International Journal of Mechanical and Industrial Technology ISSN 2348-7593 (Online)
Vol. 12, Issue 1, pp: (8-17), Month: April 2024 - September 2024, Available at: www.researchpublish.com

AN EVALUATION AND MODELING OF A SOLAR-POWERED AUTONOMOUS CONTROL SYSTEM FOR A RESIDENTIAL WELL-WATER DELIVERY SYSTEM

[1]*Arowolo, M.O., [1]Daniel, C.U., [1]Martins, O.O., [1]Adebimpe, A.M., [2]Fadiji, E.A., [2]Oginni, O.T.

[1] Department of Mechatronics Engineering, Federal University Oye, Ekiti State, Nigeria.

[2] Department of Mechanical Engineering, Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Ekiti State, Nigeria.

DOI: https://doi.org/10.5281/zenodo.12528059

Published Date: 25-June-2024

Abstract: **Water is essential to human life and to the health of the environment. The paper aimed at a theoretical framework for domestic well water purification, distribution, and management for human use. The sources of water and treatment technologies that remove contaminants for consumption were examined. The type of treatment operation performed at a drinking water treatment plant and the treatment chemicals used were found to be dependent on the contaminants present at the source of the water. A physical design system for a well-water treatment plant, purification, and distribution driven by a solar automation control system is thereby proposed. The model would minimize water losses, improve accuracy, pump efficiency, and the purity of water conveyed along the pipe network due to less or no contamination. This would eventually reduce energy waste, save money, be useful in rural areas, developing countries, and small and medium-sized industries, prevent environmental damage, and enhance municipal treatment for all Nigerian industrialization.**

Keywords: **water, human life, treatment technologies, solar power, control system.**

1. INTRODUCTION

Water is essential to sustain life, and a satisfactory (adequate, safe, and accessible) supply must be available to all in quantity and quality. As a valuable natural resource, it comprises marine, estuarine, freshwater, and groundwater environments. Water quality is commonly defined by its physical, chemical, biological, and aesthetic (appearance and smell) characteristics (Hegde and Adarsh, 2019). Water plays a very important role in human life, whether for daily routine purposes or human health. A healthy environment is one in which the water quality supports a rich and varied community of organisms and protects public health. Water quality in a body of water influences the way in which communities use the water for activities such as drinking, swimming, washing, and commercial purposes. Water quality is important not only to protect public health but also to provide ecosystem habitats, be used for farming, fishing, and mining, and contribute to recreation and tourism. Improving access to safe drinking water can result in tangible health benefits. Water obtained from shallow wells has poor quality and often contains impurities that rise to the surface of the water (Sokratis et al., 2022). However, this creates a high-risk situation for the villagers as the water they acquire is contaminated and could lead to communicable diseases of the intestinal tract such as cholera, typhoid, dysentery, and water-borne diseases like infectious hepatitis (Cpheeo, 2019).

According to the NDWG, drinking water should be clear, colorless, and well aerated, with no unpalatable taste or odor, and it should contain no suspended matter, harmful chemical substances, or pathogenic microorganisms (Sharath, 2021). The process from rainwater to tap water is more complex than can be imagined. The water that comes out of one’s tap has been through various processes that cleanse and change its original properties, both physically and chemically. This is done by water plant engineers that incorporate water treatment plants to treat water, which ensures clean, potable water gets to every household. Water plant engineers design, monitor, and maintain water treatment plants and water supplies for every household. Water supply is the water that comes into one's house from the water mains nearby a service pipe and through the water meter (Ravi and Bagade, 2020). In developing countries such as Nigeria, water-borne disease leads to millions of deaths and billions of illnesses annually. Water disinfection is one of several interventions that can improve public health (Vinothini and Suganya, 2020). Water purification is the process of eradicating detrimental chemicals, biologicals, poisons, suspended solids, and gases from contaminated water. The goal of water treatment is to remove existing contaminants from the water or reduce the concentration of such contaminants so the water becomes fit for its desired end-uses. Water treatment is the act or process of making water more portable or useful by purifying, clarifying, softening, or deodorizing it (Eswaran and Aswin, 2021). The process involved in treating water is solids separation using a physical process and a chemical process (Anselmo and Alexandre, 2021). Water treatment plants strive to add sufficient treatment chemicals to source water to remove contaminants without adding excessive levels of additional pollutants (AWWA, 2019). In general, the methods used in water treatment include physical processes such as sedimentation, distillation, coagulation, filtration, disinfection, biological processes, chemical processes such as flocculation and chlorination, and the use of electromagnetic radiation such as ultraviolet light. There are many parameters that can be used to measure the quality of water, of which a common one is turbidity, the purpose of which is to measure impurities in the water. The removed contaminants and treatment chemical composition impact the content and quantity of residuals generated (Stuart et al., 2022).

