Development of a Conceptual Decision Support System for Drinking Water Treatment Process

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ABSTRACT

Drinking Water Decision Support System (DW-DSS) model is an integration of knowledge based information and programming tool aimed at tackling the overwhelming task of providing water under the condition of poor raw water quality and limited financial capacity. Visual Basic 6.0 was selected for the development due to its event driven ability, its capability of object oriented programming and a user-friendly interface. DW-DSS was developed to help water resource technical personnel and manager in acquiring information on the processes of drinking water treatment plant. Examples of data types, Graphical User Interface (GUI) and simulation results were presented. The simulation result demonstrates the use of DW-DSS model and an algorithm for the process design for drinking water treatment plant in Kachia, Kaduna State. It also estimates coagulation and flocculation detention time, amount of bags of alum needed for treating water of different turbidity, pumping cost of machine and it efficiency with a summary of the treatment process. It was concluded that DW-DSS is a useful tool in drinking water treatment plant

Keywords: Decision Support System, Kachia Water Treatment Plant, Kaduna State, Modeling, Visual Basic

1 INTRODUCTION

Consumption of water of low quality is often accompanied with significant problems ranging from chronic detrimental health effects, retard economic development and loss of thousands of lives (Animashaun *et al.,* 2015; United Nation, 2005). Ensuring good water quality for the developing nation amidst limited financial capability is thus becoming a topical issue. To achieve the goal of save drinking water for all, the use of a simulator or model is being adopted in recent time. With the growing pressure on drinking water demand, there is a greater need to optimize water treatment plant; so as to whether increase the throughput, reduce operational costs, or minimize capital expenditure (Luuk and Jeremy, 2006)). However, making decision concerning complex systems often pose a challenge to our cognitive capabilities and thus, human initiative judgment and decision making can be far from optimal (Marek *et al.,* 2002; Adeogun and Nwude, 2016). A tool that can be of great assistance in decision making is a Decision Support System (DSS) model (Luuk and Jeremy, 2006).

A number of DSS models used in drinking water treatment has been developed over the years (Luuk and Jeremy, 2006). They are either used to simulate individual treatment process or the whole treatment plant, to enable process engineers and plant operators to optimize the response of the works to changes in raw water quality, plant throughput or process operating conditions (Luuk and Jeremy, 2006). The two main components of DW-DSS are Knowledge based information and Programming Tool.

The process of building knowledge-based system is called knowledge engineering. It has a great deal in common with software engineering and is related to many computer science domain such as artificial intelligence, databases, data mining, expert system, decision support systems and geographic information system (Negnevitsky, 2004). Though, there are varieties of programming languages, Visual Basic 6.0 (VB) programming language which is an event driven programming language has proved effective. It allows programmers to easily create simple graphical user interface application and as well to develop fairly complex application (Mckeown, 2004). In this study, Drinking Water Decision Support System (DW-DSS) was designed to ease appropriate selection of vital procedure for water treatment in order to save cost and time

2 METHODOLOGY

The method adopted in this study is similar to that of Hong (2006), though with a little modification. The choice of the data type for developing DSS for drinking water treatment process was informed by the importance of the data and also as available in literature (Adeogun and Nwude, 2016). As compared to Hong (2006) fewer parameters which can reflect the status of the water were considered. The main focus of this work is the process design of the water treatment plant. As part of the process design, password and username are required in other to enhance security for the software in a user friendly interface.

2.1 Graphical User Interface Decision Support System with a Simulation study

The DW-DSS (Figure 2) was developed having 13 forms (1 to 13) which were created using Visual Basic 6.0. Each of the forms except the welcome, summary and appreciation form is for data entry. The Password and Username are entered into form1 and a welcome screen (form 2) is displayed. The water quality parameters are imputed into the parameter input form (form 3) for simulation. On this form (form 3), Nigeria established standard (Table 1) for drinking water quality parameter is displayed. Various treatment processes are being suggested for those inputs. Other responses such as Alum jar test, Aeration, Coagulation and flocculation, Sedimentation, Chemical Demand, Filtration, Disinfection, Pump horsepower and efficiency were entered into respective forms with parameters imputed for simulation (Figure 1). The last form being summary form showed the water parameter capturing the whole treatment process with decision on each parameter to allow for conclusion to be drawn (Figure 2). It has its input parameter from the Parameter Input form.

