Mobile Phone Application (WATERDSS) Water Decision Support System for Water Management

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Abstract - ***In this paper, we present the design of a set of mobile applications to provide access to simulation and experimental results on flow water- quality conditions and to offer sophisticated scenario testing capabilities for research and drinking water treatment plant planning through the graphical user interface with known controls. The main issue addressed in the study is the evaluation of water quality for drinking of Tigris River within Baghdad city area. The design of drinking water treatment plant in WATERDSS depends on the characteristic of raw water and the water quality objectives. We presents many strategies to manage water quality and water pollution to protecting human health by build a mobile application decision support system to help an authority of water supply stations to find information about water management available as an online service. The water quality service uses a set of (13) water-quality parameters according to water quality index (WQI) analysis and (24) water-pollution parameters. The system suggests a decision for treatment the water. We develop the application to contain Data base, Alerts messages, Treatment water advices, optimization algorithms of machine learning, decision tree based on the Evolutionary Computing principles and Water pollution causes.***

Key Words: *Decision support system, water quality, water pollution*

1. INTRODUCTION

The development of mobile phone technologies is creating new opportunities for water and environment operation and management. For example, current mobile phones applications have become an important element in early warning systems to inform the water authority about current status of water; they are being used to inform modelers about the current status of long computational running times; they have been used for environmental monitoring by promoting public participation; they are an important element within community information services in general.

During the last few years there has been an explosion of mobile phone applications promoted by a fast technological development that has come with new tools, more computational power.

The new opportunities that mobile phones provide are creating, however, at the same time, a series of experiments that have had major drawbacks that limit their application to real case studies, ranging from inadequacy of the local infrastructure to the social implications for privacy. Mobile phones are applied in practically every field in which human communication is required, ranging from religion [1] to disaster management [2-5]. An interesting area of mobile phone applications is the data collection by the community in the field known as Citizen Science.

Interestingly, there is very limited scientific literature about the use of mobile phones specifically for water-related studies. One of the few studies in relation with the hydrological cycle is an application for drought prediction in developing countries [6]. As reported in [7] mobile phones have been used as instruments to carry out water quality analyses using optical methods. Other studies include monitoring canal water levels [8-9], warning people for poor quality in water supply networks [10], warning population about urban flood [11] and Tsunami events [12], and reporting water quality at lakes for recreation [13-14]. Other studies have explored the use of mobile phones in education in hydraulics [15].

The aim of this research is presents environment application phone DSS in detail including water management issues. An application phone DSS provides, how to calculate the water quality and water pollution from the document, how to find the solution for water pollution result, compute the climate effect with water quality's factors and how to avoid the risks of water

2. RELATED WORK

[16] Design of a set of mobile applications and their role in water quality management in rural and under resourced areas in developing countries. Several tools were developed to allow data relating to water quality to be collected remotely using low-cost mobile devices. The so-called "Water Quality Reporter" (WQR) tool is a J2ME application that allows collection of form-based data on mobile devices.
The "Water Quality Management" (WQM) tool is a web-based system that allows managers to set up automatic data point threshold warnings, delivery of periodic reports, and provides a data overview using Google Maps. The WQM mobile application is built for the Android platform and provides managers with a daily overview of data collected [16].
The fast developments in mobile phone technologies are creating new opportunities for water and environment operation and management, particularly in relation to the involvement of communities. However, at the same time, this fast development is generating series of experiments that have had major drawbacks that limit their application to real case studies, ranging from inadequacy of the local infrastructure to the social implications for privacy, which are worth documenting.
Finally, the section addresses the advantages and disadvantages of the applications in a general way. It is expected that this review can provide useful information about the development and application challenges that need to be faced in the near future in this field together with the identification of research needs [17].
Applications supporting technical and information management capacities dominate the market. These applications are predominantly designed for collection and distribution of information on water quality or the condition of water supply infrastructure such as hand pumps.
For example, in a number of African countries, well monitoring systems have been developed to provide real time operation data. To understand the extent of current mobile applications in IWRM, we apply a systematic framework to identify the IWRM challenges that are addressed by available applications.
The capacities needed for implementation of IWRM can be divided into six categories: Framework to evaluate mobile application contribution to IWRM implementation, (institutional, human resources, technical, financial, actor (stakeholder) network; and information management) [18].Interestingly, there is very limited scientific literature about the use of mobile phones specifically for water-related studies.
One of the few studies in relation with the hydrological cycle is an application for drought prediction in developing countries [19]. As reported in [20] the mobile phones have been used as instruments to carry out water quality analyses using optical methods.
Other studies include monitoring canal water levels [21] warning people for poor quality in water supply networks [22], and reporting water quality at lakes for recreation[23] In any case, real implementations seem to be much bigger in number than those reported in the literature.

