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Analysis and Design an Expert System for Identifying the Types of Water Quality in the Context of Physical Indicators

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ABSTRACT— ***The expert system (ES) proposed in this paper is able to easily identify the major types of water quality and make appropriate recommendations according to the users' needs for bottle drinking water, sea water, and even for irrigation water. Although water is important of all living substances human-animals-fish-plants-agriculture, water is uninterruptedly polluted naturally and artificially which finally effects on its quality. Due to the dearth of data and facts about the quality of water, the harmful effects of water to the animals' body including human, and also necessity of perfect water for agriculture remain unknown. As a result all the creatures depend on water suffer a lot. To identify the types of water in this research paper we analyzed the physical indicators of water namely: positive hydrogen-pH level, total dissolved solids-TDS level, electrical conductivity-EC level, and temperature-T^0C level. The inspiration behind this exertion was due to the inadequate knowledge about the quality of water and the need to provide novel approaches towards water quality identification and management. A rule-based, web enabled expert system shell: expertise2go was used to design about 56 rules which involved a knowledge component, decision component, design component, graphical user interface component, and the user component.***

Keywords— Water quality, Expert system, pH, TDS, EC, Temperature, Rule-based, Knowledge

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1. INTRODUCTION

Expert systems (ES) are a division of artificial intelligence (AI), and were established by the artificial intelligence research group in the mid-1960s [1]. ES is defined as an intelligent-based computer program that uses data and facts as knowledge and inference actions to solve problems that are complicated to necessitate major human proficiencies for their solutions [2] [3]. We can understand from this definition that expertise can be transferred from a human to a computer and then stored in the computer in a suitable form that users can call upon the computer for specific advice as needed. Then the system can make a specific conclusion towards giving specific recommendations and clarification. ES present prevailing, influential and flexible means for acquiring elucidations to a range of troubles that often cannot be managed by other established or conventional methods [1]. The expressions of ES and knowledge-based system (KBS) are frequently utilized synonymously. The main components of KBS are: a knowledge base (KB), an inference engine (IE), a knowledge engineering tool (KET), and a specific user interface (UI). Some of KBS important applications include the following: medical treatment-handling-management and, engineering malfunction analysis, decision support system and decision making system and learning system, knowledge demonstration or representation, weather or climate forecasting, chemical procedure controlling and many more.

Advantages of using expert systems [4]

- An ES can be accessible all time from any place.
- Creative ES are able to unmistakably elucidate in detail the interpretation that led to a conclusion.
- Unwillingly individual expert possibly will be too exhausted to do what the expert system can do.
- The expertise is everlasting or never-ending.
- The expert system's knowledge will last forever or indefinitely.
- ES is very fast, quick, speedy and rapid depending on the hardware and software we use.
- An entire expert system is the composed knowledge of many individual experts.
- A multi-user ES is able to provide more users at a time.

By taking the above considerations into the account, our contributions are as follows:

- Analysis the factors of physical indicator of water that are directly related to its quality.

- Identify the major water quality types, namely: neutrality of water, fresh water types, drinking water quality, salinity, acidity, and alkalinity of water according to the factors EC, TDS, T^0C, and pH for designing the proposed expert system.
- Design a rule-based expert system which is able to analysis rules and facts automatically according to the users' demands and also able to make necessary recommendations when needed following the rules of certainty factors (CF).

After analyzing the physicochemical indicators of water our expert system classified and obtained the result of water quality types into: neutral, acidic, severe acidic, alkaline, brine, saline, slightly saline, moderate saline, highly saline, sea and rain water, fresh water, drinking and excellent drinking water including bottled drinking water, brackish to highly brackish water.

The proposed expert system will be very helpful for the researchers to identifying water types, and recommendations necessary for life stock, aquatic life, cattle, and plants. As the proposed system is web-based, so at any time from any place any user can access to it and get recommendations he needed.

This paper is organized in this way, Section 2 Problem definition. Section 3 Analysis the major types of water quality; Section 4 Expert system's main components and an analytical model for the proposed system; Section 5 Design of the proposed expert system, Section 6 Conclusion and finally Section 7 References.

2. PROBLEM DEFINITION

One of the significant characteristics of water is-"extraordinarily versatile molecules" all recognized structure of life existing on earth, from mammals to microbes including plant life depends on water [5].

