# BUILDING OF AN EXPERT SYSTEM FOR WWTP OPERATION AND MANAGEMENT: RUSTIMIYAH SOUTH WWTP AS A CASE-STUDY

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## ABSTRACT

This paper presents the building of expert system to enable the inexperience plants operators to application of better of wastewater treatment plant. This methodology consists of three steps: (i) creation of a decision trees (algorithms) for the diagnosis operational problems; (ii) implementation into a real-based system; and (iii) verification. This system called expert system for Rustimiyah south wastewater treatment plant operation (ES-RS-WWTPO). The knowledge acquisitions to build this system ware extracted from literature. Moreover local experience ware also incorporated using the results of a well designed questionnaire. The results obtained in the application three operational states showed that the system was able to diagnosis (correctly) state of plant with reasonable accuracy. The programmer language for built this system id Visual Basic 6.0.

## INTRODUCTION

Wastewater is a combination of the waster-carried wastes produced from domestic, commercial and industrial sources. It has very complex composition, containing many different substances, both suspended, dissolved and a heterogeneous dispersion of organic and inorganic solids **(11)**.

Wastewater treatment use complexity process and the success of wastewater treatment plants depended on their correct and safe operation. The treatment of the water and wastewater has become one of the most important environmental issues. Wastewater treatment id fundamental for keeping water natural resources (rivers, lakes, and seas) as high quality as possible **(7)**. If wastewater id not effectively treated, several problems can occur: pollutants will be returned to the environment; decomposition of organic component evolves malodorous gases, disease may be spread by microorganisms present in the water or by poising due to toxic compounds, the organic nutrient in the wastewater may stimulate growth of aquatic plants **(10)**.

## Operational State of WWTP

The operational state is described by a series of parameters (4). Also it is defined as a region that includes only influent parameters and process state variables, or it can also include adequate effluent quality variables **(9)**. This may be a multidimensional region, where all the process state variables and parameters are located, thus if some of the state variables or parameters drift a way from this region, the process is assumed to be in a different operational state, to determine this state, many measurement and observation are required **(6)**.

**Operational Problems**

A compilation of the different operational states that may occur in WWTPs ware generated based on the explanation that found in literature as shown in table (1).

**Table (1)** typical operational problems that may occur in WWTPs

| |
|---|
| Rising sludge (Denitrification in the secondary clarifier). |
| Biological foams at the aeration tank (Foaming). |
| Industrial wastes. |
| Storms and Rainy water. |
| Toxic shock or poisoning. |
| Light filamentous bulking. |
| Primary sedimentation tank problems. |
| Strange wastes. |
| Many problems from mechanical or electrical origin. |
| Organic overloading. |
| Overflow. |
| High secondary clarifier sludge level. |
| Loading shock. |
| Solids shock. |
| Side streams. |
| Abnormal environmental temperature. |
| Other activated solids separation problems. |

**Artificial Intelligent**

Artificial intelligent is a branch of informatics that was widely adopted in industrial automation during the past fifteen years. AI programs are developed and used in computer science since the early days of digital computers **(2)**.

Recently, application of AI techniques, such as decision support systems, expert systems for municipal sewage treatment in towns and cities of different sizes are increasingly attracting the interest of national and international private institutions and is gradually being considered as an attractive and proven alternative to conventional control **(5)**.

## EXPERT SYSTEMS (ES)

There are popular AI techniques in industries. Where ES is a computer program that uses knowledge and inference procedures to solve problems that are ordinary solved through human expertise. The main components of an ES are: (i) Inference engine, (ii) Data base; and (iii) User-interface **(12)**.

ES incorporated rule kind of programming. They are currently being used in many applications in the area of wastewater treatment plant, power systems and power electronics.

During the last decade, the research of wastewater treatment has been concentrated mainly on the operation rather than the design and construction of the treatment plants. This is due to the fact that the management and operation of the plants is the key step for the efficiency of water pollution control **(8)**.

## Advantages of Expert Systems

According to Gonzales **(3)** an expert systems have a number of distinct advantages. The advantages are:

- Wide distribution of scares experts.
- Ease of modification.
- Consistency of answering.
- Preservation of experts.
- Perpetual accessibility.
- Solution of problem involving incomplete data.

## Statement of problem

In Iraq, by now suffer from sever lack of experience in wastewater treatment plant operation and management. This is due to the circumstances prevailed during the last two decades: wars; sanction; and low secure conditions led to the migration of so many expertises outside Iraq. Low and lack of maintenance and training capabilities forces the authorities to wastewater treatment plants. This is premise upon which the building of an efficient ES is necessary.

