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A ROUGH SET BASED SOLAR POWERED FLOOD WATER PURIFICATION SYSTEM WITH A FUZZY LOGIC MODEL

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ABSTRACT

Water Purification is essential and a human need especially in time of calamities. During calamities many people will require mass amounts of clean water. The problem is during calamities electricity is usually unavailable so a city's water purification system will not work. A portable water purification is needed so clean water can be provided to the victims of the calamity. This research is about a rough set based solar powered water purification system that is integrated with a Fuzzy Logic model. This system is designed to be used in calamities like typhoons because it can convert flood water into clean drinking water an area affected in the calamity. This system is powered by solar panels so even if electricity from traditional power plants is unavailable it will still work. The system is composed of microcontroller unit, solar power system, 7 stage filtering system, and a temperature control unit. This system uses Rough Set Theory and Fuzzy Logic to determine the acceptable Total suspended solids (TSS) of the drinking water.

Keywords: water filtering system, potable water, solar power, rough set theory, fuzzy logic.

1. INTRODUCTION

At the present engineers are doing experiments on how to improve technology to solve problems that are caused by natural disasters [1]. One natural problem in particular is flooding caused by typhoons. Typhoons can deal a lot of damage and may paralyze a city. During typhoons essential supplies like electricity and drinking water will be unavailable [2]. These resources are important to sustain and continue the relief efforts during calamities.

This research will develop a system to turn flood water into drinking water. It will take advantage of the vast amounts of flood water during typhoons and convert them into drinking water. The beneficiaries of this research are the people who reside in low lying areas that are prone to experience flooding due to typhoons. This study can help people by giving them an option to turn flood and rain water into a potable drinking water. This research installed solar panels in the prototype to store energy coming from the sun; this is to provide a power source for the water purification system. The main idea for this research is to use dirty water from floods and convert it to a potable drinking water. A rough set and fuzzy logic algorithm was used to determine the acceptable Total suspended solids (TSS) of the drinking water. This research aims to solve the need for safe drinking water to lessen the cases of people acquiring illnesses due to drinking contaminated water.

2. WATER PURIFICATION

Water Purification is the process of removing undesirable chemicals in contaminated liquid [3]. The objective is to remove substances like parasites and manmade pollutants. Many of these contaminants are dangerous but it is possible to improve the water's appearance, smell and taste [4]. One method to clean the water is to add small amounts of disinfectants at the end of the purification process. This is to prevent re-contamination when distributed back to the system. In general groundwater is cheaper to treat but aquifers have limited capacity and take long to recharge [5]. Surface water like flood water is sure to have contaminants so it has to be carefully treated. Turbidity is also a problem in drinking water. Turbidity refers to the cloudiness by a large number of individual particles and is visible to the naked eye. Turbidity also refers to suspended solids. Some examples why it is undesirable because of aesthetic considerations, solids may contain pathogens or heavy metals and turbidity can decrease the effectiveness of water treatment techniques by shielding the pathogens from thermal or chemical damage. Water purification is also essential because bacteria and viruses can grow in water and it causes people to get sick. That is the reason why water needs to be purified. Bacteria and viruses can grow in water and it causes people to get sick [6].

There are many type of ways to treat water. Some examples are slow sand filters, activated charcoal filters, soil air water, chemical treatment, heat treatment, reverse osmosis, distillation, micro-filters and soil air water treatment. Most of these treatments contain at least three processes [7]. These processes have primary, secondary and tertiary treatment stages. Treatment equipments vary in size, usability and processes. One method to treat water is by using heat treatment. A way to do this is by boiling the water. This method is easy to do but will not provide a comprehensive way to treat the water. Some contaminants might remain in the water, making it unsafe for human consumption. Another treatment method that can be used is reverse osmosis. What reverse osmosis do is it forces the water pressure through an impermeable membrane to remove most of its contaminants [8]. One major disadvantage of using reverse osmosis is it removes most of the minerals from the water thus leaving it with a high acidity. Also in the process a high percentage of water is flushed down the drain for every gallon that is converted to clean water [9]. Another major disadvantage of using

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reverse osmosis is it takes too long to clean the water. The time may take from 3 to 4 hours. In times of calamities, people needs drinking water as soon as possible so water has to be cleaned immediately. Another method to clean water is to use distillation. It is the process of separating components of the liquid through evaporation and condensation. This process is effective as it provides complete separation. It gives nearly pure components [10]. This treatment has two major disadvantages. One is it uses a huge amount of power which is very scarce it times of calamities. Another is it is possible that chemical contaminants may still be available in the water. Another way to treat water is by using micro filters. These filters just basically filter the water [11]. One advantage in using micro filters is they can be re-used by just cleaning them. There are devices called Slow Sand Filters (SSF). These devices also known as SSF place the devices through sands and let the turbidity naturally dry off. A disadvantage in using this method is that it does not completely clean the water. Harmful bacteria parasites may still be left in the water [12].

A method that can be used without electricity is chemical treatments. This can be performed by adding chemicals like iodine, hydrogen peroxide and chlorine [13]. In using chlorine treatments, the most commonly used is halazone. These chemicals are in tablet form and for a liter of water two halazone tablets are placed. Using hydrogen peroxide is also effective in treating water as it eliminates bacteria [14]. This research is effective because it combines several water treatments like Reverse Osmosis (RO) and Granulated Activated Carbon (GAC) filters in its purification stages for a more cleaner and drinkable water.

