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Development of salinity intrusion model (Munaf Q. 2019) In the Shatt Al-Arab River

iD Munaf Q. Albattat[1*], iD Emaan T. Khalid[2], iD Abdul Haleem A. Al-Muhyi[1] and Waleed H. AL-Mosuwi[3]

1-*Marine Science Center, 2-Education Pure Science, University of Basrah, 3-Directorate of Protection and Improvement of Environment Southern Area, Ministry of Environment, Iraq*
[*]*Corresponding Author: e-mail munaf.jaber@uobasrah.edu.iq*

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Abstract - Mathematical model (Munaf Q. 2019) was developed to predict the intrusion of salt into the Shatt Al-Arab River, which addresses the problem of the difficulty of measurements and prediction of the level of salinity along the Shatt Al-Arab River during the measurement period and in a very short time, where it is possible to identify the level of salinity along the Shatt Al-Arab River when it changes at the estuary. In this article, a mathematical model was used with an automatic computing system to predict the penetration of the salt intrusion into the Shatt Al-Arab, based on the development of a previous mathematical model. The results obtained through the application of the model showed that there is a great convergence between the results at a high level and at most of the stations under study (Al-Fadaqhiyah, Seyhan, Basrah, Al-Hartha) for the field-measured values with the theoretical values respectively, as follows: 27-26 ppt., 2.6-2.9 ppt., 1.85-1.96 ppt., 0.86-0.92 ppt., when the flow is 50m3/sec. When the flow is 5m3/sec, the results are as follows: 30.4-30.2 ppt., 25.3-25.1 ppt., 11.4-12.6 ppt., 1.50-1.97 ppt., Therefore the adoption of this mathematical model can be enhanced to predict the penetration of the salt as a result of any situation that may occur at any time along the Shatt Al-Arab River. The reason for using mathematical models is because it is an easy, cheap and fast way of obtaining the desired results to address some of the problems that occur for many reasons, the most important of which are direct events that may occur as a result of a sudden change in the variables dependent on them.

تطوير موديل(Munaf.Q.2019) للتوغل الملحي في نهر شط العرب

مناف قاسم البطاط[١] , ايمان ثابت خالد٢, عبد الحليم علي١ و وليد حميد الموسوي٣
١-مركز علوم البحار، ٢-كلية التربية للعلوم الصرفة، جامعة البصرة، ٣-دائرة حمياية وتحسين البيئة في المنطقة الجنوبية، العراق

المستخلص - تم تطوير الموديل الرياضي (Munaf. Q., 2019) للتنبؤ بتوغل اللسان الملحي في شط العرب والذي يعالج مشكلة صعوبة القياسات والتنبؤ بمستوي توغل اللسان الملحي على طول شط العرب خلال فترة القياس وبفترة زمنية قصيرة جدا. حيث يمكن التعرف على مستوى الملوحة على طول شط العرب عندما تتغير عن مستواها في منطقة المصب. في هذا البحث أستخدم موديل رياضي مع نظام حوسبة أوتوماتيكي للتنبؤ بتوغل اللسان الملحي في شط العرب بناءً على تطوير نموذج رياضي سابق. اظهرت النتائج التي تم الحصول عليها من خلال تطبيق الموديل ان هناك تقارب كبير بين النتائج وبشكل عال المستوى وعلى معظم المحطات قيد البحث (الفداغية وسيحان والبصرة والهارثة) للقيم المقاسة حقليا" مع القيمة النظرية على التوالي وكلاتي: 5m^3/sec (26 - 27)ppt, (2.9 -2.6)ppt, (1.96 -1.85)ppt, (0.92-0.86)ppt,عندما يكون التصريف 50m^3/sec.اما عندما يكون التصريف فتكون النتائج كالاتي: ppt(30.4 - 30.2), ppt(25.3 -25.1), ppt(12. 6 -11.4), ppt(1.97-1.50), وبالتالي يمكن ان يتعزز اعتماد هذا النموذج الرياضي للتنبؤ بتوغل اللسان الملحي نتيجة لأي حالة طارئة قد تحدث في اي وقت على طول شط العرب. ان السبب في استخدام الموديلات الرياضية كونها طرق سهلة ورخيصة وسريعة الحصول على النتائج المرجوة لمعالجة بعض المشاكل التي تحدث لأسباب عديدة أهمها الأحداث المباشرة التي قد تحدث نتيجة لتغير مفاجئ في المتغيرات المعتمدة عليها.

