Predictive Modeling of Hawiza Marsh Eutrophication

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Abstract

The term "eutrophic" refers to system rich in nutrients, and hence Eutrophication means nutrient enrichment, particularly by increasing levels of nitrogen and phosphorus [1]. In lakes, phosphorus is generally regarded as the limiting nutrient for primary production [2] implying that increasing phosphorus concentrations will result in increasing production of phytoplankton and benthic algae. Excessive amounts of phytoplankton cause low Secchi depths and may consequently wipe out the benthic flora by shading the light [3]. Toxic cyanobacteria tend to bloom when nutrient levels are high [4]. Apart from being a nuisance in their own right, settling phytoplankton may cause anoxia in hypolimnetic waters as their decomposition consumers oxygen [5], and this may result in extinction of the benthic fauna [6] and fish feeding on such animals. Altogether, these Eutrophication effects threaten the foundations of aquatic ecosystems. The low oxygen levels in hypolimnetic waters associated with Eutrophication may also cause mobilization of phosphorus in the sediments, thus inducing a feedback mechanism where already high nutrient levels increase even more.

Keywords: - Hawiza marsh, Eutrophication.

موديل تنبؤي للأثراء الغذائي في هور الحويزة

الخلاصة

يشير التعبير(eutrophic) الى النظام البيئي الغني بالمواد المغذية والذي يطلق عليه الاثـــراء الغذائي، خصوصاً بزيادة تراكيز كل من النتروجين والفـــسفور[1] .يعتبـــر عنـــصر الفـــسفور فـــي البحيرات المغذي والمحدد للانتاج الاولي[2] ويشير الى زيادة في اعداد التجمعات وخاصة الهائمـــات النباتية والطحالب والقاعيات حيث تسبب الكميات الكبيرة والمفرطة في اعداد الهائمات النباتيـــة الـــى انخفاض المستوى الذي يقرأ فيه قرص ساكي والذي يدل على مستوى عكورة المياه ممـــا يقلـــل مـــن كمية الضوء الداخل للمياه[3] .بكتريا cyanobacteria السامة تكون تجمعات نتيجـــة زيـــادة تراكيـــز المغذيات[4] .التحلل الحاصل في الهائمات النباتية وتفسخها يؤدي الى حدوث اضرار في تلـــك البيئـــة اهمها استهلاك الاوكسجين المذاب مما يؤدي الى انقراض العديد من الاحياء ومنها الاســـماك وكـــذلك الاحياء القاعية[6] وبما ان الاسماك تعتمد على الاحياء القاعية التي قد تاثرت ســـلبا ايـــضا بـــالاثراء الغذائي مما يؤثر على السلسلة الغذائية في النظام البيئي المائي فضلاً عن انخفاض تركيز الاوكـــسجين المذاب كما وان التراكيز العالية من المغذيات سوف يتركز في الرواسب ويحدث نفس الاضرار.

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1- Introduction

Both phosphorus and nitrogen are elements essential to life. A availability of these biolimiting nutrients therefore exerts a major control on the carbon cycle through ocean productivity, bringing about change in ocean-atmosphere chemistry and climate. This review begins with a brief account of the biological importance of phosphorus and nitrate to the cell, and introduces current terminology relating to the interlinked carbon-nutrient cycles in the oceans.

The importance of nutrient minerals containing phosphate and nitrate to the fertility of the soil is familiar in everyday life. The presence of nutrients in adequate amounts ensures healthy plant growth and the rapid accumulation of biomass, beneficial in the annual yield of crops.

The relationship between the nutrients and productivity may therefore provide a clue to climate history. Nutrients also have growing relevance to a range of pollution-related problems. These include the response of delicate ecosystems to human effluent, fertilizer and detergent run-off, methane, and CO2 from fossil fuels which may contribute to 'global warming'. Not least, nutrient levels may hold important clues to major episodes of evolutionary diversification and mass extinction. Nutrient-related studies can therefore provide an important dimension to geology and environmental palaeontology. [7]

2- Predictive (mass-balance) modeling

Since modeling is a wide concept, this section will try to clarify the intention and methods of the modeling contained within this search.

Basically, a predictive model is defined by its intention to predict masses or fluxes of specified target variables in a given type of system at a given frame of time. Models for predicting mass balances of substances in aquatic systems have been widely used since Vollenweider proposed his famous phosphorus model in 1968 [8].

