0.18, 0.87±0.23, 0.91±0.31 and 0.75±0.25, respectively, and average of 0.99±0.30.

4.5.13 Ammonia NH_3-N (mg/l) (Figure 4.51)

Ammonia in shrimp pond no.1-4 have Mean±SD 0.87±0.93, 0.72±0.49, 0.14 ±0.16 and 0.45±0.57, respectively, and average of 0.54±0.32.

4.5.14 Sulfate SO_4^{2-} (mg/l) (Figure 4.52)

Sulfate in shrimp pond no.1-4 have Mean±SD 800.85±77.95, 493.53±287.14, 674.07±191.96 and 623.57±463.41, respectively, and average of 648.00±127.15.

4.5.15 Total phosphorus TP (mg/l) (Figure 4.53)

Total phosphorus in shrimp pond no.1-4 have Mean±SD 0.50±0.38, 0.58±0.24, 0.59±0.13 and 0.55±0.31, respectively, and average of 0.56±0.04.

4.5.16 Iron Fe (mg/l) (Figure 4.54)

Iron in shrimp pond no.1-4 have Mean±SD 1.14±0.52, 1.46±1.37, 1.45±0.66 and 0.95±0.26, respectively, and average of 1.25±0.25.

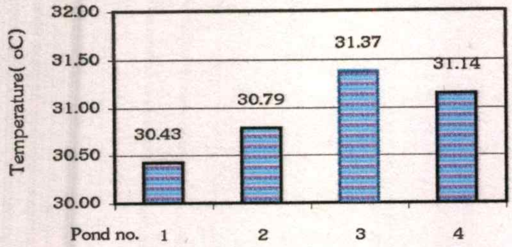


Figure 4.39 Average Temperature (°c) of water in pond no.1-4 during culture period.

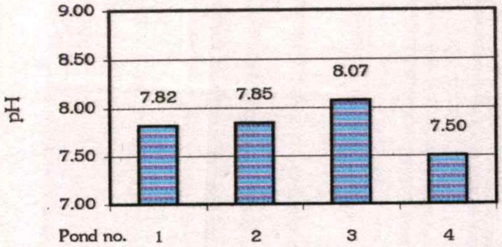


Figure 4.40 Average pH of water in pond no.1-4 during culture period.

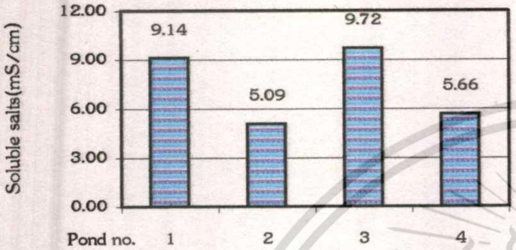


Figure 4.41 Average Soluble salts of water in pond no.1-4 during culture period.

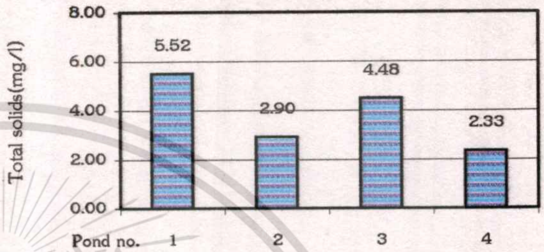


Figure 4.42 Average Total solids of water in pond no.1-4 during culture period.

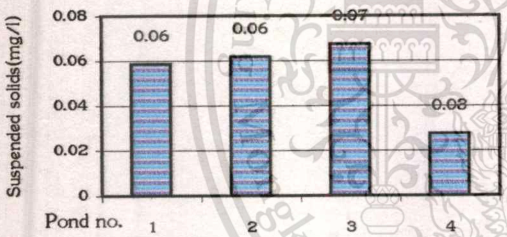


Figure 4.43 Average Suspended solids of water in pond no.1-4 during culture period.

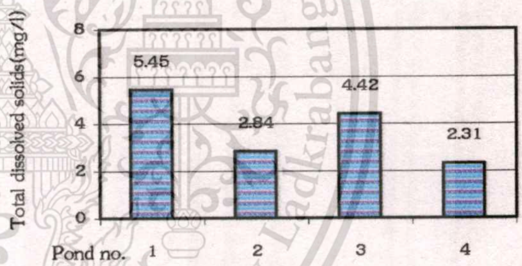


Figure 4.44 Average Total dissolved solids of water in pond no.1-4 during culture period.

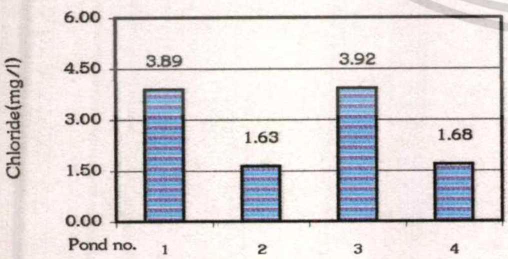


Figure 4.45 Average Chloride of water in pond no.1-4 during culture period.

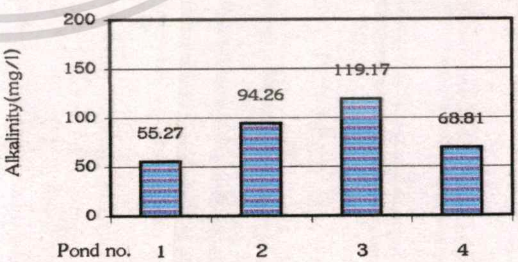


Figure 4.46 Average Alkalinity of water in pond no.1-4 during culture period.

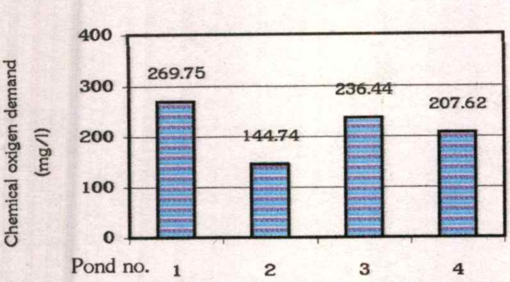


Figure 4.47 Average Chemical oxygen demand of water in pond no. 1-4 during culture period.

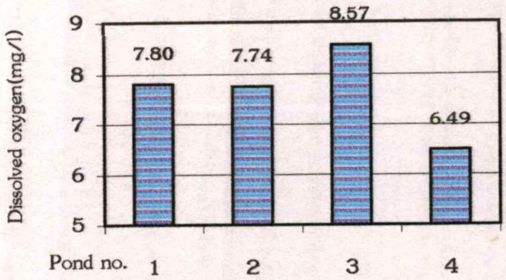


Figure 4.48 Average Dissolved oxygen of water in pond no.1-4 during culture period.

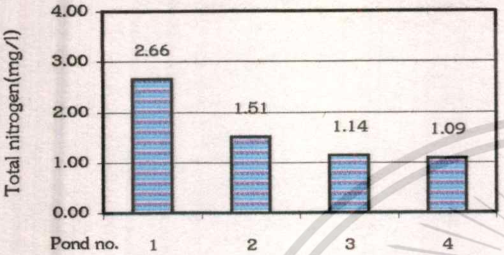


Figure 4.49 Average Total nitrogen of water in pond no.1-4 during culture period.

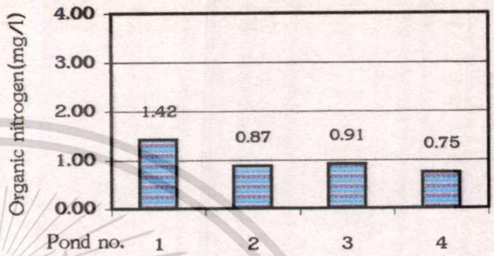


Figure 4.50 Average Organic nitrogen of water in pond no.1-4 during culture period.

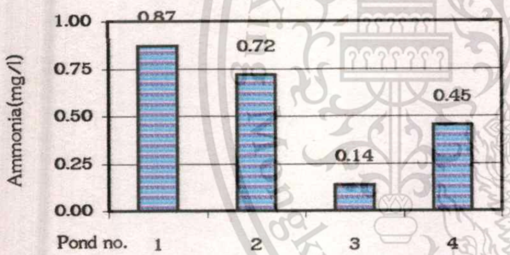


Figure 4.51 Average Ammonia of water in pond no.1-4 during culture period.

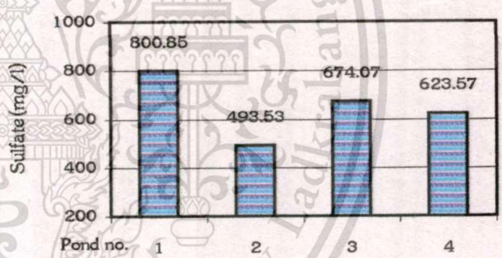


Figure 4.52 Average Sulfate of water in pond no.1-4 during culture period.

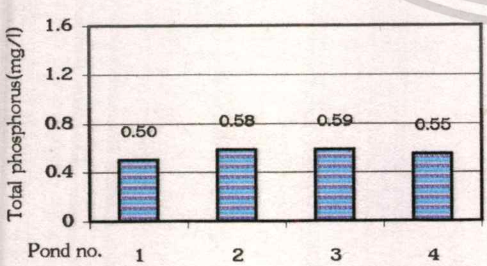


Figure 4.53 Average Total phosphorus of water in pond no.1-4 during culture period.

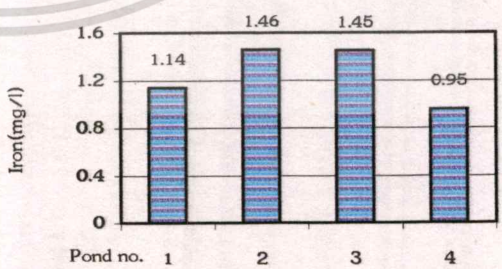


Figure 4.54 Average Iron of water in pond no.1-4 during culture period.

4.6 Average Shrimp growth.

4.6.1 Length (cm)

Length in shrimp pond no.1-4 have Mean±SD 3.50±2.35, 7.63±5.29, 3.67±3.79 and 7.57±4.15, respectively, and average of 5.59±0.41.

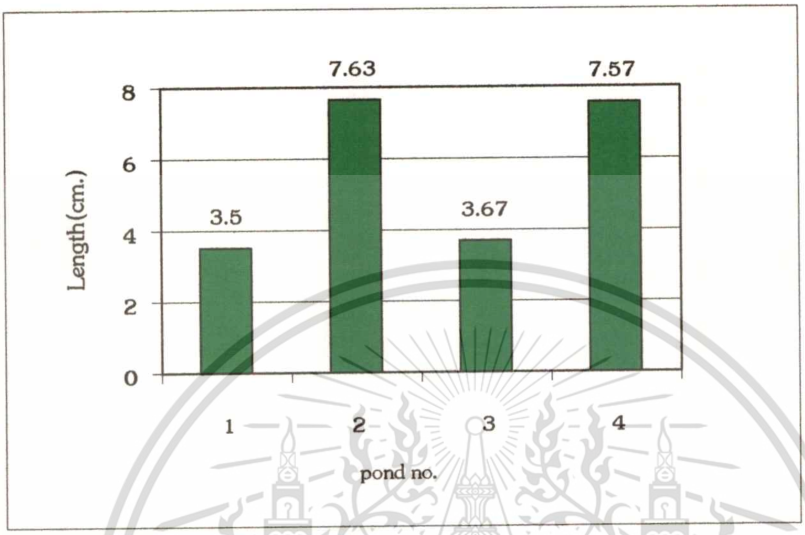


Figure 4.55 Average Length of shrimp in pond no. 1-4 during culture period.

4.6.2 Weight (g)

Weight in shrimp pond no.1-4 have Mean±SD 1.70±1.81, 6.61±5.60, 3.18±5.04 and 4.38±3.81, respectively, and average of 3.97±0.42.

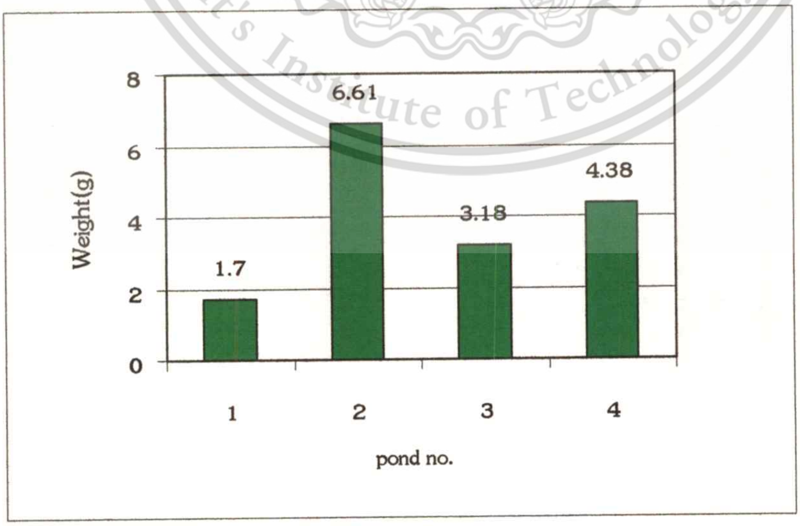


Figure 4.56 Average Weight of shrimp in pond no. 1-4 during culture period.

Correlation study of basic data related with quality of soil, water and growth rate of shrimp from pearson coefficient, could be divided into five parts as:

- The correlation between soil sediment quality of various shrimp ponds.
- The correlation between water quality in shrimp ponds.
- The correlation between length with soil sediment and water quality in shrimp ponds.
- The correlation between weight with soil sediment and water quality in shrimp ponds.
- The correlation of growth rate in four shrimp ponds.

4.7 Pearson Correlation Coefficient in soil sediment at 95 percent Confident.

4.7.1 Correlation analysis of soil sediment quality in first shrimp pond is shown in Appendix B, Table B-1 as:

Sulfate has positive correlated with Iron (value 0.0001) and seems to be highly significant effect ($P < 0.01$).

4.7.2 Correlation analysis of soil sediment in second shrimp pond is shown in Appendix B, Table B-2 as:

pH have negative correlated with Soluble salts (0.004**), Sulfate (0.043*) and Iron (0.04*), respectively.

Soluble salts have positive correlation with Organic matter (0.002**), Sulfate (0.02*) and Iron (0.02*), respectively, and have negative correlation with Exchangeable Al^{3+} (0.011*).

Organic matter have positive correlation with Soluble salts (0.002**), Sulfate (0.002**) and Iron (0.002**), respectively, and have negative correlation with Exchangeable Al^{3+} (0.013*) and Exchange H^{+} (0.049*).

Total nitrogen has negative correlation with Exchangeable H^{+} (0.017*).

Exchangeable Al^{3+} have negative correlation with Soluble salts (0.011*), Organic matter (0.013*), Sulfate (0.03*) and Iron (0.03*), respectively.

Exchange H^{+} have negative correlation with Organic matter (0.049*), Total nitrogen (0.017*), Sulfate (0.03*) and Iron (0.03*), respectively.

Sulfate have positive correlation with Soluble salts (0.02*), Organic matter (0.002**) and Iron (0.0001**), and have negative correlation with pH (0.043*), Exchangeable Al^{3+} (0.03*) and Exchange H^{+} (0.03*), respectively.

Iron have positive correlation with Soluble salts (0.02*), Organic matter (0.002**) and Sulfate (0.0001**), and have negative correlation with pH (0.04*), Exchangeable Al^{3+} (0.03*) and Exchanged H^{+} (0.03*), respectively.

4.7.3 Correlation analysis of soil sediment in third shrimp pond is shown in Appendix B, Table B-3 as:

pH and Exchangeable Al^{3+} have positive correlation with Exchangeable Al^{3+} (0.0001**) in highly significant effect ($P<0.01$).

Sulfate has positive correlation with Iron (0.04*) in significant level ($P<0.05$).

pH has positive correlated with Exchangeable Al^{3+} (value 0.0001) in highly significant level ($P<0.01$).

4.7.4 Correlation analysis of soil sediment in fourth shrimp pond is shown in Appendix B, Table B-4 as:

pH has positive correlation with Total nitrogen (0.04*).

Soluble salts have positive correlation with Cation exchange capacity (0.02*).

Organic matter have positive correlation with Sulfate(0.03*) and Iron (0.03*), respectively.

Total nitrogen have positive correlation with pH (0.04*) and Exchangeable Al^{3+}(0.045*), respectively.

Cation exchange capacity has positive correlation with Soluble salts (0.02*).

Exchangeable Al^{3+} has positive correlation with Total nitrogen (0.045*).

Sulfate have positive correlation with Organic matter (0.03*) and Iron (0.0001**), respectively.

Iron have positive correlation with Organic matter (0.03*) and Sulfate (0.0001**), respectively.

Iron has highly significant correlation with sulfate ($P < 0.01$), value 0.0001.

4.8 Pearson Correlation Coefficient in water quality.

4.8.1 Correlation analysis of water quality in first shrimp pond is shown in Appendix B, Table B-5 as:

Soluble salts have negative correlation with Suspended solids (0.04*) and Sulfate (0.03*), respectively.

Total solids have positive correlation with Total dissolved solids (0.0005**) Chloride (0.03*), Total nitrogen (0.02*) and Ammonia (0.04*), respectively.

Suspended solids have positive correlation with Soluble salts (0.04*).

Total dissolved solids have positive correlation with Total solids (0.0005**) Chloride (0.03*), Total nitrogen (0.02*) and Ammonia (0.04*), respectively.

Chloride have positive correlation with Total solids (0.03*), Total dissolved solids (0.03*), Organic nitrogen (0.006**) and Ammonia (0.02*), respectively.

Alkalinity has negative correlation with Sulfate (0.008**).

Total nitrogen have positive correlation with Total solids (0.02*) and Total dissolved solids (0.02*), respectively.

Organic nitrogen have positive correlation with Chloride (0.006**), Ammonia (0.04*) and Total phosphorus (0.049*), respectively.

Ammonia have positive correlation with Total solids (0.04*) Total dissolved solids (0.04*), Chloride (0.02*) and Organic nitrogen(0.04*), respectively.

Sulfate has positive correlation with Soluble salts (0.03*), and has negative correlation with Alkalinity (0.008**).

Total phosphorus has positive correlation with Organic nitrogen (0.049*) in significant level ($P<0.05$).

4.8.2 Correlation analysis of water quality in second shrimp pond is shown in Appendix B, Table B-6 as:

Temperature has positive correlation with Dissolved Oxygen (0.009**).

Soluble salts have positive correlation with Total solids (0.001**), Total dissolved solids (0.0003**), Chemical Oxygen Demand (0.007**), Total nitrogen (0.01*) and Sulfate (0.005**), respectively, and has negative correlation with Chloride (0.002*).

Total solids have positive correlation with Soluble salts (0.001**), Total dissolved solids (0.0001**), Chloride (0.0001**), Chemical Oxygen Demand (0.02*) and Sulfate (0.012*), respectively.

Suspended solids has positive correlation with Ammonia (0.02*).

Total dissolved solids have positive correlation with Soluble salts (0.0003**), Total solids (0.0001**), Chloride (0.0001**), Chemical Oxygen Demand (0.02*) and Sulfate (0.0001**), respectively.

Chloride have positive correlation with Soluble salts (0.002**), Total solids (0.0001**), Total dissolved solids (0.0001**), Chemical Oxygen Demand (0.008**), and Sulfate (0.009**), respectively.

Alkalinity has positive correlation with Total nitrogen (0.04*).

Chemical Oxygen Demand have positive correlation with Soluble salts (0.007**), Total solids (0.02*), Total dissolved solids (0.02*), Chloride (0.008**), Total nitrogen* (0.014*) and Sulfate (0.049*), respectively.

Total nitrogen have positive correlation with Soluble salts (0.01*), Alkalinity (0.04*), Chemical Oxygen Demand (0.014*), and Sulfate(0.04*), respectively.

Ammonia have positive correlation with Suspended solids (0.02*), and Iron (0.02*), respectively.

Sulfate have positive correlation with Soluble salts (0.0005**), Total solids (0.012*), Total dissolved solids (0.014*), Chloride (0.009*), Chemical Oxygen Demand (0.049*) and Total nitrogen (0.04*), respectively.

Iron has positive correlation with Ammonia (0.02*) in significant level ($P < 0.05$).

4.8.3 Correlation analysis of water quality in third shrimp pond is shown in Appendix B, Table B-7 as:

Soluble salts have positive correlation with Chloride (0.003*) and Sulfate (0.007**), respectively.

Total solids has positive correlation with Total dissolved solids (0.003**).

Suspended solids have positive correlation with Chloride (0.049*) and Sulfate (0.045*), respectively.

Chloride have positive correlation with Soluble salts (0.003**), Suspended solids (0.049*) and Sulfate (0.004**), respectively.

Chemical Oxygen Demand has negative correlation with Total phosphorus (0.03*).

Sulfate have positive correlation with Soluble salts (0.007**), Suspended solids (0.045*) and Chloride (0.004**), respectively.

4.8.4 Correlation analysis of water quality in fourth shrimp pond is shown in Appendix B, Table B-8 as:

Temperature have positive correlation with Suspended solids (0.04*), and have negative correlation with Sulfate (0.03*).

pH has positive correlation with Chemical Oxygen Demand (0.006**).

Soluble salts have positive correlation with Chloride (0.0001**), Chemical Oxygen Demand (0.011*), Total nitrogen (0.03*) and Organic nitrogen (0.03*), and have negative correlation with Alkalinity (0.003**).

Total solids have positive correlation with Total dissolved solids (0.0001**), Chloride (0.02*) and Total nitrogen (0.006**), respectively.

Total dissolved solids have positive correlation with Total solids (0.0001**), Chloride (0.02*) and Total nitrogen (0.006**), respectively.

Chloride have positive correlation with Soluble salts (0.0001**), Total solids (0.02*), Total dissolved solids (0.02*), Chemical Oxygen Demand (0.011*), Total nitrogen (0.016*) and Organic nitrogen (0.03*), respectively, and has negative correlation with Alkalinity (0.011*).

Alkalinity have positive correlation with Soluble salts (0.003**) and Chloride (0.011*), respectively.

Chemical Oxygen Demand have positive correlation with Soluble salts (0.011*), Chloride (0.011*), Total nitrogen (0.02*) and Organic nitrogen (0.01*), respectively, and has negative correlation with pH (0.006**).

Total nitrogen have positive correlation with Soluble salts (0.03*), Total solids (0.006**), Total dissolved solids (0.006**), Chloride (0.016*), Chemical Oxygen Demand (0.02*), Organic nitrogen (0.02*) and Ammonia (0.02*), respectively.

Organic nitrogen have positive correlation with Soluble salts (0.03*), Chloride (0.03*), Chemical Oxygen Demand (0.01*) and Total nitrogen (0.02*), respectively.

Ammonia has positive correlation with Total nitrogen (0.02*).

Sulfate has negative correlation with Temperature (0.03*).

Total phosphorus has positive correlation with Iron (0.03

4.9 Pearson Correlation Coefficient between length and weight of shrimp in each pond (Appendix B, Table B-9 and Figure 57) are shown the trend of regression in each shrimp pond as:

4.9.1 Correlation analysis of the first shrimp pond, Length and weight have positive correlation. These have significant values ($p<0.05$) but shrimp grow rapid is in first pond and died in 30 days.

4.9.2 Correlation analysis of growth rate of second shrimp pond, Length and Weight have positive correlation. They have highly significant value ($p<0.01$). The correlation of length in second shrimp pond, found that when the weight was increased, the length will increase also. Both rates are related together. It is specification index, if we measure and record length and weight rate of shrimp during culture. The calculated value will be linear correlation and linear regression.

If the correlation is positive and have linear regression line, the shrimp growth depend on the environmental, effects, such as soil sediment and water quality in this study have encouraging. The environmental factors in this pond are good, the shrimp can growth to be a marketing size.

4.9.3 Correlation analysis of growth rate of shrimp in third pond, Length and weight have not correlation together. They have no significant value ($p<0.05$). It is specification index that this culture has problems in environmental management and they could be solved the soil quality and water quality for successful. The growth rate of shrimp will grow rapidly in the first week until they died in fourth week show in figure 57 and it has similar pattern as the first ponds.

4.9.4 Correlation analysis of growth rate of shrimp in fourth pond, Length and Weight have positive correlation. They have significant value ($p<0.05$).

4.10 Pearson Correlation Coefficient of growth and quality in shrimp pond.

4.10.1 Correlation analysis of growth and quality in first shrimp pond is shown in Appendix B, Table B-10.1 and B-10.2 as:

4.10.1.1 Correlation of Length and quality in first shrimp pond, Length have positive correlation with Dissolved Oxygen (0.013*).

4.10.1.2 Correlation of Weight and quality in first shrimp pond, Weight have not significant with any quality of water and soil sediment in this pond, at 95 percent confident but has trend of positive correlation with Dissolved Oxygen (R^2=0.94, 0.06^{NS}) and negative correlation with Total nitrogen (R^2=0.94, 0.06^{NS}).

4.10.2 Correlation analysis of growth and quality in second shrimp pond is shown in Appendix B, Table B-11.1 and B-11.2 as:

4.10.2.1 Correlation of Length and quality in second shrimp pond. Length have positive correlation with pH (0.0001**) in soil, and have negative correlation with Soluble salts (0.003**), Total solids (0.0008**), Total dissolved solids (0.0009**), Chloride (0.004**), Alkalinity (0.02*), and Sulfate (0.014*) in water, respectively.

4.10.2.2 Correlation of Weight and quality in second shrimp pond, Weight have positive correlation with pH (0.0002**), Soluble salts (0.049*) in soil and Soluble salts (0.006**), Total solids (0.003**), Total dissolved solids (0.003**), Chloride (0.012*), Alkalinity (0.03*), and Sulfate (0.02*) in water, respectively.

4.10.3 Correlation analysis of growth and quality in third shrimp pond is shown in Appendix B, Table 12-1 and 12-2 as:

4.10.3.1 Correlation of Length and quality in third shrimp pond, Length has positive correlation with Organic matter (0.001**) in soil.

4.10.3.2 Correlation of Weight and quality in third shrimp pond, Weight have not significant effect with any quality of water and soil sediment in this pond, at 95 percent confident but has trend of positive correlation with Organic matter R^2= 0.995, 0.06^{NS}) and negative correlation with Total nitrogen (R^2=-0.99, 0.08^{NS}) in soil.

4.10.4 Correlation analysis of growth and quality in fourth shrimp pond is shown in Appendix B, Table B-13.1 and B-13.2 as:

4.10.4.1 Correlation of Length and quality in fourth shrimp pond, Length have positive correlation with Chloride (0.006**) and Alkalinity (0.012*) in water, and have negative correlation with Soluble salts (0.017*) in soil, Soluble salts (0.005**) and Chemical Oxygen Demand (0.015*) in water, respectively.

4.10.4.2 Correlation of Weight and quality in fourth shrimp pond, Weight have not significant effect with any quality of water and soil sediment in this pond, at 95 percent confident but has trend of positive correlation with Total phosphorus (R^2= 0.70, 0.08^{NS}) in soil and Alkalinity (R^2=0.70, 0.08^{NS}) in water, and have negative correlation with Soluble salts (R^2=-0.70, 0.08^{NS}) and Chloride (R^2=-0.72, 0.07^{NS}) in water, respectively.

Pearson correlation of basic value that almost concerns with quality of soil, water growth rate of shrimp, found that they have correlation of value in positive and negative as show in Appendix B, Table B-10.1 – B-13.2 and after select the R value (>0.5) for the calculation of multiple regression by Forward selection procedure (Table C1- C16), could be divided into four parts as:

- The multiple linear regression between soil sediment quality in shrimp pond.
- The multiple linear regression between water quality in shrimp pond.
- The multiple linear regression between length with soil sediment and water quality in shrimp pond.
- The multiple linear regression between weight with soil sediment and water quality in shrimp pond.