3. WATERDSS DESIGN

The use of water decision support systems (WATERDSS) to support decision making is important within the water management because they allow authors of water supply to quickly gather information and process it in various ways in order to assist with making diagnosis and treatment decisions when water pollution accidents.
The areas these systems could help in is diverse from the storing and retrieval of water quality records, storing and retrieval of key treatment from pollution causes, examination of real-time data gathered from documents information of water parameters values, analysis of correlation criteria that effected for water state , analysis of statuses history for the purposes of disease that related with water and effect with human health, analysis the results of water quality and water pollution calculation in many other stations.
The necessity of the research described in this thesis is stated by the fact that environmental pollution, as a result of water pollution, adversely affects health. The term (water pollution) includes factors such as Organic chemicals, Infectious agents, Inorganic chemicals, Sediment, Plant nutrients, Oxygen-demanding wastes and Thermal.
This research considers the necessity to assist responsible water supplier's authority for drink water in decision making. Because there are many approaches to decision making and because of the wide range of domains in which decisions are made, the concept of decision support system (DSS) is very broad. A DSS can take many different forms.
In general, it is accepted that a DSS is a computerized system for helping make decisions. A decision is a choice between alternatives based on estimates of the values of those alternatives. A model integrating Decision support system, Data mining and agent System was proposed to build. An approach has been made to develop a decision support system which will take decision under complex environment [24].
Designing an effective decision-support system has become crucial in recent years. Systems have to be able to deal with the uncertainty information. The systems have the ability to learn and adapt to new conditions in the environment.

3.1 Water Quality report

We developed DSS to WQI infrastructure prototype for water quality management system in Tigris River. DSS of WQI (water quality index) implementation is described below which had been developed to make the decision of water quality and send it by email when compute the water quality index. The DSS infrastructure uses two stations to compare state of water for each station and then give it to the users that working on water quality decision. The application is used (machine learning (ML)) algorithm which also used Decision Tree method (C4.5) algorithm. These, enable the computer program to automatically analysis a huge data and decide what information is most relevant. This crystallized information can then be used to automatically make predictions or to help the people to make faster decisions and more accurately.

3.1.1 Calculation of Water Quality Index

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. It becomes an important factor to estimate and management the water as a pastiche indicator. WQI is a mathematical instrument used to transform large quantities of data water quality into a single number, which provides a simple and understandable tool to managers and decision makers on the quality. Water quality index is provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. 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 [25]. 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):

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

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):

$$wi = \frac{1}{si} \qquad (2)$$

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

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

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).

$$WQI = \frac{\sum_1^n wiqi}{\sum_1^n wi} \qquad (4)$$

Based on the calculated WQI, the classification of water quality types are given for raw water, the samples were calculated under the following conditions, “Excellent” (range 0-50), and “Good” range 50-100. Water quality was indicated, Tigris River water is generally “Poor” (range 100-200) and is either “Poor”, “Very poor” (range 200-300) or “Unsuitable” (above 300). This might be reflecting the effect of pollution from urban wastes and anthropogenic activities [25].