Essential characteristics of water related to human body, animal life, and plants including: [6]

- First of all our body is made of 90% water, blood contains 80% which is vital for many or our organisms.
- Almost all our body cells including plants live in a watery environment.
- For synthesis of protein needs water.
- Water is the regulator of body temperature, helps cooling body; and a buffering agent to regulate pH (acidity or alkalinity) of body fluids.
- Seed absorb water for growing up. [7].
- Water is applied in irrigation system. Under irrigation, soil and water compatibility is very important [8].

The earth's surface is covered by water and the mount is almost 71%. But 97 % of this amount of water is saltwater we find in oceans and seas. The other 3 % are fresh water in form of surface and ground water, whereof 2.5 % are unavailable because they are bounded in glaciers, ice caps, rocks or soils. Another 0.497 % is polluted water, so that only 0.003 % of the whole water on earth is usable for drinking water [9]. This water we can find in lakes, rivers, reservoirs. And this amount is regularly increased and renewed by rain and snowfall, the present fresh water condition around the globe is presented in Figure 1[10].

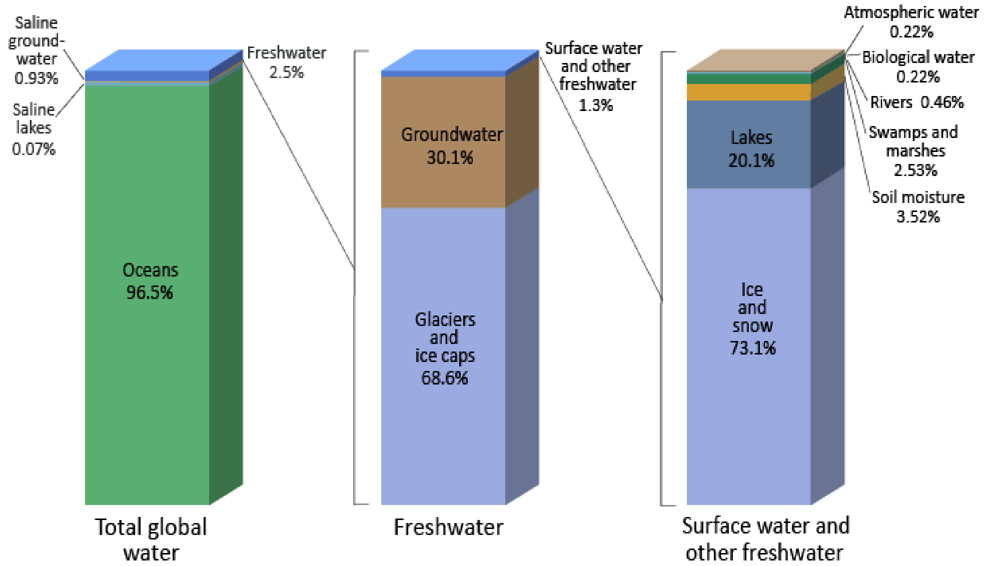

Figure 1: Distribution of earth's water [10]

Physical, chemical and microbiological water quality indicators are used to identify the types of water [11]. In our paper we emphasized over the physical quality indicator. The main factors related to this indicator are: pH, TDS, EC, SAR, and Temperature [12]. The amount of these quality factors in all types of water is not same. That is why the quality of water is varied and is classified as: neutral water, fresh water, drinking water, sodic water, alkaline water, acidic water, saline water, brackish water, brine water [13][14].

In this paper we proposed ES with facts and rules in a form that it could easily be evaluated water types and made necessary decisions.

3. ANALYSIS OF THE MAJOR TYPES OF WATER QUALITY

As we already known that water is indispensable for life for every organism and for healthy ecosystems. But its quality varies region to region worldwide. The water quality worldwide depends on several factors such as, soil structure, groundwater, and water table.

Water salinity or sodicity (in some cases alkalinity) globally depend on the following factors: Temperature, TDS (Total Dissolved Salts/ Solids: mg/L), EC (Electrical conductivity: µS/cm), SAR (Sodium Absorption Ratio), ESP (Exchangeable Sodium Percentage), pH (Positive Hydrogen), and Anions and Cations: eg. Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}, CO_3^{2-}, HCO_3^{-} [15].

The water salinity is calculated by electrical conductivity, for the case of water it is symbolized by EC_w, as shown in Table 1 [16]. The conversation system of EC and TDS unit is depicted in Table 2 and Table 3 separately [17].