4.11 Regression of soil quality in shrimp pond.

4.11.1 Regression of soil quality in first shrimp pond is shown in Appendix A, Table A-16. The equation of soil sediment could be described as:

Significant(P<0.05) of regression line has 1 equation:

$$OM = 8.91+22.43H^{+}+0.004Fe$$

Highly significant(P<0.01) of regression line have equations:

$$TP = 10.22-0.004CEC-501.13Al^{3+}$$

$$Fe = 0.07+0.50SO_4^{2-}$$

4.11.2 Regression of soil quality in second shrimp pond is shown in Appendix A, Table A-17. The equation of soil sediment could be described as:

Highly significant (P<0.01) of regression line have 5 equations:

$$pH = 7.34-0.23EC$$
$$EC = 8.48-1.68pH+0.46OM$$
$$OM = 10.70+0.94EC-24.72H^{+}$$
$$SO_4^{2-} = 1.13-9.15H^{+}+1.98Fe$$
$$Fe = -0.57+4.62H^{+}+0.51SO_4^{2-}$$

4.11.3 Regression of soil quality in third shrimp pond is shown in Appendix A, Table A-18. The equation of soil sediment could be described as:

Significant (P<0.05) regression line has equations :

$$Fe = -6.29+0.52SO_4^{2-}$$

Other have R^2 = 1.00 has 1 equation :

$$pH = -14.31+1100Al^{3+}$$

4.11.4 Regression of soil quality in fourth shrimp pond, is shown in Appendix A, Table A-19. The equation of soil sediment could be described as:

Significant (P<0.05) of regression line have 4 equations :

$$OM = 8.88+0.005SO_4^{2-}$$
$$TN = 25.39+1.44pH+839.40Al^{3+}$$
$$CEC = 23.93+9.88EC$$
$$TP = -0.33-0.16EC+0.02SO_4^{2-}$$

Highly significant of regression line have 2 equations :

$$SO_4^{2-} = -0.05+0.40EC+1.98Fe$$
$$Fe = 0.03+0.20EC+0.51SO_4^{2-}$$

4.12 Regression of water quality in shrimp pond.

4.12.1 Regression of water quality in first shrimp pond is shown in Appendix A, Table A-20. The equation of water quality could be described as:

Significant of regression line have 5 equations :

$$EC = 17.71-0.22TN-0.01SO_4^{2-}$$
$$SS = 0.18-0.01EC$$
$$COD = -131.92+0.33SO_4^{2-}+119.37Fe$$
$$DO = 1.72+2.17Cl^{-}-2.70NH_3$$
$$TP = -2.42+2.06ORN$$

Highly significant of regression line have 7 equations :

$$TS = -0.11+0.97TDS+0.0005SO_4^{2-}$$
$$TDS = 0.12+1.03TS-0.0005SO_4^{2-}$$
$$Cl^- = -1.36+0.15TN+3.43ORN$$
$$ALK = 115.60+5.83ORN-0.09SO_4^{2-}$$
$$ORN = 0.40+0.29Cl^- -0.04TN$$
$$NH_3 = 0.63+0.80Cl^- -0.37DO$$
$$SO_4^{2-} = 1512.97-12.89ALK$$

4.12.2 Regression of water quality in second shrimp pond is shown in Appendix A, Table A-21. The equation of water quality have thirteen regression lines, as show below:

Significant of regression line have 2 equations :

$$SS = 0.009+0.10NH_3$$
$$NH_3 = -1.22+0.02ALK+0.25Fe$$

Highly significant of regression line have 10 equations :

$$TEM = 24.24+0.85DO$$
$$EC = 4.85+2.12TS-1.33Cl^- -0.09ALK+2.34TN+0.003SO_4^{2-}$$
$$TS = -0.37-0.02EC+1.01TDS+0.04Cl^- +0.004ALK +0.0008COD +0.0002SO_4^{2-}$$
$$TDS = -2.01+0.46EC+0.68Cl^- +0.04ALK-1.08TN-0.001SO_4^{2-}$$
$$Cl^- = -0.56+0.57TS+0.004COD$$
$$COD = 51+18.42EC$$
$$DO = -15.56+0.76TEM$$
$$TN = -1.91+0.25EC-0.40TDS+0.03ALK+0.003COD$$
$$SO_4^{2-} = 193.58+58.95EC$$
$$Fe = 0.92-0.34TS+2.14NH_3$$

4.12.3 Regression of water quality in third shrimp pond is shown in Appendix A, Table A-22. The equation of water quality could be described as:

Significant of regression line have 3 equations :

$$SS = -0.13+0.0003\ SO_4^{2-}$$
$$COD = 974.14-1257.44TP$$
$$TP = 0.77-0.0008COD$$

Highly significant of regression line have 6 equations :

$$EC = 2.20+1.92Cl^-$$
$$TS = 0.02+1.01TDS$$
$$TDS = -0.02+0.99TS$$

$Cl^- = -1.15+0.52EC$

$SO_4^{2-} = 458.19+55.02Cl^-$

4.12.4 Regression of water quality in fourth shrimp pond is shown in Appendix A, Table A-23. The equation of water quality could be described as:

Significant of regression line have 8 equations :

$TEM = 32.76-33.14SS-0.001SO_4^{2-}$

$SS = 0.37-0.01TEM$

$COD = 525.13-47.80pH+7.26EC$

$ORN = 0.46+0.05EC$

$NH_3 = -0.07+0.49TN$

$SO_4^{2-} = 11501.40-349.29TEM$

$TP = -2.68+0.38DO+0.80Fe$

$Fe = 0.58+0.67TP$

Highly significant of regression line have 7 equations :

$pH = 9.66-0.01COD$

$EC = 3.13+2.27Cl^- -0.04ALK+2.44ORN-0.94NH_3$

$TS = 0.05+0.99TDS-0.03ORN+0.03NH_3$

$TDS = -0.05+1.01TS+0.03ORN-0.03NH_3$

$Cl^- = -0.74+0.32EC+8.94TS-8.78TDS$

$ALK = 84.09-4.13EC+7.43TN$

$TN = -2.60+0.32TS+5.57SS+0.02ALK+2.29ORN$

4.13 Regression of growth in shrimp pond. (Table A-24)

4.13.1 Regression of growth rate of shrimp in first pond from correlation of length and weight, and when select the value of R square for calculation the linear regression equation has significant value ($p<0.05$) such as:

Model Length = 1.34+1.27Weight ; $R^2 = 0.965$

Weight = -0.96+0.76Length

Comparison between this study and the trend line from graph (Figure 57, could give the suitable equation as:

Model Length = $0.991x^{1.3248}$; $R^2 = 0.997$

Weight = $0.0522e^{1.1342x}$; $R^2 = 0.985$ (Exponential)

4.13.2 Regression of growth rate of shrimp in second pond from the correlation of length and weight, and when select the high value of R square for calculation the linear regression equation and compare with equation from trend line of graph in Figure 57, found that they have same Model in linear equation. The length and weight have R square = 0.996 and 0.979, respectively. Both correlation of the weight was increased when the length was increased. They have highly significant statistically value ($p<0.01$).

Model Length = 1.43+0.94Weight ; $R^2 = 0.984$
Weight = -1.40+1.05Length

4.13.3 Regression of growth rate in third shrimp pond from the correlation of length and weight, and when select the high value of R square of calculation the linear regression equation, found that the equation is not linear. It has no significant value ($p<0.05$). Similar the equation from trend line of graph in figure 57, found that the model of length and weight are exponential equation $y = 0.315 e^{1.0397x}$, $0.082e^{2.2499x}$, have R square = 0.964, 0.965, respectively. The shrimp was grow rapidly in the first week until they died in twenty three days.

Model Length = 1.29+0.75Weight ; $R^2 = 0.991$
Weight = -1.68+1.33Length

4.13.4 Regression of growth rate of shrimps in forth pond from the correlation of length and weight, and when select the high value of R square for calculation the linear regression equation and compare equation from trend line of group in Figure 57, found that they have the same model in linear equation and similar in the second pond. The length and weight have R square = 0.996, and 0.979, respectively. Both correlation of growth rate in this shrimp pond, found that when the weight was increased, the length was increased also. They have significant statistically value ($p<0.05$)

Model Length = 3.41+0.95Weight ; $R^2 = 0.762$
Weight = -1.69+0.80Length

4.14 Regression of growth, soil sediment and water quality in shrimp pond. (Table A-25)

4.14.1 The correlation between growth rate of shrimp with soil sediment and water quality in first pond, found that :

The length in this model is base on temperature and dissolve oxygen in water quality.

Model Length* = -21.24+0.24Temp+2.22DO
Weight^{NS} = 22.32+0.39Temp+1.54DO

4.14.2 The correlation between growth rate of shrimp with soil sediment and water quality in second pond, found that:

The length and weight in this model depend on many quality but important pH, EC, organic matter and sulfate in soil and water.

Model $Length^{**} = -162.97 - 21.93PH_S + 1.71OM_S - 0.18pH_W - 0.09EC + 0.39Cl^{-} + 0.0002SO_4^{2-} + 0.20TP$.

$Weight^{**} = -201.04 + 27.24PH_S + 0.08EC_S + 1.29OM_S - 0.01SO_4^{2-}{}_S + 4.27SS + 0.81Cl^{-} - 1.02ORN$

4.14.3 The correlation between growth rate of shrimp with soil sediment and water quality in third pond, found that:

The length and weight depend on organic matter soil sedimentation.

Model $Length^{**} = -89.11 + 8.23OM_S$

$Weight^{NS} = -119.76 + 10.91OM_S$

4.14.4 The correlation between growth rate of shrimp with soil sediment and water quality in fourth pond, found that:

The length and weight depend on many quality but same importance are organic matter, soluble salts and suspended solids.

Model $Length^{**} = 8.48 + 0.19OM_S - 0.82EC_W - 68.0SS + 0.07ALK - 0.002SO_4^{2-}$

$Weight^{NS} = -53.12 - 3.67EC_S + 6.24OM_S - 53.61SS - 2.72Cl^{-} + 2.40TN$

Remark : ** = Highly significant

* = Significant

NS = No significant

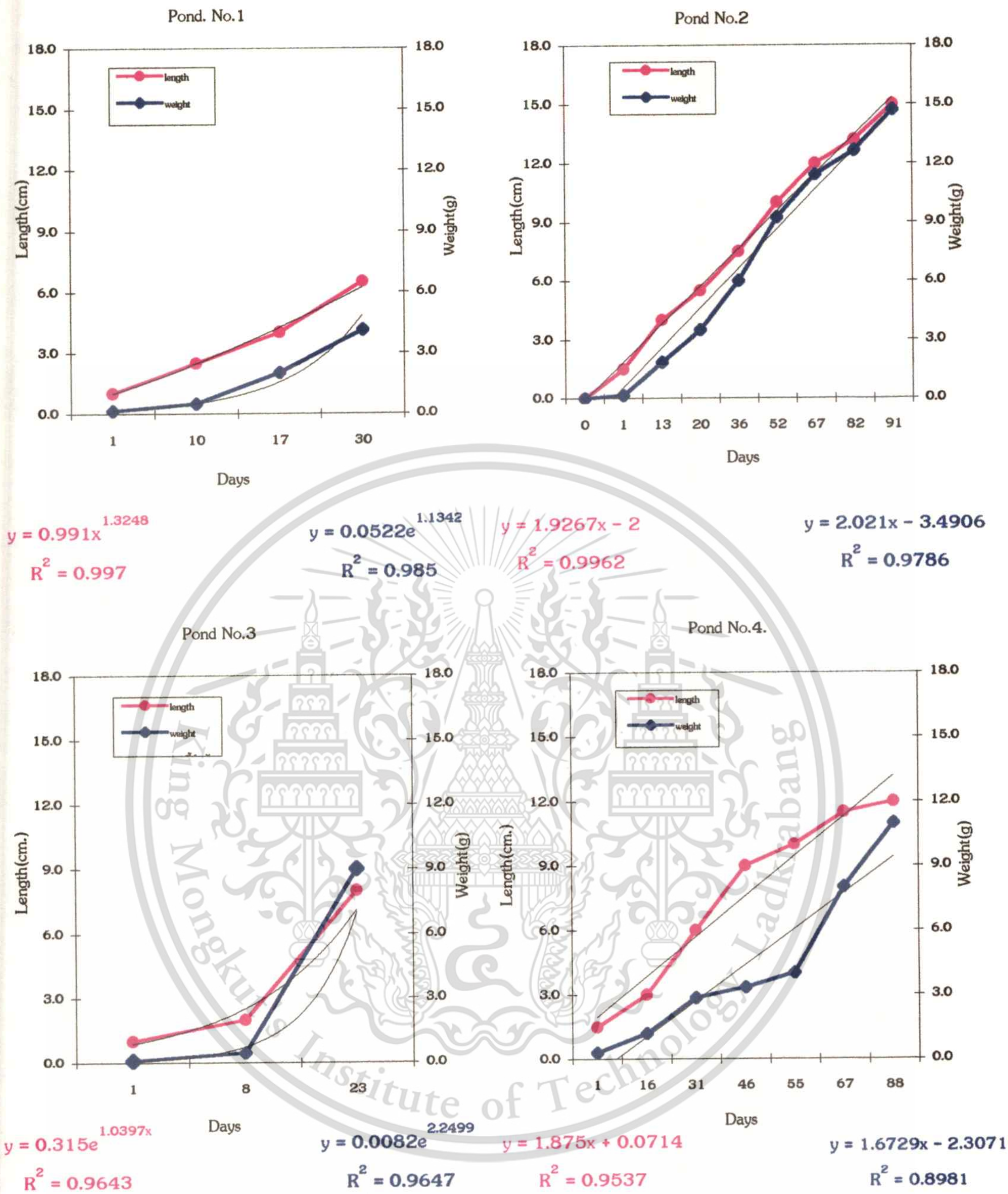


Figure 57 Growth rate and trend line during culture period in each pond.

4.15 Production of shrimp. (shown in Appendix Table D-1)

The production performance in shrimp pond no. 2 is 2,400 kilograms in 90-105 days, with the survival rate of 54 % and FCR of 1.33.

In pond no. 4, the growth performance of shrimp is 3,000 kilograms in 110-120 days, with the survival rate of 65 % and FCR of 1.30. The growth performance of shrimp in pond no. 4, had the highest feed conversion. (used feed 1.3 kg convert to weight of shrimp 1 kg.) and had the least mortality and have survival rate 65%.

In pond no. 1 and pond no. 3 shrimp was died during culture period. They have no production performance of shrimp. In pond no. 1 and 3, the dynamic changes of physical and chemical of soil sediment and low saline water quality, is shown in Appendix Tables A-1 - A-8. The trend of shrimp died in pond no. 1, may be correlated with some parameters of water and soil sediment quality such as: Organic carbon and organic nitrogen, aluminum, sulfate and iron in soil sediment. The acid condition, average pH is 6.35 in bottom soil, was the toxic of metal ions such as iron and aluminum. The condition is anaerobic, then the decomposition of organic matter, feed residues, and used sulfate is a source of oxygen for bacteria used decomposition, and give toxic substance such as H_2S, CH_4, CO_2, (shown in Figure 2.2) in marine condition (Peter, 1993).

In pond no. 3, the trend of shrimp died in pond no. 3, may be correlated with some parameter of water and soil sediment quality. The organic mater is accumulated in soil sediment and high iron and have basic condition in water, pH is 8.7, when the shrimp is knocked and have high oxygen. Jensen and Groman (1993) revealed that the high of iron in basic condition and oxygen could make the iron is precipitated to Ferric oxide and Ferric hydroxide suspended in water, and make the problem to gill of shrimp. The oxygen can not also exchange, then it disturb respiration process and make disease from bacteria and the environment in water and soil, could be accumulate of organic matter and toxic substance for shrimp culture.

CHAPTER 5
CONCLUSION

The results of changing physical and chemical quality of water and soil sediment in four shrimp ponds at Ampure Bang Nam Preaw, Chacherngsao province, are:

6.1 The shrimp in the first pond and third pond are dead during culture period, and found that :

- The quality of soil sediment and water in first pond, pH is acid = 6.35, Exchange aluminum = 0.0198 mg/kg, Organic matter = 10.90%, Total nitrogen = 1.51%, Sulfate = 390.82 mg/kg and Iron = 197.23 mg/kg in soil sediment. The water pH = 7.82, Alkalinity value quite low = 55.27 mg/l and high organic, for example as Chemical Oxygen Demand was high value = 269.75 mg/l, Organic nitrogen = 1.42 mg/l and have Ammonia = 0.87 mg/l, Sulfate = 800.85 mg/l, Iron 1.14 mg/l.

- The quality of soil sediment and water in third pond, pH = 7.32, Organic matter = 11.27%, Total nitrogen = 1.59%, Total Phosphorus = 0.06 mg/kg in soil sediment. The water pH is Alkaline = 8.07, Temperature = 31.37 °C, high value of Chemical Oxygen Demand = 236.44 mg/l, Dissolved Oxygen = 8.57 mg/l, Organic nitrogen = 0.91 mg/l and high value of sulfate = 674.07 mg/l and Iron = 1.45 mg/l.

6.2 The shrimp in the second pond and fourth pond, respectively, the growing rate is good.

- The quality of soil sediment has correlated to many factor, neutral pH = 7.02 and 7.10, Organic matter = 10.28 and 10.35%, Total-nitrogen = 1.36 and 1.34%, Sulfate = 272.47 and 273.89 mg/kg, Iron = 137.48 and 138.16 mg/l, respectively.

- The quality of water has neutral pH =7.85 and 7.50, Alkalinity =94.26 and 68.81 mg/l, Organic matter such as Chemical Oxygen Demand = 144.74 and 207.62 mg/l, Organic nitrogen = 0.87 and 0.75 mg/l, Sulfate = 493.53 and 623.57 mg/l, Iron = 1.46 and 0.95 mg/l, respectively. The concentration of toxic substance such as Organic matter, Organic nitrogen, Chemical Oxygen Demand, and Iron was found less than the first and third pond.

6.3 The regression equation of growth rate between length and weight in four shrimp ponds, is shown the correlated regression line as below:

$$\text{Length} = 2.14+0.19\ \text{Weight}$$

Factor that has effect on increase the length is base on the weight of shrimp. It has 87.85 % confidence, and highly significant ($p<0.01$).

6.4 Study from regression equations of growth rate with soil sediment and water quality in four shrimp ponds, are correlated line as below:

Model pond 1

$$Length = -21.24+0.24Temp+2.22DO$$

Factors of water quality (temperature and dissolved oxygen in water) has resulted in increase the length and weight of shrimp in the first pond.

Model pond 2

$$Length = -162.97+21.93pH_s+1.71OM_s-0.18pH-0.09EC+0.39Cl^- +0.0002SO_4^{2-}+0.02TP.$$

Factors related to increase the length of shrimp are depended on pH, organic matter in soil and chloride, sulfate and total phosphorus in water.

$$Weight = -201.04+27.24pH_s+0.08EC_s+1.29OM_s-0.01SO_4{}^{2-}{}_s+4.27SS +0.81Cl^- -1.02ORN.$$

Factors related to increase the weight are depended on pH, soluble salt, organic matter in soil and suspended solids, chloride in water.

Model pond 3

$$Length = -89.11+8.23OM_s$$

Factor of soil quality (organic matter) has resulted to increase the length and weight of shrimp in the third pond.

Model pond 4

$$Length = 8.48+0.19OM_s-0.82EC-68.01SS+0.07ALK-0.002SO_4^{2-}$$

Factors related to increase the length of shrimp are depended on organic matter in soil and alkalinity in water.

$$Weight = -53.12-3.67EC_s+6.24OM_s-53.61SS-2.72Cl^- +2.40TN$$

Factors related to increase the weight of shrimp are depended on organic matter in soil and total nitrogen in water.

Remark : S = soil sediment quality

SUGGESTIONS

Suggestions for further study :

Further studies may be undertaken on the following aspects.

- Study LC_{50} of sulfate compounds and iron compounds when change the pH in low salinity.
- Impact assessment of heavy metals in soil sediment and water for shrimp production.
- Sampling the sample (soil sediment and water) should keep every days for study.
- Study utilization of organic nitrogen and organic matter in water and soil sediment on shrimp production, for more benefit and love environmental.

BIBLIOGRAPHY

AOAC. 1995. **Analytical Official method of Analysis Association.**

APHA, AWWA and WPCF. 1992. American Water Works Association and Water Pollution. Control Federation. **Standard method for the examination of water.** American Public Health Association.

APHA. 1980. **Standard method for the examination of water and waste water.** 15^{th} ed. New York : American Public Health Association.

APHA. 1989. **Standard methods for the examination of water and waste water.** 17^{th} ed. Washington D.C. : American Public Health Association.

Ashley, L.M. 1970. "Action of iron salts in solution on goldfish." **Progressive Fish Culturist.** 32 : 109.

Banabe, G. 1990. **Aquaculture vol. 1.** England : Ellis Horwood.

Banabe, G. 1994. **Aquaculture biology and ecology of culture speies.** England : Ellis Horwood.

Boyd, C.E. 1973. "Summer algal communities and primary productivity in fish ponds." **Hydrobiologia.** 41 : 357-390.

Boyd, C.E. 1979. **Water quality in warmwater fish ponds.** Agriculture experiment station. Auburn University. Auburn Alabama, 359 pp.

Boyd, C.E. 1982. **Water quality management for pond fish culture.** New York : Elsevier Scientific.

Boyd, C.E. 1989. **Water quality management and aeration in shrimp pond : Fisheries and Allied Agriculture Dept. Series No.2.** Auburn University. Auburn Alabama. 83pp.

Boyd, C.E. 1990. **Water Quality in Ponds for Aquacuture.** Agricultural Experiment Station. Auburn University. Auburn Alabama.

Boyd, C.E. 1995. **Bottom soils, Sediment, and Pond aquaculture.** New York : Chapman and Hall Publishers.

Boyd, C.E. *et. al.* 1978. "Predicting early morning dissolved oxygen concentrations in channel catfish pond." **Trans. Am Fish. Soc.** 107 : 484-492.

Boyd, C.E. and Fast, A.W. 1992. **Pond Monitoring and Mangement.** Marine Shrimp Culture. Elsevie Science Publishers.

Boyd, C.E. and Fast, A.W. 1992. "Larval quality."

Boyd, C.E. and Holleman, W.D. 1981. **Determination of nitrate in waters from fish ponds.** Agriculture Experiment Station. Auburn University. Auburn Alabama.

Boyd, C.E. and Tucker, C.S. 1979. "Emergency aeration of fish ponds." **Trans. Am Fish. Soc.** 108 : 299-306.

Burrows, R.E. 1964. **Effect of accumulated excretory product on hatchery reared salmonids.** U.S. Fish and Wildlife Service Research Report 66. Washington, D.C. U.S.A. : Fish and Wildlife Service.

Cairns, J.Jr. 1967. "Suspended solids standards for the protection of aquatic organisms." Purdue Univ. **Eng. Bull.** 129 : 16-27.

Cheng-ILIU. 1997. **Water management : Shrimp disease, prevention and treatment.** Chung-Hsing University Tai Chung, Taiwan, Republic of China.

C.P. SHRIMP NEWS. 1993. 1(1).

C.P. SHRIMP NEWS. 1994. "The importance of limiting for water quality control." 2(2) : 4.

C.P. SHRIMP NEWS. 1994. "Lack of tiger shrimp culture in low saline water in Thailand." 2(3) : 2.

Deangsakul, S. 1994. **Improvement of Sustainable shrimp culture.** Seminar conference, Chanthaburi. 25 - 26 June.

Department of Business Economics Ministry of Commerce, 1998.

Emerson, K.R. *et. al.* 1975. "Aqueous ammonia equilibrium calculation." **J. Fish. Res. Bd.** Canada 32 : 2379-2383.

Fast, A.W. and James, L. L. 1992. **Marine shrimp culture.** Principles and practices. London : Elsevier Science Publishers.

Franz, S. *et. al.* 1996. **Organic carbon by dry combustion. Methods in Soil Chemistry.** Germany : Springer–Verlag Publishers.

Fujimura, T. 1966. **Notes on the development of a practical mass culturing techniques of the gaint prawn *Macrobrachium rosenbergii.*** Indo-Pacific Fisheries Council, 12th Session. FAO Regional Office for Asia and the Far East, Bangkok, Thailand.

Grande, M. and Andersen, S. 1981. "Lethal levels of pH for Atlantic salmon." **Vatten.** 37(2) : 109-114.

Habil, T.F. 1993. **Water quality in shrimp ponds**. Paper presented at C.P. Shrimp Research Center. Samutsakhon. 25 pp.

Hem, J.D. 1970. **Study and Interpretation of the Chemical Characteristics of Natural Water.** U.S. Geological Survey Water-Supply Paper 1473, Washington , D.C. : U.S. Government Printing office.

Heath, A.G. 1995. **Water pollution and fish physiology.** Printed in The United States of American : CRC press.

Horneck, D. A. *et. al.* 1990. **Method of soil analysis.** used in the soil testing laboratory at Oregon State University.

Hutchinson, G.E. 1957. **A Treatise on Limnology, Vol. I. Geography, Physics, and Chemistry.** New York : John Wiley and Sons.

Jensen, M. and Groman, D. 1993. "The effect of high Concentrations of Iron on Impounded American Lobsters" : A case study in **Journal of Aquatic Animal Health** 5 : 155-156.

James, L.L. and Josefa Ma. R.P. 1992. **Penaeid Temperature and Salinity Response in Marine Shrim Culture :** Principles and Practices. Fast A.W and Lester L.J.(eds). Amsterdam : Elsevier Science Publishers.

Lawrence, A.L. *et. al.* 1994 . **Penaeid shrimp culture.** Crustacean and Mollusk aquaculture in the united states. New York : Van Nostrand Reinhold Publishers.

Lee, S.P. and Wickins, J. F. 1992. **Crustacean farming.** London : Blackwell scientific Publications.

Lloyd, R. 1961. "The toxicity of ammonia to rainbow trout." **Water & Waste Treat Journal.** 8 : 278-279.

Lock Wood, A.P.M. 1967. **Aspects of the physiology of crustacea.** Sanfancisco : W.H. Freeman.

Longdon, J.S. 1988. **Investigation of fish kills. Pages refresher course for velerinarians. Port Graduate committee in Veterinary Science.** Proceeding 106, Sydney, Australia : University of Sydney Press.

Khung thai Bank. 1999. Khung thai economic report. December, 59-60p.

Meade, J.W. 1989. **Aquaculture Management.** New York : Van Nostrand Reinhold Publishers.

Menasveta, P. 1996. "Mangrove destruction and shrimp culture systems." **Thai journal of aquatic science.** 2(2).

Menasveta, P. and Jarayabhand, P. 1995. "Environmental planning in the coastal for sustainable culture operation." **Thai journal of aquatic science.** 2(1).

Michael, B. 1982. **New, Gaint prawn farming.** New York : Elsevier Scientific Publishers.

Moore, J.W. and Ramamoothy, S. 1984. **Heavy metals in natural waters.** New York : Springer-Verlag.

Motoh, H. 1981. **Studies on the Fisheries Biology of the Giant Tiger Prawn, *Penaeus Monodon* in the Philippines.** Agriculture Department. SEAFDEC Technical Report No. 7, 128 pp.

Nulplub, B. 1987. ***Penaeid monodon* shrimp culture.** Bangkok : Thunkrasettakum.

Peter , O' Nell. 1993. **Environmental Chemistry.** 2nd ed. London, UN : Chapman and Hall Publishers.

Phengburanapim, V. no. year. **Map of Thailand :** 73 province. Bangkok, Thailand.

Piper, R. G. *et al.* 1982. **Fish hatchery management.** Washington, D. C. : U. S. Fish and Wildlife Service.

Poolpipatana, S. 1994. "SOILSOLN : A computer program for modeling of soil solution." **Journal of King Mongkut's Institute of Technology Lardkrabang.** 2(1) : 54-62.

Rajyalakshmi, T. and Chandra, D.M. 1987. "On culture of Peneaeus monodon Fabricius in saline and fresh water ponds in Andhra Pradesh, India." **Indian J. Anim. Sci.** 57 : 348-358.

Sas Institute. 1982. **User's Guide : Statistics.** Edition Cary, NC : SAS Institute Inc. 584 pp.

Sawyer, C.N. and McCarty, P.L. 1978. **Chemistry for Environment Engineering.** 3rd. Ed. New York : McGraw-Hill Publishers.

Schmidt-Nielsen, K. 1979. **Animal Physiology : Adaptation and Environment.** New York : Cambridge University Press.

Snoeyink, V.L. 1980. Water chemistry: Composition of several types of water. New York : Jon Wiley and Sons Publishers.

Smith, T.I.T. *et. al.* 1976. "Pond culture of the Malasian prawn, Macrobrachium rosenbergii (de man), in South Carolina, 1974-1975." **Proc. World Maricult. Soc.** 7 : 625-645.

Spotte, S.H. 1970. **Fish and invertebrate culture.** New York : John Wiley and Sons Publishers.

Standard methods of Analysis for soil, plant tissue, water and fertilizer. 1988. Republic of the Philippines Philippine council for Agriculture and Resources research. Farm resources and Systems Research Divition Los Banos, Laguna. 194 pp.

Steeman, N.E. 1975. **Marine photosynthesis.** Elsevier Oceanography Series, 13. Amsterdam : Elsevier Scientific Publishers.

Stemler, A. and Govindjee. 1973. "Bicarbonate ion as a critical factor in photosynthetic oxygen evolution." **Plant Physiol.** 53 : 119-123.

Stickney, R.R. 1994. **Principles of Aquaculture.** New York : John Wiley and Sons Publishers.

Stumm, W. and Morgan, J.J. 1970. **Aquatic chemistry.** Wiky- Interscience Publishers..

Surin, M. 1989. **Marine animals of Thailand.** Bangkok : Parepitaya Publishers.

Swingle, H.S. 1947. **Management of farm fish ponds.** Agriculture Experiment Station. Auburn University. Auburn Alabama.

Swingle, H.S. 1969. **Methods of Analysis for Water Organic Matter and Pond Bottom Soils Used in Fisheries Research.** Auburn University. Auburn Alabama.

Swingle, H.S. 1961. "Relationship of pH of pond waters to their suitability for fish culture." **Proc. Pacific Sci.** Congr. 9, 1957. 72-75.

Sverdrup, H.N. *et. al.* 1942. **The Oceans.** New York : Prentice-Hall Publishers.

Thrimsongruchamee, B. 1987. **Marine shrimp culture.** Bongkok : Augsornjarounthut.

Trussell, R.P. 1972. "The percent un-ionized ammonia in aqueous ammonia solutions at different pH levels and temperatures." **Journal Fish. Res. Bd Canada.** 29 : 1505-1507.

Tunvilai, *et. al* 1993. **Pollution loading of effluent form intensive tiger shrimp ponds.** Technical paper no.4/2536. National Institute of Coastal Agriculture and Department of Fisheries Ministry of Agriculture and Cooperatives. 16 pp.

Tunvilai, *et. al* 1993. **Variation of sediment quality and quantity in intensive tiger shrimp culture ponds.** Technical paper no.5/2536. National Institute of Coastal Agriculture and Department of Fisheries Ministry of Agriculture and Cooperatives. 20pp.

Van Breeman. 1982. "Genesis, morphology and classification of acid sufate weathering." Spec. Publ. **Soil Sci. Soc. Of Am.,** 10 : 95-108.

Wallen, I.E. 1951. "The direct effect of turbidity on fishes." **Bull. Okla. Agric.** Mech. Coll. 48 : 1-27.

Wheaton, F.W. 1977. **Aquaculture engineering.** New York : Wiley Interscience Publishers.

Witzel, R.G. 1975. **Limnology.** New York : Saunders College Publishers.

Wooster, W.S. *et. al.* 1969. Redefinition of salinity. **J. Mar. Res.** 27 : 358-360.

World shrimp farming. 1998. "Annual report, shrimp News International."

Yoo, K.H. and Boyd, C.E. 1994. **Hydrology and water supply for pond aquaculture.** Newyork : Chapman and Hall Publishers.

APPENDIX

A

SAMPLE STATISTICS

Table A-1 Data analysis of soil sediment quality in shrimp pond no.1.

Day	pH	EC (mS /cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
1	6.19	1.67	10.6	0.87	49.6904	0.0198	0.0496	0.0788	256.41	129.36
10	6.41	1.97	10.22	1.34	37.0480	0.0197	0.0296	0.1845	287.88	145.37
17	6.41	2.84	11.43	1.83	44.6340	0.0199	0.0595	0.0513	513.93	259.37
30	6.40	2.41	11.34	2.00	37.6340	0.0198	0.0595	0.1333	505.07	254.81
Mean	6.35	2.22	10.90	1.51	42.25	0.0198	0.05	0.11	390.82	197.23
SD	0.11	0.51	0.58	0.51	6.04	0.0001	0.01	0.06	137.69	69.46
Min	6.19	1.67	10.22	0.87	37.05	0.0197	0.03	0.05	256.41	129.36
Max	6.41	2.84	11.43	2.00	49.69	0.0199	0.06	0.18	513.93	259.37

Table A-2 Data analysis of soil sediment quality in shrimp pond no.2.