3.1.2 Local Search Algorithms

```
1: N: = Number of water quality parameters repetitions
2: S: = Standard value of parameters
3: Wi: = Relative weight values of parameters
4: Ci: = Observed concentration values of parameters
5: qi: = quality rating scale for each parameter
6: WQI: = The overall Water Quality Index (WQI)
7: For i: = 1 to N do
     S1:= sum (qi:=(ci/si)x1oo  ) * wi:=1/si  ) / sum wi
           if (s1 <= 50){
             Water value=Excellent;
               }
           if ((s1 > 50) & (s1 <= 100)) {
             Water value=Good water;
               }
            if (s1 > 100 & s1 <= 200) {
             Water value=Poor water;
              }
        if (s1 > 200 & s1 <= 300) {
       Water value= very Poor water;
       }
      if (s1 > 300) {
   Water value= Water unsuitable for drinking;
        }
        End if
       Return S1;
   End for
```

3.1.3 Quality Rating and Weighting

Water quality parameters were studied in respect to their suitability for human consumption. The ‘standards’ (permissible values of various pollutants) for the drinking water, recommended by the World Health Organization and unit weights are given in Table 1 [26].

Table -1: Drinking water standards and unit weights

NO.	Water quality parameters	Standards	Unit Weights (Wn)
1	pH value (pH unit)	6.5-8.5	0.007990
2	Alkalinity (mg/L)	100	0.000679
3	Turbidity (NTU)	5.0	0.013583
4	Dissolved Solids (mg/L)	500	0.000136
5	Hardness (mg/L)	100	0.000679
6	Calcium (mg/L)	100	0.000679
7	Magnesium (mg/L)	30	0.002264
8	Chloride (mg/L)	250	0.000272
9	Sulphate (mg/L)	250	0.000272
10	Ammonia (mg/L)	0.2	0.339574
11	Fluoride (mg/L)	1.0	0.067915
12	Iron (mg/L)	0.3	0.226383
13	Aluminum (mg/L)	0.2	0.339574

3.1.4 Practical results

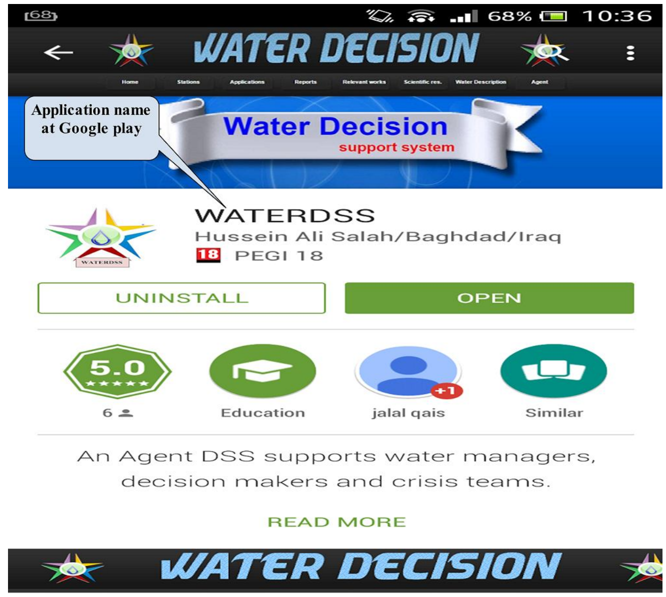


Fig – 1: Application name at Google play store

Figure 1 shows the application name at Google play store, which could download it and start the work with WATERDSS application for the authority of drinking water plant.