Automation is the integration of sensors, controls, and actuators designed to perform a function with minimal or no human intervention. The field concerned in this course is called 'Mechatronics, which is an interdisciplinary branch of engineering that combines mechanical, electrical, and electronic systems. Automation is an integral part of industries that increase accuracy, efficiency, safety, and prevent dangerous accidents that can be caused by human errors. It is also the creation and application of technologies to produce and deliver goods and services with minimal human intervention. Consequently, automation describes a wide range of technologies that reduce human intervention in processes. The amount of work done by humans is reduced by predetermining decision criteria and related actions, and having the machines perform them plays a very important role in human life, whether for daily routine purposes or human health. An automated water supply system will therefore enhance proper purification and distribution of water to all users, reduce waste of water, and identify leakages along the distribution line to avoid uneven distribution (Dankoo and John, 2019).

2. HISTORICAL INFORMATION OF WATER

According to Encarta (2019), water is a clear, colorless liquid that is odorless and tasteless when pure, that occurs as rain, snow, and ice, forms rivers, lakes, and seas, and is essential for life. Naturally occurring water picks up color and taste from substances in its environment. With advancements in technology, inventions are made, and most things are being substituted, but this is not the case with water. In view of the significance of water to life, it is expected that if the present generation in the country will be self-sustained, there is a need to have access to pure and quality water (Ayamal and Mohammed, 2021).

2.1 Sources of Water

There are three main sources of water for domestic use, according to Encarta, 2019. The first is rainwater collected from the roofs of buildings or special water sheds and stored in cisterns or ponds. The second is natural spring water that energies in ponds, streams, and lakes, and the third is underground water stored in the earth's crust. The untreated water from any of these sources is transported to a water treatment plant, where it is processed to produce treated water known as portable or finished water. Properties such as the characteristics of raw materials, relevant drinking standards, the treatment process used, and the characteristics of the distribution system are very important in water treatment (Sorokhaibam and Ranade, 2019).

2.2 Water Cycle (Hydrological Cycle)

Surface water is described as water on the earth's surface, such as lakes, reservoirs, rivers, and streams, while all water that is beneath the earth's surface is called groundwater. The water cycle is also referred to as the hydrological cycle. The process begins with energy from the sun reaching water in oceans, seas, rivers, and lakes. Water evaporates and becomes water vapor. As the water vapor rises, it cools and condenses into billions of droplets to form clouds. Vegetation is another source of water vapor. The roots of plants pump water out of the ground and pass it into the atmosphere in a process known as transpiration. Clouds hold rainwater as long as they stay warm. If the air cools, the droplets merge until they are so heavy that they fall back to earth as rain, hail, or snow. The atmosphere is capable of holding about 10 days' supply of rain—

enough to drop about 25 millimeters of freshwater over the entire surface of the planet (Gritsenko, 2022). Rain and snow falling within catchments can take several routes. Some evaporate, seep into the ground to become groundwater, and some stay on or near the surface to form streams and ultimately rivers.