Day	pH	EC (mS /cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
0	6.63	2.10	10.36	0.56	33.2851	0.0196	0.0784	0.1303	372.81	188.10
1	6.70	1.90	10.82	0.87	35.6125	0.0196	0.0885	0.1908	306.11	154.74
13	6.66	3.82	12.81	1.77	34.5656	0.0195	0.0585	0.1210	391.33	197.43
20	7.02	0.76	9.053	1.29	33.8197	0.0198	0.0692	0.3575	165.63	83.39
36	7.10	0.73	9.269	1.36	26.9730	0.0200	0.0798	0.0695	196.88	99.35
52	6.97	1.81	12.32	2.54	42.7368	0.0196	0.0117	0.0605	535.57	270.26
67	7.30	0.59	9.277	1.39	48.7368	0.0198	0.0891	0.0968	189.99	95.86
82	7.38	0.55	9.117	1.53	50.7210	0.0197	0.0887	0.1425	176.27	88.97
91	7.43	0.32	9.496	0.97	24.5266	0.0198	0.0691	0.1090	117.65	59.24
Mean	7.02	1.40	10.28	1.36	36.78	0.0197	0.07	0.14	272.47	137.48
SD	0.31	1.13	1.43	0.57	8.99	0.0002	0.02	0.09	137.71	69.53
Min	6.63	0.32	9.05	0.56	24.53	0.0195	0.01	0.06	117.65	59.24
Max	7.43	3.82	12.81	2.54	50.72	0.0200	0.09	0.36	535.57	270.26

Table A-3 Data analysis of soil sediment quality in shrimp pond no.3.

Day	pH	EC (mS /cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
1	7.36	1.41	10.95	1.44	32.2133	0.0197	0.0986	0.0545	384.56	193.63
8	7.25	2.00	11.07	1.29	37.0426	0.0196	0.0788	0.0210	369.21	186.46
23	7.36	1.66	11.8	2.03	35.9837	0.0197	0.0118	0.0908	352.08	176.75
Mean	7.32	1.69	11.27	1.59	35.08	0.0197	0.06	0.06	368.62	185.61
SD	0.06	0.30	0.46	0.39	2.54	0.0001	0.05	0.03	16.25	8.47
Min	7.25	1.41	10.95	1.29	32.21	0.0196	0.01	0.02	352.08	176.75
Max	7.36	2.00	11.80	2.03	37.04	0.0197	0.10	0.09	384.56	193.63

Table A-4 Data analysis of soil sediment quality in shrimp pond no.4.

Day	pH	EC (mS /cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
1	7.21	2.10	10.72	1.26	48.8252	0.0195	0.0780	0.0755	361.81	182.35
16	7.03	1.53	10.65	1.15	33.3336	0.0195	0.0782	0.0240	264.03	133.08
31	7.25	0.70	10	1.75	29.1300	0.0199	0.0598	0.0270	239.23	120.76
46	7.20	0.59	9.779	1.68	32.5256	0.0198	0.0891	0.0363	221.21	111.60
55	6.99	0.78	10.17	1.15	31.3177	0.0196	0.0781	0.1423	262.74	132.60
67	7.02	0.57	10.35	1.08	32.7468	0.0195	0.0973	0.0453	225.21	113.66
88	6.99	0.84	10.76	1.30	29.8536	0.0199	0.0895	0.2755	342.98	173.09
Mean	7.10	1.02	10.35	1.34	33.96	0.0197	0.08	0.09	273.89	138.16
SD	0.12	0.58	0.38	0.27	6.73	0.0002	0.01	0.09	56.38	28.40
Min	6.99	0.57	9.78	1.08	29.13	0.0195	0.06	0.02	221.21	111.60
Max	7.25	2.10	10.76	1.75	48.83	0.0199	0.10	0.28	361.81	182.35

Table A-5 Data analysis of water quality in shrimp pond no.1.

Day	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
1	31.0	8.75	8.59	6.40	0.06	6.34	4.79	53.55	300.00	6.60	3.61	1.64	2.05	836.16	1.06	1.26
10	28.1	6.77	8.47	6.13	0.07	6.07	4.19	51.67	360.00	7.60	3.55	1.47	1.18	846.05	0.45	1.79
17	31.0	7.37	10.46	4.71	0.04	4.67	3.14	64.17	207.00	8.00	1.93	1.23	0.20	684.11	0.20	0.94
30	31.6	8.37	9.02	4.83	0.06	4.72	3.42	51.67	212.00	9.00	1.56	1.33	0.06	837.06	0.30	0.57
Mean	30.43	7.82	9.14	5.52	0.06	5.45	3.89	55.27	269.75	7.80	2.66	1.42	0.87	800.85	0.50	1.14
SD	1.58	0.91	0.91	0.87	0.01	0.88	0.75	6.00	73.79	0.99	1.07	0.18	0.93	77.95	0.38	0.52
Min	28.10	6.77	8.47	4.71	0.04	4.67	3.14	51.67	207.00	6.60	1.56	1.23	0.06	684.11	0.20	0.57
Max	31.60	8.75	10.46	6.40	0.07	6.34	4.79	64.17	360.00	9.00	3.61	1.64	2.05	846.05	1.06	1.79

Table A-6 Data analysis of water quality in shrimp pond no.2.

Day	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
0	30.0	8.69	10.32	7.11	0.05	7.06	5.21	105.83	300.00	6.60	2.04	0.98	1.07	868.99	0.50	0.67
1	31.5	7.65	13.13	5.83	0.05	5.77	3.13	106.67	295.33	7.90	3.16	0.94	0.51	844.25	0.90	0.25
13	31.6	8.49	6.45	3.32	0.03	3.29	2.03	95.00	77.33	8.70	1.45	0.95	0.63	788.03	0.53	1.00
20	30.0	7.44	3.96	3.51	0.03	3.48	1.15	100.00	48.00	8.00	0.68	0.95	0.47	334.59	0.78	0.72
36	31.5	7.29	2.85	1.42	0.05	1.37	0.81	90.00	120.00	7.50	1.56	0.88	0.06	179.85	0.28	0.67
52	30.5	7.23	2.12	1.14	0.22	0.92	0.57	110.83	121.33	7.80	1.87	0.71	1.72	501.03	0.68	4.27
67	29.0	7.05	2.99	1.40	0.11	1.30	0.84	79.17	140.00	6.00	1.12	0.60	0.73	541.51	0.24	0.88
82	31.0	8.31	2.14	1.35	0.02	1.33	0.50	85.83	80.67	8.50	1.23	1.29	0.97	211.33	0.49	3.28
91	32.0	8.47	1.83	1.05	0.00	1.05	0.46	75.00	120.00	8.70	0.50	0.54	0.29	172.20	0.86	1.41
Mean	30.79	7.85	5.09	2.90	0.06	2.84	1.63	94.26	144.74	7.74	1.51	0.87	0.72	493.53	0.58	1.46
SD	0.98	0.64	4.07	2.24	0.07	2.26	1.60	12.67	91.23	0.93	0.80	0.23	0.49	287.14	0.24	1.37
Min	29.00	7.05	1.83	1.05	0.00	0.92	0.46	75.00	48.00	6.00	0.50	0.54	0.06	172.20	0.24	0.25
Max	32.00	8.69	13.13	7.11	0.22	7.06	5.21	110.83	300.00	8.70	3.16	1.29	1.72	868.99	0.90	4.27

Table A-7 Data analysis of water quality in shrimp pond no.3.

Day	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
1	31.6	8.25	17.32	9.58	0.13	9.45	7.88	135.00	411.33	8.70	1.46	1.16	0.06	891.49	0.45	2.04
8	31.0	7.23	7.15	1.97	0.05	1.91	2.60	118.33	99.33	9.00	1.57	1.02	0.32	602.69	0.70	1.56
23	31.5	8.74	4.70	1.90	0.02	1.88	1.29	104.17	198.67	8.00	0.37	0.56	0.04	528.02	0.61	0.74
Mean	31.37	8.07	9.72	4.48	0.07	4.42	3.92	119.17	236.44	8.57	1.14	0.91	0.14	674.07	0.59	1.45
SD	0.32	0.77	6.69	4.41	0.06	4.36	3.49	15.43	159.39	0.51	0.66	0.31	0.16	191.96	0.13	0.66
Min	31.00	7.23	4.70	1.90	0.02	1.88	1.29	104.17	99.33	8.00	0.37	0.56	0.04	528.02	0.45	0.74
Max	31.60	8.74	17.32	9.58	0.13	9.45	7.88	135.00	411.33	9.00	1.57	1.16	0.32	891.49	0.70	2.04

Table A-8 Data analysis of water quality in shrimp pond no.4.

Day	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
1	32.0	6.49	13.25	7.04	0.01	7.03	4.75	53.33	318.00	6.00	3.20	1.15	1.42	561.76	0.32	0.77
16	31.0	6.88	9.50	1.12	0.02	1.10	2.66	50.00	252.00	6.60	0.75	0.91	0.02	892.83	0.75	1.04
31	29.0	7.21	3.77	1.67	0.05	1.62	1.18	75.00	226.67	5.90	0.84	0.63	0.63	1545.55	0.20	0.98
46	31.0	8.21	3.72	0.85	0.04	0.81	1.03	76.67	174.00	6.70	1.06	0.86	1.00	440.29	1.11	1.44
55	32.0	8.32	3.35	1.98	0.03	1.95	0.90	74.17	117.33	6.70	0.22	0.37	0.02	386.77	0.50	0.67
67	32.0	8.27	3.11	1.96	0.01	1.95	0.79	72.50	174.67	7.00	0.54	0.58	0.03	371.02	0.63	1.02
88	31.0	7.14	2.90	1.71	0.02	1.69	0.48	80.00	190.67	6.50	1.01	0.73	0.06	166.76	0.34	0.73
Mean	31.14	7.50	5.66	2.33	0.03	2.31	1.68	68.81	207.62	6.49	1.09	0.75	0.45	623.57	0.55	0.95
SD	1.07	0.75	4.07	2.12	0.02	2.12	1.52	11.98	64.77	0.40	0.98	0.25	0.57	463.41	0.31	0.26
Min	29.00	6.49	2.90	0.85	0.01	0.81	0.48	50.00	117.33	5.90	0.22	0.37	0.02	166.76	0.20	0.67
Max	32.00	8.32	13.25	7.04	0.05	7.03	4.75	80.00	318.00	7.00	3.20	1.15	1.42	1545.55	1.11	1.44

Tale A-9 Pond no.1. Data of shrimp growth during culture period.

Day	Length(cm.)	Weight(g)
1	1.00	0.15
10	2.50	0.50
17	4.00	2.02
30	6.50	4.13
Mean	3.50	1.70
SD	2.35	1.81
Min	1.00	0.15
Max	6.50	4.13

Table A-10 Pond no.2. Data of shrimp growth during culture period.

Day	Length(cm.)	Weight(g)
0	0.00	0.00
1	1.50	0.15
13	4.00	1.85
20	5.50	3.50
36	7.50	6.00
52	10.00	9.23
67	12.00	11.43
82	13.20	12.66
91	15.00	14.71
Mean	7.63	6.61
SD	5.29	5.60
Min	0.00	0.00
Max	15.00	14.71

Table A-11 Pond no.3. Data of shrimp growth during culture period.

Day	Length(cm.)	Weight(g)
1	1.00	0.10
8	2.00	0.45
23	8.00	9.00
Mean	3.67	3.18
SD	3.79	5.04
Min	1.00	0.10
Max	8.00	9.00

Table A-12 Pond no.4. Data of shrimp growth during culture period.

Day	Length(cm.)	Weight(g)
1	1.50	0.30
16	3.00	1.20
31	6.00	2.86
46	9.00	3.33
55	10.00	4.00
67	11.50	8.00
88	12.00	11.00
Mean	7.57	4.38
SD	4.15	3.81
Min	1.50	0.30
Max	12.00	11.00

Table A-13 Physical and Chemical of soil sediment quality.

Parameters	Pond No.1	Pond No.2	Pond No.3	Pond No.4	$\bar{X}$+SD
pH	6.35 ± 0.11	7.02 ± 0.31	7.32 ± 0.06	7.10 ± 0.12	6.95 ± 0.42
EC(mS/cm)	2.22 ± 0.51	1.40 ± 1.13	1.69 ± 0.30	1.02 ± 0.58	1.58 ± 0.51
OM(%)	10.90 ± 0.58	10.28 ± 1.43	11.27 ± 0.46	10.35 ± 0.38	10.70 ± 0.47
TN(%)	1.51 ± 0.51	1.36 ± 0.57	1.59 ± 0.39	1.34 ± 0.27	1.45 ± 0.12
CEC(meq./100g)	42.25 ± 6.04	36.78 ± 8.99	35.08 ± 2.54	33.96 ± 6.73	37.02 ± 3.68
Al^{3+}(meq./100g)	0.0198 ± 0.0001	0.0197 ± 0.0002	0.0197 ± 0.0001	0.0197 ± 0.0002	0.0197 ± 0.0001
H^{+}(meq./100g)	0.05 ± 0.01	0.07 ± 0.02	0.06 ± 0.05	0.08 ± 0.01	0.07 ± 0.01
TP(mg/kg)	0.11 ± 0.06	0.14 ± 0.09	0.06 ± 0.03	0.09 ± 0.09	0.10 ± 0.03
SO_4^{2-}(mg/kg)	390.82± 137.69	272.47± 137.71	368.62 ± 16.25	273.89 ± 56.38	326.45 ± 62.18
Fe(mg/kg)	197.23± 69.46	137.48 ± 69.53	185.61 ± 8.47	138.16 ± 28.40	164.62 ± 31.31

Table A-14 Physical and Chemical of water quality.

Parameters	Pond No.1	Pond No.2	Pond No.3	Pond No.4	$\bar{X}$+SD
TEM(°C)	30.43 ± 1.58	30.79 ± 0.98	31.37 ± 0.32	31.14 ± 1.07	30.93 ± 0.41
pH	7.82 ± 0.91	7.85 ± 0.64	8.07 ± 0.77	7.50 ± 0.75	7.81 ± 0.23
EC(mS/cm)	9.14 ± 0.91	5.09 ± 4.07	9.72 ± 6.69	5.66 ± 4.07	7.40 ± 2.37
TS(mg/l)	5.52 ± 0.87	2.90 ± 2.24	4.48 ± 4.41	2.33 ± 2.12	3.81 ± 1.46
SS(mg/l)	0.06 ± 0.01	0.06 ± 0.07	0.07 ± 0.06	0.03 ± 0.02	0.05 ± 0.02
TDS(mg/l)	5.45 ± 0.88	2.84 ± 2.26	4.42 ± 4.36	2.31 ± 2.12	3.75 ± 1.44
Cl^{-}(mg/l)	3.89 ± 0.75	1.63 ± 1.60	3.92 ± 3.49	1.68 ± 1.52	2.78 ± 1.30
ALK(mg/l)	55.27 ± 6.001	94.26 ± 12.67	119.17 ± 15.43	68.81 ± 11.98	84.38 ± 28.27
COD(mg/l)	269.75 ± 73.79	144.74 ± 91.23	236.44 ± 159.39	207.62 ± 64.77	214.64 ± 50.07
DO(mg/l)	7.80 ± 0.99	7.74 ± 0.93	8.57 ± 0.51	6.49 ± 0.40	7.65 ± 0.86
TN(mg/l)	2.66 ± 1.07	1.51 ± 0.80	1.14 ± 0.66	1.09 ± 0.98	1.60 ± 0.73
ORN(mg/l)	1.42 ± 0.18	0.87 ± 0.23	0.91 ± 0.31	0.75 ± 0.25	0.99 ± 0.30
NH_3(mg/l)	0.87 ± 0.93	0.72 ± 0.49	0.14 ± 0.16	0.45 ± 0.57	0.54± 0.32
SO_4^{2-}(mg/l)	800.85 ± 77.95	493.53 ± 287.14	674.07 ± 191.96	623.57 ± 463.41	648.01± 127.15
TP (mg/l)	0.50 ± 0.38	0.58 ± 0.24	0.59 ± 0.13	0.55 ± 0.31	0.56 ± 0.04
Fe(mg/l)	1.14 ± 0.52	1.46 ± 1.37	1.45 ± 0.66	0.95 ± 0.26	1.25 ± 0.25

Table A-15 Growth rate of shrimp.

Parameters	Pond No.1	Pond No.2	Pond No.3	Pond No.4	$\bar{X}$+SD
Length(cm)	3.50 ± 2.35	7.63 ± 5.29	3.67 ± 3.79	7.57 ± 4.15	5.59 ± 0.41
Weight(g)	1.70 ± 1.81	6.61 ± 5.60	3.18 ± 5.04	4.38 ± 3.81	3.97 ± 0.42

Table A-16 Regression of soil quality in shrimp pond no.1.

Parameters	Regression equation	R^2	Statistic
pH	pH=6.09+0.17TN	0.6704	0.1812^{NS}
EC(mS/cm)	No equation		
OM(%)	OM=8.91+22.43H^++0.004Fe	0.9976	0.0488*
TN(%)	No equation		
CEC(meq./100g)	CEC=259.34-33.12H^+-59.91TP	0.9565	0.2087^{NS}
Al^{3+}(meq./100g)	Al^{3+}=0.02-0.0013TP	0.8486	0.0788^{NS}
H^+(meq./100g)	No equation		
TP(mg/kg)	TP=10.22-0.004CEC-501.13Al^{3+}	0.9999	0.0058**
SO_4^{2-}(mg/kg)	SO_4^{2-}=-0.15+0.98Fe	0.9999	0.0001**
Fe(mg/kg)	Fe=0.07+0.50 SO_4^{2-}	0.9999	0.0001**

Table A-17 Regression of soil quality in shrimp pond No.2.

Parameters	Regression equation	R^2	Statistic
pH	pH=7.34-0.23EC	0.7085	0.0044**
EC(mS/cm)	EC=8.48-1.68pH+0.46OM	0.9026	0.0009**
OM(%)	OM=10.70+0.94EC-24.72H^+	0.9382	0.0002**
TN(%)	No equation		
CEC(meq./100g)	No equation		
Al^{3+}(meq./100g)	No equation		
H^+(meq./100g)	No equation		
TP(mg/kg)	No equation		
SO_4^{2-}(mg/kg)	SO_4^{2-}=1.13-9.15H^++1.98Fe	0.9999	0.0001**
Fe(mg/kg)	Fe=-0.57+4.62H^++0.51SO_4^{2-}	0.9999	0.0001**

Table A-18 Regression of soil quality in shrimp pond no.3.

Parameters	Regression equation	R^2	Statistic
pH	pH=-14.31+1100 Al^{3+}	1.00	
EC(mS/cm)	No equation		
OM(%)	OM=11.91-10.07H^+	0.9922	0.0564^{NS}
TN(%)	TN=0.99+10.68TP	0.9084	0.1958^{NS}
CEC(meq./100g)	No equation		
Al^{3+}(meq./100g)	Al^{3+}=0.02-0.0013TP	0.8486	0.0788^{NS}
H^+(meq./100g)	No equation		
TP(mg/kg)	TP=-0.08+0.09TN	0.9084	0.1958^{NS}
SO_4^{2-}(mg/kg)	SO_4^{2-}=-13.17+1.92Fe	0.9970	0.0350*
Fe(mg/kg)	Fe=-6.29+0.52 SO_4^{2-}	0.9970	0.0350*

Table A-19 Regression of soil quality in shrimp pond no.4.

Parameters	Regression equation	R^2	Statistic
pH	pH=6.74+0.30TN-0.46TP	0.7455	0.0645^{NS}
EC(mS/cm)	No equation		
OM(%)	$OM=8.88+0.005SO_4^{2-}$	0.6244	0.0345*
TN(%)	$TN=-25.39+1.44pH+839.40Al^{3+}$	0.9400	0.0038*
CEC(meq./100g)	CEC=23.93+9.88EC	0.7190	0.0159*
Al^{3+}(meq./100g)	No equation		
H^+(meq./100g)	No equation		
TP(mg/kg)	$TP=-0.33-0.16EC+0.02SO_4^{2-}$	0.8907	0.0120*
SO_4^{2-}(mg/kg)	$SO_4^{2-}=-0.05+0.40EC+1.98Fe$	0.9999	0.0001**
Fe(mg/kg)	$Fe=0.03+0.20EC+0.51SO_4^{2-}$	0.9999	0.0001**

Table A-20 Regression of water quality in shrimp pond no.1.

Parameters	Regression equation	R^2	Statistic
TEM(°C)	TEM=33.59-2.78Fe	0.83	0.0887^{NS}
pH	pH=-5.93+0.45TEM	0.61	0.2161^{NS}
EC(mS/cm)	$EC=17.71-0.22TN-0.01SO_4^{2-}$	0.9998	0.0155*
TS(mg/l)	$TS=-0.11+0.97TDS+0.0005\ SO_4^{2-}$	0.9999	0.0005**
SS(mg/l)	SS=0.18-0.01EC	0.9224	0.0396*
TDS(mg/l)	$TDS=0.12+1.03TS-0.0005\ SO_4^{2-}$	0.9999	0.0066**
Cl^-(mg/l)	$Cl^-=-1.36+0.15TN+3.43ORN$	0.9999	0.0067**
ALK(mg/l)	$ALK=115.60+5.83ORN-0.09\ SO_4^{2-}$	0.9999	0.0035**
COD(mg/l)	$COD=-131.92+0.33\ SO_4^{2-}+119.37Fe$	0.9984	0.0400*
DO(mg/l)	$DO=1.72+2.17Cl^--2.70NH_3$	0.9995	0.0222*
TN(mg/l)	TN=-2.65+1.79TDS-3.14ORN	0.9951	0.0697^{NS}
ORN(mg/l)	$ORN=0.40+0.29Cl^--0.04TN$	0.9999	0.0082**
NH_3(mg/l)	$NH_3=0.63+0.80Cl-0.37DO$	0.9999	0.0088**
SO_4^{2-}(mg/l)	$SO_4^{2-}=1512.97-12.89ALK$	0.9845	0.0078**
TP(mg/l)	TP=-2.42+2.06ORN	0.9033	0.0496*
Fe(mg/l)	Fe=-64+0.007COD	0.8867	0.0583^{NS}

Table A-21 Regression of water quality in shrimp pond no.2.

Parameters	Regression equation	R^2	Statistic
TEM(°C)	TEM=24.24+0.85DO	0.6398	0.0097**
pH	No equation		
EC(mS/cm)	$EC=4.85+2.12TS-1.33Cl^{-}-0.09ALK+2.34TN+0.003SO_4^{2-}$	0.9911	0.0028**
TS(mg/l)	$TS=-0.37-0.02EC+1.01TDS+0.04Cl+0.004ALK+0.0008COD+0.0002SO_4^{2-}$	0.9999	0.0001**
SS(mg/l)	$SS=-0.009+0.10NH_3$	0.5417	0.0238*
TDS(mg/l)	$TDS=-2.01+0.46EC+0.68Cl^{-}+0.04ALK-1.08TN-0.001SO_4^{2-}$	0.9942	0.0015**
Cl^{-}(mg/l)	$Cl^{-}=-0.56+0.57TS+0.004COD$	0.9363	0.0003**
ALK(mg/l)	$ALK=73.07+9.49TN+9.55NH_3$	0.5969	0.0655^{NS}
COD(mg/l)	COD=51.00+18.42EC	0.6765	0.0065**
DO(mg/l)	DO=-15.56+0.76TEM	0.6398	0.0097**
TN(mg/l)	TN=-1.91+0.25EC-0.40TDS+0.03ALK+0.003COD	0.9508	0.0070**
ORN(mg/l)	No equation		
NH_3(mg/l)	$NH_3=-1.22+0.02ALK+0.25Fe$	0.7411	0.0174*
SO_4^{2-}(mg/l)	$SO_4^{2-}=193.58+58.95EC$	0.6992	0.0050**
TP(mg/l)	No equation		
Fe(mg/l)	$Fe=0.92-0.34TS+2.14NH_3$	0.8689	0.0023**

Table A-22 Regression of water quality in shrimp pond no.3.

Parameters	Regression equation	R^2	Statistic
TEM(°C)	$TEM=31.65-2.01NH_3$	0.9523	0.1402^{NS}
pH	$pH=8.74-4.77NH_3$	0.9341	0.1653^{NS}
EC(mS/cm)	$EC=2.20+1.92Cl^{-}$	0.9999	0.0030**
TS(mg/l)	TS=0.02+1.01TDS	0.9999	0.0029**
SS(mg/l)	$SS=-0.13+0.0003SO_4^{2-}$	0.9949	0.0453*
TDS(mg/l)	TDS=-0.02+0.99TS	0.9999	0.0029**
Cl^{-}(mg/l)	$Cl^{-}=-1.15+0.52EC$	0.9999	0.0030**
ALK(mg/l)	ALK=85.86+23.02Fe	0.9618	0.1253^{NS}
COD(mg/l)	COD=974.14-1257.44TP	0.9978	0.0227*
DO(mg/l)	DO=7.71+0.76TN	0.9551	0.1360^{NS}
TN(mg/l)	TN=-9.69+1.26DO	0.9551	0.1360^{NS}
ORN(mg/l)	ORN=0.23+0.47Fe	0.9780	0.0948^{NS}
NH_3(mg/l)	$NH_3=15.01-0.47TEM$	0.9523	0.1402^{NS}
SO_4^{2-}(mg/l)	$SO_4^{2-}=458.19+55.02Cl^{-}$	0.9999	0.0044**
TP(mg/l)	TP=0.77-0.0008COD	0.9978	0.0296*
Fe(mg/l)	Fe=-0.44+2.07ORN	0.9780	0.0948^{NS}

Table A-23 Regression of water quality in shrimp pond no.4.

Parameters	Regression equation	R^2	Statistic
TEM(°C)	$TEM=32.76-33.14SS-0.001SO_4^{2-}$	0.7926	0.0430*
pH	pH=9.66-0.01COD	0.8032	0.0062**
EC(mS/cm)	$EC=3.13+2.27Cl^{-}-0.04ALK+2.44ORN-0.94NH_3$	0.9980	0.0040**
TS(mg/l)	$TS=0.05+0.99TDS-0.03ORN+0.03NH_3$	0.9999	0.0001**
SS(mg/l)	SS=0.37-0.01TEM	0.6096	0.0383*
TDS(mg/l)	$TDS=-0.05+1.01TS+0.03ORN-0.03NH_3$	0.9999	0.0001**
Cl^{-}(mg/l)	$Cl^{-}=-0.74+0.32EC+8.94TS-8.78TDS$	0.9964	0.0004**
ALK(mg/l)	ALK=84.09-4.13EC+7.43TN	0.98	0.0002**
COD(mg/l)	COD=525.13-47.80pH+7.26EC	0.8942	0.0112*
DO(mg/l)	$DO=4.43+0.31pH-0.0004SO_4^{2-}$	0.7009	0.0895^{NS}
TN(mg/l)	TN=2.60+0.32TS+5.57SS+0.02ALK+2.29ORN	0.9999	0.0003**
ORN(mg/l)	ORN=0.46+0.05EC	0.6616	0.0261*
NH_3(mg/l)	$NH_3=-0.07+0.49TN$	0.6812	0.0222*
SO_4^{2-}(mg/l)	$SO_4^{2-}=11501.40-349.29TEM$	0.6493	0.0287*
TP(mg/l)	TP=-2.68+0.38DO+0.80Fe	0.8509	0.0222*
Fe(mg/l)	Fe=0.58+0.67TP	0.6296	0.0332*

Table A-24 Regression of growth rate of shrimp in pond no.1-4.

Pond No.1	Parameters	Regression equation	R^2	Statistic
	Length(cm.)	Length =1.34+1.27Weight	0.9653	0.0175*
	Weight(g.)	Weight =-0.96+0.76Length	0.9653	0.0175*
Pond No.2	Length(cm.)	Length =1.43+0.94Weight	0.9837	0.0001**
	Weight(g.)	Weight =-1.40+1.05Length	0.9837	0.0001**
Pond No.3	Length(cm.)	Length =1.29+0.75Weight	0.9905	0.0622^{NS}
	Weight(g.)	Weight =-1.68+1.33Length	0.9905	0.0622^{NS}
Pond No.4	Length(cm.)	Length =3.41+0.95Weight	0.7616	0.0104*
	Weight(g.)	Weight =-1.69+0.80Length	0.7616	0.0104*

Table A-25 Regression between growth and soil quality and water quality in pond no.1-4.

Pond No.1	Parameters	Regression equation	R^2	Statistic
	Length(cm.)	Length =-21.24+0.24TEM+2.22DO	0.9994	0.0248*
	Weight(g.)	Weight =22.32+0.39TEM+1.54DO	0.9933	0.0818^{NS}
Pond No.2	Length(cm.)	$Length=-162.97+21.93pH_s+1.71OM_s-0.18pH-0.09EC+0.39Cl^{-}+0.0002SO_4^{2-}+0.20TP$	0.9999	0.0024**
	Weight(g.)	$Weight=-201.04+27.24pH_s+0.08EC_s+1.29OM_s-0.01SO_4^{2-}{}_s+4.27SS+0.81Cl^{-}-1.02ORN$	0.9999	0.0024**
Pond No.3	Length(cm.)	$Length=-89.11+8.23OM_s$	0.9999	0.0020**
	Weight(g.)	$Weight=-119.76+10.91OM_s$	0.9908	0.0612^{NS}
Pond No.4	Length(cm.)	$Length=8.48+0.19OM_s-0.82EC-68.01SS+0.07ALK-0.002SO_4^{2-}$	0.9999	0.0024**
	Weight(g.)	$Weight=-53.12-3.67EC_s+6.24OM_s-53.61SS-2.72Cl^{-}+2.40TN$	0.9999	0.0091**

Remark : $_s$ = Parameters in soil quality.

APPENDIX

B

PEARSON CORRELATION COEFFICENTS

Table B-1 Correlation analysis of soil sediment quality in shrimp pond no.1.

	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
pH	1.00	0.72	0.32	0.82	-0.81	-0.00	-0.02	0.36	0.63	0.64
	0.0	0.28	0.68	0.18	0.19	1.00	0.98	0.64	0.37	0.36
EC (mS/cm)		1.00	0.83	0.88	-0.24	0.69	0.60	-0.37	0.94	0.94
		0.0	0.17	0.12	0.76	0.31	0.40	0.63	0.06	0.06
OM (%)			1.00	0.77	0.05	0.84	0.94	-0.60	0.93	0.93
			0.0	0.23	0.95	0.16	0.06	0.40	0.07	0.07
TN (%)				1.00	-0.58	0.04	0.53	-0.01	0.94	0.94
				0.0	0.42	0.61	0.47	0.99	0.06	0.06
CEC (meq./100g)					1.00	0.51	0.32	-0.81	-0.28	-0.28
					0.0	0.49	0.68	0.19	0.72	0.72
Al^{3+} (meq./100g)						1.00	0.87	-0.92	0.67	0.67
						0.0	0.13	0.08	0.33	0.33
H^{+} (meq./100g)							1.00	-0.74	0.76	0.76
							0.0	0.26	0.24	0.24
TP (mg/kg)								1.00	-0.33	-0.33
								0.0	0.67	0.67
SO_4^{2-} (mg/kg)									1.00	1.00
									0.0	0.0001
Fe (mg/kg)										1.00
										0.0

Remark : $P < 0.01$ = Highly Significant

$P < 0.05$ = Significant

$P > 0.05$ = No Significant

Table B-2 Correlation analysis of soil sediment quality in shrimp pond no.2.