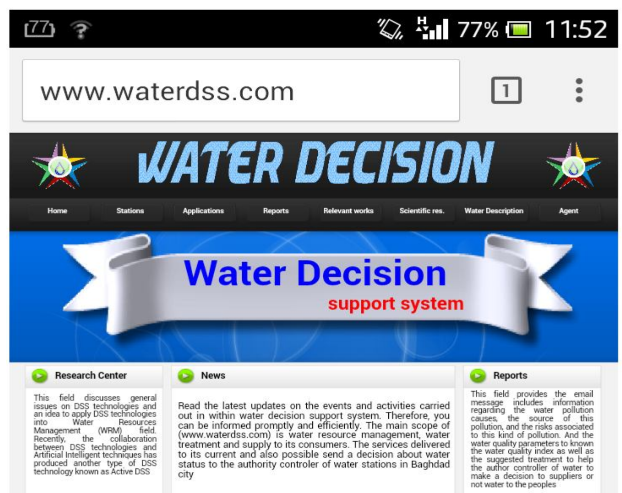


Fig – 2: Home page of (WATERDSS) phone application

The components of the WATERDSS approach are many fields as links (see figure 2), 1-Home page: which contained information about the web site of WATERDSS such as the news, stations details, research center and reports to send the water statuses to the authority controller.2-stations:
shows the locations of each water stations in Baghdad city.3- Applications: Includes the programs for calculating a water quality and water pollution.4-report: send the

report of water state for decisions to supplying the water or not to the peoples.5-relevant work: includes many researches that relevant with WATERDSS project.6-Scientific research: includes a program for computing the correlation between climate events and water parameters values 7-water descriptions: provided all the parameters of water quality to know the suitability of the water.8-Agent:responsible for uploading the file of water parameters values and processing it in Applications programs(see figure 2). The propagation of uncertainty at each step of the decision process is the key of WATERDSS components. Data from a wide variety of different sources, as well as stakeholder values and preferences, will be combined as part of the decision analysis process. Highly uncertain information and data are essentially weighted inversely to their uncertainty.

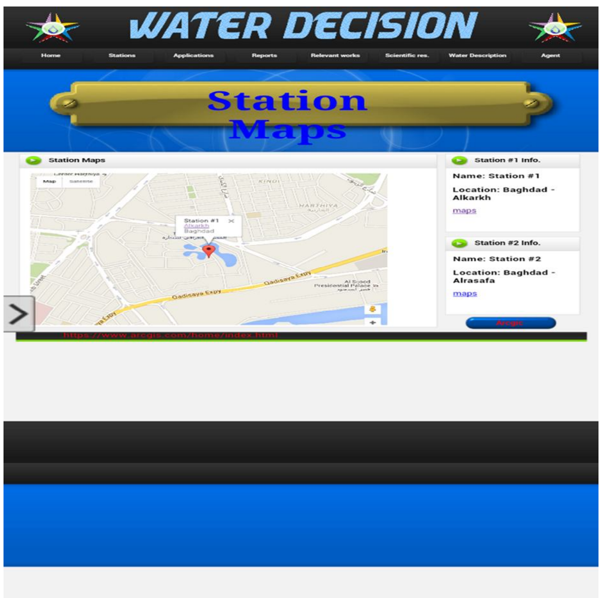


Fig – 3: Stations location at the Tigris River

The river divides the city into two sides: west (Alkarkh) and east (Alrasafa), 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.
Figure 3 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.

Fig – 4: Stations Maps by using ArcGIS online

The WATERDSS uses standard image/GIS data browsing (Figure 4) 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-RASAFA (Figure 5). 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.