## EXPERIMENTAL SYSTEM

### plant description

An expert system to support the diagnosis and solution of the operational problems was built for Rustimiyah South wastewater treatment plant located in the Diyala river bank (Baghdad city, Iraq). According to Bechtel report **(1)** Rustimiyah south WWTP was designed to serve a total population equivalent of 1500000 capita and produce an average final effluent quality of 20mg/l BOD and 30mg/l TSS in order to meet the Iraqi national standards set by regulation No. 25 at 1967. It has three stages R0; R1; and R2.

This plant includes a primary treatment and a secondary treatment to remove organic matter and suspended solids from wastewater. Primary treatment is designed to physically remove solids material from the incoming wastewater. Coarse particles are removed by screens. Inorganic solids are removed in Detritor units and after that sewage flow passes to the pre-aeration tanks and many of the organic suspended solids are removed by sedimentation tanks. Table (2) shows the No. Detritors in plant and table (3) shows specifications of the pre-aeration tanks and table (4) shows No. of sedimentation tanks.

**Table (2)** the No. detritors in Rustimiyah south WWTP.

| Plant: Process stream | Cross flow Detritos |
|---|---|
| R0 | 2 |
| R1 | 1 |
| R2 – stream A | 2 |
| R2 – stream B | 2 |

**Table (3)** Specifications of the pre-aeration tanks in Rustimiyah south WWTP.

| Plant: process stream | No. of Pre-aeration tanks | Pre-aeration capacity (m3) | Aeration system |
|---|---|---|---|
| R0 | 1 | 560 | Diffused air-Blowers |
| R1 | None | None | None |
| R2-stream A | 1 | 445 | Mechanical aerators |
| R2-stream B | 1 | 445 | = |

**Table (4)** No. of sedimentation tanks in Rustimiyah south WWTP.

| Parameter | R0 | R1 | R2 |
|---|---|---|---|
| Maximum flow (l/s) (FTFT) | 1852 | 2083 | 4166 |
| Design surface over flow rate a DWF (m/hr) (SOR) | 0.45 | 2.02 | 0.5 |
| Design surface over flow rate max flow (m/hr) (SOR) | 1.78 | 4.05 | 2.01 |
| Surface area (m2) | 3730 | 1850 | 7440 |
| Total number of tanks | 8 | 2 | 8 |
| Diameter of each tank (m) | 24.4 | 34.4 | 34.4 |

Secondary treatment consists of a biological conversion of dissolved and colloidal organic compounds into stabilized, low-energy compounds and new biomass cells, caused by a much diversified group of microorganisms, in the presence of oxygen. This mixture of microorganisms (living biomass) together with inorganic as well as organic particles contained in the suspended solids constitutes what is known as activated sludge. This mixture is kept in aeration tanks, where table (5) shows No. of aeration tanks in Rustimiyah south WWTP.

**Table (5)** No. of aeration tanks in Rustimiyah south WWTP.

| Plant: process stream | No. of Aeration tanks | Aeration capacity (m3) | Aeration systems | Total number of aerators | Aerator capacity for each unit (kw) |
|---|---|---|---|---|---|
| **R0** | 1 | 14000 | Mechanical aerators | 64 | 7.5 |
| **R1** | 1 | 18000 | = | 20 | 37.5 |
| **R2** | 1 | 25000 | = | 60 | 18.5 |

An aeration tank followed by a secondary sedimentation tanks (**SSTs**), Where table (6) shows No. of **SSTs** in Rustimiyah south WWTP.

**Table (6)** No. of **SSTs** in Rustimiyah south WWTP.

| Parameter | R0 | R1 | R2 |
|---|---|---|---|
| Number of installed tanks | 4 | 4 | 8 |
| Number of duty tanks | 4 | 4 | 8 |
| Diameter of each tank (m) | 21.3 | 26 | 26 |
| Original design MLSS (ml/g) | 3500 | 4000 | 4000 |
| Design $SSVI_{3.5}$ at average DWF (ml/g) | 94 | 85 | 85 |
| Recommended operating MLSS | 2500 | 2500 | 2500 |
| Design $SSVI_{3.5}$ at recommended MLSS and DWF (ml/g) | 145 | 158 | 158 |
| Average plant DWF (MLD) | 40 | 45 | 90 |
| FTFT (MLD) | 80 | 90 | 180 |
| RAS Flow(MLD) | 68.6 | 63.6 | 68.7 |

## ES-RS-WWTPO

In this research an expert system is called expert system for Rustimiyah south wastewater treatment plant operation (ES-RS-WWTPO). This system was built in Visual Basic 6.0 language. The ES-RS-WWTPO takes into account the operational problems as mentioned in the literature review, questionnaire sheet, and these problems are occurred in Rustimiyah south WWTP as shown in table (7).