3. HARDWARE AND SOFTWARE DESIGN

3.1. Hardware design

Several components comprise the system like the microcontroller, solar power system, water purification system, and temperature control unit. The system has the option to be powered by plugging it to an AC outlet or connecting it to the solar power module if there is no electricity during a calamity. The untreated water undergoes a series of filters and treatments namely: 10-micron sediment filter, softener, 1-micron filter, 2 Granulated Activated Carbon (GAC) filters, Reverse Osmosis (RO) membrane, polisher, and Ultraviolet (UV) treatment respectively. It provides cold and hot purified water by the use of compressors and electric heater. It has a water inlet mesh filter for untreated water to pass through to be stored into a container. There are three (3) water storages for untreated water, cold purified water, and hot purified water. Each storage utilizes water level sensors and motor valves that prevents overflowing. The prototype is able to maintain a certain cooling temperature of -5^{0}C and heating temperature of 95^{0}C through the use of temperature sensors.

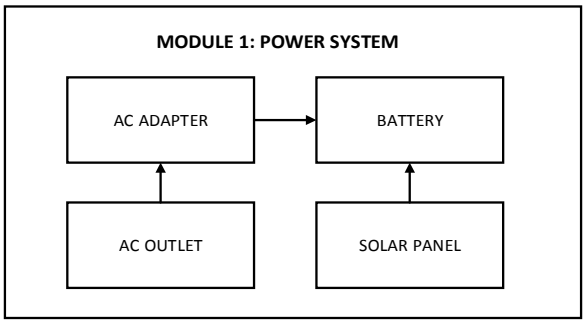

Figure-1. Power system module.

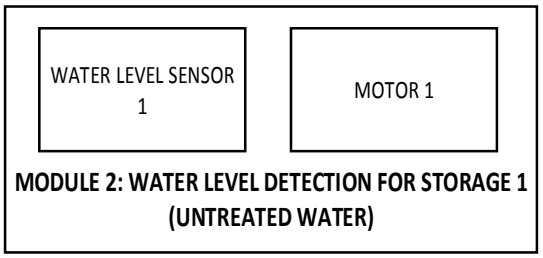

Figure-2. Water level detection module for storage 1.

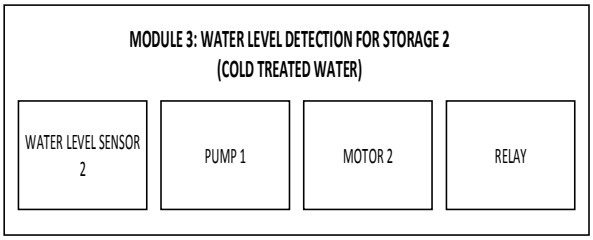

Figure-3. Water level detection module for storage 2.

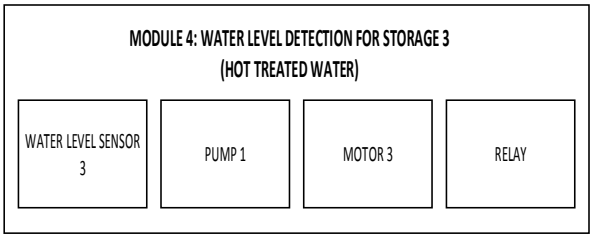

Figure-4. Water level detection module for storage 3.

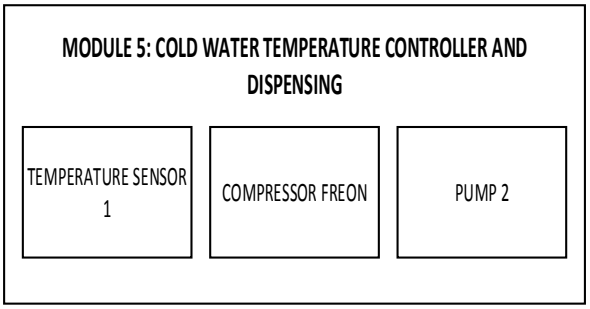

Figure-5. Module for cold water temperature controller and dispensing.

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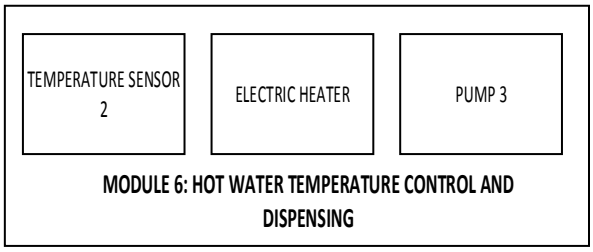

Figure-6. Module for hot water temperature controller and dispensing.

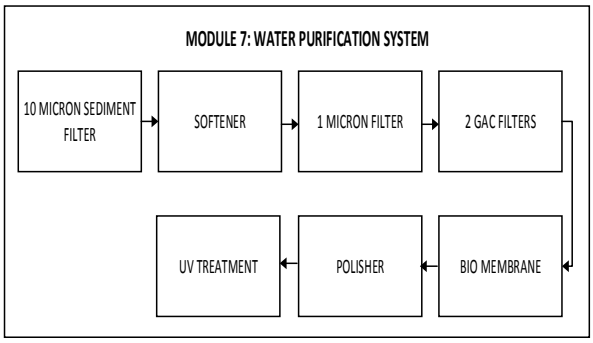

Figure-7. Module for the water purification system.

