DEVELOPMENT OF A REAL-TIME WEB- ECOLOGICAL DECISION SUPPORT SYSTEM TO CALCULATE WATER QUALITY AND WATER POLLUTION (WATERDSS) IN THE CITY OF BAGHDAD

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The main issue addressed in our case study is the evaluation of the drinking water resource from the Tigris River within the Baghdad City area. Water quality has an important impact on human health since different diseases can be the result of poor quality. This paper presents several strategies to manage water quality and water pollution in order to protect human health by building a web-based decision support system to help the authority of water supply stations to find information about water management available on an on-line service. The water quality service uses a set of (13) water-quality parameters according to the water quality index (WQI) analysis and (24) water-pollution parameters. The system suggests a decision for treatment the water so that it can be used by humans after detecting the causes and type of pollution. WATERDSS tests the data from the water management stations in real-time by using mathematical models. In this paper we use Web technologies, Machine learning and Data mining to build the decision making system.

Keywords: water decision support system, water quality, water pollution, Tigris River

1. Introduction

The issue of drinking water quality is very important in the world, so a web-based decision support infrastructure has been developed to provide access to simulation results on flow water- quality conditions and to offer sophisticated scenario testing capabilities for research and water-quality planning through the graphical user interface with known controls [1]. Water crises around the world often occur because of global climate change and the increasing intensity of human activity. The main cause for water crises is the lack of sustainable methods

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of water resource management. In response to the real water resource management problems, a WEB-DSS has been designed as an easy-to-use and user-friendly interface. The DSS consists of an information management system that leads data collection, verification, management and visualization, and models estimated water demand and water distribution [2]. The management of water is a complex engineering problem that includes various technical, social, economic, environmental, cultural and legal issues depending on the various forms of uncertainties such as fluctuations, randomness, the cognitive nature of parameters and model algorithms. The application of the DSS is employed in various areas of the management of water resources such as the management of water resources, water and wastewater treatment [3]. The visualization, design and implementation of an online course on the topic of Decision Support Systems in River Basin Management is very useful to avoid the pollution crises. The Planning and Management of Water Resources increasingly depends on the ways of decision support such as simulation and Multi Criteria Analysis [4]. The drinking water networks of the surface water are weak in the short-term variation of inputs of organic matter. This affects raw water quality and increases the intensity of rainfall as well as the frequency of heavy rainfall events. These changes may strongly affect the water quality and processing operations [5]. The development steps of a decision tool prototype of geographic information systems (GIS) and the general framework are based on the decision support system of the river health diagnosis (RHD-DSS). The system integrates data, mathematical models and human knowledge on the river health status, causal factors diagnosis and restoration decision making in order to assist decision makers during river restoration and management. It has four functional components: input module, database management, diagnostic indicators management and visual result module [6]. The problem of water quality degradation and the lack of water quantity is urgent in different parts of the world [7]. The new application model for designing this software system-composite, service-oriented and multilayered web information system for the management of lakes and reservoirs, describes the architecture and services of the application model, together with the structure and functionalities of the software solution [8] and is then connected with the Water Management Information System [9]. To support water quality management under hybrid uncertainties, we have developed a model-based decision support system based on a hybrid uncertain programming model with fuzzy and interval coefficients. The system provides an effective tool for decision makers in dealing with the problems of water quality and developing policies and strategies [10]. The fields of water resources, water quality and river management have greatly influenced the DSS over the past few decades, resulting in a variety of decision support systems, such as the Sonhua River Pollution EDSS [11], WaterWare [12], AQUATOOL [13], FLOODSS [14].

The aim of this paper is to present an available online tool to support water managers and scientists who have used the predictive capabilities of the water management models. These models typically use mathematical process representations. In addition, monitoring and geospatial data to estimate water-quality and water pollution conditions over time have been included.