**Table (7)** types of problems these are applied in the ES-RS-WWTPO

| Treatment types | Types of operational problems |
|---|---|
| Primary treatment | Old sludge, Septic sludge, Sludge removed systems break down, Clogged pumps or pipes, Low efficiency of grit removal, Primary high sludge density, Inadequate sludge purges, Hydraulic shock, High solids loading. |
| Secondary treatment | **(Biological origin)**<br>Toxic shock<br>Activated sludge solids separation problems:<br>Filamentous bulking, Non-filamentous bulking, Biological foaming, Dispersed growth, Pin-point floc, Rising sludge. |
| | **(Non-Biological origin)**<br>Clarifier problems<br>Under loading<br>Over loading |

## Establishing high; normal; and low values for most operational parameters

At this point, the action range determined for every parameter nigh; normal; and low value for each operational parameters used in ES-RS-WWTPO as shown in table (8).

**Table (8)** High; normal; and low value for each operational parameter used in ES-RS-WWTPO.

| Parameter | Low value | Normal value | High value |
| --- | --- | --- | --- |
| COD-I | <650 | 650-850 | >850 |
| COD-PE | <500 | 500-655 | >655 |
| COD-E | <98 | 98-128 | >128 |
| BOD-I | <300 | 300-400 | >400 |
| BOD-PE | <210 | 210-280 | >280 |
| BOD-E | <30 | 30-40 | >40 |
| SS-I | <230 | 230-330 | >330 |
| SS-PE | <70 | 70-100 | >100 |
| SS-E | <23 | 23-33 | >33 |
| DO | <1 | 1-2.5 | >2.5 |
| pH | <6.5 | 6.5-8.5 | >8.5 |
| SRT | <5 | 5-8 | >8 |
| V30 | <50 | 50-200 | >200 |
| SVI | <50 | 50-100 | >100 |
| F/M | <0.25 | 0.25-0.35 | >0.35 |
| MLSS | <1000 | 1000-2000 | >2000 |
| COD (E)/P | <400 | 400-600 | >600 |
| COD (E)/N | <45 | 45-68 | >68 |

## Description of ES-RS-WWTPO

The built system consists of many interaction windows, as explained in details:

**A- User name and password window:** as shown in figure (1)

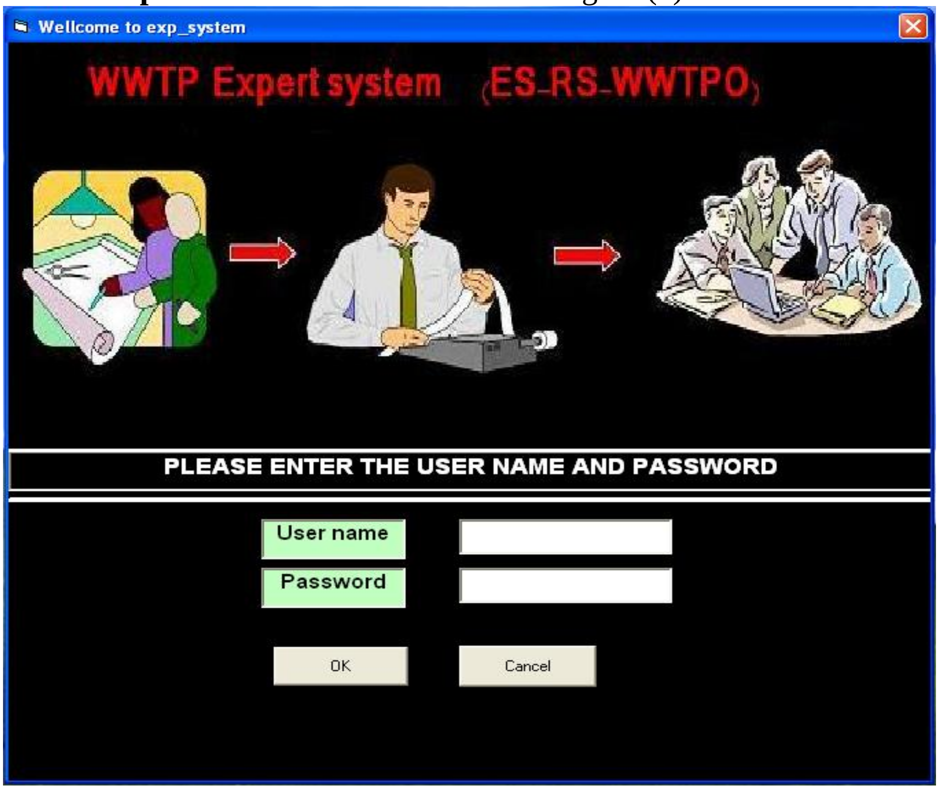


**Figure (1)** The (input user name and password) window for ES-RS-WWTPO.

After the operator of plant was input the user name and password and click on cmd (ok), new window will appear; as shown in figure (2)


**Figure (2)** The starting window for ES-RS-WWTPO.

If the operator wants to run f ES-RS-WWTPO, he clicks on cmd (start).