Figures 1 to 7 shows the modules that makes the system work. Each module contributes a different function to the whole system. The microcontroller is the core unit that interacts with each module. The first module is called the Power System it is responsible for giving power to the whole machine. The battery can be charged either by using solar panels or by using the AC outlet through the use of the AC adapter. Module 2 detects the level of untreated water in the first storage by the use of water level sensor and prevents overflowing by activating the motor which closes the valve. Module 3 and 4 functions are to detect water levels and temperature in storage 2 (cold treated water) and storage 3 (hot treated water). Each storage has water level sensors and motors. The pump and relay are activated upon detection of treated water either of the water storages in at 2 and 3. The pump pushes the water from the untreated tank to pass through the filters. A relay is used as a switching mechanism for the UV treatment. Modules 5 and 6 are for temperature control and dispensing in both storage 2 and 3. The two storages have temperature sensors for temperature monitoring and pump for dispensing water. A compressor with Freon is used as a refrigerant in storage 2 to cool the treated water while electric heater is used in storage 3 to heat treated water. Module 7 is the water purification system that is composed of: 10-micron sediment filter, softener, 1-micron filter, 2 Granulated Activated Carbon (GAC) filters, Reverse Osmosis (RO) membrane, polisher, and Ultraviolet (UV) treatment.

3.2. Software design

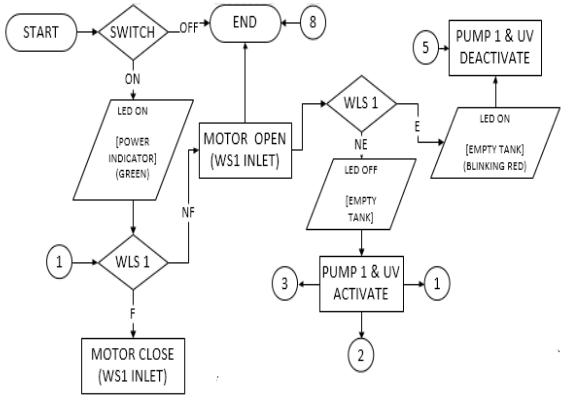

Figure-8. Part 1 of the software design.

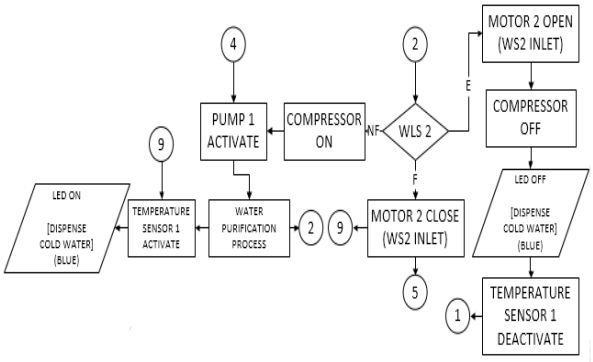

Figure-9. Part 2 of the software design.

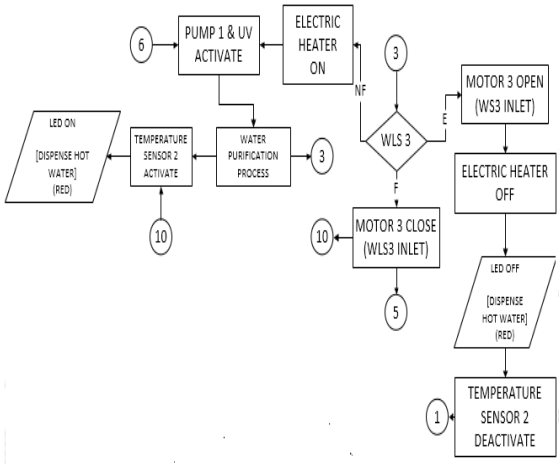

Figure-10. Part 3 of the software design.

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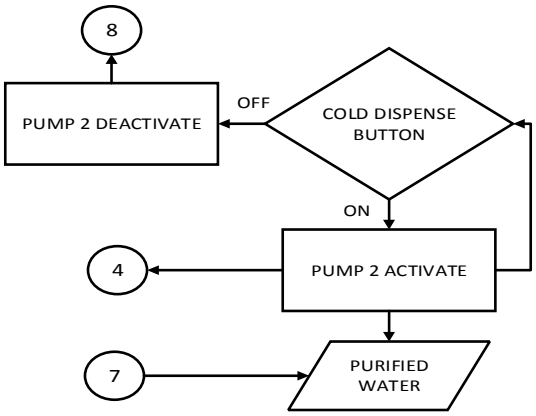

Figure-11. Part 4 of the software design.