	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
pH	1.00	-0.84	-0.65	0.12	0.21	0.63	0.17	-0.14	-0.68	-0.68
	0.0	0.004	0.06	0.76	0.58	0.07	0.66	0.72	0.043	0.04
EC (mS/cm)		1.00	0.88	0.19	-0.07	-0.79	-0.33	-0.11	0.74	0.74
		0.0	0.002	0.63	0.86	0.011	0.38	0.79	0.02	0.02
OM (%)			1.00	0.50	0.01	-0.78	-0.67	-0.31	0.88	0.88
			0.0	0.17	0.99	0.013	0.049	0.42	0.002	0.002
TN (%)				1.00	0.42	-0.16	-0.76	-0.30	0.49	0.49
				0.0	0.26	0.68	0.017	0.44	0.18	0.18
CEC (meq./100g)					1.00	-0.27	0.02	-0.08	0.16	0.16
					0.0	0.49	0.96	0.84	0.69	0.69
Al^{3+} (meq./100g)						1.00	0.34	0.006	-0.71	-0.71
						0.0	0.38	0.99	0.03	0.03
H^{+} (meq./100g)							1.00	0.23	-0.71	-0.71
							0.0	0.55	0.03	0.03
TP (mg/kg)								1.00	-0.33	-0.33
								0.0	0.39	0.39
SO_4^{2-} (mg/kg)									1.00	1.00
									0.0	0.0001
Fe (mg/kg)										1.00
										0.0

Remark : $P < 0.01$ = Highly Significant

$P < 0.05$ = Significant

$P > 0.05$ = No Significant

Table B-3 Correlation analysis of soil sediment quality in shrimp pond no.3.

	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
pH	1.00	-0.91	0.38	0.66	-0.67	1.00	-0.30	0.85	-0.03	-0.09
	0.0	0.28	0.75	0.54	0.53	0.0001	0.81	0.35	0.98	0.94
EC		1.00	0.04	-0.28	0.92	-0.91	-0.13	-0.55	-0.39	-0.34
(mS /cm)		0.0	0.97	0.82	0.26	0.28	0.92	0.63	0.74	0.78
OM			1.00	0.95	0.43	0.38	-1.00	0.81	-0.94	-0.95
(%)			0.0	0.21	0.72	0.75	0.06	0.40	0.23	0.19
TN				1.00	0.12	0.66	-0.92	0.95	-0.77	-0.81
(%)				0.0	0.92	0.54	0.26	0.20	0.44	0.40
CEC					1.00	-0.67	-0.51	-0.19	-0.72	-0.68
(meq./100g)					0.0	0.53	0.66	0.88	0.49	0.52
Al^{3+}						1.00	-0.30	0.85	-0.03	-0.09
(meq./100g)						0.0	0.81	0.35	0.98	0.94
H^{+}							1.00	-0.75	0.96	0.98
(meq./100g)							0.0	0.46	0.17	0.14
TP								1.00	-0.55	-0.59
(mg/kg)								0.0	0.63	0.60
SO_4^{2-}									1.00	0.998
(mg/kg)									0.0	0.04
Fe										1.00
(mg/kg)										0.0

Remark : $P < 0.01$ = Highly Significant

$P < 0.05$ = Significant

$P > 0.05$ = No Significant

Table B-4 Correlation analysis of soil sediment quality in shrimp pond no.4.

	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)
pH	1.00	0.19	-0.43	0.79	0.35	0.28	-0.53	-0.54	-0.07	-0.07
	0.0	0.69	0.33	0.04	0.44	0.54	0.22	0.21	0.89	0.89
EC (mS/cm)		1.00	0.66	-0.31	0.85	-0.53	-0.23	-0.10	0.69	0.69
		0.0	0.10	0.49	0.02	0.22	0.62	0.84	0.08	0.08
OM (%)			1.00	-0.66	0.43	-0.37	0.18	0.45	0.79	0.79
			0.0	0.11	0.34	0.41	0.71	0.31	0.03	0.03
TN (%)				1.00	-0.24	0.77	-0.47	-0.24	-0.28	-0.28
				0.0	0.61	0.045	0.28	0.60	0.55	0.55
CEC (meq./100g)					1.00	-0.56	0.002	-0.17	0.60	0.60
					0.0	0.19	0.997	0.72	0.16	0.16
Al^{3+} (meq./100g)						1.00	-0.25	0.37	-0.05	-0.05
						0.0	0.59	0.41	0.92	0.92
H^{+} (meq./100g)							1.00	0.27	-0.02	-0.02
							0.0	0.55	0.96	0.96
TP (mg/kg)								1.00	0.61	0.61
								0.0	0.15	0.15
SO_4^{2-} (mg/kg)									1.00	1.00
									0.0	0.0001
Fe (mg/kg)										1.00
										0.0

Remark : $P < 0.01$ = Highly Significant

$P < 0.05$ = Significant

$P > 0.05$ = No Significant

Table B-5 Correlation analysis of water quality in shrimp pond no.1.

	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
TEM	1.00	0.78	0.43	-0.53	0.58	-0.54	-0.33	0.29	-0.85	0.28	-0.64	-0.24	-0.31	-0.30	0.02	-0.91
(°C)	0.0	0.22	0.57	0.47	0.42	0.46	0.67	0.71	0.15	0.72	0.36	0.76	0.69	0.70	0.98	0.09
pH		1.00	-0.19	0.07	-0.05	0.05	0.29	-0.23	0.35	-0.12	-0.11	0.39	0.25	0.27	0.57	-0.56
		0.0	0.81	0.93	0.95	0.95	0.71	0.77	0.65	0.88	0.89	0.61	0.75	0.73	0.43	0.44
EC			1.00	-0.79	-0.96	-0.77	-0.79	0.94	-0.76	0.34	-0.66	-0.81	-0.64	-0.97	-0.61	-0.49
(mS /cm)			0.0	0.21	0.04	0.23	0.21	0.06	0.24	0.66	0.33	0.19	0.36	0.03	0.39	0.51
TS				1.00	0.68	1.0	0.97	-0.54	0.89	-0.83	0.98	0.95	0.96	0.63	0.84	0.78
(mg/l)				0.0	0.32	0.001	0.03	0.46	0.11	0.17	0.02	0.06	0.04	0.37	0.16	0.22
SS					1.00	0.66	0.63	-0.94	0.77	-0.16	0.58	0.64	0.47	0.95	0.38	0.54
(mg/l)					0.0	0.34	0.37	0.06	0.23	0.84	0.42	0.36	0.53	0.053	0.62	0.46
TDS						1.00	0.97	-0.51	0.89	-0.85	0.98	0.94	0.96	0.60	0.83	0.79
(mg/l)						0.0	0.03	0.49	0.11	0.15	0.02	0.06	0.04	0.40	0.17	0.21
Cl^-							1.00	-0.56	0.78	-0.83	0.91	0.99	0.98	0.66	0.93	0.62
(mg/l)							0.0	0.44	0.23	0.17	0.09	0.006	0.02	0.34	0.07	0.38
ALK								1.00	-0.55	0.01	-0.38	-0.60	-0.37	-0.99	-0.39	-0.24
(mg/l)								0.0	0.45	0.99	0.62	0.40	0.63	0.008	0.61	0.76
COD									1.00	-0.62	0.92	0.72	0.74	0.60	0.50	0.94
(mg/l)									0.0	0.38	0.08	0.28	0.26	0.40	0.50	0.06
DO										1.00	-0.87	-0.79	-0.93	-0.13	-0.84	-0.65
(mg/l)										0.0	0.13	0.21	0.07	0.87	0.16	0.35
TN											1.00	0.86	0.93	0.48	0.75	0.88
(mg/l)											0.0	0.14	0.07	0.52	0.25	0.12
ORN												1.00	0.96	0.70	0.95	0.54
(mg/l)												0.0	0.04	0.30	0.049	0.46
NH_3													1.00	0.48	0.94	0.65
(mg/l)													0.0	0.52	0.06	0.35
SO_4^{2-}														1.00	0.50	0.30
(mg/l)														0.0	0.50	0.70
TP															1.00	0.35
(mg/l)															0.0	0.65
Fe																1.00
(mg/l)																0.0

Remark : $P < 0.01$ = Highly Significant, $P < 0.05$ = Significant, $P > 0.05$ = No Significant

Table B-6 Correlation analysis of water quality in shrimp pond no.2.

	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
TEM (°C)	1.00	0.42	0.06	-0.10	-0.43	-0.09	-0.13	-0.10	-0.06	0.80	0.11	0.11	-0.40	-0.20	0.42	-0.004
	0.0	0.26	0.87	0.79	0.25	0.82	0.75	0.79	0.89	0.009	0.77	0.79	0.28	0.61	0.26	0.99
pH		1.00	0.27	0.37	-0.60	0.38	0.45	-0.10	0.18	0.41	-0.07	0.34	0.01	0.21	0.22	-0.06
		0.0	0.49	0.33	0.09	0.31	0.23	0.80	0.64	0.27	0.86	0.37	0.98	0.59	0.57	0.87
EC (mS/cm)			1.00	0.93	-0.18	0.93	0.87	0.57	0.82	-0.17	0.80	0.27	-0.03	0.84	0.30	-0.54
			0.0	0.001	0.65	0.0003	0.002	0.11	0.007	0.67	0.010	0.48	0.93	0.005	0.44	0.13
TS (mg/l)				1.00	-0.23	1.00	0.96	0.60	0.76	-0.23	0.61	0.34	0.03	0.79	0.26	-0.54
				0.0	0.56	0.0001	0.0001	0.08	0.02	0.55	0.08	0.37	0.94	0.012	0.50	0.14
SS (mg/l)					1.00	-0.26	-0.16	0.44	0.04	-0.38	0.27	-0.35	0.74	0.17	-0.14	0.57
					0.0	0.51	0.69	0.23	0.91	0.31	0.48	0.35	0.02	0.66	0.71	0.11
TDS (mg/l)						1.00	0.96	0.59	0.75	-0.22	0.60	0.35	0.01	0.78	0.26	0.55
						0.0	0.0001	0.10	0.02	0.57	0.09	0.36	0.98	0.014	0.50	0.13
Cl^- (mg/l)							1.00	0.54	0.81	-0.34	0.60	0.27	0.11	0.81	0.09	-0.48
							0.0	0.13	0.008	0.37	0.09	0.49	0.77	0.009	0.83	0.20
ALK (mg/l)								1.00	0.42	-0.06	0.68	0.30	0.51	0.60	0.31	0.11
								0.0	0.26	0.88	0.04	0.44	0.16	0.09	0.41	0.77
COD (mg/l)									1.00	-0.45	0.77	0.003	0.11	0.67	0.15	0.36
									0.0	0.23	0.014	0.99	0.77	0.049	0.71	0.34
DO (mg/l)										1.00	-0.19	0.26	-0.17	-0.31	0.57	0.27
										0.0	0.63	0.50	0.67	0.42	0.11	0.48
TN (mg/l)											1.00	0.25	0.24	0.69	0.14	0.12
											0.0	0.51	0.54	0.04	0.71	0.76
ORN (mg/l)												1.00	0.08	0.09	-0.07	0.09
												0.0	0.83	0.82	0.85	0.83
NH_3 (mg/l)													1.00	0.31	0.01	0.75
													0.0	0.41	0.98	0.02
SO_4^{2-} (mg/l)														1.00	0.09	-0.32
														0.0	0.82	0.41
TP (mg/l)															1.00	0.03
															0.0	0.93
Fe (mg/l)																1.00
																0.0

Remark : $P < 0.01$ = Highly Significant, $P < 0.05$ = Significant, $P > 0.05$ = No Significant

Table B-7 Correlation analysis of water quality in shrimp pond no.3.

	TEM (°C)	pH	EC (mS /cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
TEM	1.00	0.89	0.48	0.62	0.40	0.63	0.47	0.20	0.84	-0.62	-0.44	-0.14	-0.98	0.47	-0.86	0.01
(°C)	0.0	0.31	0.68	0.57	0.74	0.57	0.69	0.87	0.37	0.58	0.71	0.91	0.14	0.69	0.34	0.996
pH		1.00	0.02	0.19	-0.07	0.20	0.01	-0.27	0.49	-0.91	-0.80	-0.58	-0.97	0.004	-0.53	-0.46
		0.0	0.99	0.88	0.96	0.87	0.99	0.82	0.67	0.27	0.41	0.60	0.17	0.997	0.64	0.70
EC			1.00	0.98	1.00	0.98	1.00	0.96	0.88	0.40	0.58	0.80	-0.27	1.00	-0.85	0.88
(mS /cm)			0.0	0.11	0.053	0.12	0.003	0.19	0.32	0.74	0.60	0.41	0.82	0.007	0.35	0.31
TS				1.00	0.97	1.00	0.98	0.89	0.95	0.23	0.43	0.69	-0.44	0.98	-0.93	0.79
(mg/l)				0.0	0.16	0.003	0.12	0.30	0.21	0.85	0.71	0.52	0.71	0.12	0.24	0.42
SS					1.00	0.97	1.00	0.98	0.83	0.47	0.65	0.85	-0.19	1.00	-0.81	0.92
(mg/l)					0.0	0.17	0.049	0.13	0.37	0.69	0.55	0.35	0.88	0.045	0.40	0.26
TDS						1.00	0.98	0.89	0.95	0.23	0.43	0.68	0.44	0.98	-0.93	0.78
(mg/l)						0.0	0.12	0.30	0.20	0.85	0.72	0.52	0.71	0.12	0.23	0.43
Cl^-							1.00	0.96	0.87	0.40	0.59	0.81	-0.27	1.00	-0.85	0.88
(mg/l)							0.0	0.18	0.32	0.74	0.60	0.40	0.83	0.004	0.35	0.31
ALK								1.00	0.70	0.65	0.79	0.94	0.02	0.96	-0.67	0.98
(mg/l)								0.0	0.51	0.55	0.42	0.22	0.99	0.18	0.53	0.13
COD									1.00	-0.09	0.12	0.42	-0.70	0.87	-1.00	0.55
(mg/l)									0.0	0.94	0.92	0.73	0.51	0.33	0.03	0.63
DO										1.00	0.98	0.87	0.77	0.41	0.14	0.78
(mg/l)										0.0	0.14	0.33	0.44	0.73	0.91	0.43
TN											1.00	0.95	0.62	0.59	-0.08	0.90
(mg/l)											0.0	0.20	0.57	0.59	0.95	0.29
ORN												1.00	0.35	0.81	-0.38	0.99
(mg/l)												0.0	0.77	0.40	0.75	0.09
NH_3													1.00	-0.26	0.73	0.21
(mg/l)													0.0	0.83	0.48	0.86
SO_4^{2-}														1.00	-0.85	0.89
(mg/l)														0.0	0.36	0.30
TP															1.00	-0.51
(mg/l)															0.0	0.66
Fe																1.00
(mg/l)																0.0

Remark : $P < 0.01$ = Highly Significant, $P < 0.05$ = Significant, $P > 0.05$ = No Significant

Table 8 Correlation analysis of water quality in shrimp pond No4

	TEM (°C)	pH	EC (mS /cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
TEM (°C)	1.00 0.0	0.24 0.60	0.25 0.59	0.39 0.39	-0.78 0.04	0.39 0.38	0.25 0.60	-0.24 0.60	-0.12 0.79	0.55 0.20	0.19 0.68	0.06 0.90	-0.07 0.89	-0.81 0.03	0.25 0.59	-0.27 0.56
pH		1.00 0.0	-0.75 0.052	-0.55 0.20	0.23 0.61	-0.55 0.21	-0.72 0.07	0.63 0.13	-0.90 0.006	0.73 0.06	-0.68 0.09	-0.72 0.07	-0.35 0.44	-0.35 0.44	0.50 0.25	0.31 0.50
EC (mS /cm)			1.00 0.0	0.75 0.05	-0.46 0.30	0.75 0.053	0.99 0.0001	-0.92 0.003	0.87 0.011	-0.45 0.31	0.79 0.03	0.81 0.03	0.53 0.22	0.14 0.76	-0.12 0.80	-0.15 0.75
TS (mg/l)				1.00 0.0	-0.50 0.25	1.00 0.0001	0.82 0.02	-0.50 0.25	0.68 0.09	-0.52 0.23	0.90 0.006	0.56 0.19	0.65 0.12	-0.08 0.86	-0.46 0.30	-0.45 0.31
SS (mg/l)					1.00 0.0	-0.51 0.25	-0.42 0.35	0.47 0.28	-0.30 0.51	-0.32 0.49	-0.37 0.42	0.32 0.48	0.12 0.79	0.59 0.16	0.06 0.90	0.38 0.40
TDS (mg/l)						1.00 0.0	0.82 0.02	0.50 0.25	0.68 0.09	-0.52 0.24	0.90 0.006	0.56 0.19	0.64 0.12	-0.09 0.85	-0.45 0.31	-0.45 0.31
Cl^- (mg/l)							1.00 0.0	-0.87 0.011	0.87 0.011	-0.51 0.24	0.85 0.016	0.80 0.03	0.63 0.13	0.16 0.73	-0.17 0.72	-0.16 0.74
ALK (mg/l)								1.00 0.0	-0.75 0.053	0.23 0.62	-0.51 0.24	-0.66 0.11	-0.24 0.61	-0.21 0.64	-0.01 0.98	0.08 0.87
COD (mg/l)									1.00 0.0	-0.67 0.10	0.82 0.02	0.87 0.01	0.59 0.16	0.37 0.42	0.30 0.51	-0.05 0.92
DO (mg/l)										1.00 0.0	-0.60 0.15	-0.42 0.35	-0.60 0.15	-0.64 0.12	0.66 0.11	0.25 0.59
TN (mg/l)											1.00 0.0	0.84 0.02	0.83 0.02	-0.02 0.96	-0.26 0.58	-0.14 0.77
ORN (mg/l)												1.00 0.0	0.69 0.09	0.04 0.93	0.11 0.81	0.23 0.62
NH_3 (mg/l)													1.00 0.0	0.17 0.71	0.005 0.99	0.26 0.57
SO_4^{2-} (mg/l)														1.00 0.0	-0.31 0.50	0.17 0.72
TP (mg/l)															1.00 0.0	0.79 0.03
Fe (mg/l)																1.00 0.0

Remark : $P < 0.01$ = Highly Significant, $P < 0.05$ = Significant, $P > 0.05$ = No Significant

Table B-9 Correlation analysis of growth in shrimp pond No1-4.

Pond No.1	Parameter	Length(cm.)	Weight(g.)
	Length(cm.)	1.00 0.0	0.9825 0.0175*
	Weight(g.)		1.00 0.00
Pond No.2	Length(cm.)	1.00 0.0	0.9928 0.0001**
	Weight(g.)		1.00 0.00
Pond No.3	Length(cm.)	1.00 0.0	0.9952 0.0622NS
	Weight(g.)		1.00 0.00
Pond No.4	Length(cm.)	1.00 0.0	0.8727 0.0104*
	Weight(g.)		1.00 0.00

Remark : P < 0.01 = Highly Significant

P < 0.05 = Significant,

P > 0.05 = No Significant

Table B-10.1 Pond no.1 Correlation analysis between Length, Soil sediment and Water quality.

	LENGTH (cm)	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq/100g)	Al^{3+} (meq/100g)	H^{+} (meq/100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_4 (mg/l)	SO_4 (mg/l)	TP (mg/l)	Fe (mg/l)
LENGTH (cm)	1.00 0.0	0.68 0.32	0.70 0.30	0.73 0.27	0.95 0.05	.0.61 0.39	0.26 0.74	0.65 0.45	0.10 0.90	0.87 0.13	0.87 0.13	0.42 0.58	0.02 0.98	0.36 0.64	-0.86 0.14	-0.23 0.77	-0.88 0.12	-0.82 0.18	0.04 0.96	-0.71 0.29	0.99 0.013	-0.92 0.08	-0.77 0.23	-0.92 0.08	-0.15 0.85	-0.77 0.23	-0.76 0.24
pH		1.00 0.0	0.72 0.28	0.32 0.68	0.82 0.18	.0.81 0.19	.0.00 1.00	.0.02 0.98	0.36 0.64	0.63 0.37	0.64 0.36	.0.27 0.73	-0.72 0.28	0.41 0.59	-0.66 0.34	-0.14 0.86	-0.66 0.34	-0.80 0.20	0.21 0.79	-0.25 0.75	0.78 0.22	-0.57 0.43	-0.83 0.17	-0.83 0.17	-0.32 0.70	-0.96 0.04	-0.12 0.88
EC			1.00 0.0	0.83 0.17	0.88 0.12	.0.24 0.76	0.69 0.31	0.60 0.40	-0.37 0.63	0.94 0.06	0.94 0.06	0.35 0.65	-0.30 0.70	0.90 0.10	-0.95 0.051	-0.77 0.23	-0.94 0.06	-0.98 0.02	0.72 0.28	-0.79 0.21	0.70 0.30	-0.86 0.14	-0.98 0.02	-0.91 0.09	-0.80 0.20	-0.88 0.12	-0.58 0.42
OM				1.00 0.0	0.77 0.23	0.05 0.95	0.84 0.16	0.94 0.06	-0.60 0.40	0.93 0.07	0.93 0.07	0.81 0.19	0.28 0.72	0.79 0.21	-0.92 0.08	-0.79 0.21	-0.92 0.08	-0.82 0.18	0.58 0.42	-1.00 0.003	0.65 0.35	-0.94 0.06	-0.77 0.23	-0.78 0.22	-0.64 0.36	-0.56 0.44	-0.92 0.08
TN					1.00 0.0	.0.58 0.42	0.40 0.61	0.53 0.47	-0.01 0.99	0.94 0.06	0.94 0.06	0.33 0.67	-0.21 0.79	0.59 0.41	-0.95 0.052	-0.42 0.58	-0.95 0.047	-0.96 0.04	0.30 0.70	-0.74 0.26	0.96 0.04	-0.93 0.07	-0.93 0.07	-1.00 0.003	-0.42 0.58	-0.92 0.08	-0.67 0.33
CEC						1.00 0.0	0.51 0.49	0.32 0.68	-0.81 0.19	.0.28 0.72	-0.28 0.72	0.43 0.57	0.53 0.47	0.19 0.81	0.29 0.71	-0.44 0.56	0.31 0.69	0.41 0.59	0.40 0.60	-0.09 0.91	-0.72 0.28	0.30 0.70	0.42 0.58	0.55 0.45	-0.30 0.70	0.66 0.34	-0.04 0.96
Al^{3+}							1.00 0.0	0.87 0.13	-0.92 0.08	0.67 0.33	0.67 0.33	0.75 0.25	0.27 0.73	0.89 0.11	-0.67 0.33	-0.97 0.03	-0.65 0.35	-0.57 0.43	0.85 0.15	-0.85 0.15	0.16 0.84	-0.62 0.38	-0.55 0.45	-0.43 0.57	-0.85 0.15	-0.26 0.74	-0.67 0.33
H^{+}								1.00 0.0	-0.74 0.26	0.76 0.24	0.76 0.24	0.96 0.04	0.57 0.43	0.65 0.35	-0.73 0.27	-0.75 0.25	-0.74 0.26	-0.57 0.43	0.49 0.51	-0.96 0.04	0.43 0.57	-0.79 0.21	-0.50 0.50	-0.53 0.47	-0.52 0.48	-0.24 0.76	-0.94 0.06
TP									1.00 0.0	.0.33 0.67	-0.33 0.67	.0.71 0.29	-0.42 0.58	.0.70 0.30	0.32 0.68	0.87 0.13	0.31 0.69	0.21 0.79	0.77 0.23	0.62 0.38	0.21 0.79	0.29 0.71	0.19 0.81	0.05 0.95	0.72 0.28	-0.12 0.88	0.47 0.53
SO_4^{2-}										1.00 0.0	1.00 0.0001	0.56 0.44	-0.03 0.97	0.77 0.23	-1.00 0.001	-0.67 0.33	-1.00 0.001	-0.96 0.04	0.52 0.48	-0.91 0.09	0.84 0.16	-0.98 0.02	-0.93 0.07	-0.95 0.048	-0.61 0.39	-0.82 0.18	-0.81 0.19
Fe											1.00 0.0	0.56 0.44	-0.03 0.97	0.77 0.23	-1.00 0.001	-0.67 0.33	-1.00 0.001	-0.96 0.04	0.52 0.48	-0.91 0.09	0.84 0.16	-0.98 0.02	-0.93 0.07	-0.96 0.048	-0.61 0.39	-0.82 0.18	-0.81 0.19
TEM												1.00 0.0	0.78 0.22	0.43 0.57	-0.53 0.47	-0.58 0.42	-0.54 0.46	-0.33 0.67	0.29 0.71	-0.84 0.15	0.28 0.72	-0.64 0.36	-0.24 0.76	-0.31 0.69	-0.30 0.70	0.02 0.98	-0.91 0.09
pH													1.00 0.0	.0.19 0.81	0.07 0.93	-0.05 0.95	0.05 0.95	0.30 0.71	0.23 0.77	-0.35 0.65	-0.12 0.88	-0.11 0.89	0.39 0.61	0.25 0.75	0.27 0.73	0.57 0.43	-0.56 0.44
EC														1.00 0.0	-0.79 0.21	-0.96 0.04	-0.77 0.23	-0.79 0.21	0.94 0.06	-0.76 0.24	0.34 0.66	-0.66 0.33	-0.81 0.19	-0.64 0.36	-0.97 0.03	-0.61 0.39	-0.49 0.51
TS															1.00 0.0	0.68 0.32	0.999 0.0005	0.97 0.03	0.54 0.46	0.89 0.11	-0.83 0.17	0.98 0.02	0.95 0.054	0.96 0.04	0.63 0.37	0.84 0.16	0.78 0.22
SS																1.00 0.0	0.66 0.34	0.63 0.37	0.94 0.06	0.77 0.23	-0.16 0.84	0.58 0.42	0.64 0.36	0.47 0.53	0.95 0.053	0.38 0.62	0.54 0.46
TDS																	1.00 0.0	0.97 0.03	0.51 0.49	0.89 0.11	-0.86 0.15	0.98 0.02	0.94 0.06	0.96 0.04	0.60 0.40	0.83 0.17	0.79 0.21
Cl^-																		1.00 0.0	0.56 0.44	0.78 0.23	-0.83 0.17	0.91 0.09	0.99 0.006	0.98 0.02	0.66 0.34	0.93 0.07	0.62 0.38
ALK																			1.00 0.0	0.55 0.45	0.01 0.99	-0.38 0.62	-0.60 0.40	-0.37 0.63	-0.99 0.009	-0.39 0.61	-0.24 0.76
COD																				1.00 0.0	-0.62 0.38	0.92 0.08	0.72 0.28	0.74 0.26	0.60 0.40	0.50 0.50	0.94 0.06
DO																					1.00 0.0	0.87 0.13	-0.79 0.21	-0.93 0.07	-0.11 0.87	-0.84 0.16	-0.65 0.35
TN																						1.00 0.0	0.86 0.14	0.93 0.07	0.48 0.52	0.75 0.25	0.88 0.12
ORN																							1.00 0.0	0.96 0.04	0.70 0.30	0.95 0.049	0.54 0.46
NH_4																								1.00 0.0	0.48 0.52	0.94 0.06	0.65 0.35
SO_4^{2-}																									1.00 0.0	0.50 0.50	0.30 0.70
TP																										1.00 0.0	0.36 0.65
Fe																											1.00 0.0

Table B-10.2 Pond no.1 Correlation analysis between Weight, Soil sediment and Water quality.