**B- Start window:** as shown in figure (3)

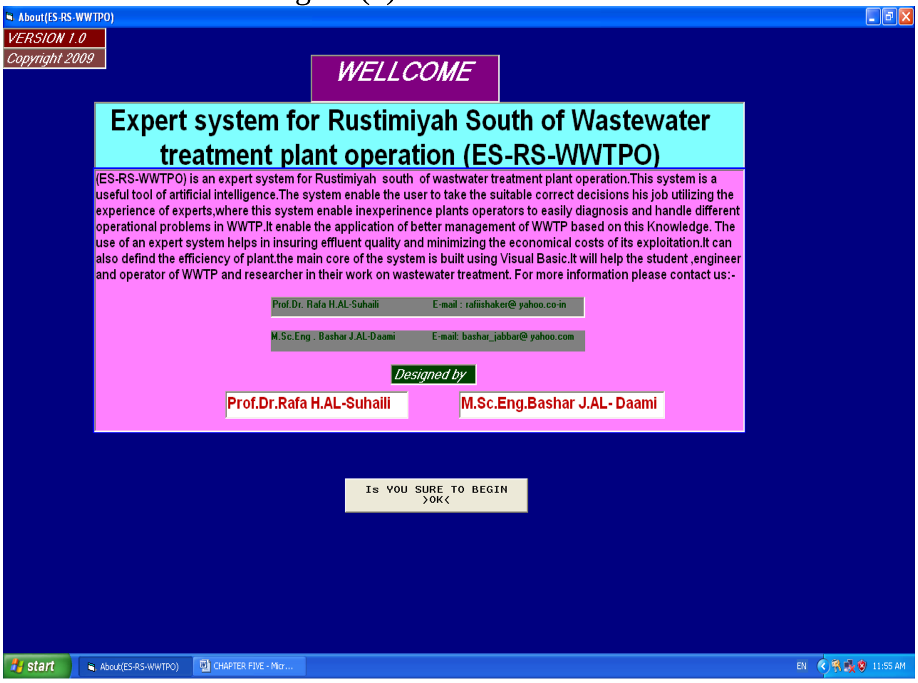


**Figure (3)** The (system name, version and copyright) window for ES-RS-WWTPO.

**C- Main window of ES-RS-WWTPO:** as shown in figure (4)

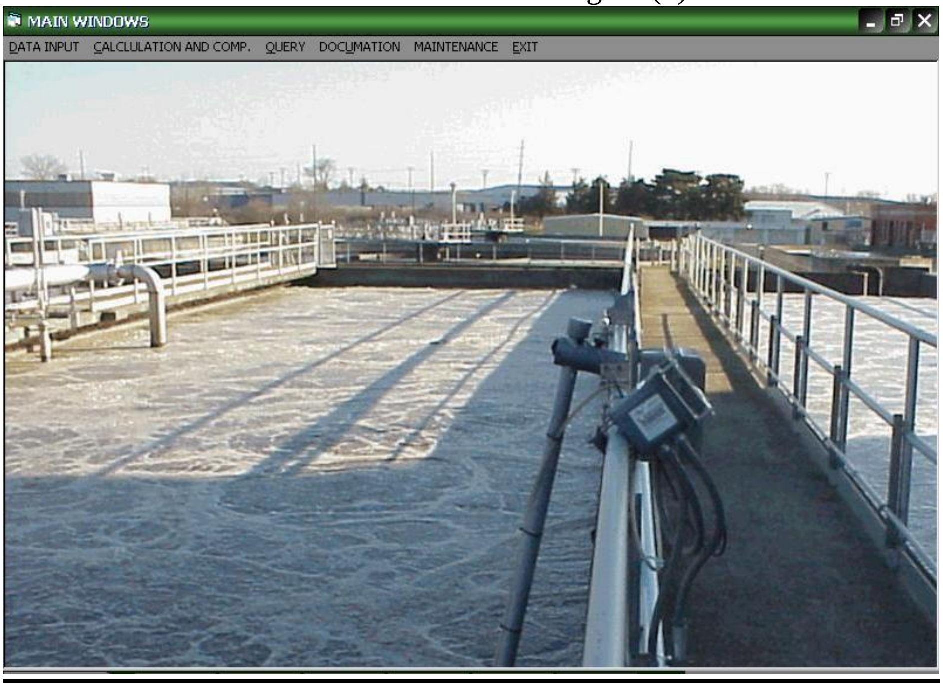


**Figure (4)** The main window for ES-RS-WWTPO.

**C1- Communication of ES-RS-WWTPO with the operator**

After the operator clicks on cms (DATA input window), window will appear as shown in figurer (5)

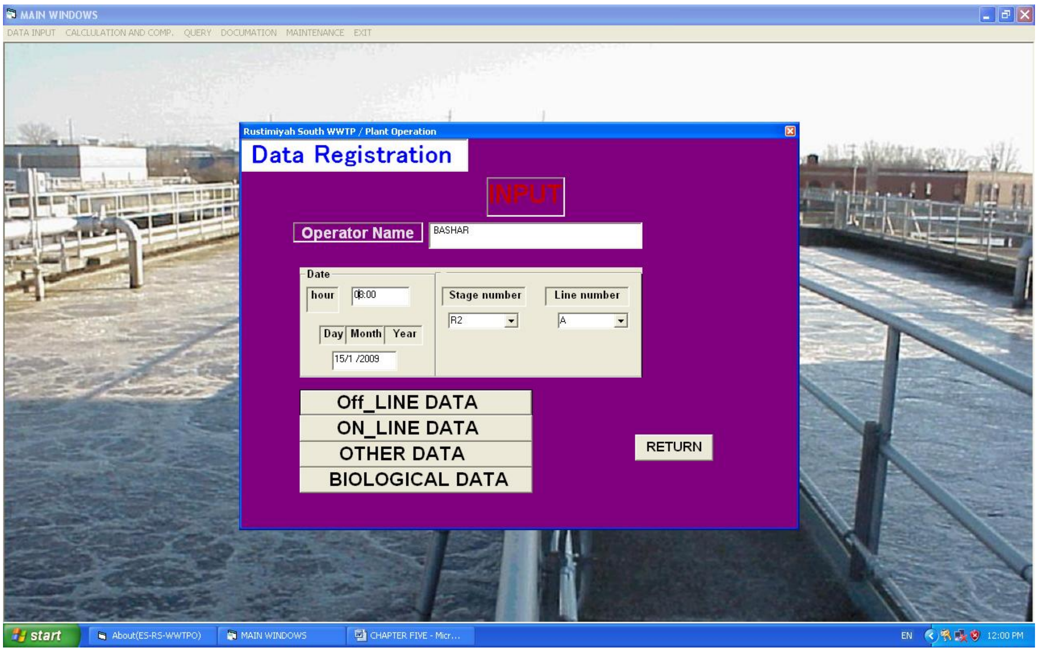


**Figure (5)** The data input window for ES-RS-WWTPO.

## C2- Role of the dynamic ES-RS-WWTPO

After the operator clicks on cmd (calculate and compared data), new window will appear as shown in figure (6)