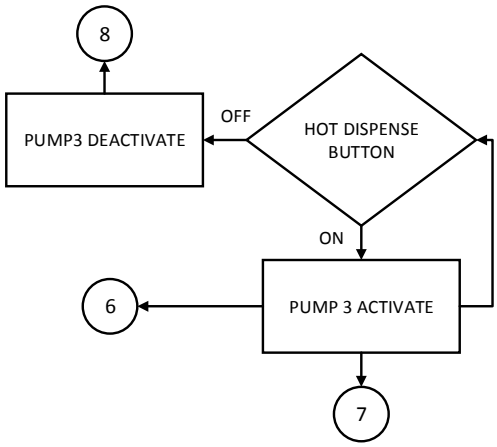

Figure-12. Part 5 of the software design.

Figures 8 to 12 shows how the software component of the system operates. If the user presses the ON button the machine will start and the green LED power indictor will light up. After the machine is powered ON the water level sensor (WLS1) in the first water storage will determine the level of untreated water that is currently stored. When water storage 1 is full the motor that controls the valve in the water inlet will close to prevent overflowing. If the first water storage is empty a signal will be sent to the user through red blinking LED light that is labeled empty and at the same time deactivates pump 1. After the untreated water undergoes water treatment it will go to water storages 2 and 3. The two storages have water level sensors, temperature sensors, motors and pumps to monitor and control the amount of water in the storages. The operation in the third water storage is almost the same in water storage 2 but instead of compressor it uses an electric heater for heating water. A red LED is used to indicate Ready to Dispense Hot Water. If the user press or hold the button for dispensing, pump 2(for cold) or pump 3(for hot) will be activated to dispense water.

4. ROUGH SET THEORY

Rough Set theory was introduces by Palwak in 1982 [15]. It is an advanced mathematical approach to handle imperfect knowledge [16]. This theory is a fundamental in Artificial Intelligence applications particularly in the fields of knowledge discovery, decision support systems and inductive reasoning. The core of the Rough Set Theory is the design to of only using the information within the data. Unlike other methods, advance heuristics and probability distribution is not required. These theories relies on the concept of indiscernibly within groups equivalent elements and generate knowledge granules. These granules are then used to built a structure for a structure of approximates for a given concept. This theory was developed to manage uncertainties from information that presents uncertainness, inexactness, noises and incompleteness. When the available data is not complete to determine the exact value for a given set, lower and upper approximations can be used by the theory to determine the representation of a concerned set. The synthesis of the approximations from the main data is the primary goal of the Rough Set Data analysis [17].

In decision making it has been shown that the Rough Set theory is a great tool in dealing with uncertainties. Rough Set Theory has been combined with other artificial intelligence methods like neural networks, fuzzy logic and optimization algorithms like genetic algorithm. The use of Rough Set Theory to solve specific complex problems have made it popular and attention was given to it for further research. Development was provided extending its original theory and widening its field of applications. Rough Set theory is an efficient technique and presents basic significance to many theoretical development and practical applications [18].

Rough Set Theory is based on the assumption that with every object in the universe a data, knowledge or information is associated with it. Objects characterized by the same information have a similar view of available data about them. The similarity that they present is the basis of the Rough Set Theory. In Rough Set Theory we call the sets of all similar objects as elementary sets. The precise or crisp set is used to determine the union of elementary sets, otherwise this set will be known as rough or imprecise. The available knowledge included in the objects which cannot be with certainty is classified as members of the set or its compliment [19]. In opposite to precise sets, rough sets cannot be distinguished in terms of information about their elements.

Rough Set approaches are always accompanied by two precise sets. These precise sets are known as lower and upper approximations. Objects of the sets either belong to the lower or upper approximation of the data [20].

Data in Rough Set Theory is usually represented as a table. In this table the row in usually known as an object and the columns are known as attributes. Each entries on the table are known as an attribute value. The tables that are formed are called Information Systems. The

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variables in information tables are called Information System attributes [21].

Rough Set theory is found in several applications like artificial intelligence and cognitive science [22]. Over the years Rough Set Theory has become an essential tool in the resolution of various problems like the representation of imprecise knowledge, analysis of knowledge, reasoning based on uncertain or the reduct information on data and many more [23]. At the present rough set theory has become widely used in applications like medicine, database analysis and process control [24]. The main advantage of the Rough Set Theory is it can reduce large amounts of data to those that are only essential [25]. In this research specific values of treatment and pump speed will produce a certain output. Traditionally if these values are generated, vast amounts of rules will be produced. In this research rough set theory is used to reduce the rules to those that are only essential.

5. FUZZY LOGIC

Fuzzy was created by Lotfi Zadeh in 1965 and an extension of Boolean Logic [26]. It is based on the mathematical theory of fuzzy sets, which is a generalization of classical set theory. Fuzzy Logic is a symbolic logic with a relative notion of truth developed in the essence of traditional logic [27]. Fuzzy Logic is used in several systems like air conditioners, washing machines, vacuum cleaner etc. This theory introduced the notion of degree in the verification of a condition [28]. Unlike traditional Boolean logic, fuzzy logic is not limited to a true or false output but is capable of representing uncertainty [29]. Fuzzy Logic provides flexibility for reasoning and can take to account uncertainties. Fuzzy Logic is a convenient way to map the input space to an output space [30].