2. Study Area

Baghdad, the largest city in Iraq, stands on the banks of the Tigris (Fig. 1). Most of Iraq's population lives in this region. The Tigris River provides the water for irrigation and drinking. The water of the Tigris River is considered the only source of potable water for Baghdad city. The river divides the city into two sides: west (Karkh) and east (Russafa), with a flow direction from north to south. In Baghdad city, there is a huge increase in the demand for the fresh water consumption due to the rapid growth in population and rapid industrialization. Agriculture is widespread on both sides of the river. Thus, river water quality monitoring is necessary to evaluate the quality of different water uses. In response to this development pressure, local planners, managers and stakeholders will assist in developing smart growth policies that allow for growth while maintaining water quality, reducing water pollution problems and protecting people's health. To achieve this, it is essential to evaluate a wide range of information and to analyze alternative development strategies. The present study seeks to address the problems facing local authority and planners in relation to issues of water management by developing the Web-based Ecological Decision Support System (WATERDSS) that will identify and prioritize local water stations using multiple environmental criteria. Fig. 1 shows the location of the water stations involved in the study. These water stations include most of the sub-stations of water supply in Baghdad city. On choosing a station, a new window is opened to input data on water quality and water pollution. Owing to these features, the effects of water pollution could be avoided and the treatment of the causes of pollution that affect human health could be applied. The kind of stations is to support the decision for supplied the water for people which collect the information about the test of water. The application is design for two stations in any city in the world ,the work depends on the user, station one is the first or the second because they have the same specifications and input the data is not affected if we began with first station or second station and could retrieval the data on any date.There are two type of water measurement, one for water quality index which is the impact of water quality effect (13 parameters) and the other for water pollution measurement (24) parameters ,we used mathematical model depends on many equations(section 4) to calculate the water quality and many conditions for calculating water pollution.

The data transmit to the server by using the application window which is available online at www.waterdss.com to input data and could retrieval the old data(fig.5).

Fig. 1. Stations location at the Tigris River

3. Design of the WATERDSS

The WATERDSS design is based on a client/server model, through which clients send requests for services running on the server and receive appropriate information (Fig. 2). The specific client-server architecture is used because it facilitates maintenance of the application. The client/server used in this study consists of three-steps: Step 1: client, web browser (e.g. Mozilla Firefox), Step2: server, Apache server (2.2) and Step 3: GIS server, ArcMap Internet Map Server. Fig. 2 shows the information flow in the client-server. (1) The user starts request by clicking on the home page tools buttons in the Web browser. (2) In the server side, the user chooses the suitable instance of ArcMap through passing the request from MySQL Web server, then performs the analysis by Scripts in the DBMS model. The images of maps and data tables of the results to Apach Web server are created by Arc Gis. Then, HTML pages are used for output formats and to provide the content of the request to the client Web browser. Finally, the results and the support of user are viewed by the Web browser on the client device. The report generator and display are implemented as a set of frames integral to the Web browser's display [15]. The Java programming environment is undesirable

because it is object-oriented and supports the development of portable, interpreted, system independent and distributed applications on the Internet [16].