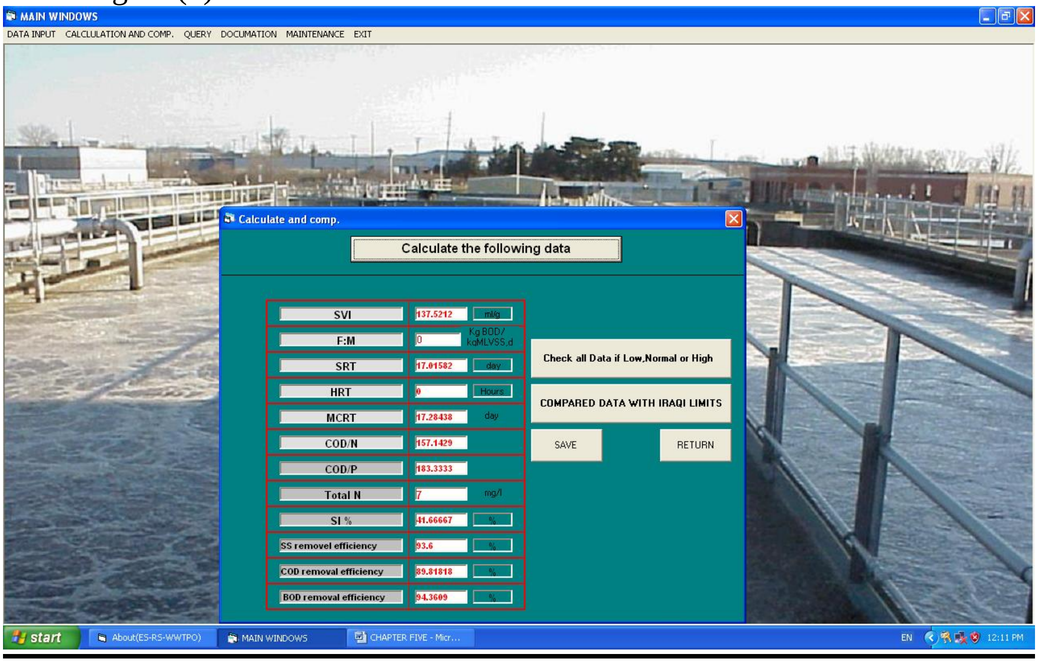


**Figure (6)** the calculation data window for ES-RS-WWTPO.

Where the operator clicks on cmd (calculate the following data), this system begins the calculate of the important parameters in the biological treatment. If the operator clicks on cmd (check all data), new window will appear as shown in figure (7)

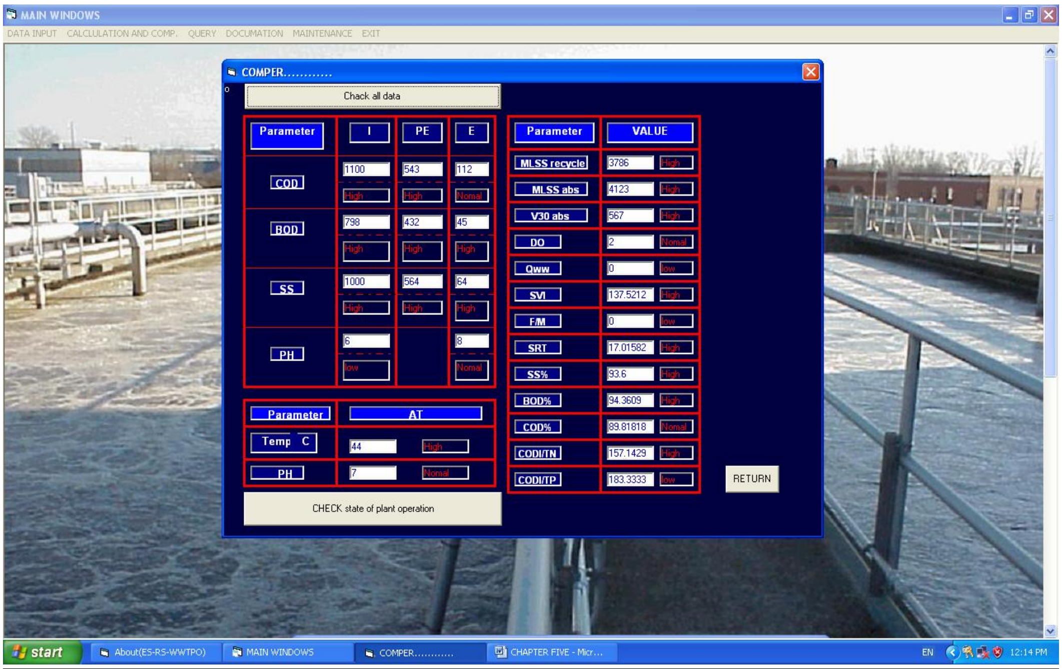


**Figure (7)** the level for each operational parameter window for ES-RS-WWTPO.

The above window will classify the input data and calculate data to high; normal; and low level for several pouts along treatment line.
Id the operator wants to check state of plant, he clicks on cmd (check state of plant operation), new window will appear as shown in figure (8)