In order to fully characterize a system using Fuzzy Logic, Fuzzy Logic Modeling has to be performed. In a general sense modeling refers to the description of the system like plants and process. It is represented in mathematical terms to characterize the input and output relationships of the system. To describe the physical system like the Water Purification System a mathematical formula or equation is used to represent the system both quantitatively and qualitatively [31]. The formulation of that system is called a Mathematical model. Many physical systems especially the ones that are complex are difficult to accurately model and provide a mathematical formula. This is because of its uncertainty, nonlinearity or randomness. For this reason approximate modeling is not only necessary but also practical in real world applications. In general approximate modeling is possible but the main challenge is to approximate as accurate as possible to produce satisfactory results [32]. Fuzzy Logic with a combination of Mathematical fundamentals like Rough Set Theory can provide a satisfactory mathematical model. When these theories are employed, the fuzzy logic membership functions and the interval of confidence are used to approximate measures leading to what we call Fuzzy Logic modeling. The input and output behavior that does not involve differential operators is called a static system while s system that uses differential operators is called a dynamic system [33].

There is a concept called fuzzy classifiers. It is a method that assigns class label to an object. The classifiers are also used to predict the class label of the object. The description of the object comes in the form of a vector that contains the features or attributes that are relevant to the classification. This classifier predicts the class label by using a training algorithm with a training data set. In instances where training data is not available, the classifier can be designed to learn from prior expertise of knowledge from the experts of that field. Once the classifiers are trained, it can be used to for operation for unseen objects [34].

Classification is a part of machine learning and pattern recognition. Concepts that must be studied in the concept of fuzzy classifiers are Soft Labeling, Interpretability and available expertise. Soft Labeling refers to the assumption in pattern recognition that classes are mutually exclusive. Interpretability is means that fuzzy classifiers must be designed to be transparent. The steps and logic that leads to the class prediction must be comprehensible and traceable. Available expertise means that the fuzzy classifiers can be created by using an expert's opinion [35].

In this research the fuzzy logic tool box of Matlab is used to map the input and output of the Water Purification system. Rough Set Theory is then used in the output of the Fuzzy Logic system to show only the rules that are essential.

6. MATLAB'S FUZZY LOGIC TOOLBOX

MATLAB or also known as Matrix Laboratory is software used for numerical computing. This software has a multi paradigm environment. This programming language is developed by Mathworks. This software allows plotting functions of data, Matrix manipulations, implementation of complex algorithms and creation of interface for several users. This software can be integrated with other programming languages like Fortran, C, C++, Python and Java. MATLAB is primary designed for numerical computing but different toolbox and add-ons are available to maximize the software's computing abilities. Some examples of these add-ons are Simulink, Communication toolbox, Control Systems toolbox, aerospace blocksets and fuzzy logic toolbox [36]. This research will mainly focus on the Fuzzy Logic toolbox.

The MATLAB Fuzzy logic toolbox provides a platform for simulating and analyzing systems that are based on fuzzy logic. This toolbox lets you model the complex behavior of fuzzy logic systems using simple logic rules. This rule can then be implemented by using the toolbox inference system. The rules can be created by hand because the program provides a Graphical User Interface (GUI). A command line is also provided to code the design to give an immediate output. Fuzzy results can be automatically created by using clustering or adaptive neuro-fuzzy techniques [37].

Fuzzy inference blocks can also be added in its Simulink interface to provide a comprehensive model and

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make the system dynamic. This toolbox allows you to run C programs directly. A standalone engine can also be customized to inference the user's created code [38].

7. FUZZY LOGIC DATA

The input parameters are treatment and pump speed, while the output parameter is the water quality. Table-1 shows the crisp values of the input parameter treatment.

Table-1. Crisp values of treatment.

#	Filter type	Stage percent
T1	10-Micron sediment filter	0
T2	Softener	10
T3	1 Micron Filter	20
T4	Granulated Activated Carbon (GAC) filters	30
T5	Reverse Osmosis Membrane	40
T6	Polisher	50
T7	Ultraviolet Treatment	60

These parameters are then inputted in the Matlab Fuzzy Logic Toolbox. Figure-13 shows the membership functions for the input parameter treatment.

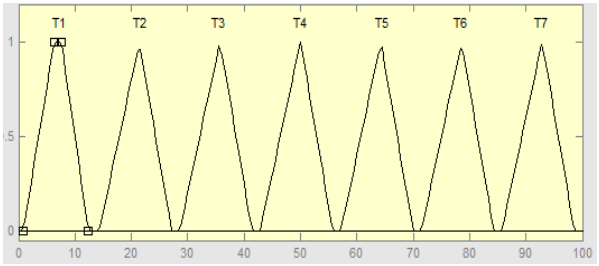

Figure-13. Membership function of treatment.

Table-2 shows the crisp values of the input parameter Pump Speed.

Table-2. Crisp values of pump speed.

Speed	Percentage speed
Very Slow (VS)	0
Slow (S)	20
Normal (N)	40
Fast (F)	60
Very Fast (VF)	80

Figure-14 shows the membership functions for the input parameter pump speed as shown by Matlab fuzzy logic toolbox.

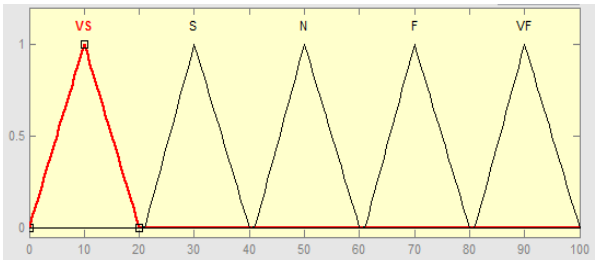

Figure-14. Membership function of pump speed.