Conductivity is often utilized as an estimate of whole dissolved salts/ solids (TDS) content of water samples. Table 4 [18] [19] show the classification of quality of water in terms of TDS. Upon studying and analyzing the Tables (1-4) mentioned above we identified the data that assess the safety of water according to its salinity level as mentioned in Table 5 It also shows relationship between TDS and EC in natural water. A relationship of TDS = 0.64 EC units is used to calculate salinity level of water.

Table 1: Classification of water based on EC

Water Types Analyzed	Electrical Conductivity is measured by unit: deciSiemens per meter (dS/m)*
Exceptional or Excellent quality	≤0.25
Good quality	0.25 - 0.75
Permissible/ allowable type	0.76 - 2.00
Doubtful/ uncertain	2.01 - 3.00
Unsuitable	≥3.00

Table 2: EC and TDS unit conversion

Symbolic presentation	Meaning of the symbol	Units in standard form
Total Salinity		
TDS	Total dissolved solids	mg/L[a]; ppm[b]
EC	Electrical conductivity	dS/m[c]; mmho/cm[d]; µmho/cm[e], µS/cm[f]
System of conversion		
1 dS/m = 1 mmho/cm = 1000 µmho/cm= 1000 µS/cm. TDS= 0.64* EC		
1 mg/L = 1 ppm		
[a]mg/L = milligrams per liter; [b]ppm = parts per million; [c]dS/m = deciSiemens per meter at 25° C; [d]mmho/cm = millimhos per centimeter at 25° C; [e]µmho/cm = micromhos per centimeter at 25°C; [f]µS/cm = microSiemens per centimeter at 25°C.		

Table 3: Conversion of natural water quality factors

Names of elements	Convert into	Multiplier	Result will be obtained in Unit
Water salinity	Electrical conductivity: EC_w (dS/m) when the condition is EC_w <5 dS/m	640	TDS (mg/L)
Water salinity hazard	Electrical conductivity: EC (dS/m) when the condition is EC >5 dS/m	800	TDS (mg/L)

Table 4: Water quality types in term of TDS

Description	TDS concentration (mg/L)	
Drinking water	<300	Neutral
Fresh water	300-999	No problems
Slightly saline	1000-2999	Satisfactory
Moderate saline	3,000-9,999	Possible diarrhea
Saline Water	10,000-14,999	Avoid usage
Highly saline	15,000-35,000	Avoid usage, sea water
Brine water	>35,000	Severe salinity

Table 5: Assessing safety of water according to its salinity level

Parameter	Generally Safe	Slight to Moderate Risk (slightly saline)	Severe Risk (highly saline)
Total dissolved solids (TDS)	< 1,000 mg/L, that is less than	1,000 to 10,000 mg/L	> 10,000 mg/L, that is more than
Electrical conductivity (EC) of water	< 1700 µS/cm, that is less than	1700 to 17,000 µS/cm	> 17,000 µS/cm, that is less than

Other than TDS and EC in water, the sodium adsorption ratio (SAR) could be used to measure the appropriateness of water for use in agricultural irrigation, which can be determined by the following formula [20]:

$$SAR = [Na^+] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}, \text{-----------} \ (1)\ [20]$$

From the equation mentioned above, all the components like sodium, calcium, and magnesium are in mill equivalents/liter and are obtained from a saturated paste soil extract. To convert ppm or mg/L Na^+ to meq/L, divide by 23, for Ca^{2+} divide by 20, and for Mg^{2+} divide by 12.2 [21].

Another factor of water is directly related to the quality of natural/ irrigation, even salinity of water, this is PH. The acidity or basicity of water is expressed as pH (< 7.0 acidic; > 7.0 basic) [22]. The normal pH range for neutral, irrigation, and saline water are 7, from 6.5 to 8.4, and 8.4 respectfully. The water quality criteria respect to TDS, EC, and SAR is shown on Table 6.

Table 6: Water quality criteria in low precipitation region

Quality	EC (dS/m)	TDS (mg/L)	SAR
Neutral, Suitable for usage, irrigation	<1.5	<1000	<9
Slightly saline, marginal usage, and irrigation	1.5-2.7	1000-1800	9-17
Highly saline; unsafe, unsuitable for use and irrigation	>2.7	>1800	>17

Water's acidity and alkalinity mainly depends on the two major factors: pH and temperature. If the temperature of water increases the pH level decrease-it means water is acidic, and when temperature decrease the pH level in water increase-it means water is alkaline [22]. Upon studying and analyzing the factors mentioned above we again classified the quality of water, namely neutral, acidic, and alkaline in respect to pH, and temperature as shown in Table 7, and Table 9. Table 8 shows the relationship between the temperature level and pH level of water.