The WATERDSS will consist of a set of guidance and software tools designed to allow decision-makers to make their own decision-specific model using interactive tools that permit them to generate graphs and input data , charts, and mathematical analyses to teach decision-makers how to use this conceptual model. Various decision options can be quantified and evaluated in the larger context of the conceptual model by using these tools. Also, the WATERDSS has a case study that can be applied to specific real-time decisions. A Spatial Decision Support System (SDSS) needs up to five major components, including (1) a Data Base Management System (DBMS), (2) a Model Management System (MMS), implementing the analysis algorithms, (3) a display generator,(4) a report generator and (5) a user interface[16]. Fig. 2 shows the components involved in the framework design of the WATERDSS.
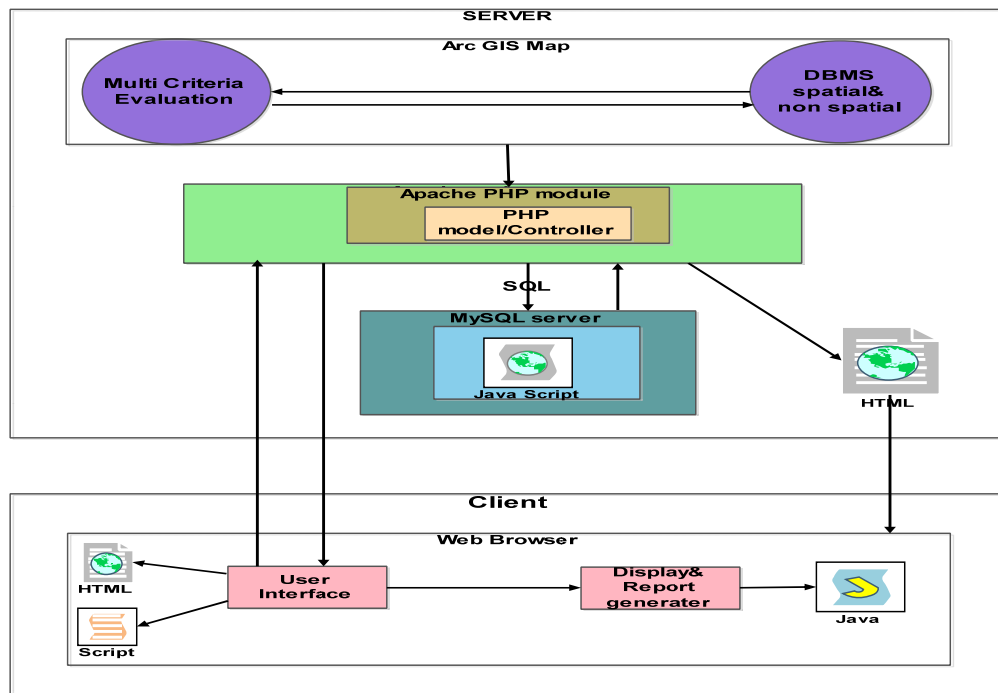

Fig. 2. WATERDSS Web Application Framework

The graphical user interface (UI) for WATERDSS was programmed in JavaScript using the JavaScript library. The content of this part of the web interface is usually created in HTML, while the JavaScript code independent source files reside in the JS file extension [16]. The presentation and styling are

controlled using Cascading Style Sheets (CSS). The CSS source code will be also stored in separate CSS files. All three kinds of files will be served by the Apache web server in response to the requests from the user's web browser, and then the browser will execute the JavaScript [17]. PHP: Hypertext Preprocessor (PHP) is an open source server-side scripting language. The PHP module will implement the model and controller which will allow users to interact directly with the tables in the MySQL database. Supported operations will include displaying table data and creating, deleting and editing rows in the table. The PHP web interface is directly connected with the Stored Procedures in the database. These stored procedures are written in Java script. The databases for the WATERDSS will be in MySQL, a highly scalable Structured Query Language (SQL) compliant with the open source object-relational database management system [18]. The GIS and mathematical technical analysis of the data will be implemented in the stored procedures written in Java script and Adobe Dreamweaver CS6, a procedural language for MySQL. The Java script provides an interface to the application of the mathematical programming language.

4. WATERDSS implementation and discussions

Water Quality Index (WQI) is one of the most effective tools to communicate information about water quality to assist the people to make a decision. WQI is a mathematical instrument used to transform large quantities of data water quality into a single number. The implementation is based on the values available for the water of Tigris River, in Baghdad. Data acquisition is made by 100 and the results are public [19]. The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter (qi) was calculated by using Equation (1):

$$qi = (\frac{ci}{si})\,x100 \tag{1}$$

A quality rating scale (qi) for each parameter is assigned by dividing its observed concentration (Ci) to each water sample by its respective standard value (Si) and the result is multiplied by 100. Relative weight (wi) is calculated by a value inversely proportional to the recommended standard value (Si) of the corresponding parameter using Equation (2):

$$wi = \frac{1}{si} \tag{2}$$

In general, water quality index (WQI) is calculated by compiling quality rating scale (qi) with unit weight (wi) written in Equation (3) as follows:

$$WQI = (\sum_{i=1}^{i=n} wixqi) \tag{3}$$

Where qi is the quality parameter, and wi is the weight unit of (i) parameter, n represents the number of parameters, WQI had been discuss for a specific use and meaning of water quality index. In this study we considered WQI for drinking purposes are (100) values using Equation (4).