كلمات مفتاحية: الملوحة، التوغل الملحي، تنبؤ، شط العرب.

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Introduction

The salinity distribution in rivers was taken different shapes depending on many factors such as the position of the estuary, freshwater discharge, salinity sources and agricultural development in estuarine environments. Estuary is a transitional watery body where fresh and salt water mixed wich each other. It is an important commercial area because it has a human activity as fishing, industrial and commercial activities. The position of estuary changes as a result of the freshwater or sea water are domain (Fischer *et al.*, 1979). The most important factors affecting the saline dispersion of the river which are tides, flow of fresh water and the geometric shape of the river (Geyer and Signell *et al*., 1992). Water contaminated by salt from the sea is no longer useable (Aerts *et al.*, 2000). The salinity increase in the rivers may be due to more than one reason, the amount of water flow, geometric shape of the river and the tide, which are essential to assess the salt intrusion (Shaha and Cho *et al*., 2009) as well as many other factors such as rain, sewage distance, and temperature (Ralston *et al.*, 2008). Due to the importance of the topic, studies focused on tides are quite available (e.g. Van Rijn, 2011; Cai *et al.*, 2012; Cai and Savenije *et al.*, 2013; Winterwerp *et al*., 2013). In order to protect the estuarin environment, the salt penetration into the estuary must be studied and solutions should be developed and treated (Huayang Caia, *et al*., 2016).

It is clear that the process taken place in gases as a result of the movement of particles of matter in the air due to different concentrations is called diffusion process, while what occurs in the transfer of salt particles through water is a process called dispersion, which occurs as a result of the movement of particles of the substance and their collision with the particles of the medium with several collisions that are transmitted. Through which salts dispersion through the water and increase their concentrations (Munaf *et al.*, 2019).

However, to assess the salt intrusion in the rivers all the parameters that affect the system such as freshwater discharge flow, geometry, distance from the estuary, rain and tide must be required. Many analytical models have been proposed by many researchers (Prandle *et al*., 1981; Savenije 1986, 1989, 1993b, 2005, 2012; Lewis and Uncles *et al.*, 2003; Gay and O'Donnell *et al*., 2007, 2009 and Kuijper and Van Rijn *et al*., 2011), yet, there is no optimal solution for such issue.

Study Area:

The Shatt Al-Arab River is located in AL-Basrah Governorate (figure1) and was previously used for river navigation to transport goods. Due to the small amount of drainage coming to it from the Tigris and Euphrates Rivers, the city of Basrah began to suffer from water crises due to the different amount of imput, whose causes were many. The city of Basrah is located in the southern part of Iraq, it is considered as the economic lung of Iraq, as it overlooks the world through the ports located in it. Therefore, it gained importance over the rest of Iraq's cities because it contains sea ports in addition to land ports, moreover it is a city rich in oil production.

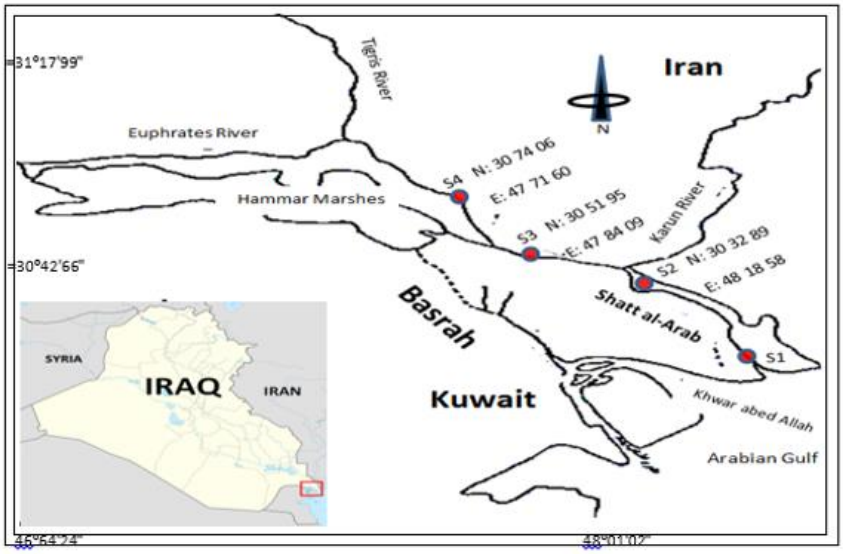

Figure 1. Shatt Al-Arab stream, southern Iraq.