Table 7: Water types identification using pH factor

Types	pH
Water neutral	=7
Fresh water	6-7.5
Water acidic	<7
Water alkaline	>7
Saline water	7.5-8.4
Brine water	>8.5

Table 8: Relationship between pH and Temperature

PH	Temperature (^{0}C)
Normal	25 ^{0}c
Decrease	>25 ^{0}c
Increase	<25 ^{0}c

Table 9: Water quality types and temperature: a relationship

Temperature Scale in Centigrade	Water types (major)
=25^{0}C	Neutral
< 25^{0}C	Alkaline/ Base
>25^{0}C	Acidic

4. AN ANALYTICAL MODEL FOR THE PROPOSED EXPERT SYSTEM

The knowledge-based system (KBS) analyzed and designed for this research depends on the structure of expert system. The structure of expert system has five main components: user interface, working memory, inference engine, knowledge base, and explanatory facility [23], with these major ES components there are some additional components in our proposed system namely: system interface, sensors, water source, and users, as shown in Figure 2. The major components are briefly explained below [24].

Knowledge base –IF THEN rules is to present KB in KB system;

Working storage – data is processing and solve din this section for solving any problem;

Inference engine –contains the coding section of the developing system which gives the result based on data and rules processing;

User interface – Creates interaction between the user and the system;

Explanation Facility-Illustrates to the user how and why the system gave a certain cause for the failure, i.e. explains the reasoning of the system to the user.

In this proposed expert system we used forward chaining (reasoning) method where an interpreter uses a set of rules and a set of facts to perform an action [25].

This method engages inspection the condition part of a rule to decide whether it is true or false. If the condition is true, then the action part of the rule is also true. This process persists in anticipation of a solution is found. Forward chaining is usually called as data-driven reasoning. This method composed of three components as mentioned bellow [26]:

The set of rules, current state of the system: working storage, and place to apply the rules: inference engine.

Rules are formulated in this way: left hand side (LHS) ==> right hand side (RHS), in short: IF---THEN.

The LHS is a combination of conditions which must be matched in working storage for the rule to be run.

The RHS must contain the actions to be taken if the LHS conditions are met.

The whole ES is executed in this way:

At first determine a rule.

Then, execute the right hand side of that rule.

And repeat until there are no rules which apply.

The syntax of the rules is:

rule <rule id>: ; is the identifier for the rule
[<N> : <condition>,.......]; not constant identification for the condition, condition - a pattern to match against working storage
==>
[<action>, ...]; something that act

The Figure 3 mentioned below represents the concept of the forward chaining algorithm.