$$WQI = \frac{\sum_{1}^{n} wiqi}{\sum_{1}^{n} wi} \tag{4}$$

Based on the calculated WQI, the classification of water quality types are given according to [19], as shown in Table 1.

Table 1

The conditions used to evaluate water quality

No.	WQI value	Water quality classification	Water quality
1	<50	Excellent	Excellent (water is clear and not in contact with domestic wastes. Ideal for all different purposes. No treated required).
2	50-100	Good water	Good (initiation of serious changes in water quality due to environmental deterioration. Useful for domestic and industrial purposes, suitable to secured wildlife and waterfowl).
3	100-200	Poor water	Poor (drastic changes in water quality begin to occur the water can be used for domestic and industrial purposes after intensive treatment).
4	200-300	Very poor water	Very poor (dangerous changes may occur in the ecosystem. Constant disturbing smell. Conventional treatment costs are augmented).
5	>300	Water unsuitable for drinking	Unfit for drinking (highly dangerous pollution. Danger in any form of water consumption).

The WATERDSS system is under test. During the development phase, each of the new functions and components will be continuously tested as offline. At the end of the development phase, the new functions and components will be deployed onto a website. The information service will provide the authority person with a suitable way to avoid the pollution accident. The user can modify, add, and delete the input data for modelling. Currently, the web-enabled WATERDSS is in online operation at www.waterdss.com.

Fig. 3 shows the interactive page that includes a set of thirteen water-quality parameters (n) were used to calculate WQI. These are: pH value (pH unit), Alkalinity (mg/L), Turbidity (NTU), Dissolved Solids (mg/L), Hardness (mg/L), Calcium (mg/L), Magnesium (mg/L), Chloride (mg/L), sulfate (mg/L), Ammonia (mg/L), Fluoride (mg/L), Iron (mg/L), Aluminum (mg/L). The user can input the
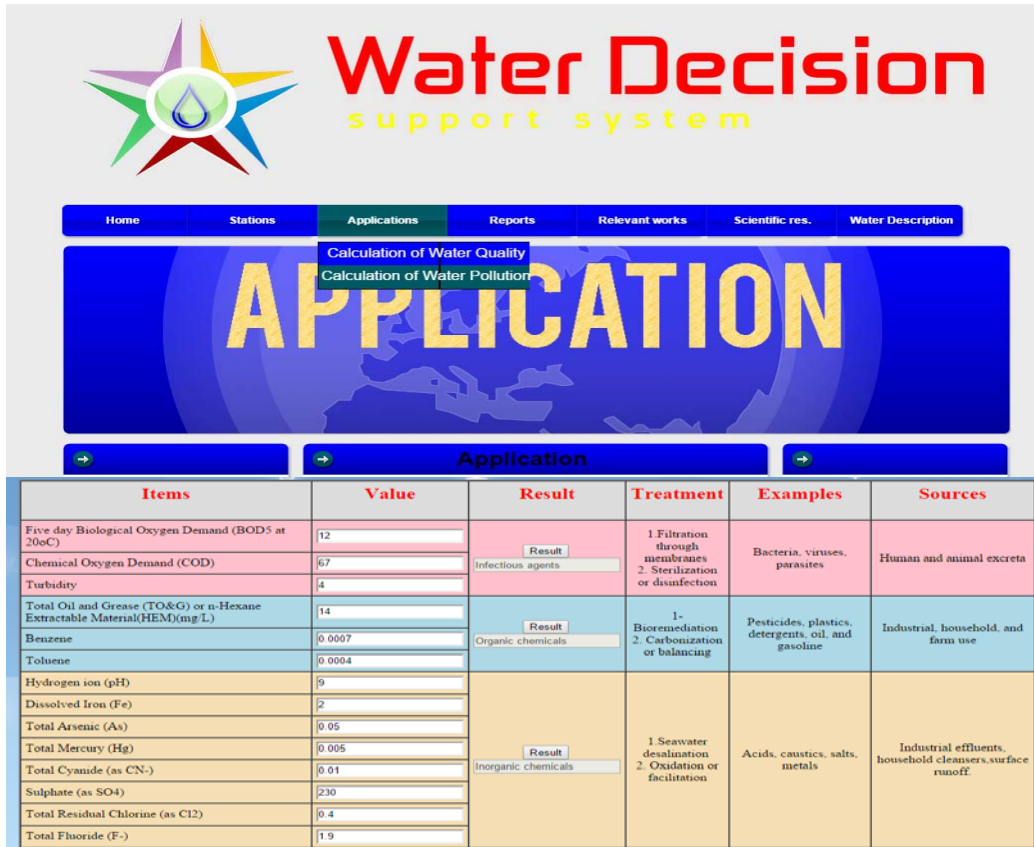
data of water quality and also perform the analysis to calculate the water quality index. The WATERDSS uses standard image/GIS data browsing (Fig.1) to allow users to interact with the map display. When used to query a water quality in the GIS layer, the tool brings up a table showing the model results and the information for the selected water quality parameters. There are two stations in Baghdad City to supply the water, AL-KARKH and AL-RUSSAFA. The data analysis and modelling environment can be retrieved through DBMS (MySQL) in order to calculate the water quality and actual water state, which is further provided as an input for analyzing the ecosystem model to obtain the actual advice and benefits of the distinct practices for avoiding water pollution. Furthermore, a simulation report generation service was also provided to the client to facilitate the comparative analysis of different possible planning strategies to achieve the optimal solution. All information is stored in a meta-database.

