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Effects of Chemical and Physical Properties of Pond Bottom Sediments on Fish Rearing in Iraqi Kurdistan Region

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Abstract

Some chemical and physical properties in soil- water interface in ponds of fish rearing in Duhok city Iraqi-Kurdistan region in summer 2014 such as (redox potential, exchange acidity, total and active calcium carbonate, soil pH and salinity, cation exchange capacity, particle-size distribution, Olsen extractable phosphorus, water total alkalinity, hardness, dissolved oxygen and water-extractable phosphorus) were studied to determine the impacts of variation in these properties on the fish biology and survival in the pond. Result showed that the clayey and very low permeable of bottom soil of pond was a suitable condition for anaerobic respiration, as a result of producing organic acid and alcohol, formation of hydrogen sulfide, nitrite, manganese, ferrous iron, and methane that makes hard poisonous conditions which negatively affect on fish survival and growth, it reduced the concentration of dissolved oxygen in the water of pond to 5.96±1.0 (mgL^{-1})..In addition long days, (16 hour), and high temperature degree ,40-50C°, during summer season, and high fertilizing led to increase the accumulation of organic matter (%) 5.84± 1.53 that serve the raw material of anaerobic respiration leading to high mortality and sensitivity to disease among fish in the pond.

Keywords. Bottom soil. Sediment. Anaerobic respiration. Oxidized layer.

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Introduction

Sediment accumulated in the bottom of pond is greatly influencing the whole life system in the pond. The material movements and reactions across the water–soil interface is very important in aquatic and intensive aquaculture systems. Concentration of nutrient such as C, N, and P, organic matter, microbial activity, intensity and diversity, oxidation-reduction potentially affected by the sediment accumulation in bottom of fish pond. The intensive biodegradation of bottom organic matter can increase the competition among microbial diversity that decompose organic matter and aquatic animal like fish and increase the biological oxygen demand causing anoxia condition in the pond which lead to the formation of toxic material such as reduced organic sulfur compounds, organic acids, reduced manganese and sulfides. These toxicants have negatively effects on the feeding and the growth of fish, increase mortality and sensitivity to diseases among fish in the pond.

As the crustaceans some fish species spend much growth time on the bottom, and most species of fish put their eggs in the bottom, benthos served as storage of nutrients and food for most fish species, contributing in nutrient cycling, gas exchange, decomposition process, and fish productivity. Because of unknown detected reason of high fish mortality in the fish rearing ponds Iraqi-Kurdistan region, this paper attention will studied some chemical reaction in soil- water interface like the formation of reduced toxicant material under anaerobic condition.

Materials and Methods

Soil samples were taken randomly from the ponds in Agricultural collage, Duhok University, Iraqi Kurdistan region ponds in summer 2014 as shown in the figure (1) by a plastic can banded to the edge of a wood rod in 3m length. Soil samples were also taken from shallow sides of ponds by digging manually the surface of soil with a tube from the pond bottom. Three replicates of each samples were analyzed for the studied parameters.

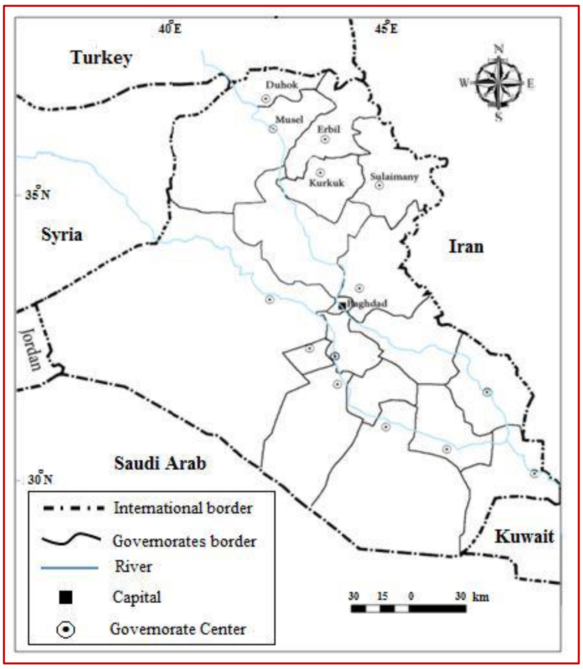

Fig. (1): Location of sampling sites showing the latitude and longitudes of Duhok city .