In contrast to most stochastic models and regression models, mass balance models try to capture the most important processes in a system using differential equations. The principal idea is to treat the system as one or several mixed reactors where mass is conserved. In its simplest form, a mass balance model for a substance in a lake may be defined as:

$$dM/dt = \text{Inflow} - \text{Outflow} - \text{Sedimentation} \qquad \ldots(1)$$

Where dM/dt is the rate of mass change of the substance. This model may be expanded with more internal processes or divisions of the system into a number of subsystems, such as surface water, deep water and sediments.

Mass balance models may be used as engineering tools in, e.g, lake management and /or as tools for water research. This work is mainly focused on scientific understanding about processes, but the ultimate aim is to strengthen the mechanistic foundation in predictive lake Eutrophication models, hoping to improve the ability to make quantitative predictions. Here, this means that the lake models are rather complex and that each included process should correspond to one well defined (and measurable) process in the natural system. In several cases, the processes may more readily accessed by mass balance calculations than by empirical studies. For instance, this is often true for processes of outflow, water mixing and phosphorus release from accumulation sediments.

3- Marshes Eutrophication

The sources of phosphorus in lakes include anthropogenic sewage, fertilizers used in agriculture and emission from industries in addition to natural sources in the 1970´s, effluent water treatment was introduced in many places and water quality improved [9]. Expected recovery was, however, delayed in some lakes where phosphorus accumulated in the sediments continued to release significant amounts even after the external emissions were reduced [10]. Today eutrophication remains a problem in a relatively small number of lakes, but these lakes tend to be situated close to populated areas where they play an important role for fishing and recreation.

4-Study area

4.1. Hawiza Marsh

4.1.1 Area and Location:-

Hawaiza marsh lies between (31 and 31.75 latitude) from north latitude. It extends between the Iraqi- Iranian borders and extends from south Almusharah in (Misan) governorate to (Qurna) city in the south, its length (80 km) and its width (30 km).

There is no specific area for the marsh, due to the fact this area of the region is not fixed and changes form one season to another and from one year to another because of the difference in water amount reaching the area from different resources like floods and rains. The marsh area covers about (2500 - 3000) km2 in flood season and is much reduced during the dry season. The area ranges from 3600km2 in the flood season to 950km2 in the dry season and average about 2400km².

The largest area of (3600km2) while is reduced during driest years to (650 km2). Through satellite imagery analysis for 1973 about (3076 – 2435) km2 in Iraq and (641 km2) in Iran (21%). [11]

4.1.2 Feeding and Discharge Resources:-

Hawaiza marsh is fed from three water sources. The western source represents Tigris river, coming down from Alkahla, Musharah, and Majar creeks. The eastern source is coming from the Iranian mountains in Karkah , Tib and Dwareege rivers, and the two latter rivers flow into Sinaf marsh; which flows into Hawaiza marsh. The most important creeks are:-

1- Alkahla, the second stage after AlBitera in down the stream basin of Tigris river has a width of about (100)m and depth of (3)m. The discharge capacity is more effective than the Tigris in that part since the channel takes (60%) of the river discharge and after a short distance, divides into three channels: Sahaji, Zabair and Um Altooz, ending in Hawiza marshes.

2- Almusharah originates from the left bank of Alkahla channel, with an average width of (45m) and depth of (3.5) m. It flows to the east, without branching about (13) km from the point of its branching from Alkahla, distance of (105)km, Um Albitoot channel from its right bank. There are other channels discharge water towards the south, ending in Jaka marsh. At (37km) from its branch divids into (2) branches (Almalih and Alama); which flow to Hawaiza marsh .

3- Majriya channel: it is considered the smallest of the main five channels in Omarah city. The maximum width for it is (25 m) and maximum depth is (2m), taking (20-25%) from the water from the Tigris river. [11]

4.1.3 Rivers coming from Iran

1. Karka river:-

It is formed in Iran and flows into Hawaiza marsh passing Hamidiya; which is (60 km2) from its origin. It forms a delta inside Hawaiza marsh where the water of this river divides into many branches inside the marsh. The average of its discharge in Hamidiya is about (6.43 billion m3) yearly.

2. Dwareege River:-

It sources from Iran and inters Faka control post. More than 85% of this river water is used by the Iranians during spring, summer and autumn days to irrigate their plants. The river continues flowing until it ends in Sinaf marsh about (11 miles) from Tib and the maximum discharge is about (100 m3/sec.)