Table-3 shows the crisp values of the output parameter Water Quality.

Table-3. Crisp values of water quality.

Quality	Total Suspended Solids (TTS)
Very Clean (VC)	0
Clean (C)	10
Dirty (D)	30
Very Dirty (VD)	40
Hazardous (H)	60

Figure-15 shows the membership functions for the output parameter water quality as shown by Matlab fuzzy logic toolbox.

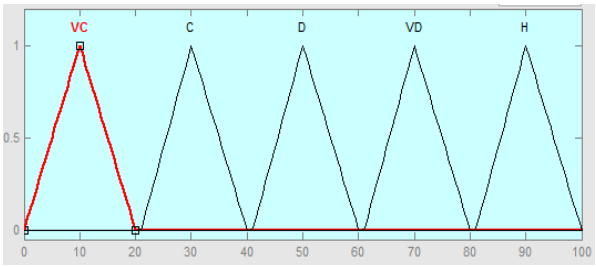

Figure-15. Membership function of output.

The surface view of the fuzzy logic parameters are then plotted to show its surface view using the Matlab fuzzy logic toolbox. Figure-16 shows the surface view of the fuzzy logic system.

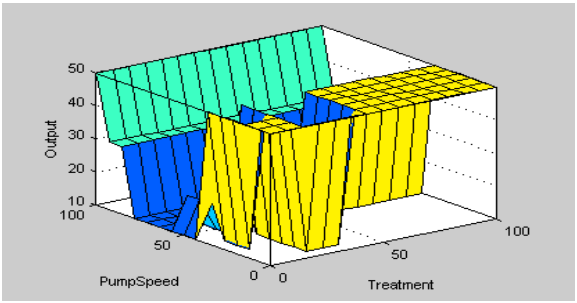

Figure-16. Surface view of the fuzzy logic system.

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8. ROUGH SET THEORY DATA

Random points are then chosen in the treatment and pump speed parameters. Their output is then recorded. A total of 35 random points were chosen. Table-4 shows the Flood Water Purification system Fuzzy Logic Parameters.

Table-4. Flood water purification system fuzzy logic parameters.

No.	**Treatment** (T)	**Pump speed** (PS)	**Output** (O)
1	10	10	50
2	10	20	50
3	10	30	10
4	10	70	10
5	10	90	30.3
6	20	10	10
7	20	20	50
8	20	60	50
9	20	90	30.3
10	30	10	10
11	30	20	50
12	30	80	50
13	30	90	50
14	40	10	10
15	40	30	10
16	40	60	50
17	50	10	50
18	50	30	50
19	50	70	10
20	60	10	50
21	60	30	50
22	60	90	30.3
23	70	10	50
24	70	40	50
25	70	80	50
26	80	20	50
27	80	50	10
28	80	90	30.3
29	90	10	50
30	90	50	10
31	90	70	10
32	90	100	50
33	100	10	50
34	100	60	50
35	100	90	30.3

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The information in Table-4 is inputted to the Rough Set Data Explorer (ROSE) [39] in order to implement the Rough Set Theory on the Flood Water Purification system Fuzzy Logic Parameters. A total of 27 rules were formulated. The rules are presented in Table-5.

Table-5. Essential rules created using rough set theory.

No.	Rule	Case	Value of symptoms in cases
1	(PS = 70) => O = 10	O = 10	PS = 70
2	(T = 40) & (PS = 10)=> (O = 10)	O = 10	T = 40, PS = 10
3	(PS = 50) => (O = 10)	O = 10	PS = 50
4	(T = 40) & (PS = 30)=> (O = 10)	O = 10	T = 40, PS = 30
5	(T = 40) & (PS = 30)=> (O = 10)	O = 10	T = 40, PS = 30
6	(T = 30) & (PS = 10)=> (O = 10)	O = 10	T = 30, PS = 10
7	(T = 10) & (PS = 30)=> (O = 10)	O = 10	T = 10, PS = 30
8	(T = 60) & (PS = 90)=> (O = 30)	O = 30	T = 60, PS = 90
9	(T = 80) & (PS = 90)=> (O = 30)	O = 30	T = 80, PS = 90
10	(T = 100) & (PS = 90)=> (O = 30)	O = 30	T = 100, PS = 90
11	(T = 20) & (PS = 90)=> (O = 30)	O = 30	T = 20, PS = 90
12	(T = 10) & (PS = 90) => (O = 30)	O = 30	T = 10, PS = 90
13	(T = 50) & (PS = 10) => (O = 50)	O = 50	T = 50, PS = 10
14	(T = 60) & (PS = 10) => (O = 50)	O = 50	T = 60, PS = 10
15	(PS = 20) => (O = 50)	O = 50	PS = 20
16	(T = 70) & (PS = 10) => (O = 50)	O = 50	T = 70, PS = 10
17	(PS = 60) => (O = 50)	O = 50	PS = 60
18	(T = 100) & (PS = 10) => (O = 50)	O = 50	T = 100, PS = 10
19	(T = 30) & (PS = 80) => (O = 50)	O = 50	T = 30, PS = 80
20	(PS = 100) => (O = 50)	O = 50	PS = 100
21	(T = 50) & (PS = 30) => (O = 50)	O = 50	T = 50, PS = 30
22	(T = 90) & (PS = 10) => (O = 50)	O = 50	T = 90, PS = 10
23	(PS = 40) => (O = 50)	O = 50	PS = 40
24	(T = 60) & (PS = 30) => (O = 50)	O = 50	T = 60 PS = 30
25	(T = 30) & (PS = 90) => (O = 50)	O = 50	T = 30, PS = 90
26	(T = 10) & (PS = 10) => (O = 50)	O = 50	T = 10, PS = 10
27	(T = 70) & (PS = 80) => (O = 90)	O = 90	T = 70, PS = 80