Methodology:

This study proposes an automatic computing system based on developing mathematical model **(**Munaf Q. 2019) to compute and predicate the salinity intrusion in the Shatt Al-Arab River. The developed model based on introduction of some mathematical functions as well as the integration process at the expense of variables in order to predict any emergency situation that may occur. The framework of the proposed system is depicted in Figure (2).

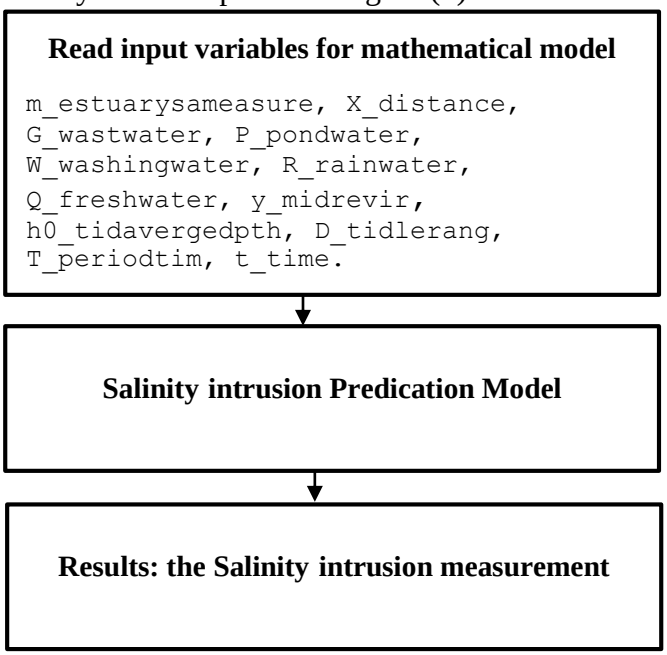

Figure 2. Framework of the proposed System for Salinity intrusion Predication.

Salinity intrusion Predication Model

Mathematical models are used, which are of several types, including experimental or the use of finite differences or the use of approximation when used or simulation, in order to give predictions for a future situation and for certain periods of time through which it is possible to develop solutions to cases that may arise as a result of emergency conditions of occurrence or occur in a period of specific time. Mathematic models are used because of their low costs and ease of application, in addition to their accuracy when the agent is subject to accuracy in empowerment and construction. The more the mathematical model is easy to apply and gives accurate results, the better it is to deal with in order to reach the results faster and more accurately.

There are several variables that must be available in order to study them, which are related to the variables in the study areas. In the case of salinity intrusion issue in theShatt Al-Arab River, such variables include the length and width of the River, the speed of flow, the amount of flow and discharge, in addition to the factors of rain, temperature and other factors that have an impact on the penetration of salts introsion through the River. In the proposed model, the geometry of the estuary can be written as functions describe the convergence of the width (B) and cross-sectional area (A) along the estuary from distance x of the mouth (Graas and Savenije *et al*., 2008) as described in equation (1).

$$A = A_0 \exp(-x/a_0) \qquad (1)$$
$$B = B_0\, exp(-x/\, b_0)$$

Where, B_0 is the cross-sectional area and width at the mouth, a_0, and b_0 are the cross-sectional area and the width convergence length, respectively. The constant tidal average depth $h(l)$(m) and h_0 (m) at the mouth along the estuary with distance (x)in cross-sectional area A_0 was given in equation (2).

$$h(l) = h_0 \exp(-x / A_0) \qquad (2)$$

The factors affecting the change in salinity in the downstream are human and natural factors, as the amount of sewage water (G), pond water (P), washing water (W) and irrigation water returning to the river through branch channels, as well as tnatural factors of rain water (R) and the amount of river drainage arriving from the rivers supplied to it are disposed of. It varies with the distance(x) along the river, according to the areas of its influence; it was observed that it changes in the form of a parabola as shown in the Figure (3). Since the parabola equation had a fixed axes and indicative equation tgat can be determined by its axes and its guide, so the use of the integration process on the positive and negative axis directions gives more integrative space when the proportions of the variables change during time and space, so the fixed equation can be expressed by an equation. It changes in time with the instantaneous variables and becomes more flexible in the calculation during any moment in time.