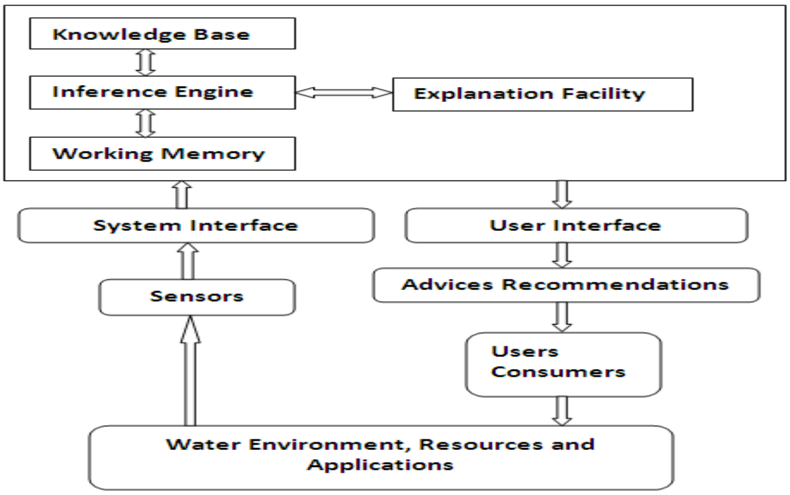

Figure 2: Structure of proposed expert system

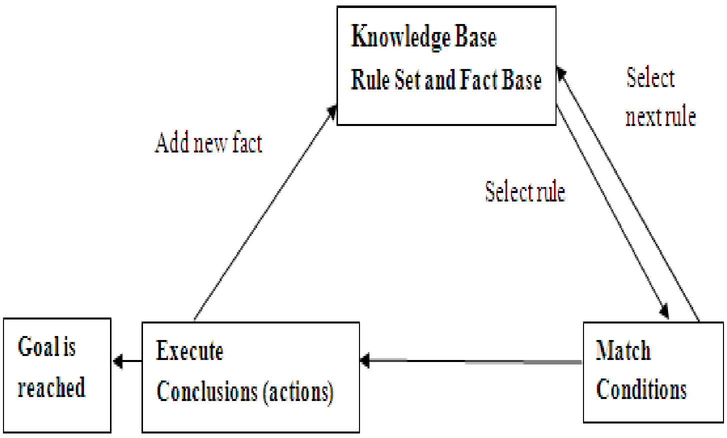

Figure 3: The forward chaining algorithm model for the proposed ES

A formal model of the proposed system was built using Unified Modelling Language (UML) [27]. A Use Case diagram portrays the interactions between the system, the external system (if any) and the user. Use case diagrams play a major role in system design because it operate as a roadmap in constructing the structure of the system; it also defines who will use the system and in what way the user expects to interact with the system. The following Figure 4 shows the user-system interaction by Use Case for this proposed expert system.

The purpose of the use case diagram is to portray:

- The actor.
- A set of use cases for a system.
- The relations between the actor and the use cases.

Here, we introduced the main Use cases which extend, include or use other Use cases.

- User Interface (UI)
- Knowledge base (KB)
- Inference Engine (IE)
- Finding solution
- Making decision, and
- Exit the system

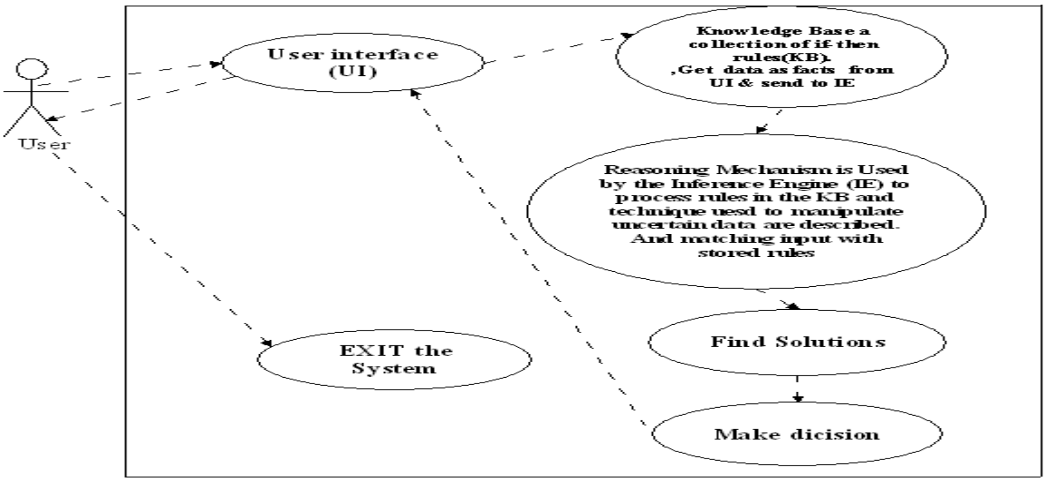

Figure 4: Use Case Diagram for proposed ES

5. DESIGN OF THE PROPOSED EXPERT SYSTEM

To formulate rules in ES the experts in specific fields obtain knowledge through standardization process. In water types identification system, the way of knowledge representation is production rule. The manufacture or production rule for our system is presented by the famous rule “IF P THEN Q”, where, P is precondition, and Q is conclusion [28].

Decision table or knowledge base table is used to proposed expert system’s knowledge base system. Where the condition part of the decision table is called the condition end and the action part the action end shown in the Figure 5 as mentioned below. Rules are represented by columns to satisfy the conditions of those columns, the actions are represented by the recommended decision columns [29].

	Rule1	**Rule2**	**Rule3**
Condition1			
Condition2			
Action1			
Action2			

Figure 5: A decision table.

In a rule-based system all the rules and decision tables are interrelated which can be easily illustrated in the following decision table as shown in Table 10 [29]. Using the concepts getting from the Table 10 we developed a new table, Table 11, which shows the combination between decision table rules for our proposed system.