Measurements of redox potential were taken directly *in situ*, using three electrodes of bright platinum and an electrode of calomel as reference; they placed in 15 cm depth of the sediment and waited to equilibrate for 30 minutes before start reading using a portable pH meter. Total calcium carbonate was measured using acid neutralization method described by Richards (10) and active calcium carbonate was determined according to Kochekov and.Yakovleva (6).

Exchange acidity was determined by observing the change in pH using a solution containing 20 g soil and 40 mL buffer made by dissolving 7.5 g boric acid, 10 g p-nitrophenol, 5.25 g potassium hydroxide and 37 g potassium chloride in a distilled water, the pH adjusted at 8.00, and diluted to 1000 mL Hue and Evans (5). A change of 0.10 U in pH in

40mL of this buffer equals to 0.08mEq of exchange acidity.

Total alkalinity in water samples were analyzed by titrating to pH 4.5with N 0.020 HCl and total hardness by titration to the endpoint of eriochrome black-T with 0.01M EDTA (3).The dry soil bulk density was calculated according to Blake and Hartge (2) in g.cm^{-3}. Soil pH was measured according to Thunjai et al. (12). Organic carbon and organic matter were measured by the Walkley-Black Method byusing $K_2Cr_2O_7$and H2SO_4 acid oxidation (9). Total phosphorus was measured according to the method described by Olsen and Sommers (7). Cation exchange capacity (CEC) was measured by saturating soil adsorbing sites with K by shaking soil samples in a 1 N (KCl) solution. Soil texture was carried out by hydrometer method as described by Weber (14).Water-soluble phosphorus was measured by ascorbic acid method (3).

Results and Discussion

Table 1 showed that the sedimentation of clay and silt particles in the bottom of ponds was higher than sand as result of continuous water current flow and fish activity lead to re-depositing, re-suspending of soil large separate in shallow zones to increase the thickness of sediments about 0.5-1 cm yr^{-1} (8) in addition the nature of the soil was clayey in this area (vertisol) that make non permeable blanket to retain the water against losing by infiltration but creating a suitable anaerobic condition for soil microorganisms to reduce such elements like sulfur and manganese and consuming soluble oxygen in the pond water that has a negative impacts on the fish life and survive .This is called anaerobic respiration, in which alcohol and organic acid are produced, hydrogen sulfide, nitrite, manganese, ferrous iron, and methane are formed during anaerobic respiration which indicated from low concentration of dissolved oxygen (mgL^{-1}) 5.96±1.0 in the pond water. This may also caused from high bulk density of this layer 0.82±0.2 (gcm^{-3}) which not exceeded usually than 0.5 (gcm^{-3}) in normal condition and thick sediment layer 18 ± 2 cm. A continuous solid material adding to the pond as organic fertilizer and feeding material will mix with water to form mud. The settlement of these solids covers the bottom of pond with sediments, by rearing fish for long time in these ponds; the thickness of this sediment layer could reach several of centimeters. Though, the term sediment usually referred to the solids settlements in the bottom of pond. The microorganisms inhibiting these sediments like fungi, bacteria, algae, tiny invertebrates, aquatic plants, and many organisms are called as benthos live in the bottom soil. (3)

Huge inputs of organic residues to the bottom soil can increase the microbial activity levels, consuming oxygen faster than supplied from the above water to the soil. Leading to the development of anaerobic respiration in which microorganisms use the oxidized inorganic compounds and deco organic compounds or instead of molecular oxygen as electron and hydrogen acceptors in respiration. Most dissolved and suspended materials in water are made from contact with the soil. Pond bottom is the storage of most materials that leached in the pond ecosystems, biological and chemical processes carrying out in the bottom of pond which have high impacts on aquaculture production and water quality (3).