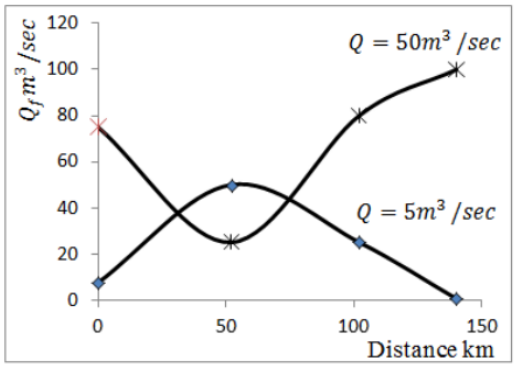

Figure 3. Relation between the Q_f (m^3/ sec) with the distance (km).

Q_f : the mixing (G),(P),(W) and (R) with fresh water.
The equation of parabola:

$$x^2 = -4py \qquad (3)$$
$$y^2 = -4px$$

Continuously changing the amount of some parameters from time to time, such as sewage water, rain water, wash water, and pond water makes it difficult to calculate as fixed quantities, so integration can be used to calculate them as a better way to deal with the continuous change in their quantities as in equation (4).

$$L^{HWS} = \left| N + exp(z).ln\left(\int_{-y}^{y} D^2 d\,y \Big/ \int_{a1}^{a2} Q\,dq \right) \right| \qquad (4)$$

Where: *HWS*, high water slack.
$N = (S_0 - m) - \left({}^{x}/_{(5+0.846m)}\right)$, $z = \frac{y}{A}$, x : distance(m), S_0: salinity of estuary(p.p.t), m: salinity measuring(ppt.), Q:discharge flow(m^3 /sec), y: integration limits according to human activity and prevailing weather conditions for D = (G,P,W,R), (a_1, a_2) limited integration (5 to 50) m^3/sec.

Results and Discussion

This article introduced an automatic computing system based on developing mathematical model to compute and predicate the salinity intrusion in the Shatt Al-Arab River. The system was implemented using Mat lab programming language on windows10, using HP notebook Intel core i7. The data were collected from samples that have been used to execute the system were taken from the Shatt Al-Arab River, the measured data that were used in this research were collected between the years 2005 to 2011 in addition to data for a complete tidal cycle for a period of 13 hours with other data from the Ministry of Water Resources (Munaf *et al*, 2019).

Since the estuary is a body of water that varies in impact according to several parameters, the variables that change periodically with time may be subject to applicable mathematical functions, changing the variables between values lower and higher, and these can be caculated by applying equation (4). The results of the applied equation (4) of salinity in units Part Per thousand (ppt.) is shown in Table (1).

Table1: The salinity measurement (ppt.)

Stations	Fadaghia(5Km)	Sehan(45Km)	Basrah(98Km)	Hartha(130Km)
Discharge(50m^3 /sec):				
Field:	26p.p.t.	2.6p.p.t	1.85 p.p.t.	0.86 p.p.t.
Model :	27 p.p.t	2.9 p.p.t	1.96 p.p.t	0.92 p.p.t.
Discharge(5m^3 /sec):				
Field:	30.4p.p.t	25.3p.p.t	11.4 p.p.t.	1.5 p.p.t
Model:	30.2 p.p.t	25.1 p.p.t	12.6 p.p.t.	1.97 p.p.t.

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From Table (1) it can be noted that in both discharges (50m^3/sec and 5m^3/sec) it gives a close result may be obtained in applying the model and this indicated that the model is a useful tool in this respect .

As a result of the industrial and social development in the country, in particular the geographical area that is closely related to the stations located on the river and on which the experimental mathematical model was built, it is possible that the results are different from the currently measured table as a result of the different ratios of the Q group, so it would give different values and since the mathematical model contains in one of its limits the integration, therefore, it would be able to calculate the variables between the highest and lowest values, and this would give the model the ability to deal with immediate and long-term variables.

Conclusion:

Due to the changes in the level of discharge of fresh water coming from upstream countries and there are many dams built on the rivers for different purposes, the salinity intrusion in the Shatt Al-Arab River is the fastest as a result of the connection of the Shatt Al-Arab River with the Arabian Gulf in in which the salinity would be of aboute (40-45) ppt. Approximately. Thus, this paper proposed an automatic computing system based on developing mathematical model to compute and predicate the salinity intrusion in the Shatt Al-Arab River. The developed model will predict the intrusion of the salty waters coming from the sea before it reaches its range in the River, thus contributes in reducing the hazardous impact on farmers and fish farming and thus the losses are slight. On the other hand, this study recommends the establishment of a dam on the Shatt Al-Arab River as a far-reaching solution for the future of the city of Basrah, to control the salinity intrusion when there is a high shortage in the upcoming discharge of the river by the rivers supplying it.

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