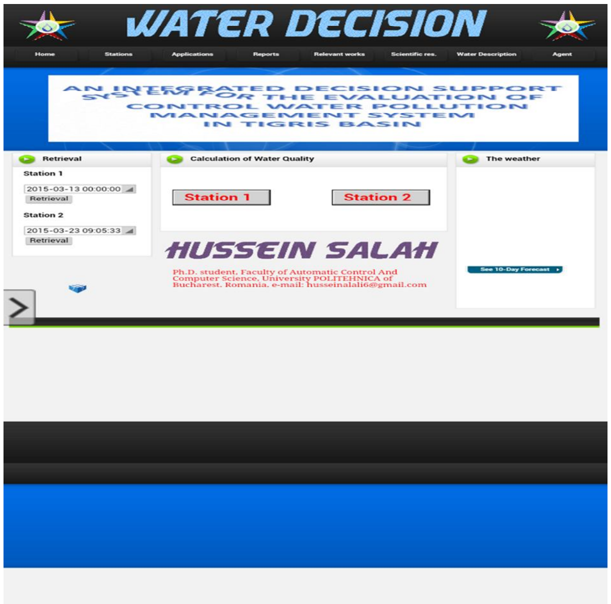
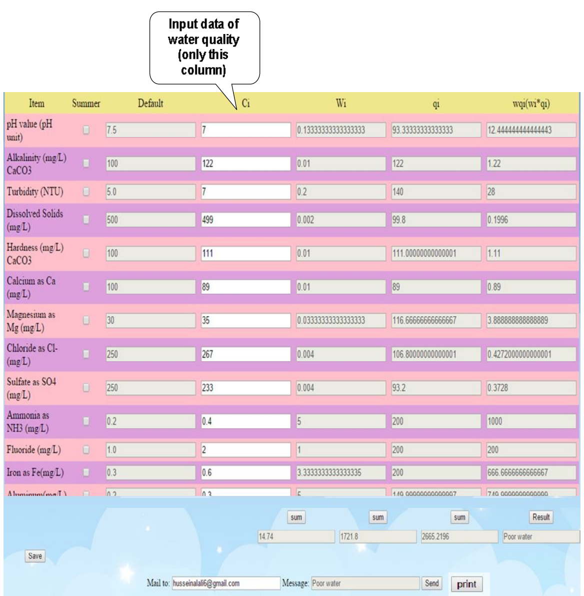


Fig – 5: Input data to calculating water quality index

Figure 5 shows the stations page to input water quality data. The user can choose the station name to input a new data or retrieval the old data and analysis the values of quality parameters.



Item	Summer	Default	Ci	Wi	qi	wqi(wi*qi)
pH value (pH unit)		7.5	7	0.13333333333333333	93.33333333333333	12.444444444444443
Alkalinity (mg/L) CaCO3		100	122	0.01	122	1.22
Turbidity (NTU)		5.0	7	0.2	140	28
Dissolved Solids (mg/L)		500	499	0.002	99.8	0.1996
Hardness (mg/L) CaCO3		100	111	0.01	111.00000000000001	1.11
Calcium as Ca (mg/L)		100	89	0.01	89	0.89
Magnesium as Mg (mg/L)		30	35	0.03333333333333333	116.66666666666667	3.888888888888889
Chloride as Cl- (mg/L)		250	267	0.004	106.80000000000001	0.42720000000000001
Sulfate as SO4 (mg/L)		250	233	0.004	93.2	0.3728
Ammonia as NH3 (mg/L)		0.2	0.4	5	200	1000
Fluoride (mg/L)		1.0	2	1	200	200
Iron as Fe(mg/L)		0.3	0.6	3.3333333333333335	200	666.6666666666667
			sum	sum	sum	Result
			14.74	1721.8	2665.2196	Poor water

Fig – 6: Input data to calculating water quality index

Figure 6 display the result for data analysis by used calculation of water quality index (see equations above). The figure shows the status of water was poor water because the result of summation last column (wqi =2665.2196) divided the summation of (Wi=14.74) = 180. the conditions used to evaluate water quality, if WQI value is 100-200 then the status of water quality is poor water (section 3.1.1).Finally the program will send an email report to the authority person includes all the information about the test.

Fig – 7: Time series of all Water parameters in the stations

Figure 7 shows the variation of water quality parameters in the stations. From these, we can choose the date of the input data from the button retrieval and make a comparison between the parameters. For example, Figure 7 shows the variation on 06/10/2015 in station 1 and on 13/10/2015 in station 2. Also the figure shows the variation of water quality parameters in the station 2. From these, we can choose the date of the input data and make a comparison between the parameters. For example, figure 7 shows the variation for (ph) parameter in station 2 and on different date of input data. Finally the report of all information is sent to the water stations suppliers.