Table 10: Combination between decision table rules in rule-based expert system

	Rule1	**Rule2**
Condition1	Y	Y
Condition2	-	-
Condition3	Y	Y
Action1	X	
Action2		X
Action3		

Tabl1 11: Combination between decision table rules in rule-based expert system for the proposed system (e.g. Rule 1, 13, 40)

	Rule1	**Rule13**	**Rule40**
PH level	7	6.5-6.9	8
TDS level	0-50	300-1200	30,000-40,000
EC level	0-81.8	470-1875	
Temperature level (degree C)	21-32	21-32	21-32
The recommendation (action)	Neutral water, excellent quality, ideal drinking water, very soft.	Fresh water, but with a bitter taste. Mere acidic. Acceptable for fresh water fish, plants, and cattle.	Sea water. Contains high degree of salts. Acceptable for sea fishes, animals, and plants.

The rule-based shell in proposed ES stores the knowledge in rules, which are logic-based structures, as shown in Figure 6.

```
REM Generated by v1.01 of e2gRulewriter 12/07/2011
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RULE [1]
If [PH level] =7 and
[TDS Level] >0 and
[TDS Level] <50 and
[EC] <81.8 and
[Temperature level] >20 and
[Temperature level] <33
Then [the recommendation] = "neutral water,
excellentquality, ideal drinking water from
reverse asmosis,fresh and safe water,
very soft."

RULE [13]
If [PH level] >6.4 and
[PH level] <7 and
[TDS Level] >299 and
[TDS Level] <1201 and
[Temperature level] >20 and
[Temperature level] <33
Then [the recommendation] = "fresh water,
but with a bitter taste (mere Acidic)surface
water Acceptobl for fresh water fish"

RULE [40]
If [PH level] =7 and
[TDS Level] >30000 and
[TDS Level] <40001 and
[EC] >50000 and
[EC] <66668 and
[Temperature level] >20 and
[Temperature level] <33
Then [the recommendation] = "Sea water , contains|
high degree of salt.Acceptable for sea fishes,
sea animals, and sea plants"

DEFAULT [the recommendation] = "The quality of water
depends on mainly on pH and TDS. Temperature
also plays a big role."

GOAL [the recommendation]

MINCF 80
```

Figure 6: Storage of knowledge in rules.

The KBS makes conclusions by making a decision which rules are satisfied by facts saved in working memory and then executes the rule with highest priority and propose proper and acceptable solution. Figure 7 explains the inference process of the system using the rules listed in Figure 6 and Figure 8 shows the relationships between the rules used in this system.

Uncertainty [30] is the important factor of any ES and we must deal with it because the expert's rules might be fuzzy or the user might be unsure of answers. In our system, the knowledge base contains data that are based on certain and proven facts and it has the capability to handle a user's uncertainty.

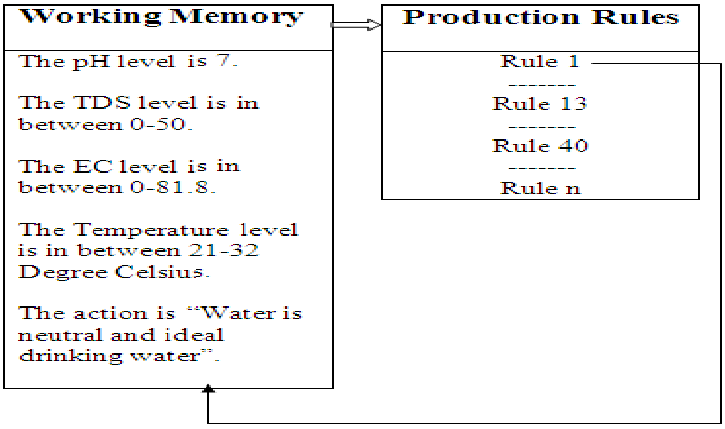

Figure 7: The production system after the Rule 1 is fired.