2.3 Water Treatment Plant and Their Processes

a. Water Quality

The quality of water depends on its origin and history. Natural water shows, in general, the qualities characteristics of its sources. Many factors, however, produce variations in the quality of waters obtained from the same types of sources. Climatic, geographic, and geologic conditions all play important parts in determining water quality. Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species or to any human need or purpose. It is most frequently used with reference to a set of standards against which compliance can be assessed. The common standards used to assess water quality relate to the health of ecosystems, the safety of human contact, and drinking water (Chatterjee, 2019).

b. Water Treatment System

A water treatment system consists of a number of unit operations and unit processes arranged in a sequence called a flow schematic or process train. Raw water is streamed through a string of operations or processes in order to attain the desired quality of water. Unit operations are referred to as physical processes, while unit processes are referred to as chemical and biological reactions. However, many processes are a combination of both physical processes and chemical and biological reactions (Chatterjee, 2019).

c. Treated Water Storage

A water supply system includes some form of treated water storage to provide a reserve of drinking water to cater for fluctuations in demand and in the event of planned maintenance or problems with the source or treatment. Storage may take the form of a small covered reservoir, providing sufficient head to supply more than one property, or it may be a suitably positioned storage tank, from which water flows under gravity to the taps. The tank or reservoir holds a volume sufficient to accommodate peak demand and the maximum period of interruption of supply, but it must not be so large that water is allowed to remain static for lengthy periods, allowing the water to stagnate and develop aesthetic issues (Jadhao, 2022). The storage tank and other parts of the water supply system may have been contaminated during construction and should therefore be disinfected before use. This is achieved by filling the system with a 20-mg/l solution of chlorine and leaving it to stand for several hours, preferably overnight. The chlorine solution should then be drained off and the system rinsed thoroughly using treated water (Varne and Wagh, 2019). The tank must be fitted with a robust, lockable, and well-fitting lid to exclude light and pollutants and prevent the ingress of insects and animals. The storage tank must be inspected regularly (Mehta and Patel, 2021).

2.4 Water Distribution Systems

The system of pipes, channels, and vessels that store and convey water following treatment to consumers' taps is known as a distribution system or distribution network. These systems may include valves, hydrants, pumps, connection facilities, inspection points, or other fittings for control and/or maintenance purposes (Shahji, 2022). The water quality impact of deficiencies in a system may not become evident until it manifests, either through monitoring (sampling and analysis) or, more usually, through objectionable taste, odor, or appearance at the point of consumption (Johnalagedda and Pare, 2019). The number of potential or actual hazards present in any distribution system can be numerous, diverse, and variable. Risks to water quality can be mitigated and controlled by an awareness of the hazards and sensible and simple management and maintenance of the system. There should be routine cleaning of storage facilities, having suitably sized, robust, and covered storage tanks and reservoirs, periodic flushing of the system through taps and hydrants, and the use of approved water fittings in any distribution system to prevent contaminants from being sucked or pushed into the system through pressure differentials (Gaikwad, 2021).

2.5 Water Storage

A water tank is a reservoir or container that has the capacity to store water. The need for a storage tank has a long history and provides storage for water, firefighting, chemical processing, food processing, and many other applications. Material types such as plastic, fiberglass, concrete, and stainless steel are used for manufacturing water tanks. A water tank or container is carefully designed so that it does not have any negative effect on the water. Water is vulnerable to a number of undesirable elements, including bacteria, viruses, algae, changes in pH, mineral accumulation, and gas accumulation

(Gaikwad, 2021). A correctly designed water tank should address and mitigate the negative effects of impurities from sources including piping, tank manufacturing materials, feces (from animals and birds), mineral intrusion, and gas intrusion.