	Weight (g)	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq./100g)	Al^{3+} (meq./100g)	H^{+} (meq./100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
Weight (g)	1.00	0.54	0.65	0.79	0.90	-0.48	0.34	0.67	-0.02	0.87	0.87	0.58	0.20	0.36	0.85	-0.27	-0.87	-0.77	0.03	-0.79	0.94	-0.94	-0.70	-0.87	-0.14	-0.66	-0.86
	0.0	0.46	0.35	0.21	0.10	0.52	0.66	0.33	0.98	0.13	0.13	0.42	0.80	0.64	0.15	0.73	0.13	0.23	0.97	0.21	0.06	0.06	0.30	0.13	0.86	0.34	0.14
pH		1.00	0.72	0.32	0.82	.0.81	-0.00	.0.02	0.36	0.63	0.64	-0.27	-0.72	0.41	-0.66	-0.14	-0.66	-0.80	0.21	-0.28	0.78	-0.57	-0.83	-0.83	-0.32	-0.96	-0.12
		0.0	0.28	0.68	0.18	0.19	1.00	0.98	0.64	0.37	0.36	0.73	0.28	0.59	0.34	0.86	0.34	0.20	0.79	0.75	0.22	0.43	0.17	0.17	0.68	0.04	0.88
EC			1.00	0.83	0.88	.0.24	0.69	0.60	-0.37	0.94	0.94	0.35	-0.30	0.90	0.95	0.77	0.94	0.98	0.72	0.79	0.70	0.86	0.98	0.91	0.80	0.88	0.58
			0.0	0.17	0.12	0.76	0.31	0.40	0.63	0.06	0.06	0.65	0.70	0.098	0.051	0.23	0.06	0.02	0.28	0.21	0.30	0.14	0.018	0.09	0.20	0.12	0.42
OM				1.00	0.77	0.05	0.84	0.94	-0.60	0.93	0.93	0.81	0.28	0.79	-0.92	-0.79	-0.92	-0.82	0.58	-1.00	0.65	-0.94	-0.77	-0.78	-0.64	-0.56	-0.92
				0.0	0.23	0.95	0.16	0.06	0.40	0.07	0.07	0.19	0.72	0.21	0.08	0.21	0.08	0.18	0.42	0.003	0.35	0.06	0.23	0.22	0.36	0.44	0.08
TN					1.00	0.58	0.39	0.53	0.006	0.94	0.94	0.33	0.21	0.59	-0.94	-0.42	-0.96	-0.96	0.304	-0.74	0.96	-0.93	-0.93	-1.00	-0.42	-0.92	-0.67
					0.0	0.42	0.61	0.47	0.99	0.06	0.06	0.67	0.79	0.41	0.06	0.58	0.04	0.043	0.70	0.26	0.04	0.07	0.07	0.003	0.58	0.08	0.33
CEC						1.00	0.51	0.32	-0.81	-0.28	.0.28	0.43	0.53	0.19	0.29	-0.44	0.31	0.41	0.40	-0.09	-0.72	0.30	0.42	0.58	-0.30	0.66	-0.04
						0.0	0.49	0.68	0.19	0.72	0.72	0.57	0.47	0.81	0.71	0.56	0.69	0.59	0.60	0.091	0.28	0.70	0.58	0.45	0.70	0.34	0.96
Al^{3+}							1.00	0.87	-0.92	0.67	0.67	0.75	0.27	0.89	0.67	0.97	0.65	0.57	0.85	0.85	0.16	0.62	0.55	0.43	0.85	0.26	0.67
							0.0	0.13	0.08	0.33	0.33	0.25	0.73	0.11	0.33	0.03	0.35	0.43	0.15	0.15	0.84	0.38	0.45	0.57	0.15	0.74	0.33
H^{+}								1.00	0.74	0.76	0.76	0.96	0.57	0.65	-0.73	-0.75	-0.74	-0.57	0.49	-0.96	0.43	-0.79	-0.50	-0.51	-0.52	-0.24	-0.94
								0.0	0.26	0.24	0.24	0.04	0.43	0.35	0.27	0.25	0.26	0.43	0.51	0.04	0.57	0.21	0.50	0.47	0.48	0.76	0.06
TP									1.00	0.33	0.33	0.71	0.42	0.70	0.32	0.87	0.31	0.21	-0.77	0.62	0.21	0.29	0.19	0.05	0.72	-0.12	0.47
									0.0	0.67	0.67	0.29	0.58	0.30	0.68	0.13	0.69	0.79	0.23	0.38	0.79	0.71	0.81	0.95	0.28	0.88	0.53
SO_4^{2-}										1.00	1.00	0.56	-0.03	0.77	-1.00	-0.67	-1.00	-0.96	0.52	-0.91	0.84	-0.98	-0.93	-0.95	-0.61	-0.82	-0.81
										0.0	0.0001	0.44	0.97	0.23	0.001	0.33	0.0005	0.04	0.48	0.09	0.16	0.02	0.07	0.048	0.39	0.18	0.19
Fe											1.00	0.56	0.03	0.77	1.00	0.67	1.00	0.96	0.52	0.91	0.84	0.98	0.93	0.95	0.61	0.82	0.81
											0.0	0.44	0.97	0.23	0.001	0.33	0.0005	0.04	0.48	0.09	0.16	0.02	0.07	0.048	0.39	0.18	0.19
TEM												1.00	0.78	0.43	-0.53	-0.58	-0.54	-0.33	0.29	-0.85	0.28	-0.64	-0.24	-0.31	-0.30	0.02	-0.91
												0.0	0.22	0.57	0.47	0.42	0.46	0.67	0.71	0.15	0.72	0.36	0.76	0.69	0.70	0.98	0.09
pH													1.00	-0.19	0.07	-0.05	0.05	0.29	-0.23	-0.35	-0.12	-0.11	0.39	0.25	0.27	0.57	-0.56
													0.0	0.81	0.93	0.95	0.95	0.71	0.77	0.65	0.88	0.89	0.61	0.75	0.73	0.43	0.44
EC														1.00	-0.79	-0.96	-0.77	-0.79	0.94	-0.76	0.34	0.66	0.81	0.64	0.97	0.61	0.49
														0.0	0.21	0.04	0.23	0.21	0.06	0.24	0.66	0.34	0.19	0.36	0.03	0.39	0.51
TS															1.00	0.68	0.999	0.97	0.54	0.89	0.83	0.98	0.95	0.96	0.63	0.84	0.78
															0.0	0.32	0.0005	0.03	0.46	0.11	0.17	0.02	0.055	0.04	0.37	0.16	0.22
SS																1.00	0.66	0.63	-0.94	0.77	-0.16	0.68	0.64	0.47	0.95	0.38	0.54
																0.0	0.34	0.37	0.06	0.22	0.84	0.42	0.36	0.53	0.051	0.62	0.46
TDS																	1.00	0.97	-0.51	0.89	-0.85	0.98	0.94	0.96	0.60	0.83	0.79
																	0.0	0.03	0.49	0.11	0.15	0.02	0.06	0.04	0.40	0.17	0.21
Cl^-																		1.00	-0.56	0.78	-0.83	0.91	0.99	0.98	0.66	0.93	0.62
																		0.0	0.44	0.23	0.17	0.09	0.006	0.02	0.34	0.07	0.38
ALK																			1.00	0.55	0.01	-0.38	-0.60	-0.37	-0.99	-0.39	-0.24
																			0.0	0.450	0.99	0.62	0.40	0.63	0.008	0.61	0.76
COD																				1.00	-0.62	0.92	0.72	0.74	0.60	0.80	0.94
																				0.0	0.38	0.08	0.28	0.26	0.40	0.50	0.06
DO																					1.00	-0.87	-0.79	-0.93	-0.13	-0.84	-0.65
																					0.0	0.13	0.21	0.07	0.87	0.16	0.35
TN																						1.00	0.86	0.93	0.48	0.75	0.88
																						0.0	0.14	0.07	0.52	0.25	0.12
ORN																							1.00	0.96	0.70	0.95	0.54
																							0.0	0.04	0.30	0.049	0.46
NH_3																								1.00	0.48	0.94	0.65
																								0.0	0.52	0.06	0.35
SO_4^{2-}																									1.00	0.50	0.30
																									0.0	0.50	0.70
TP																										1.00	0.35
																										0.0	0.65
Fe																											1.00
																											0.0

Table B-11.1 Pond no.2 Correlation analysis between Length, Soil sediment and Water quality.

	LENGTH (m)	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq/100g)	Al^{3+} (meq/100g)	H^{+} (meq/100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^{-} (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
LENGTH (m)	1.00 0.0	0.94 0.0001	-0.65 0.06	-0.37 0.33	0.36 0.34	0.27 0.48	0.43 0.25	-0.09 0.82	-0.32 0.40	-0.44 0.23	-0.44 0.23	0.05 0.91	-0.16 0.68	-0.86 0.003	-0.90 0.0008	0.09 0.82	-0.90 0.0009	-0.85 0.004	-0.74 0.02	-0.59 0.10	0.19 0.62	-0.65 0.06	-0.35 0.35	0.01 0.98	-0.78 0.014	-0.12 0.75	0.53 0.14
pH		1.00 0.0	-0.84 0.004	-0.65 0.06	0.12 0.76	0.21 0.58	0.63 0.07	0.17 0.66	-0.14 0.72	-0.68 0.043	-0.68 0.04	-0.03 0.94	-0.20 0.61	-0.80 0.009	-0.81 0.008	-0.10 0.80	-0.80 0.009	-0.79 0.011	-0.80 0.009	-0.53 0.14	0.09 0.82	-0.68 0.04	-0.26 0.504	-0.18 0.64	-0.86 0.003	-0.16 0.68	0.33 0.38
EC			1.00 0.0	0.88 0.002	0.19 0.63	-0.07 0.86	-0.79 0.01	-0.33 0.38	-0.11 0.79	0.74 0.02	0.74 0.02	0.18 0.63	0.35 0.36	0.54 0.14	0.49 0.18	0.11 0.78	0.48 0.19	0.52 0.15	0.54 0.13	0.21 0.58	0.16 0.68	0.46 0.21	0.20 0.61	0.27 0.49	0.78 0.014	0.07 0.86	-0.09 0.81
OM				1.00 0.0	0.50 0.17	0.01 0.99	-0.78 0.01	-0.67 0.049	-0.31 0.42	0.88 0.002	0.88 0.002	0.23 0.54	0.16 0.68	0.30 0.44	0.19 0.62	0.44 0.24	0.18 0.65	0.24 0.54	0.56 0.12	0.11 0.77	0.24 0.53	0.43 0.24	-0.06 0.89	0.49 0.18	0.62 0.08	0.19 0.62	0.26 0.50
TN					1.00 0.0	0.42 0.26	-0.16 0.68	-0.76 0.017	-0.30 0.44	0.49 0.18	0.49 0.18	-0.04 0.93	-0.41 0.27	-0.55 0.12	-0.62 0.08	0.69 0.04	-0.63 0.07	-0.60 0.09	0.17 0.67	-0.59 0.09	0.23 0.55	-0.12 0.76	-0.09 0.82	0.53 0.14	-0.19 0.62	-0.13 0.73	0.75 0.02
CEC						1.00 0.0	-0.27 0.49	0.02 0.96	-0.08 0.84	0.16 0.69	0.16 0.69	-0.56 0.12	-0.26 0.502	-0.17 0.66	-0.21 0.59	0.42 0.25	-0.22 0.57	-0.20 0.61	0.01 0.99	-0.13 0.75	-0.27 0.47	0.07 0.85	0.29 0.45	0.60 0.09	0.09 0.82	-0.34 0.37	0.52 0.15
Al^{3+}							1.00 0.0	0.34 0.38	0.006 0.99	-0.71 0.03	-0.71 0.03	-0.04 0.92	-0.45 0.22	-0.52 0.15	-0.49 0.18	-0.19 0.63	-0.48 0.19	-0.49 0.18	-0.54 0.14	-0.31 0.42	-0.20 0.61	-0.46 0.21	-0.24 0.53	-0.60 0.09	-0.76 0.02	-0.34 0.37	-0.22 0.58
H^{+}								1.00 0.0	0.23 0.55	-0.71 0.03	-0.71 0.03	-0.05 0.90	0.16 0.68	0.30 0.44	0.27 0.49	-0.70 0.04	0.29 0.46	0.23 0.55	-0.45 0.22	0.27 0.48	-0.24 0.53	0.03 0.95	0.31 0.42	-0.62 0.08	-0.02 0.96	-0.25 0.52	-0.64 0.06
TP									1.00 0.0	-0.33 0.39	-0.33 0.39	-0.18 0.63	-0.03 0.94	0.23 0.56	0.37 0.33	-0.39 0.29	0.38 0.32	0.12 0.76	0.22 0.58	-0.14 0.72	0.18 0.65	-0.15 0.70	0.33 0.39	-0.24 0.53	0.01 0.97	0.47 0.20	-0.35 0.36
SO_4^{2-}										1.00 0.0	1.00 0.0001	-0.06 0.88	0.003 0.99	0.32 0.40	0.29 0.45	0.68 0.04	0.27 0.49	0.37 0.33	0.77 0.015	0.29 0.45	-0.07 0.87	0.57 0.11	0.02 0.96	0.74 0.02	0.63 0.07	0.07 0.86	0.39 0.30
Fe											1.00 0.0	-0.06 0.88	0.003 0.99	0.32 0.40	0.29 0.45	0.68 0.04	0.27 0.49	0.37 0.33	0.77 0.015	0.29 0.45	-0.07 0.87	0.57 0.11	0.02 0.96	0.74 0.02	0.63 0.07	0.07 0.86	0.39 0.30
TEM												1.00 0.0	0.42 0.26	0.05 0.87	-0.10 0.79	-0.43 0.25	-0.09 0.82	-0.13 0.75	-0.10 0.79	-0.06 0.89	0.50 0.0097	0.11 0.77	0.11 0.79	-0.40 0.28	-0.20 0.61	0.42 0.26	-0.004 0.99
pH													1.00 0.0	0.27 0.49	0.37 0.33	-0.60 0.09	0.38 0.31	0.45 0.23	-0.10 0.80	0.18 0.64	0.41 0.27	-0.07 0.86	0.34 0.37	-0.01 0.98	0.21 0.59	0.22 0.57	-0.06 0.87
EC														1.00 0.0	0.93 0.0003	-0.18 0.66	0.93 0.0003	0.87 0.002	0.57 0.11	0.82 0.007	-0.17 0.67	0.80 0.0104	0.27 0.48	-0.03 0.93	0.84 0.005	0.30 0.44	-0.54 0.13
TS															1.00 0.0	-0.23 0.56	0.9996 0.0001	0.96 0.0001	0.60 0.08	0.76 0.02	-0.23 0.55	0.61 0.08	0.34 0.37	0.03 0.94	0.79 0.01	0.26 0.50	-0.54 0.14
SS																1.00 0.0	-0.26 0.51	-0.16 0.67	0.44 0.23	0.04 0.91	-0.38 0.31	0.27 0.48	-0.35 0.35	0.74 0.02	0.17 0.66	-0.14 0.71	0.57 0.11
TDS																	1.00 0.0	0.96 0.0001	0.59 0.10	0.78 0.02	-0.22 0.57	0.60 0.09	0.35 0.36	0.01 0.98	0.78 0.014	0.26 0.50	-0.55 0.13
Cl^{-}																		1.00 0.0	0.54 0.13	0.81 0.008	-0.34 0.37	0.60 0.09	0.27 0.49	0.11 0.77	0.81 0.009	0.09 0.83	-0.48 0.20
ALK																			1.00 0.0	0.42 0.26	-0.06 0.88	0.68 0.04	0.30 0.44	0.51 0.16	0.59 0.09	0.31 0.41	0.11 0.77
COD																				1.00 0.0	-0.45 0.23	0.77 0.014	0.003 0.99	0.11 0.77	0.67 0.049	0.15 0.71	-0.36 0.34
DO																					1.00 0.0	-0.19 0.63	0.26 0.50	-0.17 0.67	-0.31 0.42	0.57 0.11	0.27 0.48
TN																						1.00 0.0	0.25 0.51	0.24 0.54	0.69 0.04	0.14 0.71	-0.11 0.76
ORN																							1.00 0.0	0.08 0.83	0.09 0.81	-0.07 0.85	0.09 0.83
NH_3																								1.00 0.0	0.31 0.41	0.01 0.98	0.75 0.02
SO_4^{2-}																									1.00 0.0	0.09 0.82	-0.32 0.41
TP																										1.00 0.0	0.03 0.93
Fe																											1.00 0.0

Table B-11.2 Pond no.2 Correlation analysis between Weight, Soil sediment and Water quality.

	Weight (g)	pH	EC (mS/cm)	OM (%)	TN (%)	CEC (meq/100g)	Al^{3+} (meq/100g)	H^+ (meq/100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)	TEM (°C)	pH	EC (mS/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
Weight (g)	1.00	0.94	0.67	0.38	0.31	0.29	0.41	0.07	0.36	0.42	0.42	0.01	-0.11	-0.82	-0.85	0.10	-0.85	-0.78	-0.73	0.50	0.13	-0.62	-0.36	0.06	-0.74	-0.13	0.54
	0.0	0.0002	0.049	0.31	0.42	0.46	0.28	0.85	0.34	0.26	0.26	0.98	0.76	0.006	0.003	0.79	0.003	0.012	0.03	0.17	0.74	0.07	0.34	0.88	0.02	0.74	0.13
pH		1.00	-0.84	-0.65	0.12	0.21	0.63	0.17	-0.14	-0.68	-0.68	-0.03	-0.20	-0.80	-0.81	-0.10	-0.80	-0.79	-0.80	-0.53	0.09	-0.68	-0.26	-0.18	-0.86	-0.16	0.33
		0.0	0.004	0.06	0.76	0.58	0.07	0.66	0.72	0.043	0.043	0.94	0.61	0.009	0.008	0.80	0.0096	0.011	0.0099	0.14	0.082	0.04	0.60	0.64	0.003	0.70	0.38
EC			1.00	0.88	0.19	-0.07	-0.79	-0.33	-0.11	0.74	0.74	0.18	0.35	0.54	0.49	0.11	0.48	0.52	0.54	0.21	0.16	0.46	0.20	0.27	0.78	0.07	-0.09
			0.0	0.002	0.63	0.86	0.011	0.38	0.79	0.023	0.023	0.63	0.36	0.14	0.18	0.78	0.19	0.15	0.13	0.58	0.68	0.21	0.61	0.49	0.014	0.86	0.81
OM				1.00	0.50	0.006	0.78	-0.47	-0.31	0.88	0.88	0.23	0.16	0.30	0.19	0.44	0.18	0.24	0.56	0.11	0.24	0.44	0.06	0.49	0.62	0.19	0.26
				0.0	0.17	0.99	0.01	0.049	0.42	0.002	0.002	0.54	0.68	0.44	0.62	0.24	0.65	0.54	0.12	0.77	0.53	0.24	0.89	0.18	0.08	0.62	0.50
TN					1.00	0.42	0.16	-0.76	-0.30	0.49	0.49	-0.04	-0.41	-0.55	0.62	0.69	0.63	0.60	0.17	0.59	0.23	0.12	0.09	0.53	0.19	0.13	0.76
					0.0	0.26	0.68	0.017	0.44	0.18	0.18	0.93	0.27	0.12	0.08	0.04	0.07	0.09	0..67	0.09	0.55	0.76	0.82	0.14	0.62	0.73	0.02
CEC						1.00	-0.27	0.02	-0.08	0.16	0.16	-0.56	-0.26	-0.17	-0.21	0.42	-0.22	-0.20	0.01	-0.13	-0.27	0.07	0.29	0.60	0.09	-0.34	0.52
						0.0	0.49	0.96	0.784	0.69	0.69	0.12	0.50	0.66	0.59	0.25	0.57	0.61	0.99	0.75	0.47	0.85	0.45	0.09	0.82	0.37	0.15
Al^{3+}							1.00	0.34	0.01	0.71	0.71	0.04	0.45	0.52	-0.49	-0.19	-0.48	-0.049	-0.54	-0.31	-0.20	0.46	0.24	0.60	0.76	0.34	0.22
							0.0	0.38	0.99	0.03	0.03	0.92	0.22	0.15	0.18	0.63	0.19	0.18	0.14	0.42	0.61	0.21	0.53	0.09	0.017	0.37	0.58
H^+								1.00	0.23	-0.71	-0.71	-0.05	0.16	0.30	0.27	0.70	0.29	0.23	0.45	0.27	0.24	0.03	0.31	-0.62	-0.02	-0.25	-0.64
								0.0	0.55	0.03	0.03	0.90	0.68	0.44	0.49	0.04	0.46	0.55	0.22	0.48	0.53	0.95	0.42	0.08	0.96	0.52	0.06
TP									1.00	-0.33	-0.33	-0.18	-0.03	0.23	0.37	0.39	0.38	0.12	0.22	0.14	0.18	-0.15	0.33	-0.24	0.01	0.47	-0.35
									0.0	0.39	0.39	0.63	0.94	0.56	0.33	0.29	0.32	0.76	0.58	0.72	0.65	0.70	0.39	0.53	0.97	0.20	0.36
SO_4^{2-}										1.00	1.00	-0.06	0.003	0.32	0.29	0.68	0.27	0.37	0.77	0.29	-0.07	0.57	0.02	0.74	0.63	0.07	0.39
										0.0	0.0001	0.88	0.99	0.40	0.45	0.04	0.49	0.33	0.015	0.45	0.87	0.11	0.96	0.02	0.07	0.86	0.30
Fe											1.00	0.06	0.003	0.32	0.29	0.68	0.27	0.37	0.77	0.29	-0.66	0.57	0.02	0.74	0.63	0.07	0.39
											0.0	0.88	0.99	0.40	0.45	0.04	0.49	0.33	0.018	0.45	0.87	0.11	0.96	0.02	0.07	0.86	0.30
TEM												1.00	0.42	0.06	0.10	0.43	0.09	0.13	0.10	0.06	0.80	0.11	0.11	-0.40	-0.20	0.42	-0.004
												0.0	0.26	0.87	0.79	0.25	0.82	0.75	0.79	0.89	0.0097	0.77	0.79	0.28	0.61	0.26	0.99
pH													1.00	0.27	0.37	0.60	0.38	0.45	0.10	0.18	0.41	-0.07	0.34	-0.01	0.21	0.22	-0.06
													0.0	0.49	0.33	0.09	0.31	0.23	0.80	0.64	0.27	0.86	0.37	0.98	0.59	0.57	0.87
EC														1.00	0.93	-0.15	0.93	0.87	0.57	0.82	-0.17	0.80	0.27	-0.03	0.84	0.30	0.54
														0.0	0.0003	0.65	0.0003	0.002	0.11	0.007	0.67	0.0104	0.48	0.93	0.005	0.44	0.13
TS															1.00	0.23	0.10	0.96	0.60	0.76	0.23	0.61	0.34	0.03	0.79	0.26	-0.54
															0.0	0.56	0.0001	0.0001	0.08	0.02	0.55	0.08	0.37	0.94	0.012	0.50	0.14
SS																1.00	-0.25	-0.16	0.44	0.04	-0.38	0.27	-0.35	0.74	0.17	-0.14	0.57
																0.0	0.51	0.69	0.23	0.91	0.31	0.48	0.35	0.02	0.66	0.71	0.11
TDS																	1.00	0.96	0.59	0.75	-0.22	0.60	0.35	0.01	0.78	0.26	-0.55
																	0.0	0.0001	0.10	0.02	0.57	0.09	036	0.98	0.014	0.50	0.13
Cl^-																		1.00	0.54	0.81	-0.34	0.60	0.27	0.11	0.81	0.09	-0.48
																		0.0	0.13	0.008	0.37	0.09	0.49	0.77	0.009	0.83	0.20
ALK																			1.00	0.42	0.06	0.68	0.30	0.51	0.59	0.31	0.11
																			0.0	0.26	0.88	0.04	0.44	0.16	0.09	0.41	0.77
COD																				1.00	-0.45	0.77	0.003	0.11	0.67	0.15	-0.36
																				0.0	0.23	0.014	0.99	0.77	0.049	0.71	0.34
DO																					1.00	-0.19	0.26	-0.17	-0.31	0.57	0.27
																					0.0	0.63	0.50	0.67	0.42	0.11	0.48
TN																						1.00	0.25	0.24	0.69	0.14	-0.12
																						0.0	0.51	0.54	0.04	0.71	0.76
ORN																							1.00	0.06	0.09	0.07	0.09
																							0.0	0.63	0.82	0.85	0.83
NH_3																								1.00	0.31	0.01	0.75
																								0.0	0.41	0.98	0.02
SO_4^{2-}																									1.00	0.09	-0.32
																									0.0	0.82	0.41
TP																										1.00	0.03
																										0.0	0.93
Fe																											1.00
																											0.0

Table B-12.1 Pond no.3 Correlation analysis between Length, Soil sediment and Water quality.

	LENGTH (cm)	pH	EC	OM (%)	TN (%)	CEC	Al^{3+} (meq./100g)	H^{+}	TP	SO_4^{2-}	Fe	TEM (°C)	pH	EC	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl (mg/l)	ALK	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_4 (mg/l)	SO_4^{2-}	TP	Fe (mg/l)
LENGTH	1.00	0.38	0.04	1.00	0.95	0.43	0.38	-0.10	0.81	-0.94	-0.95	0.23	0.66	0.74	-0.62	-0.80	-0.61	-0.75	-0.91	-0.33	-0.91	-0.98	-0.996	-0.44	-0.76	0.29	-0.97
	0.0	0.75	0.97	0.001	0.21	0.72	0.75	0.06	0.40	0.23	0.19	0.85	0.54	0.47	0.58	0.41	0.58	0.46	0.28	0.78	0.27	0.14	0.06	0.71	0.46	0.81	0.16
pH		1.00	-0.91	0.38	0.66	-0.67	1.00	-0.30	0.85	-0.03	-0.09	0.99	0.95	0.33	0.49	0.25	0.50	0.33	0.05	0.74	-0.73	-0.57	-0.29	-1.00	0.32	-0.78	-0.15
		0.0	0.28	0.75	0.54	0.53	0.0001	0.81	0.35	0.98	0.94	0.10	0.21	0.78	0.67	0.84	0.67	0.79	0.97	0.46	0.48	0.61	0.81	0.04	0.79	0.44	0.90
EC			1.00	0.04	-0.28	0.92	-0.91	-0.13	-0.56	-0.39	-0.34	-0.96	-0.73	-0.70	-0.81	-0.64	-0.82	-0.70	-0.46	-0.96	0.38	0.17	-0.14	0.88	-0.69	0.97	-0.28
			0.0	0.97	0.82	0.26	0.28	0.92	0.63	0.74	0.78	0.18	0.48	0.51	0.39	0.66	0.39	0.51	0.69	0.19	0.76	0.89	0.91	0.12	0.51	0.16	0.82
OM				1.00	0.95	0.43	0.38	-0.10	0.81	-0.94	-0.96	0.23	0.66	-0.74	-0.61	-0.80	-0.61	-0.75	-0.90	-0.33	-0.91	-0.98	-1.00	-0.44	-0.76	0.29	-0.97
				0.0	0.21	0.72	0.75	0.06	0.40	0.23	0.19	0.85	0.54	0.47	0.58	0.41	0.58	0.46	0.28	0.79	0.27	0.14	0.06	0.71	0.46	0.81	0.16
TN					1.00	0.12	0.66	-0.92	0.95	-0.77	-0.81	0.53	0.86	-0.49	-0.33	-0.56	-0.33	-0.49	-0.72	-0.01	-0.99	-0.99	-0.91	-0.70	-0.80	-0.03	-0.84
					0.0	0.92	0.54	0.26	0.20	0.44	0.40	0.64	0.34	0.67	0.78	0.62	0.78	0.67	0.49	0.99	0.07	0.07	0.27	0.50	0.66	0.98	0.36
CEC						1.00	-0.67	-0.51	-0.19	-0.72	-0.68	-0.78	-0.40	-0.92	-0.98	-0.89	-0.98	-0.92	-0.77	-0.99	-0.02	-0.23	-0.51	0.62	-0.92	0.99	-0.63
						0.0	0.53	0.66	0.88	0.49	0.52	0.43	0.74	0.25	0.14	0.30	0.14	0.25	0.44	0.07	0.99	0.85	0.66	0.57	0.26	0.10	0.56
Al^{3+}							1.00	-0.30	0.85	-0.03	-0.09	0.99	0.95	0.33	0.49	0.25	0.50	0.33	0.05	0.74	-0.73	-0.57	-0.29	-1.00	0.32	-0.78	-0.18
							0.0	0.81	0.35	0.98	0.94	0.10	0.21	0.78	0.67	0.84	0.67	0.79	0.97	0.46	0.48	0.61	0.81	0.04	0.79	0.43	0.90
H^{+}								1.00	-0.76	0.96	0.98	-0.16	-0.59	0.80	0.68	0.65	0.68	0.80	0.94	0.41	0.87	0.95	1.00	0.16	0.81	-0.37	0.99
								0.0	0.46	0.17	0.14	0.91	0.60	0.41	0.52	0.36	0.52	0.41	0.22	0.73	0.33	0.19	0.004	0.77	0.40	0.76	0.10
TP									1.00	-0.55	-0.59	0.76	0.98	-0.21	-0.03	-0.29	-0.03	-0.21	-0.48	0.29	-0.98	-0.91	-0.76	-0.89	-0.22	-0.33	-0.64
									0.0	0.63	0.60	0.45	0.14	0.87	0.98	0.82	0.98	0.87	0.68	0.81	0.13	0.27	0.46	0.31	0.86	0.78	0.56
SO_4^{2-}										1.00	0.996	0.12	-0.35	0.93	0.86	0.96	0.85	0.93	1.00	0.64	0.70	0.84	0.96	0.10	0.94	-0.61	0.99
										0.0	0.04	0.92	0.77	0.24	0.35	0.18	0.35	0.23	0.08	0.56	0.50	0.37	0.17	0.94	0.23	0.58	0.08
Fe											1.00	0.07	-0.40	0.91	0.82	0.94	0.82	0.91	0.99	0.60	0.74	0.87	0.98	0.15	0.92	-0.56	0.10
											0.0	0.96	0.74	0.27	0.38	0.22	0.39	0.27	0.09	0.59	0.47	0.33	0.14	0.90	0.26	0.62	0.04
TEM												1.00	0.89	0.48	0.62	0.40	0.63	0.47	0.20	0.84	-0.62	-0.44	-0.14	-0.98	0.47	-0.86	0.01
												0.0	0.31	0.68	0.57	0.74	0.57	0.69	0.87	0.37	0.58	0.71	0.91	0.14	0.69	0.34	0.996
pH													1.00	0.02	0.19	-0.07	0.20	0.01	-0.27	0.49	-0.91	-0.80	-0.58	-0.97	0.004	-0.83	0.46
													0.0	0.99	0.88	0.96	0.87	0.99	0.82	0.67	0.27	0.41	0.60	0.17	0.997	0.64	0.70
EC														1.00	0.98	1.00	0.98	1.00	0.96	0.88	0.40	0.58	0.80	-0.27	1.00	-0.88	0.88
														0.0	0.11	0.053	0.12	0.003	0.19	0.32	0.74	0.60	0.41	0.82	0.007	0.36	0.31
TS															1.00	0.97	1.00	0.98	0.89	0.95	0.23	0.43	0.69	-0.44	0.98	-0.98	0.79
															0.0	0.16	0.003	0.12	0.30	0.21	0.85	0.71	0.52	0.71	0.12	0.23	0.42
SS																1.00	0.97	1.00	0.98	0.83	0.47	0.66	0.85	-0.19	1.00	-0.81	0.92
																0.0	0.17	0.0497	0.13	0.37	0.69	0.55	0.35	0.88	0.045	0.40	0.26
TDS																	1.00	0.98	0.89	0.95	0.23	0.43	0.68	-0.44	0.98	-0.93	0.78
																	0.0	0.12	0.30	0.20	0.85	0.72	0.52	0.71	0.12	0.23	0.43
Cl^{-}																		1.00	0.96	0.87	0.40	0.59	0.81	-0.27	1.00	-0.88	0.88
																		0.0	0.18	0.32	0.74	0.60	0.40	0.83	0.004	0.36	0.31
ALK																			1.00	0.70	0.65	0.79	0.94	0.02	0.96	-0.67	0.98
																			0.0	0.51	0.55	0.42	0.22	0.99	0.18	0.53	0.13
COD																				1.00	-0.09	0.12	0.41	-0.70	0.87	-1.00	0.55
																				0.0	0.94	0.92	0.73	0.51	0.33	0.03	0.63
DO																					1.00	0.98	0.88	0.77	0.41	0.14	0.78
																					0.0	0.14	0.33	0.44	0.73	0.91	0.43
TN																						1.00	0.95	0.62	0.59	-0.08	0.90
																						0.0	0.20	0.57	0.59	0.95	0.29
ORN																							1.00	0.35	0.81	-0.38	0.99
																							0.0	0.77	0.40	0.76	0.09
NH_3																								1.00	0.26	0.73	0.21
																								0.0	0.83	0.48	0.86
SO_4^{2-}																									1.00	-0.86	0.89
																									0.0	0.36	0.30
TP																										1.00	-0.81
																										0.0	0.66
Fe																											1.00
																											0.0

Table B-12.2 Pond no.3 Correlation analysis between Weight, Soil sediment and Water quality.