3.2 Water pollution report

The DSS uses the concept of an integrated water pollution management scheme (WATERDSS), defined as a set of scenarios for variables that cannot be directly influenced by the decision maker (i.e. water quality patterns constituting scenario and population growth formulating a demand scenario) and the application of one or more water management interventions.
WATERDSS is based on a database containing information on the water infrastructure in a certain region and reference year, which the implementation of scenarios and strategies begins. A base case is always present, serving as input for the creation of new WATERDSS instance. User interaction with the DSS falls under three functional groups, accessed via a hierarchical decision tree.

3.2.1 Types and Effects of Water Pollution

Table -2: Main type of water pollutants

No.	Type	Examples	Sources
1.	Infectious agents	Bacteria, viruses, parasites	Human and animal excreta
2.	Organic chemicals	Pesticides, plastics, detergents, oil, and gasoline	Industrial, household, and farm use
3.	Inorganic chemicals	Acids, caustics, salts, metals	Industrial effluents, household cleansers, surface runoff.
4.	Radioactive materials	Uranium, thorium, cesium, iodine, radon	Mining and processing of ores, power plants, weapons production, natural sources
5.	Sediment	Soil, silt	Land erosion
6.	Plant nutrients	Nitrates, phosphates, ammonium	Agricultural and urban fertilizers, sewage, manure
7.	Oxygen-demanding wastes	Animal manure and plant residues	Sewage, agricultural runoff, paper mills, food processing
8.	Thermal	Heat	Power plants, industrial cooling