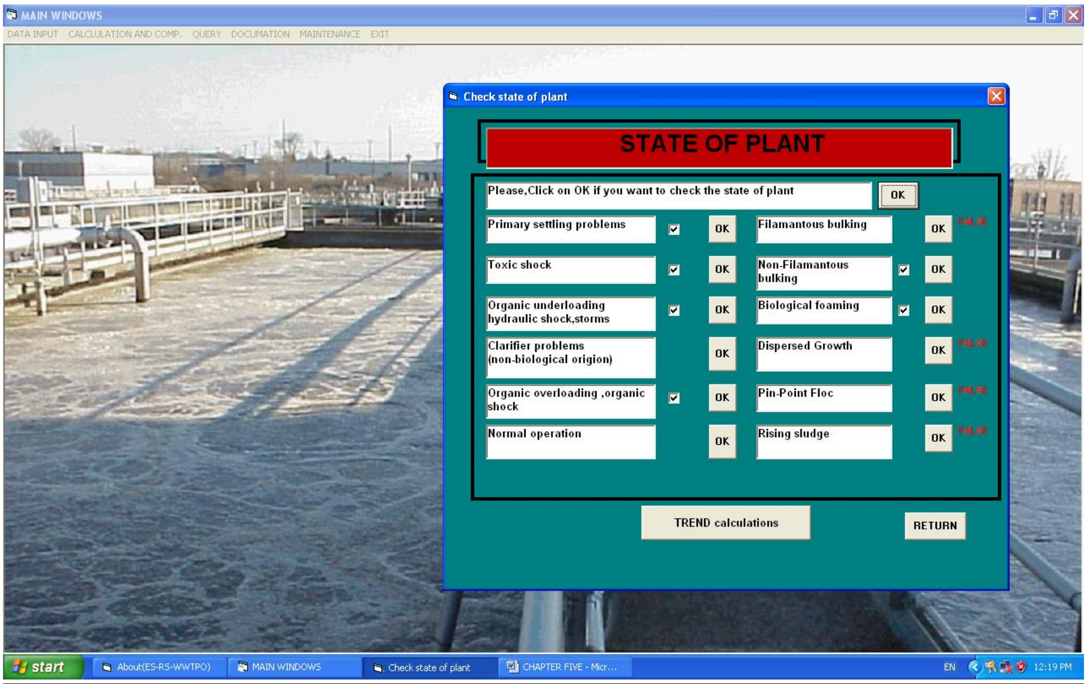


**Figure (8)** The level for each operational parameter window for ES-RS-WWTPO.

When this system has concluded that the process is affected by (such as biological foaming problem), the operator can clicks on cmd (ok) that refers to the problem and new window will appear as shown in figure (9)