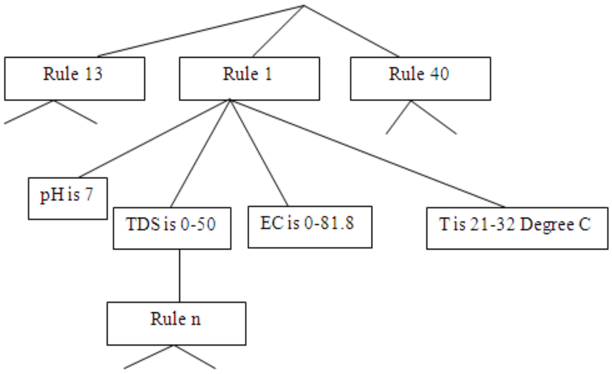

Figure 8: Relationships among Rules.

6. CONCLUSION

In this paper we analyzed and designed an expert system to identify the major water quality types. The quality of water is a very vital issue all around the world, and of course this quality depends on physical, chemical and microbiological water quality indicators. All these three indicators are varying region to region due to precipitation, natural and man-made contaminant, etc. In this paper we gave our attention over the physical factor. Now we are looking forward to design an expert system to identify the types of water quality using all three water quality indicators. During the design period we had to analysis all of the factors related to physical indicator of water quality, namely pH, TDS, EC, SAR, and Temperature. Our system never gave the wrong recommendation/ action according to the rules used. In summary, the system has the characteristics of good expert systems, such as high performance, adequate response time, understandability.

7. REFERENCES

[1] http://www.scribd.com/doc/39880379/Paper-1-Expert-System-Methodologies-and-Applications-A-Decade-Review-From-1995-to-2004
[2] http://www.massey.ac.nz/~wlxu/paper472/expsyshm/ESIntro.htm
[3] http://blue.cs.ksi.edu/dl/video/cis509/ch01a.html
[4] http://radio-weblogs.com/0101842/stories/2003/06/01/theUseOfExpertSystemsInConservation.html
[5] Water's important characteristics: http:// www. nscdelhi.org/national-science-seminar.php? menu =11
[6] Water for life: http://en.wikipedia.org/wiki/Water
[7] Water for plants: http://www.ebfarm.com/why organic/ kids/PlantNeeds.aspx

[8] North Dakota State University and U.S. Department of Agriculture cooperating: Water for irrigation: http://www.ag.ndsu.edu/pubs/ ageng/irrigate/ eb66w.htm
[9] http://www.forbes.com/sites/investor/2011/08/05/is-water-a-better-investment-than-oil/
[10] Igor Shiklomonov, on Peter H Gleick, Water in crisis: A guide to the world's fresh water resources published in 1993.
[11] A. Karafistan, F. A. Colafokru, Physical, Chemical, and Microbiological Water Quality of the Manyase Lake, Turkey, mitigation and adaption strategies ofr global change (2005) 10: 127-143.
[12] University of waterloo, water chemistry 4 life: http://www.science. uwaterloo.ca/~cchieh/cact/applychem/waterchem.html
[13] Water glossary: http://www.lenntech.com/water-glossary.htm
[14] Water types: http://www.pondkoi.com/waterquality.htm
[15] Water factors: http://www.dwcwater.com/technologies/others/ water-quality-tester/index.html
[16] EC in Irrigation water: http://www.ext.colostate.edu/ pubs/crops/00506.html
[17] EC to TDS conversation: http://www.ext.colostate.edu/pubs/crops/00506. html
[18] TDS in water: salinity test: http://www.spe.org/glossary/wiki/doku.php/terms: saline_water
[19] TDS in water: http://www.pacificro.com/watercla.htm
[20] http://en.wikipedia.org/wiki/Sodium_Adsorption_Ratio
[21] SAR: http://web.jjay.cuny.edu/~acarpi/NSC/7-ph.htm
[22] PH: http://www.h2ou.com/ h2wtrqual.htm
[23] Ahmad T. Al-Taani. An Expert System for Car Failure Diagnosis, World Academy of Science, and Engineering
[24] http://www.openlearningworld.com/books/Expert%20Systems/Expert%20Systems/Expert%20Systems.htm
[25] Forward chaining method: http://www.myreaders.info/ 07_ Expert_Systems.pdf
[26] http://www.amzi.com/ExpertSystemsInProlog/05forward.htm
[27] UML: http://en.wikipedia.org/wiki/UnifiedModeling_Language
[28] Production Rules:http://www.ijcaonline.org/journal/number23/pxc
[29] KB and KBT: http://www.expertise2go.com/ e2g3g/e2g3gdoc/e2gRuleWriterRef.htm
[30] http://www.amzi.com/ExpertSystemsInProlog/01introduction.htm