The rules were reduced from 27 from an original of 35 giving a 22.85% reduction. The rules that are produced are only the essential ones meaning, these rules are what is needed to determine the output of the system.

9. DISCUSSIONS OF RESULTS

The Fuzzy Logic Data has two inputs and one output. The input is treatment and speed while the output is in terms of Terms of Total Suspended Solids (TTS). The input treatment is divided into seven segments while the input speed is in five segments. The output in TTS is also divided into five segments. The diagram and the surface view of the fuzzy system were plotted using the Matlab Fuzzy Logic Toolbox.

The dataset to be used in the Rough Set model originally has 35 rules. The rules were reduced to 27 numbers of rules giving a 22.85% percent decrease. Empirical test is then applied on the rules to find the value of *a* and *b*. From table 6 the value of a is 27. By inspecting tables 5 and table 6, the value of b is 27. The percent validity is computed using the formula: *(b/a) x 100*. Substituting *a* and *b* to the equation, the percent validity is computed as 100%. Empirical Testing showed that the rules produced by the Rough Set Theory using the Rough Set Data Explorer (ROSE) are valid. The results showed

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that the output Total Suspended Solids (TTS) obtained by fuzzy logic can be determined with only the minimum number of information using rough set theory. This research is valuable because it can reduce the number of trials needed for TTS identification.

10. CONCLUSIONS AND RECOMMENDATIONS

This research developed a novel way to turn unclean water into a purified drinking water. This system is useful especially during calamities where electricity is nonexistent and clean water is scarce. This system can be used in a large scale, depending on the capacity of the solar and power module. In theory the higher the capacity of the solar and power module the more people it can accommodate. The system also utilized seven stages of purification to make sure that the output water is free from dirty substances and is safe for drinking. This research was able to utilize fuzzy logic and rough set theory to make sure the water is clean and is safe for drinking. 35 random samples are used in different points in the fuzzy controller treatment and pump speed parameter. These samples became the initial rules of the system for water purification. Rough Set theory was able to reduce it to 27 rules, giving an approximate of 22.85% reduction.

For future research, it is recommended to obtain more samples because in theory the larger the data the more accurate the fuzzy logic and rough set model will become. The solar panels and battery pack can also be redesigned to make it more portable so it can be easily transported especially in times of calamities

REFERENCES

[1] Klomp J. 2016. Economic development and natural disasters: A satellite data analysis. Global Environmental Change. 36(1): 67-88.

[2] Tsuchida T., Athapaththu A., Hanoaka T. and Kawaguchi M. 2015. Investigation of landslide calamity due to torrential rainfall in Shobara City, Japan. Soils and Foundations. 55(5): 1305-1317.

[3] Harikishore R. and Yun Y. 2016. Spinnel Ferite Absorbents: Alternative future materials for water purification. Coordination Chemistry Reviews. 315(1): 90-11.

[4] Wang Z., Cheng Y., He C., Zhuang J. and Sheng L. 2015. Purification of small-scale stagnant water in urban regions: Human-powered water lift and bank-based constructed wetland. Ecological Engineering. 83(1): 108-111.

[5] Agloyeh R. and Khalafi H. 2014. Design of dual column water purification system for industrial gamma irradiator based of PUROLITE resins. Annals of Nuclear Energy. 69(1): 90-96.

[6] Li J., Zheng L. and Li Y. 2016. Experiment and simulation of the purification effects of multi-level series constructed wetlands on urban surface runoff. Ecological Engineering. 91(1): 108-111.

[7] Elasaad H., Bilton A., Kelley L., Duayhe O. and Dubowski S. 2015. Field evaluation of a community scale solar powered water purification technology: A case study of a remote Mexican community application. Desalination. 375(1): 71-80.

[8] Lane M. and Seelig B. 2016. Highly efficient recombinant production and purification of streptococcal cysteine protease streptopain with increased enzymatic activity. Protein Expression and Purification. 121(1): 66-72.

[9] Masinga S., Nxumalo E., Mamba B. and Sabeilo M. 2014. Purification Microwave-induced synthesis of β-cyclodextrin/N-doped carbon nanotube polyurethane nanocomposites for water purification. Physics and Chemistry of the earth. 67(1): 105-110.

[10] Niu J., Kasuga I., Kuriso F., Furumai H. and Shigeeda T. 2013. Evaluation of autotrophic growth of ammonia-oxidizers associated with granular activated carbon used for drinking water purification by DNA-stable isotope probing. Water Research. 47(19): 7053-7065.