	Weight (g)	pH	EC	OM (%)	TN (%)	CEC	Al^{3+}	H^+	TP	SO_4^{2-}	Fe	TEM (°C)	pH	EC	TS (mg/l)	SS	TDS (mg/l)	Cl^- (mg/l)	ALK	COD	DO	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
Weight (g)	1.00	0.47	0.05	0.995	0.97	0.34	0.47	0.98	0.86	0.90	-0.92	0.33	0.73	0.68	-0.64	-0.73	-0.54	-0.68	-0.86	-0.24	-0.95	-0.99	-0.98	-0.63	-0.68	0.19	-0.94
	0.0	0.69	0.97	0.06	0.14	0.78	0.69	0.12	0.34	0.29	0.26	0.79	0.48	0.53	0.64	0.47	0.64	0.52	0.34	0.85	0.21	0.08	0.17	0.65	0.57	0.88	0.27
pH		1.00	-0.91	0.38	0.66	-0.67	1.00	-0.30	0.85	-0.03	0.09	0.99	0.95	0.33	0.49	0.25	0.50	0.33	0.05	0.74	-0.73	-0.57	-0.29	-1.00	0.32	-0.78	-0.15
		0.0	0.28	0.75	0.54	0.53	0.0001	0.81	0.35	0.98	0.94	0.10	0.21	0.78	0.67	0.84	0.67	0.79	0.97	0.46	0.48	0.61	0.81	0.04	0.79	0.44	0.90
EC			1.00	0.04	-0.28	0.92	-0.91	0.13	0.55	0.39	0.34	0.96	0.73	0.70	0.81	0.64	0.82	0.70	0.46	0.96	0.38	0.17	0.14	0.88	0.69	0.97	0.28
			0.0	0.97	0.82	0.26	0.28	0.92	0.63	0.74	0.78	0.18	0.48	0.51	0.39	0.56	0.39	0.51	0.69	0.19	0.76	0.89	0.91	0.32	0.52	0.16	0.82
OM				1.00	0.95	0.43	0.38	-0.996	0.81	-0.94	-0.95	0.23	0.66	-0.74	-0.61	-0.80	-0.61	-0.75	-0.90	-0.33	-0.91	-0.98	-1.00	-0.44	-0.75	0.29	-0.97
				0.0	0.21	0.72	0.75	0.06	0.40	0.23	0.19	0.85	0.54	0.47	0.58	0.41	0.58	0.46	0.28	0.79	0.27	0.14	0.06	0.71	0.46	0.81	0.15
TN					1.00	0.12	0.66	-0.92	0.95	-0.77	-0.81	0.53	0.86	-0.49	-0.33	-0.56	-0.33	-0.50	-0.72	-0.01	-0.99	-0.99	-0.91	-0.70	-0.50	-0.03	-0.84
					0.0	0.92	0.54	0.26	0.20	0.44	0.40	0.64	0.34	0.67	0.78	0.62	0.79	0.67	0.49	0.99	0.07	0.07	0.27	0.503	0.66	0.98	0.36
CEC						1.00	-0.67	-0.61	-0.19	-0.72	-0.68	-0.78	-0.40	-0.92	-0.98	-0.89	-0.98	-0.92	-0.77	-0.99	-0.02	0.23	0.51	0.62	0.97	0.99	0.63
						0.0	0.53	0.66	0.88	0.49	0.52	0.43	0.74	0.26	0.14	0.30	0.14	0.26	0.44	0.07	0.99	0.85	0.66	0.57	0.26	0.10	0.56
Al^{3+}							1.00	0.30	0.85	0.03	0.09	0.99	0.95	0.33	0.49	0.25	0.50	0.33	0.05	0.74	0.73	-0.57	-0.29	-1.00	0.32	-0.78	-0.15
							0.0	0.81	0.35	0.98	0.94	0.10	0.21	0.78	0.67	0.84	0.67	0.79	0.97	0.46	0.48	0.61	0.81	0.04	0.79	0.43	0.90
H^+								1.00	-0.75	0.96	0.98	-0.15	-0.59	0.80	0.68	0.85	0.68	0.80	0.94	0.41	0.87	0.95	1.00	0.36	0.81	-0.37	0.99
								0.0	0.46	0.17	0.14	0.91	0.60	0.41	0.52	0.36	0.52	0.41	0.22	0.73	0.33	0.19	0.004	0.77	0.40	0.76	0.10
TP									1.00	-0.66	-0.59	0.76	0.98	-0.21	-0.03	-0.29	-0.03	-0.21	-0.48	0.29	-0.98	-0.91	-0.75	-0.89	-0.22	-0.33	-0.64
									0.0	0.63	0.60	0.45	0.14	0.87	0.98	0.82	0.98	0.87	0.68	0.81	0.13	0.27	0.46	0.31	0.86	0.78	0.56
SO_4^{2-}										1.00	0.996	0.12	-0.35	0.93	0.85	0.96	0.85	0.93	1.00	0.64	0.70	0.84	0.96	0.10	0.94	0.61	0.99
										0.0	0.04	0.92	0.77	0.24	0.35	0.18	0.35	0.23	0.05	0.56	0.502	0.37	0.17	0.94	0.23	0.58	0.08
Fe											1.00	0.07	0.40	0.91	0.82	0.94	0.82	0.91	0.99	0.60	0.74	0.87	0.98	0.15	0.92	-0.56	1.00
											0.0	0.96	0.74	0.27	0.38	0.22	0.39	0.27	0.09	0.59	0.47	0.33	0.14	0.90	0.26	0.62	0.04
TEM												1.00	0.89	0.48	0.62	0.40	0.63	0.47	0.20	0.84	-0.62	-0.44	-0.14	-0.98	0.47	-0.86	0.01
												0.0	0.31	0.68	0.57	0.74	0.57	0.69	0.87	0.37	0.58	0.71	0.91	0.14	0.69	0.34	1.00
pH													1.00	0.02	0.19	-0.07	0.20	0.01	-0.27	0.49	-0.91	-0.80	-0.58	-0.97	0.004	-0.53	-0.46
													0.0	0.99	0.88	0.96	0.87	0.99	0.82	0.67	0.27	0.41	0.60	0.17	1.00	0.64	0.70
EC														1.00	0.98	1.00	0.98	1.00	0.96	0.88	0.40	0.58	0.80	0.27	1.00	0.85	0.88
														0.0	0.11	0.053	0.12	0.003	0.19	0.32	0.74	0.60	0.41	0.82	0.007	0.35	0.31
TS															1.00	0.97	1.00	0.98	0.89	0.95	0.23	0.43	0.69	0.44	0.98	-0.93	0.79
															0.0	0.16	0.003	0.12	0.30	0.21	0.85	0.71	0.52	0.71	0.12	0.24	0.42
SS																1.00	0.97	1.00	0.98	0.83	0.47	0.65	0.85	-0.19	1.00	-0.81	0.92
																0.0	0.17	0.0497	0.13	0.37	0.69	0.55	0.35	0.88	0.045	0.40	0.26
TDS																	1.00	0.98	0.89	0.95	0.23	0.43	0.68	-0.44	0.98	-0.93	0.78
																	0.0	0.12	0.30	0.20	0.85	0.72	0.52	0.71	0.12	0.23	0.43
Cl^-																		1.00	0.96	0.87	0.40	0.59	0.81	0.27	1.00	0.85	0.88
																		0.0	0.18	0.32	0.74	0.60	0.40	0.83	0.004	0.35	0.31
ALK																			1.00	0.70	0.65	0.79	0.94	0.02	0.96	-0.67	0.98
																			0.0	0.51	0.55	0.42	0.22	0.99	0.18	0.53	0.13
COD																				1.00	0.09	0.12	0.42	-0.70	0.87	-1.00	0.55
																				0.0	0.94	0.92	0.73	0.51	0.33	0.03	0.63
DO																					1.00	-0.98	0.87	0.77	0.41	0.14	0.78
																					0.0	0.14	0.33	0.44	0.73	0.91	0.43
TN																						1.00	0.95	0.62	0.59	0.08	0.90
																						0.0	0.20	0.57	0.59	0.95	0.29
ORN																							1.00	0.35	0.81	-0.38	0.99
																							0.0	0.77	0.40	0.75	0.09
NH_3																								1.00	-0.26	0.73	0.21
																								0.0	0.83	0.48	0.86
SO_4^{2-}																									1.00	0.85	0.89
																									0.0	0.36	0.30
TP																										1.00	-0.51
																										0.0	0.66
Fe																											1.00
																											0.0

Table B-13.1 Pond no.4 Correlation analysis between Length, Soil sediment and Water quality.

	LENGTH (cm)	pH	EC	OM (%)	TN (%)	CEC	Al^{3+}	H^{+}	TP (mg/kg)	SO_4^{2-}	Fe (mg/kg)	TEM (°C)	pH	EC	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^{-} (mg/l)	ALK	COD	DO (mg/l)	TN	ORN	NH_3 (mg/l)	SO_4^{2-}	TP	Fe (mg/l)
LENGTH (cm)	1.00 0.0	-0.52 0.22	-0.84 0.017	-0.26 0.57	-0.07 0.88	-0.66 0.10	0.39 0.39	0.57 0.18	0.52 0.24	-0.30 0.51	-0.30 0.52	0.13 0.78	0.74 0.06	-0.90 0.005	-0.55 0.20	0.07 0.88	-0.55 0.20	-0.90 0.006	0.87 0.012	-0.85 0.016	0.63 0.13	-0.64 0.12	-0.71 0.07	-0.66 0.20	-0.53 0.22	0.14 0.76	-0.01 0.99
pH		1.00 0.00	0.19 0.69	-0.43 0.33	0.79 0.04	0.35 0.44	0.28 0.54	-0.53 0.23	-0.54 0.21	-0.07 0.89	-0.07 0.89	-0.51 0.24	-0.29 0.52	0.30 0.51	0.34 0.46	0.49 0.26	0.33 0.47	0.40 0.38	-0.09 0.84	0.51 0.24	-0.70 0.08	0.54 0.21	0.47 0.28	0.86 0.013	0.59 0.16	-0.06 0.89	0.42 0.35
EC			1.00 0.0	0.66 0.10	-0.31 0.49	0.85 0.02	-0.53 0.22	-0.22 0.62	-0.10 0.84	0.69 0.08	0.69 0.08	0.28 0.54	-0.80 0.30	0.98 0.0001	0.77 0.04	-0.51 0.24	0.77 0.04	0.96 0.0007	-0.88 0.009	0.84 0.02	-0.48 0.28	0.79 0.03	0.77 0.04	0.45 0.31	0.07 0.89	-0.24 0.60	-0.32 0.48
OM				1.00 0.0	-0.66 0.11	0.43 0.34	-0.37 0.41	0.18 0.71	0.45 0.31	0.79 0.03	0.79 0.03	0.36 0.42	-0.67 0.10	0.54 0.21	0.47 0.29	-0.79 0.04	0.47 0.29	0.47 0.29	-0.52 0.23	0.51 0.24	-0.10 0.82	0.41 0.37	0.41 0.37	-0.17 0.71	-0.29 0.53	-0.42 0.35	-0.61 0.14
TN					1.00 0.0	-0.24 0.61	0.77 0.045	-0.47 0.28	-0.24 0.60	-0.28 0.55	-0.28 0.55	-0.76 0.04	-0.02 0.97	-0.24 0.61	-0.22 0.64	0.85 0.02	-0.22 0.63	-0.18 0.71	0.39 0.38	0.05 0.91	-0.51 0.24	0.06 0.90	0.11 0.82	0.51 0.24.	0.53 0.22	0.05 0.92	0.52 0.23
CEC						1.00 0.0	-0.56 0.19	0.002 0.997	-0.17 0.72	0.60 0.16	0.60 0.16	0.48 0.28	-0.52 0.23	0.87 0.011	0.93 0.002	-0.55 0.20	0.94 0.002	0.92 0.004	-0.67 0.10	0.73 0.06	-0.37 0.41	0.92 0.004	0.74 0.06	0.70 0.08	-0.13 0.78	-0.14 0.76	-0.19 0.68
Al^{3+}							1.00 0.0	-0.25 0.59	0.37 0.41	-0.05 0.92	-0.05 0.92	-0.72 0.07	0.04 0.94	-0.58 0.17	-0.41 0.36	0.71 0.07	-0.42 0.35	-0.56 0.20	0.72 0.07	-0.26 0.59	-0.32 0.49	-0.20 0.66	-0.20 0.67	0.05 0.91	0.20 0.66	-0.17 0.71	0.14 0.76
H^{+}								1.00 0.0	0.27 0.55	-0.02 0.96	-0.02 0.96	0.68 0.10	0.44 0.33	-0.23 0.62	-0.12 0.79	-0.60 0.16	-0.12 0.80	-0.26 0.57	0.20 0.67	-0.33 0.47	0.80 0.03	-0.11 0.82	-0.002 0.996	-0.24 0.60	-0.86 0.013	0.52 0.23	0.19 0.68
TP									1.00 0.0	0.61 0.15	0.61 0.15	0.20 0.66	-0.06 0.90	-0.29 0.53	0.02 0.97	-0.22 0.64	0.02 0.97	-0.32 0.49	0.43 0.34	-0.29 0.53	0.07 0.88	-0.05 0.92	-0.22 0.64	-0.32 0.48	-0.59 0.16	-0.37 0.42	-0.62 0.13
SO_4^{2-}										1.00 0.0	1.00 0.0001	0.27 0.56	-0.71 0.07	0.55 0.20	0.71 0.08	-0.51 0.24	0.71 0.08	0.55 0.21	-0.31 0.49	0.54 0.21	-0.46 0.30	0.70 0.08	0.50 0.25	0.27 0.56	-0.30 0.51	-0.64 0.21	-0.67 0.10
Fe											1.00 0.0	0.27 0.56	-0.71 0.07	0.55 0.20	0.71 0.08	-0.51 0.25	0.71 0.08	0.54 0.21	-0.31 0.50	0.54 0.21	-0.46 0.30	0.70 0.08	0.50 0.25	0.27 0.56	-0.30 0.51	-0.55 0.20	-0.67 0.10
TEM												1.00 0.0	0.24 0.60	0.25 0.59	0.39 0.39	-0.78 0.04	0.39 0.38	0.25 0.60	-0.24 0.60	-0.12 0.79	0.55 0.20	0.19 0.68	0.06 0.90	-0.07 0.89	-0.81 0.03	0.25 0.59	-0.27 0.56
pH													1.00 0.0	-0.75 0.052	-0.55 0.20	0.23 0.61	-0.55 0.21	-0.72 0.07	0.63 0.13	-0.90 0.006	0.73 0.06	-0.67 0.09	-0.72 0.07	-0.35 0.44	-0.35 0.44	0.50 0.25	0.31 0.50
EC														1.00 0.0	0.75 0.052	-0.46 0.30	0.75 0.052	0.99 0.0001	-0.92 0.003	0.87 0.011	-0.45 0.31	0.79 0.03	0.81 0.03	0.53 0.22	0.14 0.76	-0.12 0.80	-0.15 0.75
TS															1.00 0.0	-0.50 0.25	1.00 0.0001	0.82 0.02	-0.50 0.25	0.68 0.09	-0.52 0.23	0.90 0.006	0.56 0.19	0.65 0.12	-0.08 0.86	-0.46 0.30	-0.46 0.31
SS																1.00 0.0	0.51 0.28	0.42 0.35	0.47 0.28	-0.30 0.51	-0.32 0.49	-0.37 0.42	-0.32 0.48	0.12 0.79	0.59 0.16	0.06 0.90	0.38 0.40
TDS																	1.00 0.0	0.82 0.02	-0.50 0.25	0.68 0.09	-0.52 0.24	0.90 0.006	0.56 0.19	0.64 0.12	-0.09 0.85	-0.45 0.31	-0.45 0.31
Cl^{-}																		1.00 0.0	-0.87 0.011	0.87 0.011	-0.51 0.24	0.85 0.016	0.80 0.03	0.63 013	0.16 0.73	-0.17 0.72	-0.16 0.74
ALK																			1.00 0.0	-0.75 0.53	0.23 0.62	-0.50 0.24	-0.66 0.11	-0.24 0.61	-0.21 0.64	-0.01 0.98	0.08 0.87
COD																				1.00 0.0	-0.67 0.10	0.82 0.02	0.87 0.01	0.59 0.16	0.37 0.42	-0.30 0.51	-0.06 0.92
DO																					1.00 0.0	-0.60 0.15	-0.42 0.35	-0.60 0.15	-0.64 0.12	0.66 0.11	0.25 0.59
TN																						1.00 0.0	0.84 0.02	0.83 0.02	-0.02 0.96	-0.26 0.58	-0.14 0.77
ORN																							1.00 0.0	0.69 0.09	0.04 0.93	0.11 0.81	0.23 0.62
NH_3																								1.00 0.0	0.17 0.71	0.006 0.99	0.26 0.87
SO_4^{2-}																									1.00 0.0	-0.31 0.50	0.17 0.72
TP																										1.00 0.0	0.79 0.03
Fe																											1.00 0.0

Table B-13.2 Pond no.4 Correlation analysis between Weight, Soil sediment and Water quality.

	Weight (g)	pH	EC (ms/cm)	OM (%)	TN (%)	CEC (me/l)	Al^{3+} (me/100g)	H^+ (me/100g)	TP (mg/kg)	SO_4^{2-} (mg/kg)	Fe (mg/kg)	TEM (°C)	pH	EC (ms/cm)	TS (mg/l)	SS (mg/l)	TDS (mg/l)	Cl^- (mg/l)	ALK (mg/l)	COD (mg/l)	DO (mg/l)	TN (mg/l)	ORN (mg/l)	NH_3 (mg/l)	SO_4^{2-} (mg/l)	TP (mg/l)	Fe (mg/l)
Weight (g)	1.00	-0.58	-0.59	0.17	-0.19	-0.52	0.39	0.58	0.70	0.05	0.05	0.09	0.34	-0.70	-0.37	-0.19	-0.37	-0.72	0.70	-0.53	0.46	-0.42	-0.46	-0.56	-0.53	-0.12	-0.20
	0.0	0.17	0.16	0.72	0.68	0.23	0.39	0.17	0.08	0.91	0.91	0.85	0.45	0.08	0.41	0.68	0.41	0.07	0.08	0.22	0.30	0.35	0.30	0.19	0.22	0.80	0.67
pH		1.00	0.19	-0.43	0.79	0.35	0.28	-0.53	-0.54	-0.07	-0.07	-0.51	-0.29	0.30	0.34	0.49	0.33	0.40	0.09	0.51	0.70	0.54	0.47	0.86	0.59	0.06	0.42
		0.0	0.69	0.33	0.04	0.44	0.54	0.22	0.21	0.89	0.89	0.24	0.52	0.51	0.46	0.26	0.47	0.38	0.84	0.24	0.08	0.21	0.28	0.013	0.16	0.89	0.35
EC			1.00	0.66	-0.31	0.85	0.53	-0.23	-0.10	0.69	0.69	0.28	-0.80	0.98	0.77	-0.51	0.77	0.96	-0.88	0.84	-0.48	0.79	0.77	0.45	0.07	-0.24	-0.32
			0.0	0.10	0.49	0.016	0.22	0.62	0.84	0.08	0.08	0.54	0.03	0.0001	0.04	0.24	0.04	0.001	0.009	0.02	0.28	0.03	0.04	0.31	0.89	0.60	0.48
OM				1.00	0.66	0.43	0.37	0.18	0.45	0.79	0.79	0.36	-0.67	0.54	0.47	-0.79	0.47	0.47	-0.52	0.51	-0.10	0.41	0.41	-0.17	-0.29	-0.42	-0.61
				0.0	0.11	0.34	0.41	0.71	0.31	0.03	0.03	0.42	0.10	0.21	0.29	0.04	0.29	0.29	0.23	0.24	0.82	0.37	0.37	0.71	0.53	0.36	0.14
TN					1.00	-0.24	0.77	0.47	-0.24	-0.28	-0.28	-0.76	-0.02	-0.24	-0.22	0.85	-0.22	-0.18	0.39	0.05	-0.51	0.06	0.11	0.51	0.53	0.05	0.52
					0.0	0.61	0.045	0.28	0.60	0.55	0.55	0.04	0.97	0.61	0.64	0.02	0.63	0.71	0.38	0.91	0.24	0.90	0.82	0.24	0.22	0.92	0.23
CEC						1.00	-0.56	0.002	0.17	0.60	0.60	0.48	0.52	0.87	0.93	0.55	0.94	0.92	0.67	0.73	0.37	0.92	0.74	0.70	-0.13	-0.14	-0.19
						0.0	0.19	0.997	0.72	0.16	0.16	0.28	0.23	0.011	0.002	0.20	0.002	0.004	0.10	0.06	0.41	0.004	0.06	0.08	0.78	0.77	0.68
Al^{3+}							1.00	-0.25	0.37	-0.05	-0.05	-0.72	0.04	-0.58	-0.41	0.71	-0.42	-0.56	0.72	-0.24	-0.32	-0.20	-0.20	0.05	0.20	-0.17	0.14
							0.0	0.59	0.41	0.92	0.92	0.07	0.94	0.17	0.36	0.07	0.35	0.20	0.07	0.59	0.49	0.66	0.67	0.91	0.66	0.71	0.76
H^+								1.00	0.27	-0.02	-0.02	0.68	0.44	-0.23	-0.12	-0.60	-0.12	-0.26	0.20	-0.33	0.80	0.11	0.002	0.24	0.86	0.52	0.19
								0.0	0.55	0.96	0.96	0.10	0.33	0.62	0.79	0.16	0.80	0.57	0.67	0.47	0.03	0.82	0.10	0.60	0.013	0.23	0.68
TP									1.00	0.61	0.61	0.20	-0.06	-0.29	0.02	-0.22	0.02	-0.32	0.43	-0.29	0.07	0.05	0.22	0.32	0.59	0.37	0.62
									0.0	0.15	0.15	0.66	0.90	0.53	0.97	0.64	0.97	0.49	0.34	0.53	0.88	0.92	0.64	0.48	0.16	0.42	0.13
SO_4^{2-}										1.00	1.00	0.27	0.71	0.55	0.71	0.51	0.71	0.55	0.31	0.54	0.46	0.70	0.50	0.27	-0.30	-0.54	-0.67
										0.0	0.0001	0.56	0.07	0.20	0.08	0.24	0.08	0.21	0.49	0.21	0.30	0.08	0.25	0.56	0.51	0.21	0.10
Fe											1.00	0.27	-0.71	0.55	0.71	-0.51	0.71	0.54	-0.31	0.54	-0.46	0.70	0.50	0.27	-0.30	-0.56	-0.67
											0.0	0.56	0.07	0.20	0.08	0.25	0.08	0.21	0.50	0.21	0.30	0.08	0.25	0.56	0.51	0.20	0.10
TEM												1.00	0.24	0.25	0.39	-0.78	0.39	0.25	-0.24	-0.12	0.55	0.19	0.06	-0.07	-0.81	0.25	0.27
												0.0	0.60	0.59	0.39	0.04	0.38	0.60	0.60	0.79	0.20	0.68	0.90	0.89	0.03	0.59	0.56
pH													1.00	-0.75	-0.55	0.23	-0.55	-0.72	0.63	-0.90	0.73	0.68	0.72	0.35	0.35	0.50	0.31
													0.0	0.052	0.20	0.61	0.21	0.07	0.13	0.006	0.06	0.09	0.07	0.44	0.44	0.25	0.50
EC														1.00	0.75	-0.46	0.75	0.99	-0.92	0.87	-0.45	0.79	0.81	0.53	0.14	-0.12	-0.15
														0.0	0.053	0.30	0.053	0.0001	0.003	0.011	0.31	0.03	0.03	0.22	0.76	0.80	0.75
TS															1.00	0.50	1.00	0.82	-0.60	0.68	-0.52	0.90	0.56	0.65	-0.06	-0.46	-0.45
															0.0	0.25	0.0001	0.02	0.25	0.09	0.23	0.006	0.19	0.12	0.86	0.30	0.31
SS																1.00	0.51	0.42	0.47	0.30	0.32	0.37	0.32	0.12	0.59	0.06	0.38
																0.0	0.25	0.35	0.28	0.51	0.49	0.42	0.48	0.79	0.16	0.90	0.40
TDS																	1.00	0.83	0.50	0.68	0.52	0.90	0.56	0.64	0.09	0.45	0.45
																	0.0	0.02	0.25	0.09	0.24	0.006	0.19	0.12	0.85	0.31	0.31
Cl^-																		1.00	-0.87	0.87	-0.51	0.85	0.80	0.63	0.16	-0.17	-0.16
																		0.0	0.011	0.011	0.24	0.02	0.03	0.13	0.73	0.72	0.74
ALK																			1.00	-0.75	0.23	-0.51	-0.66	-0.24	-0.21	-0.01	0.08
																			0.0	0.053	0.62	0.24	0.11	0.61	0.64	0.98	0.87
COD																				1.00	0.67	0.82	0.87	0.59	0.37	0.30	0.05
																				0.0	0.10	0.02	0.01	0.16	0.42	0.51	0.92
DO																					1.00	0.60	0.42	0.60	0.64	0.66	0.25
																					0.0	0.15	0.35	0.15	0.12	0.11	0.59
TN																						1.00	0.84	0.83	-0.02	-0.26	-0.14
																						0.0	0.02	0.02	0.96	0.66	0.77
ORN																							1.00	0.69	0.04	0.11	0.23
																							0.0	0.09	0.93	0.81	0.62
NH_3																								1.00	0.17	0.01	0.26
																								0.0	0.71	0.99	0.87
SO_4^{2-}																									1.00	-0.31	0.17
																									0.0	0.60	0.72
TP																										1.00	0.79
																										0.0	0.03
Fe																											1.00
																											0.0

APPENDIX

C

MULTIPLE LINEAR REGRESSION BY FORWARD SELECTION PROCEDURE

Table C-1 Soil and Water parameter. Pond no.1 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	2	16.4898	8.2449	810.64	0.0248*
Error	1	0.0102	0.0102		
C Total	3	16.5000			

R-square = 0.9994

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-21.2377	1.1357	3.5568	349.70	0.0340
TEM	0.2428	0.0385	0.4054	39.86	0.1000
DO	2.2244	0.0610	13.5237	1329.65	0.0175

* = Significant No other variable met the 0.2500 significance level for entry into the model.

Table C-2 Soil and Water parameter. Pond no.1 Forward selection Procedure for Dependent Variable WEIGHT.

Source	DF	SS	MS	F Value	Prob >F
Regression	2	9.7839	4.8920	74.28	0.0818[NS]
Error	1	0.0659	0.0659		
C Total	3	9.8498			

R-square = 0.9933

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	22.3146	2.8899	3.9266	59.62	0.0820
TEM	0.3936	0.0979	1.0656	16.18	0.1551
DO	1.5433	0.1552	6.5098	98.85	0.0638

NS = No Significant No variable met the 0.2500 significance level for entry into the model.

Table C-3 Soil and Water parameter. Pond no.2 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	7	223.5800	31.9400	1.019E7	0.0024**
Error	1	0.000003	0.000003		
C Total	8	223.5800			

R-square = 0.9999

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-162.9689	0.0564	26.1590	8344957	0.0020
PHS	21.9341	0.0072	28.8420	9200843	0.0020
OMS	1.7138	0.0013	5.1086	1629681	0.0020
PH	-0.1765	0.0016	0.0381	12143.1	0.0058
EC	-0.0949	0.0005	0.1075	34284.6	0.0034
CL	0.3933	0.0016	0.1887	60183.8	0.0026
SO4	0.0002	0.000008	0.0014	456.69	0.0298
TP	0.2043	0.0035	0.0107	3426.98	0.0109

** = Highly Significant No other variable met the 0.2500 significance level for entry into the model

Table C-4 Soil and Water parameter. Pond no.2 Forward selection Procedure for Dependent Variable WEIGHT.

Source	DF	SS	MS	F Value	Prob >F
Regression	7	250.4346	35.7764	1519687	0.0024**
Error	1	0.00002	0.00002		
C Total	8	250.4346			

R-square = 0.9999

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-201.0397	0.1458	44.7884	1902496	0.0020
PHS	27.2421	0.0173	58.2272	2473340	0.0020
ECS	0.0825	0.0079	0.0025	107.93	0.0611
OMS	1.2927	0.0097	0.4213	17896.5	0.0048
SO4S	0.0103	0.0001	0.2297	9758.72	0.0064
SS	4.2690	0.1085	0.0365	1548.68	0.0162
CL	0.8124	0.0035	1.2572	53403.2	0.0028
ORN	-1.0229	0.0150	0.1096	4653.50	0.0093

** = Highly Significant No other variable met the 0.2500 significance level for entry into the model.

Table C-5 Soil and Water parameter. Pond no.3 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	28.6666	28.6666	364008	0.0020**
Error	1	0.00008	0.00008		
C Total	2	28.6667			

R-square = 0.9999

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-89.1088	0.1539	26.4161	335432	0.0020
OMS	8.2296	0.0136	28.6666	364008	0.0020

** = Highly Significant No other variable met the 0.2500 significance level for entry into the model.

Table C-6 Soil and Water parameter. Pond no.3 Forward selection Procedure for Dependent Variable WEIGHT.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	50.3441	50.3441	107.68	0.0612[NS]
Error	1	0.4675	0.4675		
C Total	2	50.8117			

R-square = 0.9908

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-119.7642	11.8547	47.7179	102.06	0.0628
OMS	10.9060	1.0510	50.3441	107.68	0.0612

NS = No Significant No variable met the 0.2500 significance level for entry into the model.

Table C-7 Soil and Water parameter. Pond no.4 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	5	103.2142	20.6428	384462	0.0024**
Error	1	0.00005	0.00005		
C Total	6	103.2143			

R-square = 0.9999

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	8.4847	0.1525	0.1661	3094.06	0.0114
OMS	0.1876	0.0140	0.0097	180.66	0.0473
EC	-0.8238	0.0020	9.3653	174424	0.0020
SS	-68.0142	0.5001	0.9932	18497.1	0.0047
ALK	0.0698	0.0008	0.4550	8473.31	0.0069
SO4	-0.0020	0.00001	1.5777	29384.5	0.0037

** = Highly Significant   No other variable met the 0.2500 significance level for entry into the model.

Table C-8 Soil and Water parameter. Pond no.4 Forward selection Procedure for Dependent Variable WEIGHT.

Source	DF	SS	MS	F Value	Prob >F
Regression	5	87.2423	17.4485	7031.93	0.0091**
Error	1	0.0025	0.0025		
C Total	6	87.2448			

R-square = 0.9999

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-53.1245	2.1607	1.5000	604.53	0.0259
ECS	-3.6714	0.3348	0.2985	120.28	0.0579
OMS	6.2425	0.2173	2.0469	824.94	0.0222
SS	-53.6061	2.8992	0.8483	341.89	0.0344
CL	-2.7234	0.1197	1.2849	517.83	0.0280
TN	2.3990	0.0437	7.4639	3008.02	0.0116

** = Highly Significant   No other variable met the 0.2500 significance level for entry into the model.

Table C-9 Growth rate. Pond no.1 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	15.9268	15.9268	55.57	0.0175*
Error	2	0.5732	0.2866		
C Total	3	16.5000			

R-square = 0.9653

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	1.3383	0.3946	3.2959	11.50	0.0770
Weight	1.2716	0.1706	15.9268	55.57	0.0175

* = Significant No other variable met the 0.1000 significance level for entry into the model.