TABLE 1: THE PARAMETERS OF NIGERIAN STANDARD FOR DRINKING WATER QUALITY (NSDWQ)

Parameter	Units(SI)	NSDWQ
Aluminum(Al)	mg/L	0.2
Chloride(Al)	mg/L	250
Hardness	mg/L	150
Lead(Pb)	mg/L	0.01
Mercury(Hg)	mg/L	0.001
Nitrate	mg/L	10
pH	-	6.5-8.5
Turbidity	NTU	0 -5.0
Color	TCU	15
Ammonia	mg/L	1.5
Copper	mg/L	1.0
Fluoride	mg/L	0.4 -0.6
Iron	mg/L	0.3

For a particular water process, certain data are required so as to achieve the set objective (Table 2). For a better appreciation of the developed DW-DSS, the system was applied on data obtained from a water treatment plant.

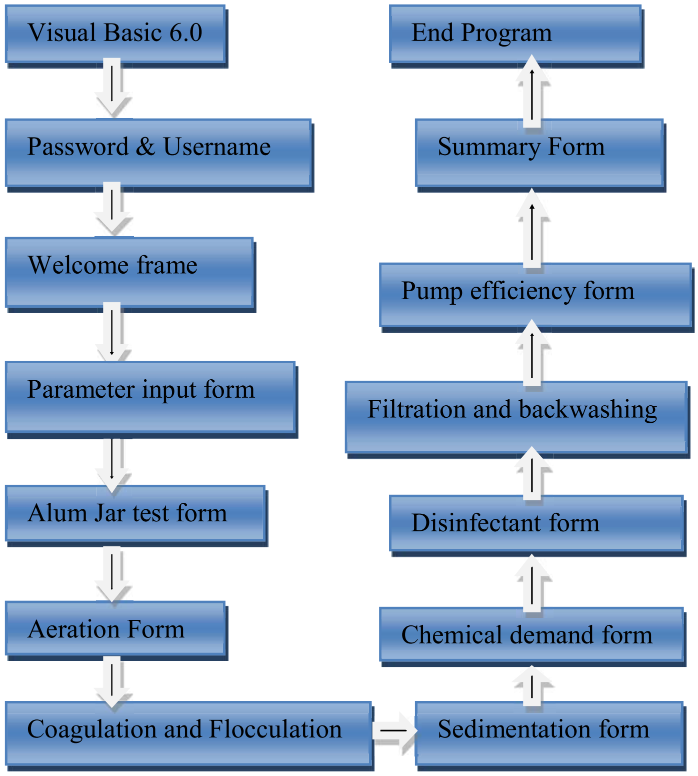

Figure1: Flow Chart of the Decision Support System (DW-DSS)