Because of continuous pond fertilizing, fish feeding, rapid eutrophication rates of algal and phytoplankton bloom as a result of high temperature in summer 40-50C° and long- light days (16 hour) lead to increase the accumulation of organic matter in the upper layer of sediment as presented in table (1) compared with arable soils in this area which was below 1% O.M , high clay percent in this sediment, the majority of organic matter adsorbed on clay colloidal system to be fermented and decomposed there, in addition non-sufficient mechanical aeration was not allowed dissolved oxygen to enter in tiny micro pores spaces and induced the formation of oxidation –reduction layer (Figure 2) and (Figure 3).

A

B

Figure2. A. The turbidity and dark green color of pond water indicate the presence of anaerobic condition .B sediment thick greenish-gray color after drying indicates the presence of oxidation-reduction zone or (ferrous iron).

The mortality level of fish in these ponds may be due to the formation of toxic materials by anaerobic microorganisms such as nitrite and hydrogen sulfide and other organic substances as result of oxygen lacks in the water that enhance the activity of these microorganisms to utilize chemical compounds like nitrite, nitrate, sulfate, manganese and iron oxides, and carbon dioxide to degraded organic residues, in the other hand they liberate ammonia, nitrogen gas, manganous manganese, hydrogen sulfide, methane, and ferrous iron as metabolic derivatives (1) and the absence of oxidized layer in sediment surface increase the flux of these toxic material to the rest of pond water. Metabolites of benthos microorganisms are significant factors in the dynamics of the pond. Microbial respiration utilize oxygen molecule as electron acceptor to oxidize organic sediments to carbon dioxide. Through decomposition process, the soluble organic substances released to the pond water may be used by fish before completely oxidation that increase the dissolved organic fractions in the water.

A B

Figure3. A. Top view of gray pond bottom soil indicates the presence of anaerobic condition. B Cross section of the same soil after releasing the cap (surface crust) with greenish black color indicate the severe presence of oxidation-reduction zone.

Total nitrogen concentration 0.16% in the sediment seem to be adequate for biological life in the pond but actually exposed to both denitrification by anaerobic bacteria that lost as nitrogen and N_2O gases to atmosphere o it volatilized as ammonia gas as a result of high temperature in summer so the daily gaining weight of fish in these pond were very low.

Table 1. Means, and standard deviations (SD) of bottom soil (sediment) and water physical and chemical properties

Variables	Mean ±SD
Bottom soil	
Sand %	3±1
Silt %	43± 3
Clay%	54±4
Texture type	Silty clay
Organic carbon (%)	2.90±0.53
Organic matter (%)	5.84± 1.53
Total nitrogen (%)	0.16± 0.04
C: N ratio	18 ± 2
Pond's area	1500 m^2
Sediment depth (cm)	18±6
Bulk density (gcm^{-3})	0.82±0.2
pH	7.10 ±0.2
Exchange acidity (meq 100 g^{-1})	0.38 ±0.11
Cation exchange capacity (meq100 g^{-1})	31.0 ±4.1
Total $CaCO_3$	26.2±2.5
Active $CaCO_3$	16.5±1.6
Active /Total $CaCO_3$	62.9±5.2
$NaHCO_3$- Olsenextractable phosphorus ($mgkg^{-1}$)	5 ±1.6
Water-extractable phosphorus ($mgkg^{-1}$)	2±0.21
Water	
pH	7.71±0.2
Total hardness (mg L^{-1} as $CaCO_3$)	61± 9
Total alkalinity (mg L^{-1} as $CaCO_3$)	64±7
Dissolved oxygen (mgL^{-1})	5.96±1.0

Available phosphorous concentrations in sediment were low due to the high Active /Total $CaCO_3$ (62.9±5.2) and high clay content in which the greatest part of available phosphorous rendered unavailable by precipitation with $CaCO_3$ and strong adsorption and fixation with clay mineral and the capacity of pond soil to adsorb phosphorus increased with increasing clay content (3).

pH of sediment is about neutral and less than of water as result of continuous organic matter accumulation and decomposition in the sediment to increase the microbial activity and some little increase in a phosphorous concentrations compared with arable soil in the same origin that not over 3 ($mgkg^{-1}$).