Table C-10 Growth rate. Pond no.1 Forward selection Procedure for Dependent Variable WEIGHT.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	9.5076	9.5076	55.57	0.0175*
Error	2	0.3422	0.1711		
C Total	3	9.8498			

R-square = 0.9653

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-0.9568	0.4121	0.9225	5.39	0.1459
Length	0.7591	0.1018	9.5076	55.57	0.0175

* = Significant No other variable met the 0.1000 significance level for entry into the model.

Table C-11 Growth rate. Pond no.2 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	219.9252	219.9252	421.22	0.0001**
Error	7	3.6548	0.5221		
C Total	8	223.5800			

R-square = 0.9837

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	1.4349	0.3863	7.2036	13.80	0.0075
Weight	0.9371	0.0457	219.9252	421.22	0.0001

** =Highly Significant No other variable met the 0.1000 significance level for entry into the model.

Table C-12 Growth rate. Pond no.2 Forward selection Procedure for Dependent Variable WEIGHT.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	246.3409	246.3409	421.22	0.0001**
Error	7	4.0937	0.5848		
C Total	8	250.4346			

R-square = 0.9837

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-1.3980	0.4663	5.2578	8.99	0.0200
Length	1.0497	0.0511	246.3409	421.22	0.0001

** =Highly Significant No other variable met the 0.1000 significance level for entry into the model.

Table C-13 Growth rate. Pond no.3 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	28.3937	28.3937	104.04	0.0622 NS
Error	1	0.2729	0.2729		
C Total	2	28.6667			

R-square = 0.9905

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	1.2870	0.3813	3.1091	11.39	0.1834
Weight	0.7475	0.0733	28.3937	104.04	0.0622

NS = No Significant No variable met the 0.1000 significance level for entry into the model.

Table C-14 Growth rate. Pond no.3 Forward selection Procedure for Dependent Variable WEIGHT.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	50.3279	50.3279	104.04	0.0622 NS
Error	1	0.4838	0.4838		
C Total	2	50.8117			

R-square =0.9905

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-1.6750	0.6230	3.4969	7.23	0.2267
Length	1.3250	0.1299	50.5279	104.04	0.0622

NS = No Significant No variable met the 0.1000 significance level for entry into the model.

Table C-15 Growth rate. Pond no.4 Forward selection Procedure for Dependent Variable LENGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	78.6061	78.6061	15.97	0.0104*
Error	5	24.6082	4.9216		
C Total	6	103.2143			

R-square = 0.7616

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	3.4099	1.3370	32.0149	6.50	0.0512
Weight	0.9492	0.2375	78.6061	15.97	0.0104

* = Significant No other variable met the 0.1000 significance level for entry into the model.

Table C-16 Growth rate. Pond no.4 Forward selection Procedure for Dependent Variable WEIGTH.

Source	DF	SS	MS	F Value	Prob >F
Regression	1	66.4440	66.4440	15.97	0.0104*
Error	5	20.8008	4.1602		
C Total	6	87.2448			

R-square = 0.7616

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F Value	Prob >F
Intercep	-1.6906	1.7044	4.0930	0.98	0.3668
Length	0.8023	0.2008	66.4440	15.97	0.0104

* = Significant No other variable met the 0.1000 significance level for entry into the model.

SAS , 1999 CORRELATION ANALYSIS

2 'VAR' Variables: LENGTH WEIGHT

Simple Statistics

Variable	N	Mean	Std Dev	Sum
LENGTH	23	6.37826	4.52919	146.70000
WEIGHT	23	4.63348	4.64574	106.57000

Simple Statistics

Variable	Minimum	Maximum
LENGTH	0	15.00000
WEIGHT	0	14.71000

CORRELATION ANALYSIS

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 23

	LENGTH	WEIGHT
LENGTH	1.00000	0.93726
	0.0	0.0001
WEIGHT	0.93726	1.00000
	0.0001	0.0

Stepwise Procedure for Dependent Variable LENGTH

Step 1 Variable WEIGHT Entered R-square = 0.87846407 C(p) = 2.00000000

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	1	396.45006967	396.45006967	151.79	0.0001
Error	21	54.84906077	2.61186004		
Total	22	451.29913043			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	2.14441283	0.48130473	51.84733351	19.85	0.0002
WEIGHT	0.91375157	0.07416668	396.45006967	151.79	0.0001

Bounds on condition number: 1, 1

Summary of Stepwise Procedure for Dependent Variable LENGTH

Step	Variable Entered Removed	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	WEIGHT	1	0.8785	0.8785	2.0000	151.7884	0.0001

Forward Selection Procedure for Dependent Variable LENGTH

Step 1 Variable WEIGHT Entered R-square = 0.87846407 C(p) = 2.00000000

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	1	396.45006967	396.45006967	151.79	0.0001
Error	21	54.84906077	2.61186004		
Total	22	451.29913043			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	2.14441283	0.48130473	51.84733351	19.85	0.0002
WEIGHT	0.91375157	0.07416668	396.45006967	151.79	0.0001

Bounds on condition number: 1, 1

No other variable met the 0.0500 significance level for entry into the model.

Summary of Forward Selection Procedure for Dependent Variable LENGTH

Step	Variable Entered	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	WEIGHT	1	0.8785	0.8785	2.0000	151.7884	0.0001

APPENDIX

D

THE GENERAL ABOUT EXPERIMENTS

Table D-1 Production performance of shrimp.

Pond.	Stocking(PL)	Feed(kg)	Wet weight(kg)	FCR	%Survival
No.1	200,000	1,100	-	-	Died
No.2	200,000	2,400	1,800	1.33	54%
No.3	300,000	1,820	-	-	Died
No.4	250,000	3,000	2,300	1.30	65%

Table D-2 The suitable level of selected environmental parameters important for giant tiger in intensive culture farms.

Parameters	A	B	C
TEM (^{o}C)	28-33	22-29	25-30
pH	8-8.5	7.8-8.3	
Salinity(ppt)	15-25	10-20	13-15
DO(mg/l)	>5	>3	4
NH_3(mg/l)	<0.1	<0.1	4.6
NO_2^-(mg/l)	0.25		
H_2S(mg/l)	<0.02	<0.1-2	<1.3
Fe(mg/l)	1.0		

A ; CHENG-I LIU, 1997

B ; Thrimsongruchamee, 1987

C ; Nulplub, 1987

Table D-3 Major Constituents of Seawater.

Constituent	mg/kg(ppm)
Sodium(Na^+)	10,500
Magnesium(Mg^{2+})	1,350
Calcium(Ca^{2+})	400
Potassium(K^+)	380
Chloride(Cl^-)	19,000
Sulfate(SO_4^{2-})	2,700
Bicarbonate(HCO_3^-)	142
Bromide(Br^-)	65
Other solids	34
Total dissolves solids	34,500
Water (balance)	965,517

Source: Snoeyink, 1980

Table D-4 Typical Analyses of Surface and Ground water in United States.

Constituent, mg/liter	A	B	C
SiO_2	9.5	1.2	10
Fe(III)	0.07	0.02	0.09
Ca^{2+}	4.0	36	92
Mg^{2+}	1.1	8.1	34
Na^+	2.6	6.5	8.2
K^+	0.6	1.2	1.4
HCO_3^-	18.3	119	339
SO_4^{2-}	1.6	22	84
Cl^-	2.0	13	9.6
NO_3^-	0.41	0.1	13
Total dissolves solids	34	165	434
Total hardness as $CaCO_3$	14.6	123	369

A. Pardee Reservoir, East Bay Municipal Utility District, Oakland, Calif. Average data for 1976.

B. Niagara River, Niagara Fall, N.Y.

C. Well Water, Dayton, Ohio.

Source: Snoeyink, 1980

Table D-5 International System (SI metric) and U.S. Customary Unit Conversion Table.

To convert from	To	Multiple
Length	**Unit symbol**	
in.	mm	25.4
	m	0.0254
	miles	1000
	ft	0.083
cm	mm	10
	m	0.01
	miles	394.0
	in	0.394
	ft	0.0328
Area	**Unit symbol**	
acres	m^2	4050.0
	ha	0.405
	ft^2	43,560
m^2	ha	0.0001
	ft^2	10.8
	yd^2	1.2
ha	m^2	10,000
	acre	2.47
Volume	**Unit symbol**	
ml	L	1000
	cm^3	1.0
L	ml	1000
	m^3	0.001
	ft^3	0.035
	gal	0.264
m^3	L	1000
	gal	264
	ft^3	35.3

Source: Yoo and Boyd, 1994

Table D-6 The percentages of un-ionized hydrogen sulfide in water at different pH values.

pH	Factor	$\%H_2S$
5	0.99	99
5.4	0.97	97
6.0	0.89	89
6.4	0.76	76
7.0	0.44	44
7.4	0.24	24
8.0	0.07	7
8.4	0.03	3
9.2	0.005	3

Source: APHA, 1980.

Table D-7 The percentages of total Ammonia in the un-ionized (NH_3) form for a few temperature and pH values.

	pH				
Temperature(°c)	6.5	7.0	7.5	8.0	8.5
10[a]	0.06	0.2	0.6	1.8	5.6
15[a]	0.09	0.3	0.9	2.78	8.0
16	0.1	0.3	0.9	2.9	8.5
18	0.1	0.3	1.1	3.3	9.8
20[a]	0.1	0.4	1.2	3.8	11.2
22	0.1	0.5	1.4	4.4	12.7
24	0.2	0.5	1.7	5.0	14.4
26	0.2	0.6	1.9	5.8	16.2
28	0.2	0.7	2.2	6.6	18.2
30[a]	0.3	0.8	2.5	7.5	20.5

Source; Emerson *et. al.* 1975

[a] APHA, 1980

Figure D-1 Map showing the location of Chacherngsao provice and study area.

APPENDIX

E

ANALYTICAL METHOD

E.1 Method of water analysis

TEMPERATURE

Apparatus

Mercury termometer

Procedure

1. Determine temperature of water sample at field.
2. Drip mercury thermometer in water sample and reading temperature.
3. Record temperature (°C)

PH (Glass Electrode Method)

Apparatus

pH meter (Metrolm 654 pH-meter)

Reagents

Buffer Solutions 4 and 7

Procedure

1. Standardizing instrument with buffers pH4, pH7.
2. Determine pH of water sample, unfiltered.
3. Equilibrium, as shown by absence of drift, must be established before read are accepted.

SOLUBLE SALTS (Electrical Conductivity Method)

Apparatus

1. Conductivity meter (Shot model cg 150)

Reagent

1. Potassium chloride standard solution 0.01 M Dissolve 745.6 mg KCl in distilled water and dilute to 1L. Solution has specific conductance of 1.4118 mmhos per cm. (ds/m) at 25°C

Procedure

1. Using the potassium chloride standard solution calibrated the conductivity meter according to instrument instructions.
2. Record the electrical conductivity reading for sample when it has reached the same temperature as the reference solution.

TOTAL SOLIDS

Apparatus

1. Hot air oven
2. Hot plate or water bath
3. Evaporating dish

Procedure

1. Bring crucible in to oven at 130 °C for 1 hour.
2. Then stand by for cool in desiccator and weight (A).
3. Pipette water sample 50 ml in to evaporating dish .
4. Evaporate to dryness.
5. Heat to constant weight at 100 - 103 °C.
6. Stand by for cool in dessicator and weight (B).

Calculation

$$\text{Total solids (mg/l)} = \frac{(B-A)(1000)}{\text{ml of sample}}$$

DISSOLVED SOLIDS AND SUSPENED SOLIDS

Apparatus

1. Hot air oven
2. What man GF/C
3. Hot plate or water bath
4. Vacuum Suction

Procedure

1. Bring Whatman GF/C paper in oven at 103°C for 1 hour.
2. Cool in dessiccator and weight (A).
3. Pipette sample 200 ml in to filter set with Whatman GF/C.
4. Suction sample of water.
5. Bring Whatman GF/C paper in to oven at 103°C for 1 hour.
6. Cool in desiccator and weight (B)

Calculation

$$\text{Suspended solids (mg/l)} = \frac{(B-A)(1000)}{\text{ml of sample}}$$

Dissolved solids (mg/l) = Total solids - Suspened solids

CHLORIDE (Mohr method)

Apparatus

1. Burette
2. Erlenmeyer flask
3. Pipette
4. Hot air oven

Reagents

1. Potassium chromate indicator: Dissolve 5 g K_2CrO_4 powder in 100 ml water.

2. Standard silver nitrate, 0.0141N. Dissolve 2.395 g $AgNO_3$ in water and dilute to 1L. Standardize against 0.0141N NaCl. Store in amber colored bottle.

3. Standard sodium chloride, 0.0141N. Dissolve 0.8241 g NaCl (dried at 140°C) In choride – free water and dilute to 1 L.

Procedure

1. Sample preparation: Use a 100 ml sample or a suitable aliquot diluted to100 ml.
2. Add 1 ml K_2CrO_4 indicator.
3. Titrate with the standard $AgNO_3$ to a pinkish yellow endpoint.
4. Make a blank by using distilled water.

Calculation

$$Cl^- \text{ (mg/l)} = \frac{(A-B) \times N \times 35{,}450}{\text{ml sample}}$$

A = ml silver nitrate used in sample

B = ml silver nitrate used in blank

N = normality of $AgNO_3$

35,450 = milliequivalent weight of Cl^-

TOTAL ALKALINITY

Apparatus

pH meter (Metrolm 654 pH-meter)

Reagents

1. Methyl orange indicator
2. Sulfuric acid 0.025 M

Procedure

1. Pipette water sample 50 ml into an Erlenmeyer flask.
2. Add 2 drops methyl orange to the solution.
3. Titrate with the standard acid to the proper equivalence point. The indicator changes to orange at pH 4.6 and to pink at pH 4.0

Calculation

$$\text{Total alkalinity as } CaCO_3 \text{ (mg/l)} = \frac{\text{ml } H_2SO_4}{\text{ml Sample}} \times \frac{M\ H_2SO_4 \times 100 \text{ g}}{\text{g mole}} \times \frac{1000 \text{ mg}}{\text{g}}$$

OXYGEN DISSOLVED
(Membrane Electrode Method)

Apparatus

1. Oxygen sensitive membrane electrode with appropriate meter

Procedure

1. Callibrate the membrane electrode against a water sample of known the concentration.
2. Calibrate with the sample of water under test.
3. Measurement sample.
4. Records data (mg/l)

OXYGEN DISSOLVED

(Azide Modification Method)

Reagents

1. Alkaline iodide-sodium azide solution ($I-NaN_3$): Dissolve 500 g NaOH (or 700 g KOH) and 135 g NaI (or 150 g KI) in H_2O, dilute to 950 ml, and cool. Slowly, with stirring, add solution of 10 g NaN_3 in 40 ml H_2O. Diluted and acidified solution must not give color with starch indicator. Store in dark bottle with rubber stopper.

2. Manganese sulfate solution ($MnSO_4$): Dissolve 364 g $MnSO_4H_2O$ in H_2O, filter and dilute to 1 L. No more than trace of I_2 should be liberated when solution is added to acidified KI solution.

3. Potassium Biiodate standard solution ($KH(IO_3)_2$ 0.025N): Dissolve 0.8125 g $KH(IO_3)_2$ in H_2O in 1 L volumetric flask and dilute to volume.

4. Sodium thiosulfate standard solutions ($Na_2S_2O_3$0.1N.): Dissolve 25 g $Na_2S_2O_3.5H_2O$ in H_2O, add 1 g NaOH or 5 ml $CHCl_3$, and dilute to 1 L. Standardize against $KH(IO_3)_2$ or $K_2Cr_2O_7$. Sodium thiosulfate solutions ($Na_2S_2O_3$0.025N.): Dilute 250 ml 0.1N $Na_2S_2O_3$ to 1 L, 1 ml = 0.2 mg O_2.

5. Starch indicator solution: Disperse 5-6 g potato or arrow-root starch in mortar with few ml H_2O. Pour into 1 L boiling H_2O, boil few min, and let settle overnight. Decent clear solution and preserve with 1.3 g salicylic acid or few drops toluene.

Procedure

Add 2.0 ml $MnSO_4$ solution and 2.0 ml alkaline $I-NaN_3$ solution to sample in 250 or, 300 ml BOD bottle, replace stopper, excluding air bubbles, and invert several times to mix. Let floc settle and repeat mixing. After floc has settled, leaving $\geq$100 ml clear supernate, remove stopper and add 2.0 ml H_2SO_4 down neck of bottle. Restopper and mix by inversion until I_2 is uniformly distributed. Immediately titrate 203 ml (3 ml is allowance for added reagents) with 0.025N $Na_2S_2O_3$ to pale straw yellow. Add 1-2 ml starch indicator and titrate to disappearance of blue. Disregard reappearance of blue.

Calculation

$$DO\ (mg/l) = (ml\ 0.025\ N\ Na_2S_2O_3 \times \frac{0.2}{200}) \times 1000$$

CHEMICAL OXYGEN DEMAND
(Titrimetric method)

Apparatus

1. Reflux apparatus, consisting of 250 ml, erlenmeyer flasks with ground - glass, condenser and a hot plate

Reagents

1. Standard potassium dichromates solution 0.0417 M: Dissolve 12.2590 g $K_2Cr_2O_7$, primary standard grade, previously dried at 103°C. for 2h, in distilled water and dilute to 1000 ml.

2. Sulfuric acid reagent: Add Ag_2SO_4, reagent grade to conc. H_2SO_4 at the rate of 5.5 g $AgSO_4$/HgH_2SO_4 Let stand 1 to 2 day to dissolve Ag_2SO_4.

3. Ferroin indicator solution: Dissolve 1.485 g. 1, 10 phenanthroline monohydrate and 695 mg $FeSO_4.7H_2O$ in distilled water and dilute to 100 ml. This indicator solution may be purchased already prepared

4. Standard ferrous ammonium sulfate (0.25 M FAS) :

Dissolve 98 g $Fe(NH_4)_2(SO_4)_2.6H_2O$ in distilled water add 20 ml conc. H_2SO_4, cool and dilute to 1000 ml. Standardize this solution daily againts standard $K_2Cr_2O_7$ solution as follows:

Dilute 10.0 ml standard $K_2Cr_2O_7$ to about 100 ml. Add 30 ml conc. H_2SO_4 and cool. Titrate with FAS titrant using 0.10 to 0.15 ml ferroin indicator.

$$\text{Molarity of FAS solution} = \frac{\text{Volume } 0.041 \text{ M } K_2Cr_2O_7 \times 0.25}{\text{Volume FAS used in titration (ml)}}$$

5. Mercuric sulfate, $HgSO_4$, powder

6. Sulfamic acid

7. Potassium hydrogen phthalate (KHP) standard: Lightly crush and then dry potassium hydrogen phthalate ($HOOCC_6H_4COOK$) to constant weight at 120°C. Dissolve 425 mg in distilled water and dilute to 1000 ml. KHP has a theoretical COD of 1.176 mg. O_2/mg. and this solution has a theoretical COD of 500 μgO_2/ml.

Procedure

1. Place 0.4 g $HgSO_4$ in a refluxing flask. Add 20 ml sample. (10 ml sample diluted to 20 ml with distilled water)

2. Add 10 ml standard $K_2Cr_2O_7$ solution and glass beads.

3. Connect the ground glass condenser

4. Slowly add 30 ml concentrated H_2SO_4 containing the Ag_2SO_4 through the open end of condenser, mixing thoroughly while adding the acid

5. Reflux for 2 hours

6. Cool and rinse condenser with distilled water

7. Dilute the mixture to about 140 ml with distilled water cool

8. Titrate the excess dichromate with the standard ferrous ammonium sulfate using ferroin indicater (End-point a sharp color change from blue-green to reddish brown)

9. Reflux in the same manner a blank consisting of 20 ml distilled water

Calculation

$$\text{COD (mg/l)} = \frac{(a-b)xMx8{,}000}{\text{ml. sample}}$$

a = ml $Fe(NH_4)_2(SO_4)_2.6H_2O$ used for blank
b = ml $Fe(NH_4)_2(SO_4)_2.6H_2O$ used for sample
M = Molarity of $Fe(NH_4)_2(SO_4)_2.6H_2O$

AMMONIA NITROGEN

Apparatus

1. Distillation apparatus
   - 800 ml borosilicate glass flask
   - condenser
2. Heating mantal
3. pH meter

Reagents

1. Distilled water

2. Borate buffer solution: Add 88 ml 0.1M NaOH Solution to 500 ml approximately 0.025 M Sodium tetraborate ($Na_2B_4O_7$) solution (9.5g $Na_2B_4O_7.10\ H_2O$/L) and dilute to 1 L.

3. Sodium hydroxide, 6M.
4. Sodium hydroxide, 1M.
5. Sulfuric acid 1N.
6. Boric acid 2%: Dissolve 20 g H_3BO_3 in water and dilute to 1L.
7. Mixed indicator
8. Sulfuric acid, 0.01N

Procedure

1. Add 500 ml water and 25 ml borate buffer.
2. Adjust pH to 9.5 with 6N NaOH solution using a pH meter.
3. Transfer to a distillation flask.
4. Add a few glass beads
5. Distil 300 ml at 6-10 ml/min in to 50 ml H_3BO_3 solution
6. Titrate ammonia in distillate with standard 0.01N H_2SO_4 titrant until indicator turns pink.
7. Blank: Carry a blank through all steps of the procedure but used distilled water.

Calculation

$$NH_3 - N\ (mg/l) = \frac{(A - B)xZ}{ml\ sample}$$

A = Volume of H_2SO_4 titrated for sample, ml and

B = Volume of H_2SO_4 titrated for blank, ml

Remark:

Sample titration 1 ml = 14 x normality of H_2SO_4 x 1000 µg Nitrogen = Z

TOTAL NITROGEN

Apparatus

1. Digestion apparatus
   - 800 ml borasilicate glass flask
   - heating mantal
2. Distillation apparatus
   - Condensor

Reagents

1. Distilled water
2. Digestion reagent: Dissolve 134 g K_2SO_4 and 7.3 g $CuSO_4$ in about 800 ml water. Add 134 ml conc. H_2SO_4. When it has cooled to room temperature, dilute to 1L.
3. Sodium hydroxide - sodium thiosulfate reagent : Dissolve 500 g NaOH and 25 g $Na_2S_2O_3 . 5H_2O$ in water and dilute to 1L.
4. Borate buffer: See NH_3
5. Sodium hydroxide, NaOH 6N

Procedure

1. Place sample into 800 ml Kjeldahl flask.
2. Add 50 ml digestion reagent and a few glass beads.
3. Boil briskly until the volume to about 25 to 50 ml.
4. digestion continues, colored samples will become transparent and pale green.
5. Let cool, dilute to 300 ml with water and mix.
6. Carefully add 50 ml sodium hydroxide thiosulfate reagent to form an alkaline layer at flask bottom (pH>11.0)
7. Connect flask to a steamed-out distillation apparatus.
8. Distill and collect 200 ml distillate. Use boric 50 ml and mixed indicator 2-3 drops as absorbent solution when ammonia is to be determined.
9. Titrate ammonia with standard 0.1N H_2SO_4 titrant until indicator turns pink.

Calculation

$$\text{Total - N (mg/l)} = \frac{(A - B)xZ}{\text{ml sample}}$$

A = Volume of H_2SO_4 titrated for sample, ml and
B = Volume of H_2SO_4 titrated for blank, ml

Remark:

Sample titration 1 ml = 14 x normality of H_2SO_4 x 1000µgNitrogen = Z

ORGANIC NITROGEN

Apparatus

1. Digestion apparatus
   - 800 ml borasilicate glass flask
   - heating mantal
2. Distillation apparatus
   - Condensor

Reagents

1. Distilled water
2. Digestion reagent: Dissolve 134 g K_2SO_4 and 7.3 g $CuSO_4$ in about 800 ml water. Add 134 ml conc. H_2SO_4. When it has cooled to room temperature, dilute to 1L.
3. Sodium hydroxide - sodium thiosulfate reagent: Dissolve 500 g NaOH and 25 g $Na_2S_2O_3 \cdot 5H_2O$ in water and dilute to 1L.
4. Borate buffer: See NH_3
5. Sodium hydroxide, NaOH 6N

Procedure

1. Ammonia removal: Ammonia has been determined by distillation method, the reagent for ammonia determination

2. Used residue in 800 ml Kjeldahl flask for organic determination.

2. Add 50 ml digestion reagent and a few glass beads.

3. Boil briskly until the volume to about 25 to 50 ml.

4. digestion continues, colored samples will become transparent and pale green.

5. Let cool, dilute to 300 ml with water and mix.

6. Carefully add 50 ml sodium hydroxide thiosulfate reagent to form an alkaline layer at flask bottom (pH>11.0)

7. Connect flask to a steamed-out distillation apparatus.

8. Distill and collect 200 ml distillate. Use boric 50 ml and mixed indicator 2-3 drops as absorbent solution when ammonia is to be determined.

9. Titrate ammonia with standard 0.1N H_2SO_4 titrant until indicator turns pink.

Calculation

$$\text{Org-N (mg/l)} = \frac{(A - B) \times Z}{\text{ml sample}}$$

A = Volume of H_2SO_4 titrated for sample, ml and

B = Volume of H_2SO_4 titrated for blank, ml

Remark:

Sample titration 1 ml = 14 x normality of H_2SO_4 x 1000 μg Nitrogen = Z

SULFATE (Turbidimetric method)

Apparatus

1. UV-Visible spectrophotometer for use at 420 nm.

Reagents

1. Conditioning reagent: Mix 50 ml. glycerol with a solution containing 30 ml concentrated HCl, 300 ml distilled water 100 ml 95% ethyl alcohol and 75 g NaCl.

2. Barium chloride, crystals, 20-30 mesh.

3. Standard sulfate solution Dissolve 147.9 mg. anhydrous sodium sulfate, Na_2SO_4, in distilled water and dilute to 1,000 ml.

Procedure

1. Measure 5 ml sample made up to 100 ml into a 250 ml erlenmeyer flask
2. Add 5 ml conditioning reagent and mix in the stirring apparatus
3. Add a spoonful of $BaCl_2$ crystals and note the time stir for exactly 1 minute at constant speed
4. Immediately after the stirring period, pour some of the solution into absorption cell of photometer and measure at 420 nm.
5. Estimate the sulfate concentration in the sample by comparing with sulfate standards carried through the entire procedure as the sample

Calculation

$$SO_4^{2-} \text{ (mg/l)} = \frac{\text{mg } SO_4^{2-} \times 1000}{\text{ml sample}}$$

PHOSPHORUS

(Vanadomolybdophosphoric Acid Colorimetric Method)

Apparatus

1. UV-Visible spectrophotometer
2. Hot plate
3. Evaporating dish

Reagents

1. Phenolphthalein indicator
2. Hydrochloric acid, concentrated
3. Activated carbon
4. Vanadate-molybdate reagent
   a. Solution A: Dissolve 25 g. ammonium molybdate $(NH_4)_6Mo_7O_{24}.4H_2O$ in 400 ml. distilled water.
   b. Solution B: Dissolve 1.25 g. ammonium
5. Standard phosphate solution: Dissolve in distilled water 0.2195 g/$KHPO_4$ and dilute to 1000ml: 50 μg PO_4^{3-}-P

Procedure

1. Pipette sample 35 ml in a 50ml volumetris flask.
2. Add 10 ml vanadate - molybdate reagent and dilute to the mark with distilled water. (Blank used 35 distilled water is substituted for sample)

3. After 10 minute measure absorbance of sample versus a blank at a wavelength of 400 nm.

4. Preparating of calibration curve: Plot a family of calibration curves at 400 nm. Analyze at least one standard with each set of sample.

Calculation

$$PO_4^{3-}\text{-P (mg/l)} = \frac{\text{mg.P(in 50 ml final volume)} \times 1000}{\text{ml sample}}$$

IRON (AAS)

Apparatus

1. Hot plate
2. Erlenmeyer flasks 125 ml.
3. Volemetric flasks 50 ml.

Funnels

5. Whattmann # 42

Reagents

1. Methyl orange indicator solution
2. Sulfuric acid, Conc. H_2SO_4
3. Nitric acid, Conc. HNO_3
4. Standard Fe^{2+} 1000 ppm.

Procedure

1. Mix sample and pipet 100 ml into a erlenmeyer flask.

2. Acidified sample (If sample in not already acidified, acidity to methyl orange end point with conc. H_2SO_4.

3. Add 5 ml Conc. HNO_3 and a few glass beads bring to slow boil on hot plate and evaporate to 15 to 20 ml.

4. Add 5 ml conc. HNO_3 and 10 ml Conc. H_2SO_4. Evaporation to fumes of SO_3. Heat to remove all HNO_3 until the solution is clear.

5. Cool and filter diluted sample and adjust to 50 ml with distilled water

6. Take portions of the solution for metals determination

7. Records data

Remark: Blank follow 1- 6 step but used distilled water instead.

Instrument Condition

HC Lamp	8 mA.	WL	248 nm.
Slit	0.2 nm.	Mode	BGC
Flame	Air-C_2H_2	Fuel	20 L/min
Oxidant	8 L/ min	Burner	10 cm.
Signal proc	Integ hold	Pre-spray	3 sec.
Integ time	5 sec	Repeat	1
Max-N	1	CV	99 %
Response	Response 2	Expansion	1
Chart speed	10 mm./min	Standard Fe:	Rang 0-25 PPM.

Calculation

$$\text{Fe (mg /l)} = \frac{\text{mg. Fe (from calibration curve) x final volume x 1000}}{\text{1000 x ml sample}}$$

$$= \frac{\text{mg. Fe (from calibration curve) x final volume}}{\text{ml sample}}$$

E.2 Methods of soil sediment analysis

pH (Potentiometric Method)

Apparatus

1. pH meter
2. Balance

Reagents

1. Standard buffer solution of pH 4.0 and pH 7.0

Procedure

1. Weight 10 g soil into a 50 ml beaker.
2. Add 50 ml distilled water. Stir thoroughly.
3. Let stand for 1 hr, stirring 2 or 3 times during the hour.
4. Calibrate the pH meter using the standard buffer solutions of pH 4.0 and 7.0.
5. Stir the sample and immediately determine the pH to the nearest 0.1 pH unit.
6. Rinse electrodes with distilled water and wipe tissue paper.
7. Record data.

SOLUBLE SALTS (Electrical Conductivity Method)

Reagents

1. Potassium chloride reference solution, 0.01 N KCl (Dissolve 0.7456 g of KCl in distilled water and dilute the solution to a volume of 1 L at 25°C. This solution has a conductivity of 1.4118 mmhos per cm (ds/m).