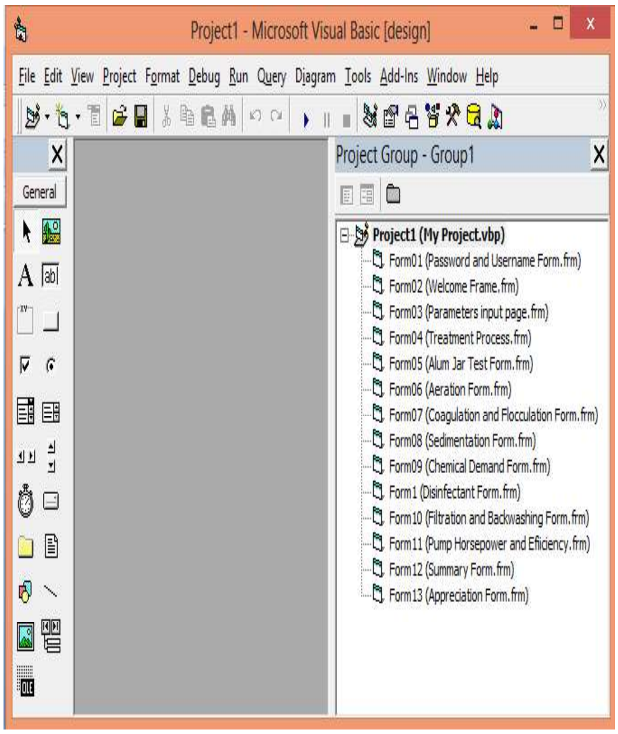

Figure 2: Graphical User Interface of the DW-DSS

TABLE 2: NECESSARY DATA FOR WATER TREATMENT PROCESS

Water Treatment process	Data	Benefit/Objective
Alum jar test	Volume of alum solution, low lift pump capacity, alum pump capacity, percentage concentration of alum and time of pumping	To know the part per million of alum solution needed, the chemical demand, the number of bags of alum per day and the stroke setting of alum pumping machine
Aeration	Parameter inputs (Physical, inorganic, metals)	To check what happens after aeration has been carried out
Coagulation and Flocculation	Length, Width and height of the coagulation and Flocculation tank	To calculate the tank volume and detention time for flash mixer and flocculation basin
Sedimentation	Length, Width and height of the sedimentary tank, flow rate of plant	To calculate the sedimentary tank volume and detention time for sedimentary basin, surface loading rate, weir loading rate
Filtration	Total gallon of water filtered, backwash flow rate, backwash time, filter run and filter surface area	For the purpose of knowing the Unit Filter Run Volume (UFRV), setting backwash pumping rate and percentage effluent water used
Disinfection	Flow rate of water, alum dose, volume of water pumped and time of pumping	For the purpose of calibration of feeders (for dry and solution chemical) and the chemical usage
Fluoridation	Plant capacity, Available fluoride ion (AFI), chemical purity, drop	For the purpose of calculating the chlorination break point, hypochlorite feed rate and the fluoride dosing
Plant pumping Horse power and Efficiency	Pump efficiency, total plant head, pump power, cost of power and overall time of operation	For the purpose knowing pump horsepower, efficiency and pumping cost

Source: Hong 2006

2.3 A case Study

Data on water treatment plant was obtained from Kachia Water-board, Kaduna State to evaluate the workability of the developed DW-DSS for selection of appropriate treatment processes.

Using the developed system on the available data of the State Water works Plant having an intake pump capacity of 1246000 liters, alum pump capacity of 7650 liters, plant capacity of 27 million liters per day and using alum concentration of 10%. These specifications were used in the alum jar test calculations to determine (simulate) the part per million of alum concentration, chemical demand , number of bags of alum and the stroke setting of the alum pumping machine. Also, the model was used in the calibration of chemical feeder (dry or solution form). Some 1.608Ib/day was used for dry chemical feed setting, while 15.7708ml/min was used for solution chemical feed setting calibration. Having a water flow rate of the plant as 10 million gallons per day, volume of chemical pumped of 1500 ml and time pumped of 1000 minutes. Furthermore, the model was used to simulate the sedimentation calculations, pump horse power and efficiency estimation and parameter input page respectively. In other to do these, the length (60ft), width (40ft), depth (20ft), the weir length (20ft) and diameter of 15ft for cylindrical sedimentation tank. For the pump horse power, pumping cost and efficiency estimation, the flow rate of the plant (15000gpm), plant head (10ft), pump efficiency (85%) and pumping operation time (500hours) were considered. The physicochemical parameters (such as 5.86NTU, 20TCU and 6.6 for turbidity, colour and pH respectively) of the raw water to be treated are inputted into parameter input form.

3.0 RESULTS AND DISCUSSION

Drinking Water Decision System was developed. Using the developed system, a case study on the Kaduna State water works was carried out for the system evaluation.

A graphical user interface algorithm was used for the evaluation of the various treatment processes with parameters from Kaduna State Water Works Plant. Figure 3 to 7 show various results simulated by DW-DSS. The result of the alum jar test indicated that the part per million of alum solution should be 90mg/L. The chemical demand of 113.76kg/hr, number of bags of alum per day needed is approximately 55 bags and the stroke setting of alum pumping machine is 3 (Figure 3). The chemical feeder setting calibration for dry and solution chemicals were 2.132Ib/min and 15ml/min respectively (Figure 4). The result of the sedimentation calculation showed detention time of 29.92 and 2.20 hours for a rectangular and cylindrical sedimentation basin respectively, surface loading rate of 15gpm/ft^2 , tank volume of 359,040 and 26,423gallons for rectangular and cylindrical volume and weir loading rate of 600gpm/ft (Figure 5). The simulated results shows that the brake horse power (44.56hp), water horse power (37.88hp), motor efficiency (75.75%), overall efficiency (89.12%) and the cost of operation (#373,000) within that time frame were estimated (Figure 6). The decisions needed to be taken on each of the water quality parameters inputted were displayed on decision parameter input form (Figure7). Colour for instance having a value (28 TCU) higher than the established standard (15 TCU), it is recommended that coagulation and filtration be done.