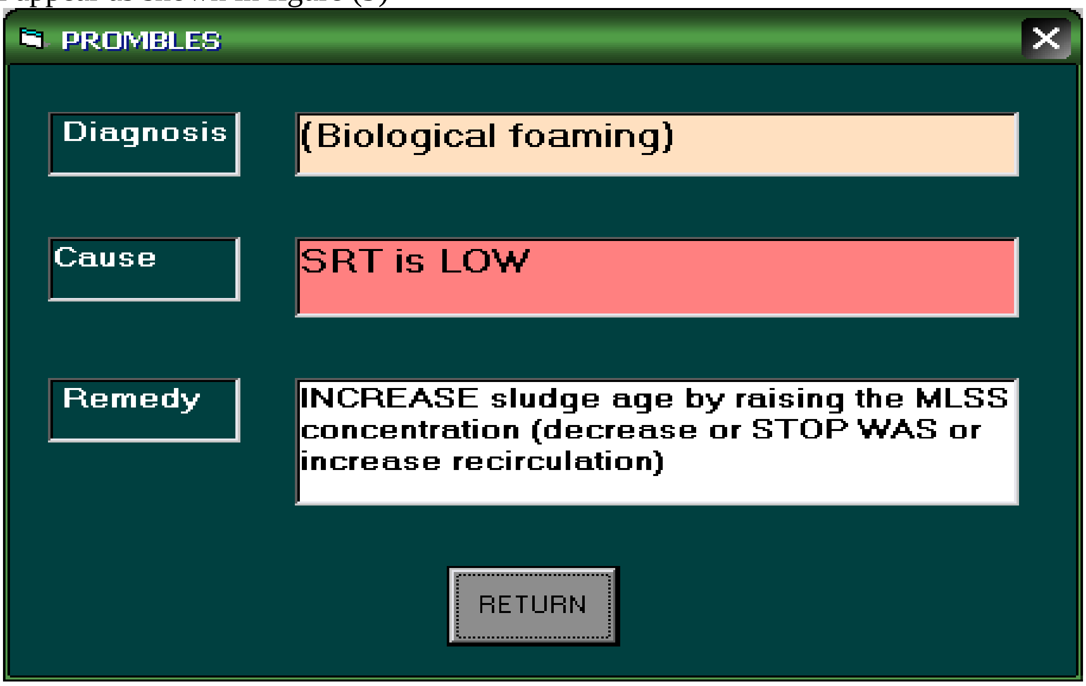


**Figure (9)** the results of diagnosis and remedies window for ES-RS-WWTPO.

The No. of interactive windows for all operational problems that included in ES-RS-WWTPO is 153 windows, as well as windows of results, documentation and maintenance methods for plant.

**C3- Query of ES-RS-WWTPO:** as shown in figure (10).

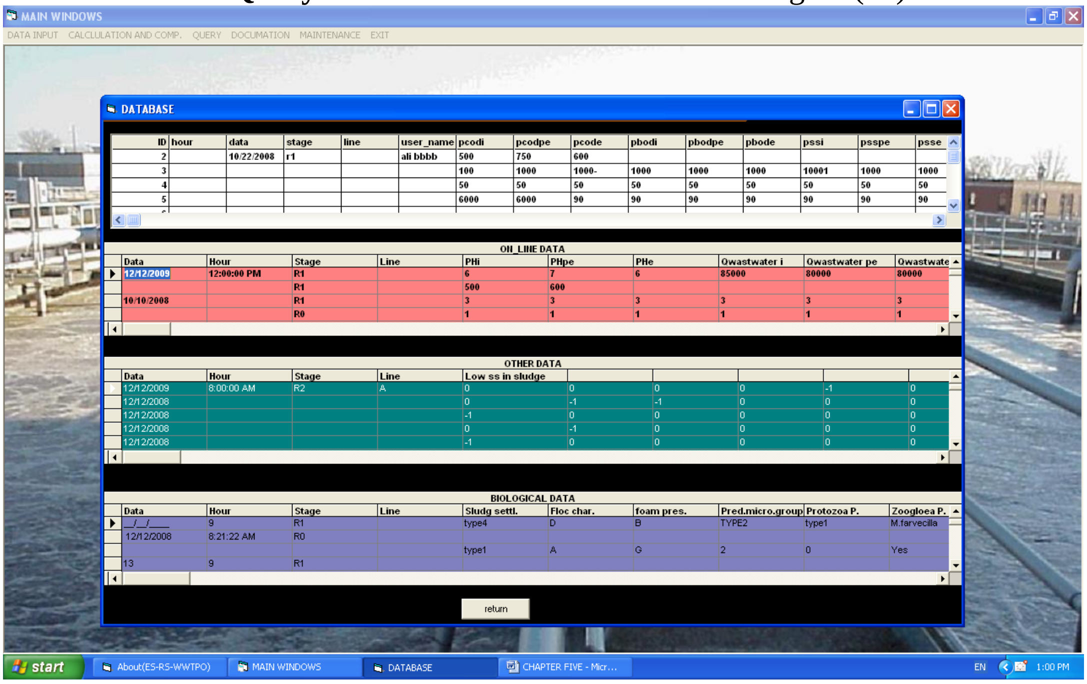


**Figure (10) (QUERY ALL DATA IN DATABASE)** window for ES-RS-WWTPO.

## CONCLUSIONS

This paper presents an expert system to operation and management of Rustimiyah south WWTP. This system contribution id based on the methodology proposed and applied, which is based on build of decision trees (algorithms). An ES-RS-WWTPO was tests by application three real operational situation in WWTP. This application proved the capability of this system to diagnosis state of plant. This system can be exported as a protocol to any wastewater treatment plant with similar technology with minor changes. The ES-RS-WWTPO built and implemented in Rustimiyah south WWTP can be a useful tools to improve urban WWTP management.

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