Conclusions

In conclusion the negligible pond managing practices in Kurdistan Region can be summarized in these points.

Oxidized layer. Most owners of fish rearing ponds do not have sufficient knowledge on the importance and presence of oxidized layer in the bottom of pond, to manage feeding rate and to prevent high accumulation of organic material in bottom from large inputs of organic matter and large nutrient content leading to heavy plankton blooms in summer, that lead to oxygen depletion in the flocculent F horizon which finally lead to the formation of toxic material by anaerobic respiration of benthos microorganisms. This problem can be solved by continuous stirring of the sediment to allow mixing the oxygen with microbial metabolites and to prevent overfeeding of fish to avoid excessive nutrient releasing to the pond. Thunjai (12) pointed out that the high organic matter placed in the pond and the absence of the oxidized layer and accumulation of dissolved substances, are the major concerns for bottom soil management in aquaculture.

Drying The drying of ponds between seasons is used very rear by fish rearing farmers in Iraqi Kurdistan Region. This practice can be done for 2-3 weeks which is useful way for aeration, minimizing oxygen demand, decomposing organic matter, eliminate the previous disease organisms, and oxidizing of inorganic toxic compounds like manganese which always related to clayey soil common in this region.

Sediment removal and tilling**.** The removal of accumulated organic sediments and reduced soil layer after long fish rearing seasons is also important to prevent the repeated issues related with reduced soil bottom layer, these sediments in Kurdistan region contain high level of organic matter content that could be used as mixing material with other residues of plants and weeds to make high compost quality for soil fertilization. This layer usually not removed and even leaved without tilling in order to aerate it, and maximizing the rate of oxidation and decomposition.

Bottom Raking**.** Steering of the sediment in the bottom surface is also a good way for aerating this layer and to prevent reducing organic layer. Most of farmers are neglect this practice that can be done by dragging steel chain in the sediment each 2-3 days to aerate this layer. Continuous water circulation and fresh water application generate dynamic water mixing of substrate and bottom layers which enhance oxygen diffusion.

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تاثير الخواص الكيميائية والفيزيائية لرواسب القاع للحوض على تربية الأسماك في إقليم كردستان العراق

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المستخلص

تم دراسه بعض الخواص الكيميائية والفيزيائية في الطبقة المتداخلة للتربة والمياه او التربة القاعية في احواض الاسماك لمدينة دهوك إقليم كردستان العراق مثل جهد الأكسدة والحموضة المتبادله وكربونات الكالسيوم الكلية والنشطة ودرجة الحموضة والملوحة للتربة والتبادل الكاتيوني وتوزيع حجم الدقائق وفوسفور أولسن القابل للاستخلاص والمجموع الكلي للعسرة والقلوية للمياه ، والأكسجين المذاب في الماء والفسفور القابل للاستخلاص في الماء ا لمعرفة تأثيرات تغير هذه الخصائص في بيولوجيا الأسماك. وخلصت النتيجة أن الطبيعة الطينية القليلة النفاذية للتربة القاعية للحوض تشكل وسطا مناسبا للتنفس اللاهوائي حيث يتم فيها إنتاج انتاج الحامض العضوي والكحول، وتشكيل كبريتيد الهيدروجين والنيتريت والمنغنيز والحديدوز والميثان الذي يجعل من الظروف متسممة وتؤثر سلبا على بقاء الأسماك ونموها، وتجعل تركيز الأوكسجين المذاب منخفض نسبيا(5.96 ± 1.0ملغم$^{-1}$. لتر) في ماء الحوض.بالاضافة إلى أيام السطوع الطويلة للشمس (16 ساعة) وارتفاع درجة الحرارة في الصيف 40- 50 درجة مئوية.والتسميد العالي للحوض ادت إلى تراكم المواد العضوية %(5.84±1.53) والتي تشكل المواد الخام للتنفس اللاهوائي مما يؤدي إلى ارتفاع معدل الوفيات والحساسية للأمراض بين الأسماك في ماء الحوض.

كلمات مفتاحيه: قاع الحوض. الرواسب. التنفس الاهوائي. طبقة الأكسدة

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