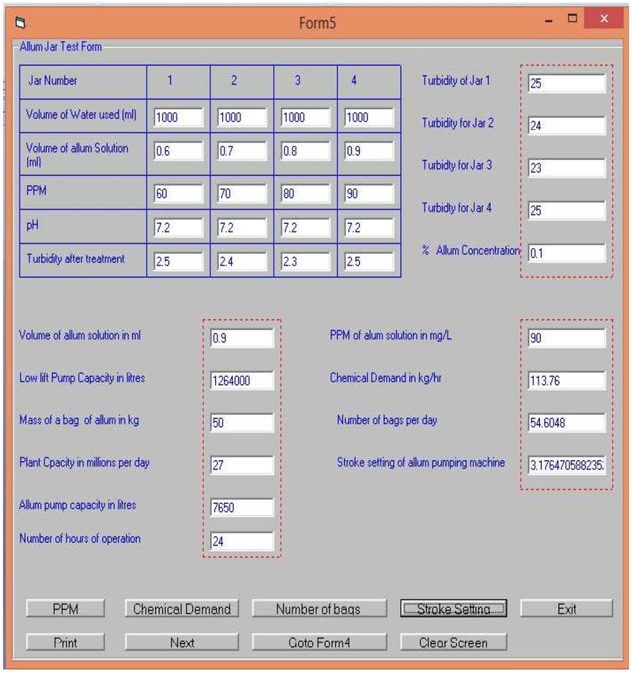

Figure3: Alum Jar Test Result

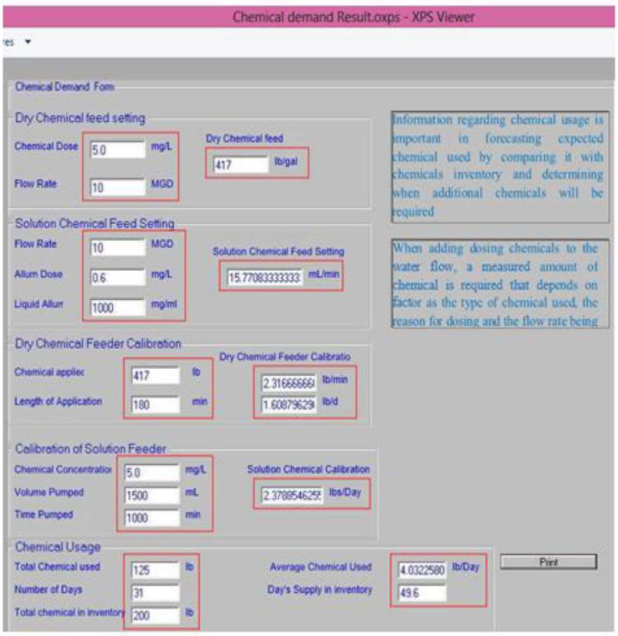

Figure 4: Chemical Demand Result

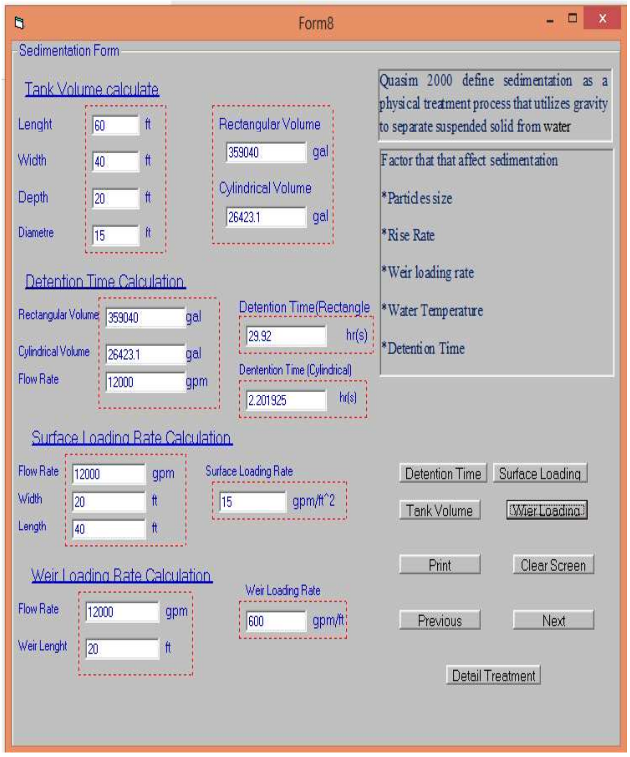

Figure5: Sedimentation Form Result

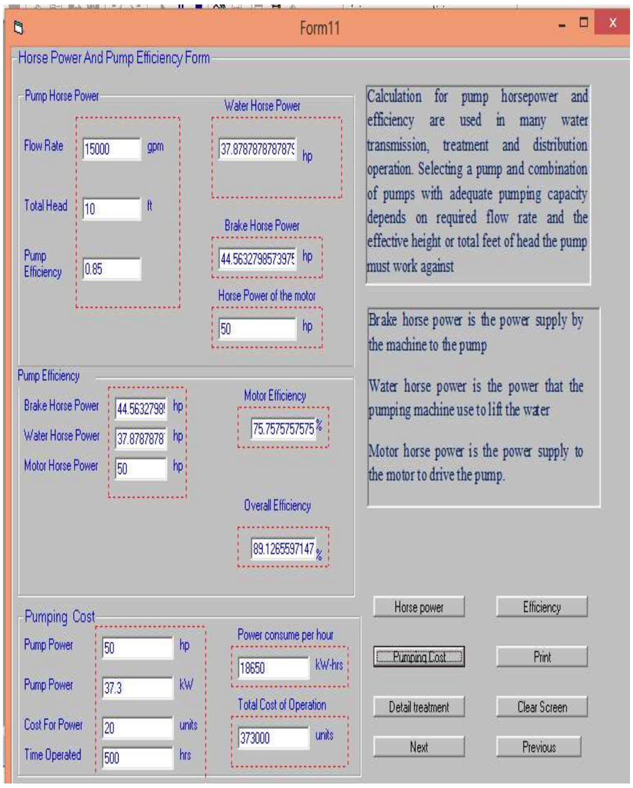

Figure 6: Horse Power and Pump Efficiency Result

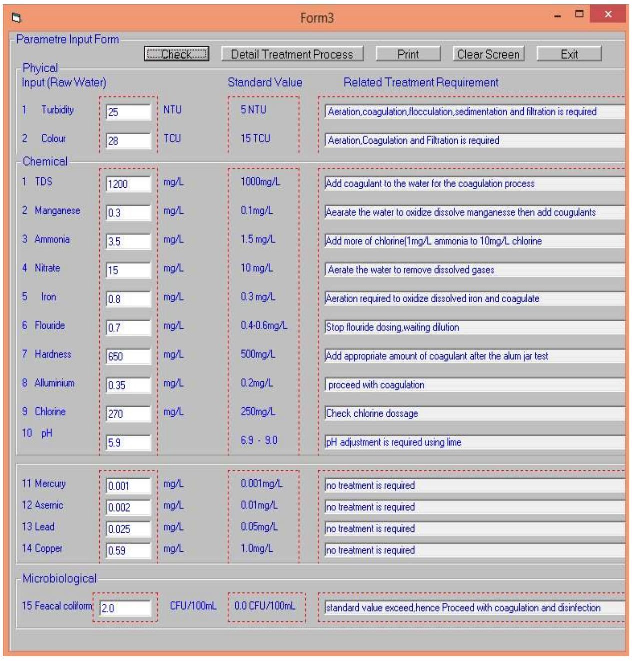

Figure7: Parameter Input and Decision Making

4 CONCLUSION

The DW-DSS was successfully developed using Visual Basic for water treatment process. The developed DW-DSS for drinking water treatment processes are decision making process via varied numbers of steps. The model succeeded in simulating results based on the plants and the quality status of raw water quality parameter. Hence, model proved suitable for simulating treatment process for treating drinking water and making decision on which water process is required for a particular parameter.

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