[11] Ozcan A. and Gencten M. 2016. Investigation of acid red 88 oxidation in water by means of electro-Fenton method for water purification. Chemosphere. 146(1): 245-252.

[12] Al-Hobaib A., Al-Sheetan K. and Elmir L. 2016. Effect of iron oxide nanoparticles on the performance of polyamide membrane for ground water purification. Material Science in Semiconductor Processing. 42(1): 107-110.

[13] Yan L., Wang J., Hao X. and Tang Z. 2014. Glacier mapping based on rough set theory in the Manas River watershed. Advances in Space Research. 53(7): 1071-1080.

[14] Fitzsimons L., Corcoran B., Young P. and Foley G. 2015. Exergy analysis of water purification and desalination: A study of exergy model approaches. Desalination. 359(1): 212-224.

[15] Palwak Z. 1982. Rough Sets. International Journal of Information in Computer Science. 11(5): 341-356.

©2006-2017 Asian Research Publishing Network (ARPN). All rights reserved.

[16] Yan J., Liu J., Hairiu L., Kang Y., Zhao C. and Fang Y. 2015. Ferrocene-containing thixotropic molecular gels: Creation and a novel strategy for water purification. Journal of Colloid and Interface Science. 448(1): 374-379.

[17] Slimalani T. 2013. Application of Rough Set Theory in Data Mining. International journal of Computer Science & Network Solutions. 1(3): 1-10.

[18] Sang Y., Liang J. and Qian Y. 2016. Decision-theoretic rough sets under dynamic granulation. Knowledge Based Systems. 91(1): 84-92.

[19] Zhang J., Zhu Y., Pan Y. and Li T. 2016. Efficient parallel boolean matrix based algorithms for computing composite rough set approximations. Information Sciences. 329(1): 287-302.

[20] Li W. and Xu W. 2015. Double-quantitative decision-theoretic rough set. Information Sciences. 316(1): 54-67.

[21] Chen D., Xhang X. and Li W. 2015. On measurements of covering rough sets based on granules and evidence theory. Information Sciences. 317(1): 329-348.

[22] Lin G., Liang J. and Qian Y. 2015. An information fusion approach by combining multigranulation rough sets and evidence theory. Information Sciences. 314(1): 184-199.

[23] Luo C., Li T., Chen H. and Lu L. 2015. Fast algorithms for computing rough approximations in set-valued decision systems while updating criteria values. Information Sciences. 299(1): 221-242.

[24] Zheng T. and Zhu L. 2015. Uncertainty measures of Neighborhood System-based rough sets. Information Sciences. 86(1): 57-65.

[25] Park I. and Choi G. 2015. A variable-precision information-entropy rough set approach for job searching. Information Sciences. 48(1): 289-295.

[26] Shareef H., Mutlag A. and Mohamed A. 2015. A novel approach for fuzzy logic PV inverter controller optimization using lightning search algorithm. Neurocomputing. 168(1): 435-453.

[27] Miranda G. and Felipe J. 2015. Computer-aided diagnosis system based on fuzzy logic for breast cancer categorization. Computer in Biology and Medicine. 64(1): 334-346.

[28] Calean I., Sirb L. and Chis A. 2015. The Qualitative Mathematical Modeling of the Ambiguity within Internal Audit using Fuzzy Logic in the Forestry Entities. Procedia Economics and Finance. 32(1): 1654-1666.

[29] Marquez J., Cortes R., Siller H., Coello V. and Escamilla D. 2013. Fuzzy logic scheme for tip-sample distance control for a low cost near field optical microscope. Journal of Applied Research and Technology. 11(6): 886-894.

[30] Yeh Y. 2013. Fuzzy logic method for motor quality types on current waveforms. Measurement. 46(5): 1682-1691.

[31] Karakis R., Guler I. and Bilir C. 2015. A novel fuzzy logic-based image steganography method to ensure medical data security. Computers in Biology and Medicine. 67(1): 172-183.

[32] Rasteli J. and Penas M. 2015. Fuzzy logic steering control of autonomous vehicles inside roundabouts. Applied Soft Computing. 35(1): 662-669.

[33] Ahmadi S. and Bathahee S. 2015. Multi-objective genetic optimization of the fuel cell hybrid vehicle supervisory system: Fuzzy logic and operating mode control strategies. International Journal of Hydrogen Energy. 40(36): 12512-12521.

[34] Le V. and Liu F. 2015. Tabulation proof procedures for fuzzy linguistic logic programming. International Journal of Approximate Reasoning. 63(1): 62-88.

[35] Atanassov K. 2015. Intuitionistic fuzzy logics as tools for evaluation of Data Mining processes. Knowledge Bases Systems. 80(1): 122-130.

[36] Ballabio D. 2015. A MATLAB toolbox for Principal Component Analysis and unsupervised exploration of data structure. Chemometrics and Intelligent Laboratory Systems. 149(2): 1-9.

[37] Pandey A. and Parhi D. 2014. MATLAB Simulation for Mobile Robot Navigation with Hurdles in Cluttered Environment Using Minimum Rule based Fuzzy Logic Controller. Procedia Technology. 14(1): 28-34.

[38] Mathworks. 2016. http://www.mathworks.com/products/matlab/

[39] ROSE 2.0. 1999. http://www.idss.cs.put.poznan.pl/rose.