Apparatus

1. Conductivity meter.
2. Suction filtration apparatus.

Procedure

1. Weight 10g of soil and add 50ml of distilled water in a 125 ml Erlenmeyer flask.
2. Stirred for prepare a saturate soil, stand at least 30 min.
3. Transfer the saturated soil paste to Buchner funnel and used Whatman No.42. Collect an aliquot in a 25 ml receiving flask.
4 Using the reference solution, calibrated the conductivity meter according to instrument instructions.
5. Record the electrical conductivity reading for saturated extract when it has reached the same temperature as the reference solution.

EXCHANGEABLE ALUMINIUM

Apparatus

1. Balance, accurate to 0.05 g

Regents

1. Potassium chloride 1N, pH 7.0: Dissolve 372 g potassium chloride to 5L. Check pH.
2. Sodium hydroxide, 0.05 N
3. Hydrochloric acid, 0.05 N
4. Sodium fluoride, 1N. Dissolve 42 g sodium fluoride to 1 L.

Procedure

1. Transfer 10 g soil to filter paper Whatman No.42 in a funnel in a 100 ml flask.
2. Add nine to 10 ml portions of 1N KCl at approximately 13 - minutes intervals so that the leaching process takes not less than 2 hours.
3. Adjust the volume of the leachate to 100 ml with 1 N KCl.
4. Measure its pH value if the pH of the soil in 1 N KCl has not been determined.
5. Transfer 50ml of soil extract to a 125 Erlenmeyer flask and add 10 ml of 1 N NaF and add 2-3 drops of phenopthalene the solution becomes pink if exchangeable aluminum is present due to the lease of hydroxide ions from the aluminum hydroxide.
6. Titrate with 0.05 N hydrochloric acid until the solution is colorless for atleast a min.

Calculation

Since milliequivalent (meq.) = N x V

V = volume in ml of 0.05 N hydrochloric acid used in the titration, and

N = 0.05 normal hydrochloric acid

$$\text{meq. } Al^{3+}/100 \text{ g soil} = 0.05 \times V \times 2 \times 10$$

where :

$$2 = \frac{100 \text{ ml extractant}}{50 \text{ ml aliquot}}$$

$$10 = \frac{100\text{g}}{10\text{g soil}}$$

EXCHANGE HYDROGEN

Apparatus

1. Balance, accurate to 0.05 g

Regents

1. Potassium chloride1N, pH 7.0: Dissolve 372 g potassium chloride to 5 L. Check pH.
2. Sodium hydroxide, 0.05 N
3. Sodium fluoride, 1N. Dissolve 42 g sodium fluoride to 1 L.

Procedure

1. Transfer10g soil to a filter paper Whatman No.42 in a funnel in a 100 ml. flask.
2. Add nine to 10 ml portions of 1N KCl at approximately 13-minutes intervals so that the leaching process takes not less than 2 hours.
3. Adjust the volume of the leachate to 100 ml with 1N KCl.
4. Measure its pH value if the pH of the soil in 1N KCl has not been determined.
5. Transfer 50 ml of soil extract to a 150 or 200 ml erlenmeyer flask and add 10 ml of 1N NaF; the solution becomes pink if exchangeable aluminum is present due to the lease of hydroxide ions from the aluminum hydroxide.
6. Titrate with 0.050N Sodium hydroxide until the solution is pink for at least a min.

Calculation

Since milliequivalent (meq.) = N x V

V = volume in ml of 0.05N Sodium hydroxide used in the titration, and

N = 0.05 normal Sodium hydroxide

$$\text{meq. } H^{+}/100 \text{ g soil} = 0.05 \times V \times 2 \times 10$$

where :

$$2 = \frac{100 \text{ ml extractant}}{50 \text{ ml aliquot}}$$

$$10 = \frac{100\text{g}}{10\text{g soil}}$$

ORGANIC MATTER (Dry ash method)

Apparatus

1. Small porcelain crucibles (10-15 ml)
2. Muffle furnace
3. Desiccator and desiccant
4. Balance

Procedure

1. Tare a clean crucible
2. Add about 2 g of air-dried soil.
3. Place the sample in an oven at 105°C for 24-48 hour.
4. Remove the sample, cool in a desiccator, and weight.
5. Place the sample in a muffle furnace at 350°C for 8 hour.
6. Remove from the furnace, cool in a desiccator, and reweigh.

Calculation

Organic matter concentration as follows :

$$OM = 100 - \frac{W_F - W_T}{W_{TS} - W_T}$$

Where:

OM = organic matter concentration (%)

W_F = weight of crucible and soil after ashing (g)

W_T = tare weight of crucible (g)

W_{TS} = tare weight of crucible and oven dry soil (g)

CEC (Ammonium Acetate Method)

Apparatus

1. Vacuum pump

Regents

1. Ammonium acetate solution (NH_4OAc), 1N pH 7.0. Dilute 114 ml of glacial acetic acid (99.5%) with water to a volume of approximately 1 L. Then add 138 ml of concentrated ammonium hydroxide (NH_4OH), and add water to obtain a reaction of pH 7.0, and dilute the solution to a volume of 2 L with water. Alternatively, dissolve 77.08 g of

ammonium acetate crystal in 400 ml of water and dilute the solution to 1 L; Adjust the pH of the resulting solution as in the foregoing procedure.

2. Isopropyl alcohol, 99%

3. Acidified sodium chloride(NaCl), 10% Dissolve 1000 g of NaCl (ammonium free) in 9 L of water and add 500 ml of 0.1 N HCl. dilute to 10 L. This solution is 0.005N in concentration with respect to acidity.

4. Sodium hydroxide solution, 4%

5. Boric acid (H_3BO_3), 2% solution

6. Standard sulfuric acid solution, 0.1 N

7. Mixed indicator. Dissolve 0.099 g of bromocresol green and 0.066 g methyl red in 100 ml of ethanol. Add 0.5 N NaOH cautiously until the solution assumes a reddish purple color at pH ca. 5.

Procedure

1. Weigh 10 g of air-dried soil into a 50-ml beaker.
2. Add 20 ml. of ammonium acetate.
3. Stir for a few minutes and allow to stand overnight.
4. Transfer the contents quantitatively on a Whatman No.42 filter paper or equivalent on a 55-mm Buchner funnel fitted on a 500 ml suction flack.
5. Apply gentle suction with a vacuum pump. After the supernatant liquid is drained, add 10 ml of ammonium acetate at a time on the surface of the soil for 10 times amounting to a total of 100 ml. Disconnect the suction and drain thoroughly. Do not allow the soil to become dry and cracked.
6. Transfer all the leachate to a 250 ml. volumetric flack, make to volume with the NH_4OAc and reserve for the determination of exchangeable cations.
7. Add 10 ml of alcohol in the soil and apply suction.
8. Repeat step 7 five times. Discard washings.
9. Replace the adsorbed ammonium ions (NH_4^+) by sodium ions (Na^+). Add 10 ml of NaCl solution to the soil for ten times to approximate 100 ml of leachate.
10. Transfer all the leachate into Kjeldahl flask and wash with water. Add 20 ml of 4% NaOH.
11. Distill 75 ml into a 125 ml erlenmeyer flask and wash with water. Add 20 ml. of 4% NaOH.
12. Titrate the distillate with standard 0.1N H_2SO_4. The color change is from bluish green to pink at the endpoint.
13. Run blanks on the reagents.

Calculation

CEC is expressed in meq. /100 g soil.

meq. of N in NH_4^+ from = (S - B) x N

where : S = volume of H_2SO_4 used in sample

B = volume of H_2SO_4 used in blank

N = normality of H_2SO_4

Therefore :

$$CEC = \frac{(S-B)xNx100}{W}$$

Where : W = oven dry weight of sample in g

Total Nitrogen (Modified Kjeldahl Method)

Apparatus

1. Macro-Kjeldahl distillation unit
2. Macro-kjeldahl flask, 800 ml.

Reagents

1. Boric acid 4%
2. Bromocresol green and
3. Catalyst mixture. (100 g Potassium sulfate and 7 g Copper sulfate)
4. Sulfuric acid, standard 0.10 N
5. Sodium hydroxide 45%
6. Sulfuric acid, concentrated

Procedure

A. Digestion

1. Weigh 2.5 g soil sample into an 800 ml kjeldahl flask.
2. Add 10 g of catalyst mixture.
3. Add 25 ml of sulfuric acid. Digest the sample until disappearance of blackish color, stop.
4. Allow the flask to cool. Add 300 ml. Water into an 800 ml kjeldahl flask.

B. Distillation

1. To determine the ammonium-N liberated by digestion, Place a 250 ml of the 4% H_3BO_3 indicator solution under the condenser of the distillation set-up so that the end of the condenser in below the surface of the H_3BO_3 solution.

2. Hold the distillation flask at a 45° angle and pour 100 ml of 45% NaOH down the neck so that the alkali reaches the bottom of the flask without mixing with the digest.

3. Attach the flask as quickly as possible to the distillation set-up mix the contents and immediately start the distillation. Check if the flow of cold water through the condenser is sufficient to keep the temperature of the distillate about 35° C.

4. When about 200 ml. of distillate have been collected, lower the receiver flask so that the end of the condenser is above the surface of the distillate.

5. After rinsing the end of the condenser with distilled water, remove the flask and stop the distillation.

6. Determine the ammonium-N on the distillate by titration with 0.10 N standard acid. The color change at the point is from green to pink.

Calculation

$$\%N \text{ in soil} = \frac{(T-B) \times N \times 14}{S} \times 100$$

T = Sample titration, ml. of standard acid
B = Blank titration, ml. of standard acid
N = Normality of standard acid
S = Oven - dry weight of sample in mg.

SULFATE (Turbidimetric Method)

Apparatus

1. Spectrophotometer

Reagents

1. Extracting solution. Dissolve 39 g $NH_4C_2H_3O_2$ in 1 L of 6.25 N acetic acid.
2. Activated charcoal, Darco G-60. Wash with extractant until free of sulfates.
3. Acid seed solution. 6NHCl, containing 20 ppm. of sulfur as K_2SO_4
4. Barium chloride ($BaCl_2.2H_2O$) crystals.
5. Standard sulfate solution.

a. Stock solution, 100 ppmS: dissolve 0.5434 g of K_2SO_4 AR. grade in 300 ml of extracting solution in a volumetric flask, and make the volume to 1 L with more extracting solution.

b. Working solution. From the 100 ppmS. solution Prepare 25 ml standard solutions with the following concentrations: 0, 1.25, 2.5, 5, 10 and 40 ppmS.

Preparation of standard curve

1. Add 0.25 g. of activated charcoal.
2. Filter the solutions through whatman No. 42.
3. Pipette 10 ml of each clear solution into separate 50 ml Erlenmeyer flask.
4. Add 1 ml of acid "seed solution".
5. Place 0.5 g of $BaCl_2.2H_2O$ crystals.
6. Allow the flask to stand for 1 minute and then swirl the contents of the flask frequently until the crystals are dissolved.
7. Transfer the solutions to a colorimeter tube and read at 420 nm. within 2 to 8 minutes.
8. Construct standard curve by plotting percent absorbance against concentration.

Procedure

1. weigh 10 g. of 20 mesh soil in to 50 ml erlenmeyer flask.
2. Add 25 ml of extracting solution.
3. Shake for 30 minutes.
4. Add 0.25 g of charcoal and resume shaking for 3 minutes.
5. Filter the soil suspension through Whatman No.42 paper.
6. Pipette 10 ml of filtrates in to 50 ml. Erlenmeyer flask.
7. Develop and measure the turbidity under the preparation of standard curve (A) starting with step 4.

Calculations

$$SO_4^{2-} \text{ (mg/kg)} = 2.5 \times \text{curve factor} \times \text{Abs.}$$

Phosphorus Bray No. 2 Method

Apparatus

1. Balance, accurate to 0.01 g
2. Mechanical shaker
3. Spectrophotometer

Reagents

1. Chloromolybdic acid reagent, 1.5 percent. dissolve exactly 15.0 g of C.P. ammonium molybdate, $(NH_4)_6Mo_7O_{24}.4H_2O$ in about 300 ml. of distilled water warmed to about 50 °C. Filter the solution to remove sediments if necessary. Cool the molybdate solution and add 350 ml of 10.0 N HCl slowly with rapid stirring. When this solution has cooled again to room temperature, dilute with distilled water to exactly 1000 ml in a volumetric flask. Mix thoroughly and store in a stoppered amber glass with 3.5 N HCl. Replace every 2 months.

2. Stannous chloride stock solution. Dissolve 10 g of reagent grade $SnCl_2.2H_2O$ in 25 ml concentrated HCl. Keep in a dark tightly stoppered bottle. This solution has to be replaced only at 2-month intervals. For each 4-hour interval, work out a freshly diluted stannous chloride solution into 330 ml of freshly boiled, cooled distilled water.

3. Extracting solution (0.1 N HCl and 0.03 N NH_4F). Dissolve 1.11 g of solid NH_4F in 1 L of 0.1 N HCl.

4. Primary phosphate standard, 50 ppm P. Dry Potassium dihydrogen phosphate (KH_2PO_4) and dissolve 0.2195 g in about 400 ml of distilled water in a 1000 ml volumetric flask. Add 15 ml. of 12 N HCl and make the solution to 1000 ml volume. This gives 50 ppm P. Preserve and store in a weathered soft-glass bottle (rather than one of Pyrex) to minimize contamination with arsenic.

5. Secondary standards, 5 ppm P. Get 50 ml of the 50 ppm P stock solution and dilute to 500 ml to produce 5 ppm P standard. Add 7.5 ml 12 N HCl before dilution to diminish microbial activity.

6. Boric acid (0.8M H_3BO_3): Dissolve 50 g of H_3BO_3 in 1 L of distilled water.

Procedure

1. Weigh 2.85 g of crushed and sieved soil sample into 250 ml erlenmeyer flask.

2. Add 20 ml. of the extraction solution (0.03 N NH_4F in 0.1 N HCl) from a pipette. Stopper and shake the bottle for 1 minute.

3. Filter the suspension immediately in a Whatman No.42 filter paper held in a filter tube. The filtrate should be clear. If not, the solution should be quickly poured back through the same filter.

4. Transfer a 5 ml aliquot of the clear filtrate to a 25 ml. volumetric flask after 1 ml has previously been discarded to rinse the pipette.

5. Add 7.5 ml of boric acid.

6. Add first 5 ml of ammonium molybdate reagent and then mix the solution.

7. Finally, add 2.5 ml of freshly diluted stannous chloride reagent with immediate mixing. Dilute the solution to volume with distilled water.

8. After 5 to 6 minutes and before 15 to 20 minutes, read the color in a colorimeter using a red filter (650 nm.)

9. The P standards are made up in the range of 0.1 to 1 ppm P through the same steps as in the procedure including 5 ml of the extracting solution in each 25 ml final volume. A reagent blank is made with each series of determination and is employed for the 100 percent transmittance setting.

Calculation

The concentration of dilute fluoride-dilute acid soluble soil phosphorus is calculated as:

$$P\ (mg/kg.) = P(mg/l)\ \text{in solution} \times \frac{25}{5} \times \frac{20}{2.85}$$
$$= P\ (mg/l)\ \text{in solution} \times 35.05$$

IRON (DTPA Method)

Reagents

1. Diethylene triamine pentaacetic acid, 0.025 M DTPA – Mix 9.83 g DTPA in glass – distilled water and dilute to a volume of 1 L.

2. Triethanolamine, 0.5 M TEA – Mix 74.60 g TEA in glass – distilled water and dilute to 1L.

3. Calcium chloride, 0.05M $CaCl_2$ – Disslove 5.55 g anhydrous $CaCl_2$ in glass – distilled water and dilute to 1L.

4. DTPA extracting solution , 0.05 M DTPA , 0.1 M TEA, and 0.01 M $CaCl_2$ – Combine reagents from steps 1,2 and 3, and dilute to 5 L with glass – distilled water. Adjust the resulting solution after it has set for 12 hour to pH 7.3 with concentrated HCl. Two ml of concentrated HCl is needed to change the pH of the DTPA solution 0.1 units. Store the solution in the refrigerator.

5. Standard solutions

a. Standard stock solutions – These are easily made from commercial standard solutions 1000 mg/l.

b. Used the 1000 mg/l Fe solution to prepare a series of standard solutions containing 0 to 5 or 0 to 10 mg/l of Fe. DTPA should be used in preparing the standard solution.

Apparatus

Atomic absorption spectroscropy

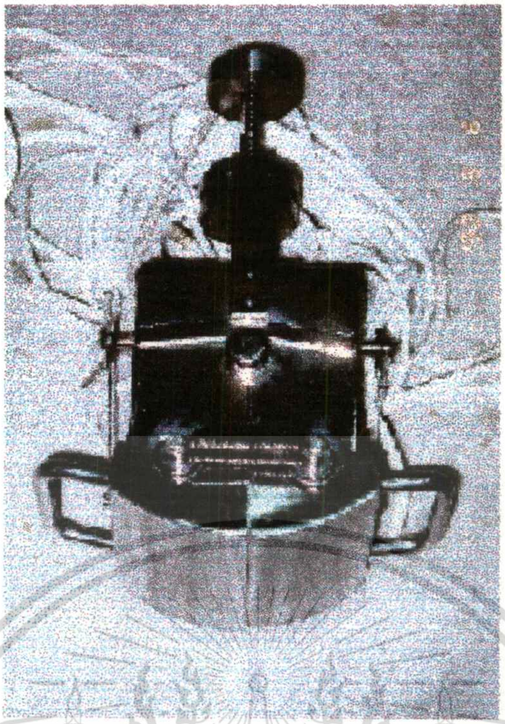
Procedure

1. Weigh 10 g of soil into a 125 Erlenmeyer flask .
2. Add 20 ml of DTPA extracting solution.
3. Shake on mechanical shaker for two hours at a speed fast enough to keep soil in suspension.
4. Immediately filter though a Whattman No.42 or equivalent filter paper. Refilter if filtrate is cloudy.
5. Calibrate the atomic absorption spectrophotometer in accordance with instrument instructions using the prepared stand work solution s. The blank is DTPA extracting solution.
6. Determine the concentration of Fe in the filtrate and report as mg/l Fe in soil in a dry weigh basis.

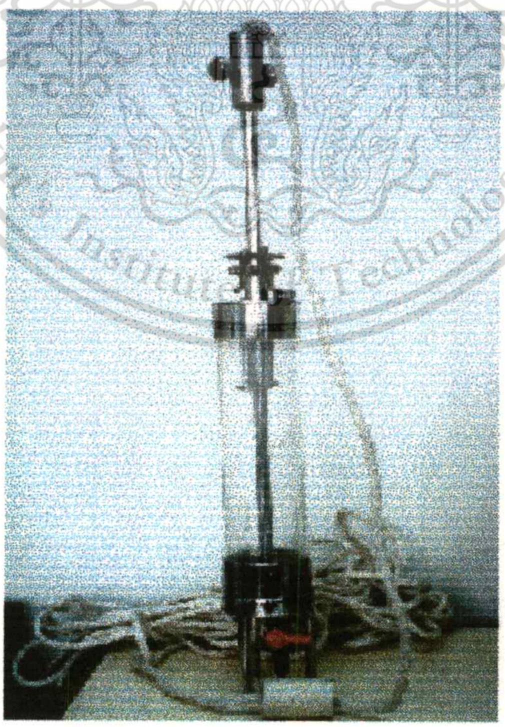
Calculations

$$\text{Fe (mg/kg.)} = \text{mg Fe in soil} \times 2$$

APPENDIX
F
THE EQUIPMENTS



F-1 Soil sampling.



F-2 Water sampling.

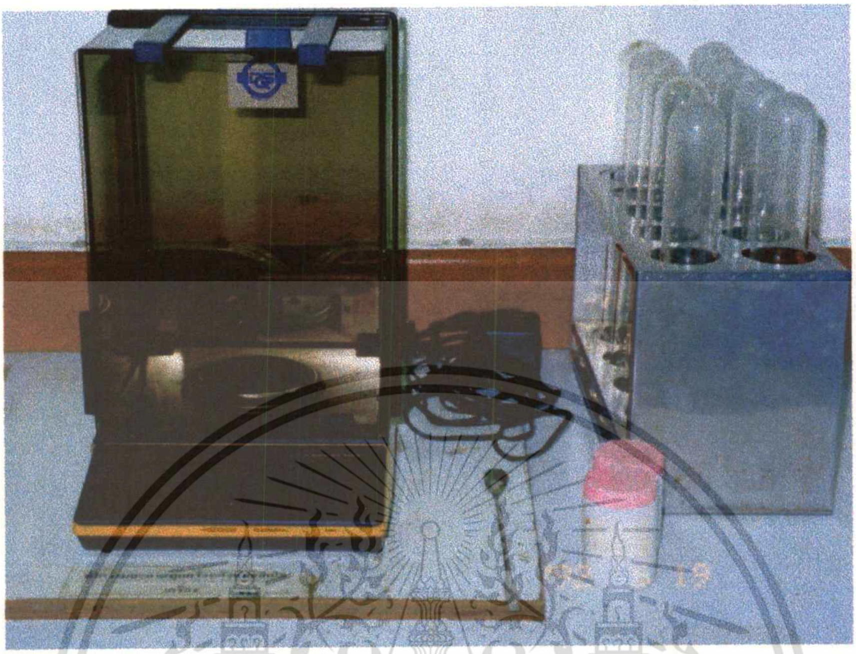


Figure F-3 Analytical balance.

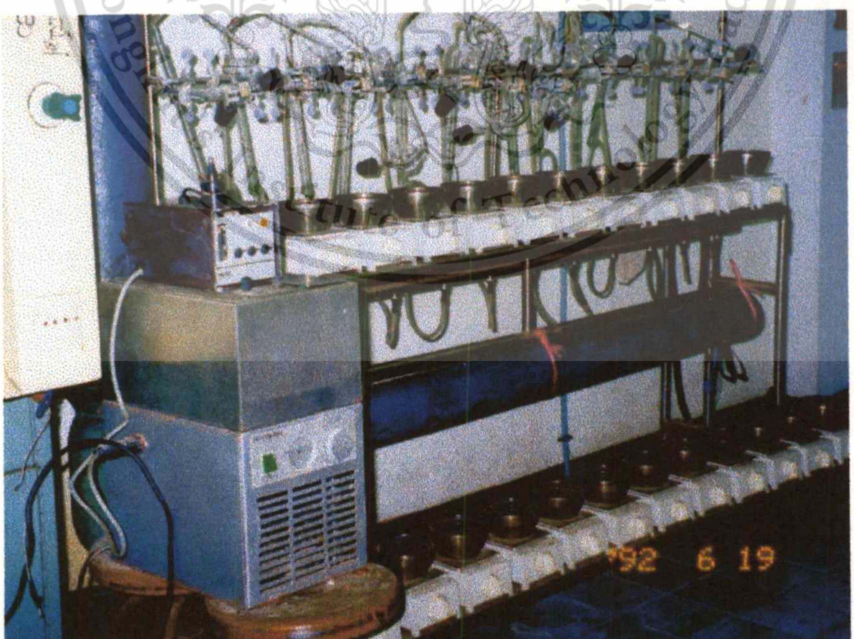


Figure F-4 Ammonia distillation set.

Figure F-5 Digestion set.

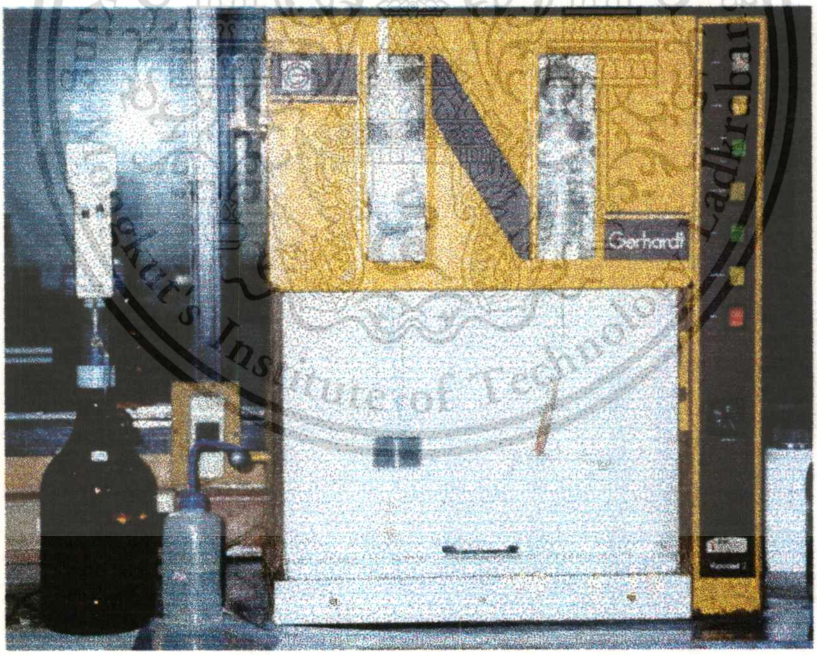


Figure F-6 Semi-auto distillation set.

Figure F-7 Cation exchange capacity analysis set.

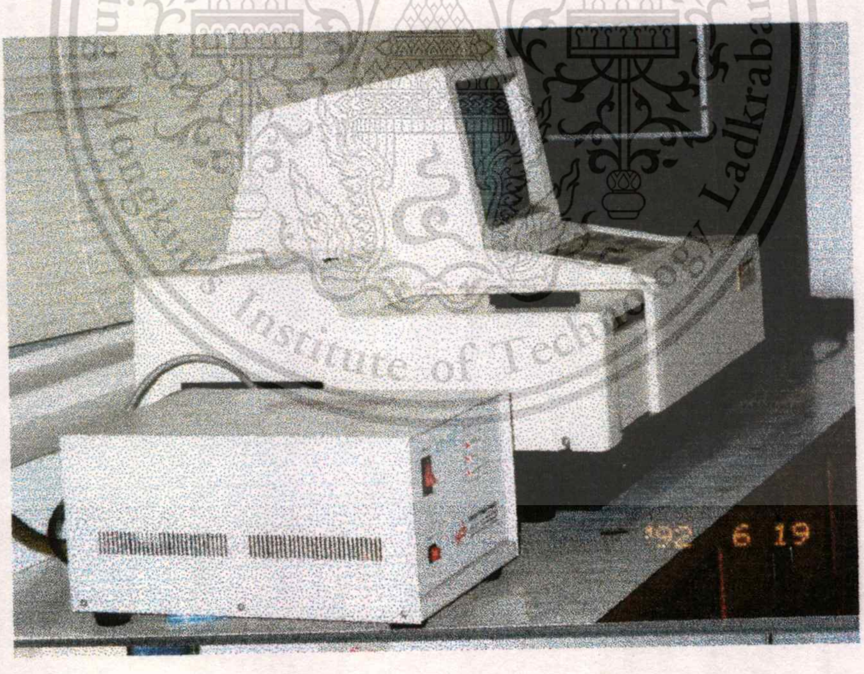


Figure F-8 UV-Visible spectrophotometer.

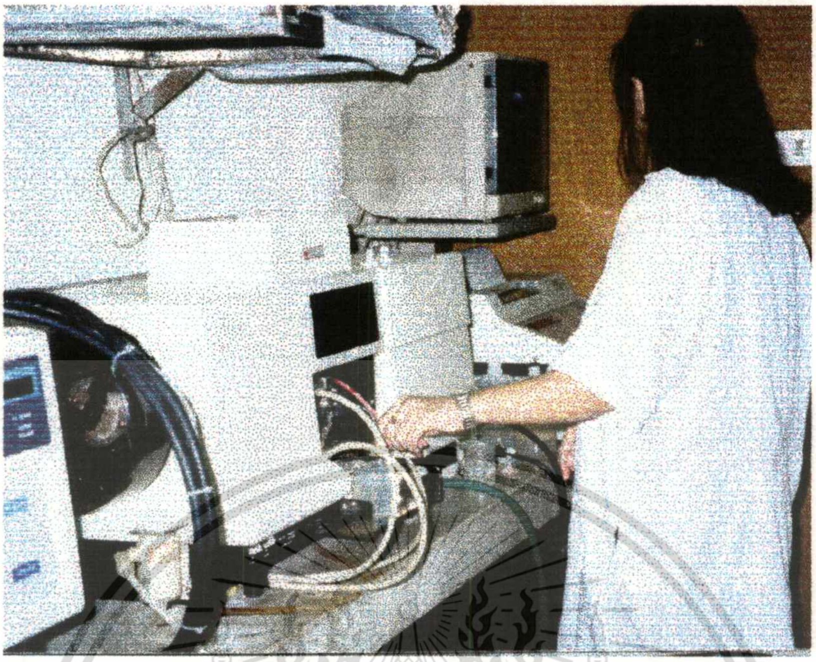


Figure F-9 Atomic Absorption Spectrophotometer.

Figure F-10 Measure Length of shrimp during culture period.

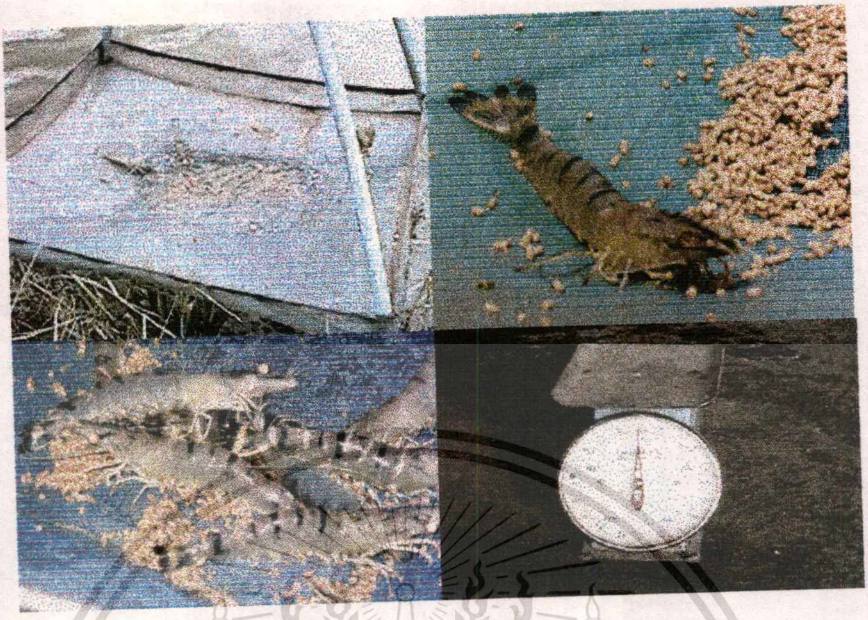


Figure F-11 Weighting of shrimp during culture period.

Figure F-12 Shrimp reach to marketing size.

AUTHOR BIOGRAPHY

Mrs. Nahatai Vijitrotai was born on September 27, 1964. I graduated with Bachelor' s Degree in Chemistry from Ramkhamhaeng University in 1986. Since 1988, I have worked at Department of Animal Production Technology, Faculty of Agricultural, King Mongkut' s Instute of Technology Lardkrabang, Bangkok.