Fig.3. Data analysis and modeling for water quality system

The overall process of water pollution model for both stations is explained in the Fig. 4. The standard values of the parameters of water pollution stored initially in the table in DBMS(MySQL server). There are different 24 parameters that can cause water pollution and For Standard values have been defined for each

specific parameter. Based on them, we can determine the type of water pollution as well as the suitable water treatment and thus, we can take a decision that contains suitable advice for the treatment of the specific kind of pollution. The application automatically sends an email to an authorized person/group of persons, with information regarding the pollution event. The measurement is daily that means send the report by e-mail one time per day for each station to the authorized person ,depends on the measuring of the station.The email message includes information regarding the water pollution causes, the source of this pollution, the risks associated to this kind of pollution as well as the suggested treatment. All information is stored in a meta-database.

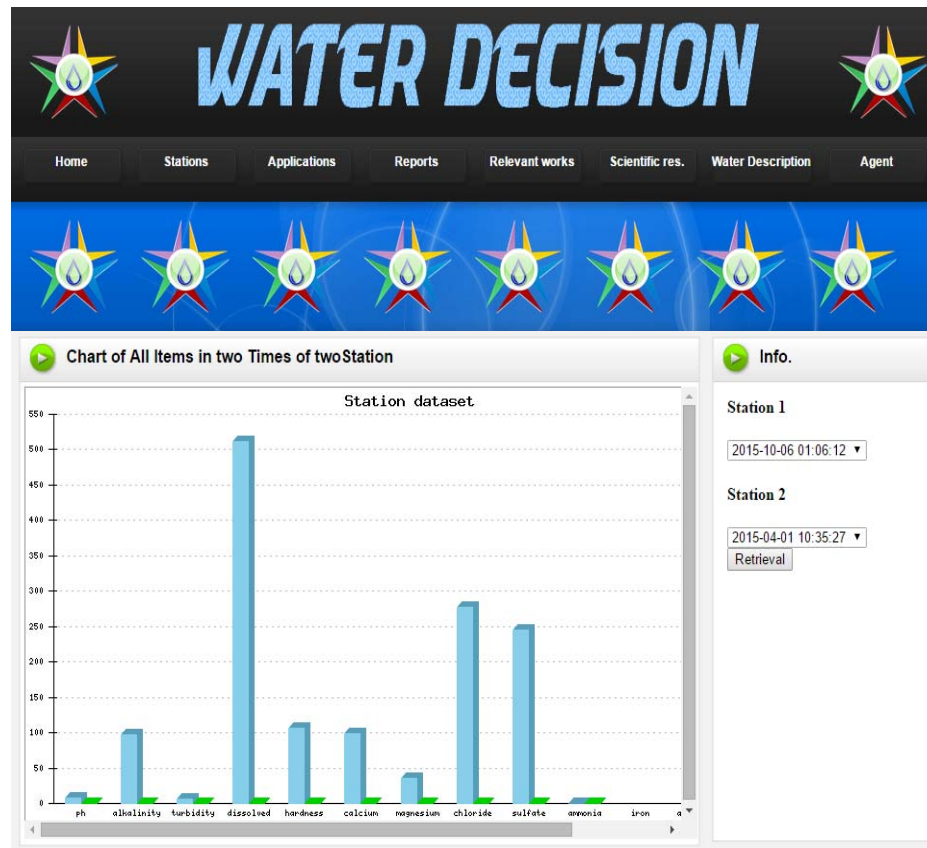Fig.4. Calculation of water pollution parameters

Fig.5. Time series of Water pollution parameters in the stations

Fig. 5 shows the variation of water quality parameters in the stations (station 1 and station 2) at the same or different date of input the data. From these, we can choose the date of input the data from the button retrieval and make a comparison between the parameters. For example, Fig. 5 shows the variation of the real values of water quality parameters on 06/10/2015 in station 1 and on 01/04/2015 in station 2. The figure depends on the values from water test analysis at exactly date for the stations. The reports of all information about water status and water treatment advices were sent for drinking water supplied. Finally, the authorities take the decision to supply the drink water or not.

5. Conclusions

The design and implementation of an environmental decision support system is a challenge in a multi-criteria, involving software engineering, environmental modelling spatial data, real time services, as well as service and