3.2.2 Local Search Algorithms

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1: N: = Number of water pollution parameters
   repetitions
2: S: = 0
3: A: = The actual value of Water pollution
4: For i: = 1 to N do
5: C: = initial value of pollution;
6: While A matching with the cause of pollution
   Type    do
7:  C: = one of the pollution type;
8:   end while
9:         if  C better than S then
10:             S: = C;
11:        End if
12:      End for
13:     Return S;
```

3.2.3 Practical results

Fig – 7: Main window for calculating water pollution of WATERDSS phone application

Figure 7 shows the main window for calculating water pollution, includes all the data of pollution parameters. Select date of input data if we need to process the old data by click on button retrieval or input a new data by use the window of analysis data (figure 8).

Fig – 8: Analysis data window of water pollution in WATERDSS phone application

The overall process of water pollution model for both stations is explained in the Figure 8. 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 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. The figure shows the type of water pollution which in the first just input the item value and the program will make the data analysis and mining the last decision that related with the kind of pollution, treatments, some examples and sources of the kinds. Finally the program will send an email report to the authority person includes all the information about the test.

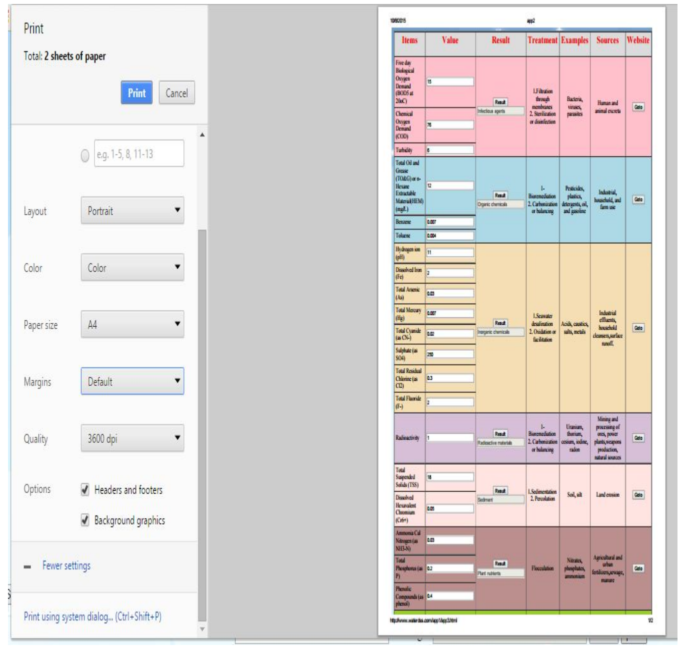

Fig – 9: Print the report for Input data to calculating water pollution parameters

Figure 9 shows the print screen to display the result for data analyses by used calculation of water pollution program depend on the information in table 2. The figure shows the options of printing the report as (paper size, the quality of picture, colors and choose the background). Finally the program will send attach file includes the information file with alert mail to provide a suitable decision for water authority.

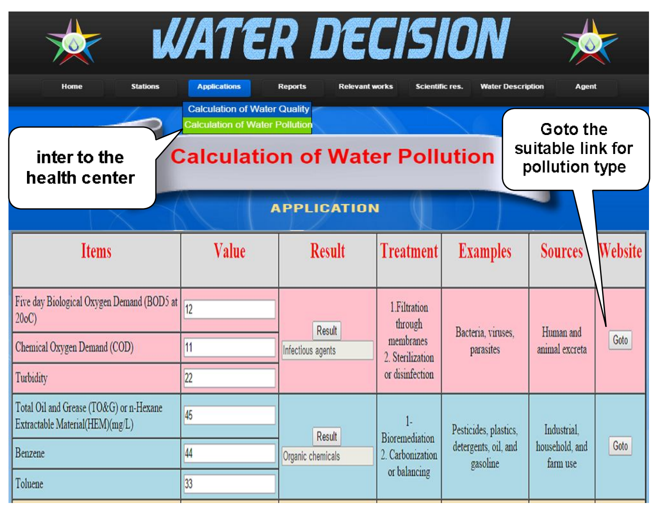

Fig – 10: Main window to inter to the health program

Figures 10 show the window for human health center. After calculating the water pollution parameters, the system gives many results includes (the type of water pollution, treatments methods, some examples for each type, causes of pollution (sources) and healthy website (human health center) for each type of water pollution includes all the information about the diseases and the treatments.

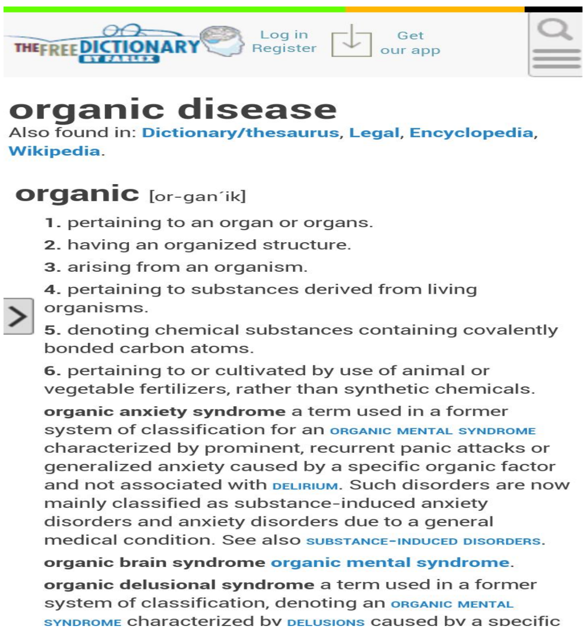

Fig – 11: The window of organic disease

Organic disease is an example of the diseases that related with the water pollution.
All the types of organic disease and the suitable methods for treatment are shown in the figure 11. The information about the disease includes (symptoms and treatments)

4. CONCLUSIONS

This article shows that emerging mobile technologies are slowly entering the field of water management. Although scientific literature on this subject is limited to prove of a concept that makes it incipient, an important number of initiatives coming from the necessities in the field are currently running.

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.

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.

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