3. Tib River:-

It sources from the Iranian mountains, east of Badra and Jassan districts, and the valley of the river inters Iraq at a point east of Iraqi Tib control post; which lies to the north of Omara city about (31 miles). Then its stream flows to the south in a deep valley until it ends in the Sinaf marsh. Inside Iraq its length is about (63 miles) and the source of water in this river is rain; therefore it becomes dry during the summer season or there is little amount of water in it. When the precipitation is increased, the discharge will reach its maximum level of about (500 m3/sec). [11]

4.1.4 Outlet resources of Hawaiza marsh

The marsh water returns to Tigris river with many outlets from north to the south

1- Um Jiri drain which ends in the Tigris river at Zajya village north of Alazeer, about (3.3 miles) and this drain returns Alkahla creek water

2- Alkars drain also flows the Tigris river to the south of the first drain at Alzajia village; discharging the middle and south water for the marsh.

3- Alkassara drain is wider than these two drains and flows into the Tigris River at kassara village about (2.8 miles) north of Alazeer.

4- There are other drains to the south of Kassara drain. These drains are “small Maniha”, “great Maniha” and Rota, returning marsh water to Tigris River.

5- Alsuaib drain is a wider one of these drains, drawing marsh water from south of Alazeer to flow into the Tigris about (5.5 miles) south of Qurna. [11]

5- Analysis of Results

It included the analysis of data and results that were obtained in table (1). [12]

6- Marsh Models

6.1 The MEEDS-model

MEEDS (Marsh Eutrophication, Effect, Dose, and Sensitivity) is a dynamic mass balance model for phosphorus in marshes. An outline of the model is given in figure (4). The model gives monthly predictions of phosphorus in 9 different compartments in water and sediments. It containts compartments for dissolved, colloidal and particulate phosphorus in surface water and deep water, phosphorus in sediments, A-sediments and phytoplankton. Only phosphorus dissolved in surface water may be taken up by phytoplankton, and only particulate phosphorus is subject to gravitational settling. Colloidal particles are too small to settle due to gravity, but phosphorus bound to such particles are still not available to phytoplankton [13]. Resuspension of particulate phosphorus may occur on shallow erosion and transport areas (ET-sediments) where wind and wave activity influence they hydraulics at the sediment-water interface. Importance and mechanisms of sediment resuspension are discussed. In deeper areas of sediment accumulation (A-sediments), phosphorus is only mobile through diffusive processes [14]. The extension of ET-and A-area are calculated from the dynamic ratio (DR= $(\text{Area}/\text{Mean depth})^{1/2}$). Mixing between deep water and surface water depends on the vertical temperature profile and is slow when the temperature difference between surface water and deep water is larger than 4°C.

6.2 The SPM-model

Suspended particulate matter (SPM) is a very important variable in aquatic systems. It has a major impact on the light penetration and the Secchi depth in the water, thereby regulating the potential for primary production [15].SPM also binds nutrients and metals, thus determining the fate of many important substances by its settling properties [16].

Furthermore, organic SPM may be used as an energy source by microorganisms in the water column [17].

The SPM-model is included as a sub-model in LEEDS, but sub-model does not require any additional variables. The following dimensionless moderator for settling velocity has been implement in the MEEDS-model and in the SPM-model:

YSPM= 1+0.45 (CSPM /2-1 ………….. (2)

Where CSPM is the concentration of SPM in $g.m^{-3}$. this dimensionless moderator is multiplied with the default settling velocity in the models to get the actual settling velocity, resulting in an increased rate of sedimentation at higher concentrations of SPM.

6.3 Sedimentation

Sedimentation of SPM and particulate forms of pollutants is one of the most important internal processes in mass balance calculation for lakes. Gross sedimentation in a lake, e.g., measured as g. DW m^2 $.d^{-1}$(DW=dry weight), may be quantified in situ with sediment traps[18], whereas properties of settling material is difficult to study outside the laboratory [19]. Settling velocity of particles (md^{-1}) may be estimated by dividing gross sedimentation by the concentration of suspended particulate matter (g DW m^{-3}) above the traps. Since particles in a lake are carried by water currents and influenced by turbulence the settling velocity measured in the laboratory and settling velocity estimated from field observations often differ orders of magnitude. Both may give valuable information.

About the mechanisms the fate of particles and associated substance in aquatic systems. Large particles generally settle faster than smaller ones according to Stokes´ law, since the impact of drag resistance (viscosity) from the medium (water) decreases relative to the influence of gravity with increasing particle size [14]

6.4 Diffusion

Molecular diffusion is the continuous redistribution of molecules resulting from random movements, acting to level out concentration gradients. Although a slow process, molecular diffusion is the dominant transport process for many substance in calm waters, such as in deep water below the wave base in lake. It is the most important process moving phosphate from sediment pore water to the overlying water column [20].