data semantics. In this paper, we have proposed an online application for environmental crises, water management systems incorporating data and presentation services as well as dynamically selected simulation models able to calculate water quality states from real time and spatial data. Also, we have provided the analysis tools for estimating strategies to avoid water pollution effects resulting from the waste industry, oil pollution and different causes. The present prototype of the WATERDSS is limited to 13 environmental criteria water quality and 24 for water pollution. In this study, a hybrid decision support system was designed and developed based on a scoring method and experimental results.

A rule-based system was also created. This system has the potential to provide useful information for the optimum selection of water treatment combinations depending on the type of application and target water quality. In the case of water pollution in the Tigris River, various causes are observed and processed by using a mathematical model. The program compares the real value of pollution parameters with the standard value of these parameters in order to identify the kind of pollution and to give an appropriate suggestion for the water pollution treatment. The evaluation procedure of the DSS compares the effect of water pollution parameters or strategic plans on the basis of well-defined comprehensive indicators. These indicators express the two major principles of the Integrated Water Pollution Management underlined in the Water Framework Directive, the risk to human health and the water treatment technologies. The commonly proposed system to be used in Iraq is the WATERDSS system. The WATERDSS system automatically computes and measures the water quality in Baghdad City. The WATERDSS collects the data for the optimal quality and also tests the data in real-time. The WATERDSS online services provide water management inputs, such as the measured water quality or the water pollution test per water application unit. The time between measuring parameters and sending e-mail to authorized person is one time per day which the report is daily.In the future, based on the feedback received from users, we hope to optimize the WATERDSS by collecting improved data sets and addressing the additional environmental criteria identified by the users.

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