Phosphorus release from accumulation sediments also includes a number of chemical reactions and is affected by physical conditions and biological processes [14].

In this work, diffusion refers to release of molecular phosphate from accumulation sediments, as opposed to phosphorus release from erosion- and transport sediments driven by resuspension.

between dissolved and iron bound phosphorus (eq). It divides phosphorus into four different operational fractions. These fractions are phosphate dissolved in pore water, organically bound phosphorus, phosphorus sorbed to iron and an inert fraction. A chemical equilibrium depending on the redox potential is assumed between the dissolved phosphate and the phosphorus sorbed to iron. Sediment redox potential is assumed to be proportional to hypolimnetic oxygen concentration. The modeled vertical profiles of the four phosphorus fractions in the sediment are similar to the observed profiles. In the model most of the phosphorus release occurs in August, and about 50% of the settling phosphorus is eventually buried.

7- Conclusions

1. All models are incomplete abstractions of more or less well-defined systems, confined by their driving variables, mathematical formulations and empirical data.

2. The assumptions and structure of a phosphorus model for lakes are critically tested and the domain of the model is given. The values predicted by the model show good agreement against empirical data.

3. A new version of this model is presented, including two new compartments for colloidal phosphorus, a sub-model for suspended particulate matter (SPM) and new algorithms for water content and organic content of accumulation sediments. New algorithms for lake outflow, mixing and diffusion are implemented.

4. A dynamic model for SPM is validated and shown to provide satisfactory predictions of SPM concentration in the tested marshes. It was also found that uncertainties in allochthonous and autochthonous production of SPM are generally much more important for predictions of SPM concentration than uncertainties in internal processes such as sedimentation and resuspension.
5. The within-site variability of settling velocity of SPM was found to be large, implying that, if possible, this variability should be taken into account when predictions of particle sedimentation are made. A dimensionless moderator for the impact of SPM concentration on settling velocity is suggested.
6. A mechanistic model for phosphorus dynamics in accumulation area sediments is defined and shown to provide accurate predictions of four different phosphorus forms at different sediment depths in marshes.
7. Simulations with a lake model indicate that temperate lakes with long water retention time appear to be more sensitive to climate warming than lakes with short water retention time with respect to phosphorus concentration and Eutrophication effects.

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Table (1) shows the Nutrients Values in Hawiza marsh

Point	NO2(mg/l)	NO3(mg/l)	NH4(mg/l)	PO4 (mg/l)
1	12.0	6.6	0.0	0.6
2	0.0	1.9	0.5	0.1
3	24.0	2.6	1.9	0.3
4	0.0	13.9	0.2	1.9
5	0.0	2.6	0.14	0.3

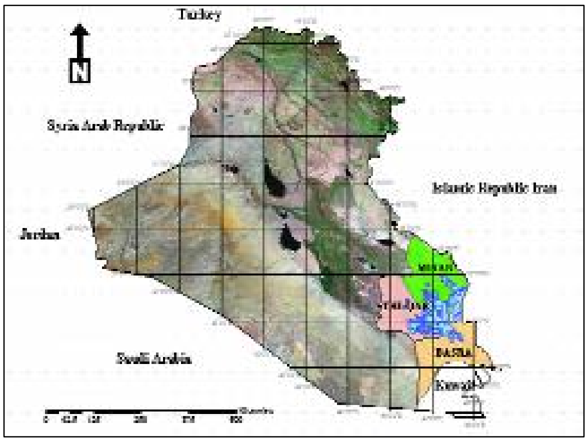

Figure (1) Shows Iraq map and Location of Iraqi Marshes.

Figure (2) Shows satellite image for Iraqi Marshes in Southern of Iraq.

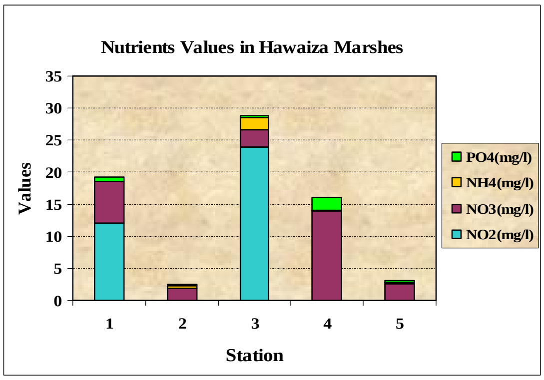

Figure (3) Shows the Values of Nutrients in Hawiza

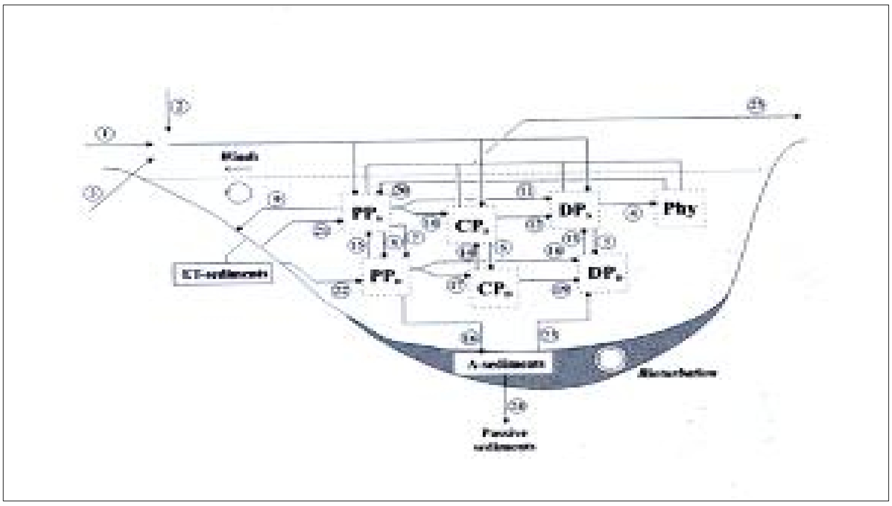

Figure (4) An outline of the phosphorus fluxes handled by the MEEDS-model.

Where DPS= Dissolved phosphorus in surface water
DPD = Dissolved phosphorus in deep water
CPS = Colloidal phosphorus in surface water
CPD= Colloidal phosphorus in deep water
PPS= Particulate phosphorus in surface water
PPD= Particulate phosphorus in deep water
Phy = Phosphorus in phytoplankton

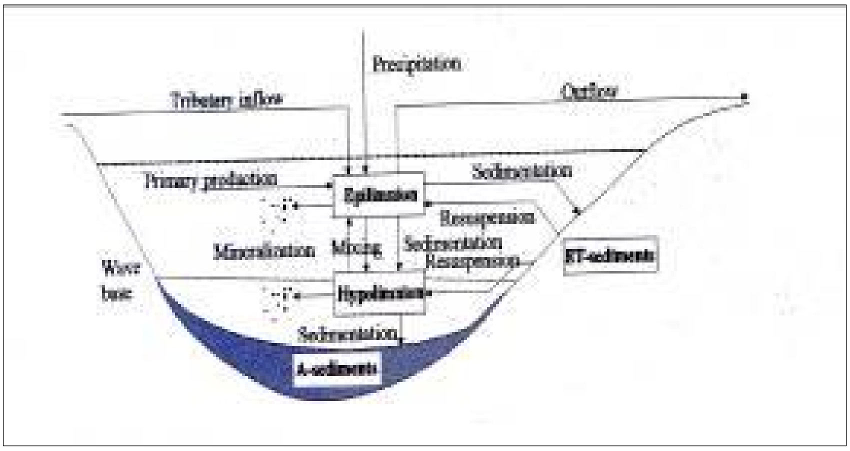

Figure (5) Schematic outline of the SPM-model.

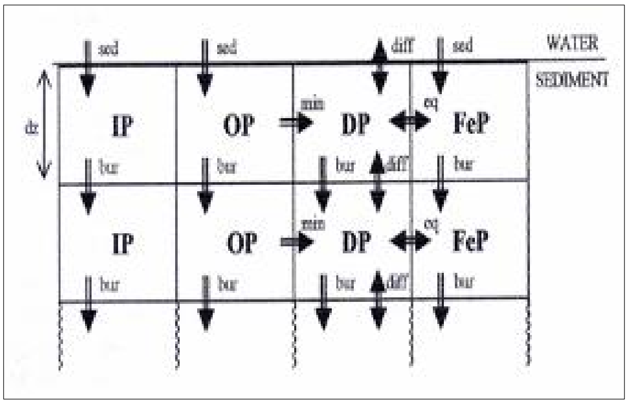

Figure (6) Illustration of the sediment phosphorus model.

Where: IP= inert phosphorus; OP= organic phosphorus; DP= phosphorus dissolved in pore water; FeP=phosphorus sorbed to iron. Phosphorus fluxes include sedimentation (sed), burial (bur), mineralization (min), molecular diffusion (diff) and chemical equilibrium between dissolved and iron bound phosphorus (eq).