2.6 Water Purification Process

This is actually the removal of pollutants from unprocessed water to make it very pure and good for drinking by humans or to be used in industry. Most drinking water is made pure for human use, but the method of purification may vary depending on the area of application. (Sagakhole and More, 2021). Generally, three main means of water treatment or purification processes are considered: physical treatment (water filtering, sedimentation, and distillation), biological treatment (sand filtering, lava filtration, and membrane filters), and chemical processes (addition of chlorine, flocculation, and ultraviolet sterilization) (Haring, 2020). Good-quality water cannot be examined physically merely by the eyes, but the use of a particular purification technique depends on some microbiological and chemical investigations. Highly sophisticated systems of water purification are used, such as softeners (potassium ion exchange), activated carbon filters, reverse osmosis and post-carbon filters, sedimentation filters, ozone generators (sterilisers), and multimedia filters. This part of the water purification process is controlled automatically by a Programmable Logic Controller (PLC) and microprocessor devices (Metcalf and Eddy, 2019).

a. Coagulation and Flocculation

Coagulation and flocculation processes mean the chemical or physical process of blending or mixing a coagulating chemical into a stream and then gently stirring the blended mixture in order to improve the particle and colloid reduction efficiency of the subsequent settling and/or filtration process (Amirtharajah and Melia, 2019). The most frequently used chemical coagulants are aluminum sulfate ($Al_2 (SO_4)_3 14H_2O$) and magnesium hydroxide (Mg(OH)2), applied in low dosages alone or in combination with the metal coagulant (Motling et al., 2020; Meda and Laxaman, 2022).

b. Pre-sedimentation

Pre-sedimentation is a pre-treatment process operated at the head of the WTPs or prior to intake (e.g., within a reservoir). Its primary purpose is to remove a significant amount of readily settleable and suspended solids and other contaminants from the source water prior to other water treatment operations. The process removes relatively high concentrations of easily settled solids (sand and silt) (Anita et al., 2021).

c. Clarification (Sedimentation and Floatation)

This is a process of separating suspension into clarified fluid and more concentrated suspension, widely used after coagulation and flocculation and before filtration in order to reduce the load on the filtration process. Sedimentation follows flocculation, which utilizes gravity settling to remove suspended solids, while floatation utilizes buoyancy for solid-liquid separation (Chatterjee, 2019). The three types of flotation are electrolytic flotation, dispersed-air flotation, and dissolved-air flotation used in circular tanks, rectangular tanks, combined flotation, and filtration tanks (Kawamura, 2020; Metcalf and Eddy, 2019).

d. Filtration

Filtration of water is the separation of colloidal and larger particles from water by passage through a porous medium, usually sand, granular coal, or granular activated carbon. Filtration further removes colloidal materials to meet public health standards promulgated after the 2019 Safe Drinking Water Act Amendments (Cleasby, 2019). Filtration consists of a number of mechanisms, such as straining, sedimentation, impaction, and interception, acting simultaneously in the solid removal process. Filters commonly utilized in water treatment are classified on the basis of filtration rate, driving force, and direction of flow. Kawamura, (2020). The factors that must be taken into consideration when a proper granular filtration process is conducted are local conditions, design guidelines set by regulatory agencies such as the state department of health, site topography, plant size, raw water quality, type of pre-treatment process, new and proven types of filters, type of filter wash system, control of the filtration rate, type of filter bed, and chemical application points. (Clifford, 2020).

e. Disinfection.

Disinfection involves the destruction or inactivation of organisms, which may be objectionable from the standpoint of either health or aesthetics. Both surface and groundwater sources require disinfection to eliminate or inactivate microbiological populations. The application of disinfecting agents to a potable water supply is recognized as one of the most successful examples of public health protection. Chlorine is the disinfectant used, but more recently, other chemicals such as chlorine dioxide, chloramines, and ozone have been used to purify water. Non-chemical methods of disinfection include heat and radiation (e.g., ultraviolet light) (Dhabadgaounkar, 2019; Chick, 2019). Disinfection achieves the desired level of microorganism kill and maintains a disinfectant residual in the finished drinking water to prevent regrowth of microorganisms as water passes through the distribution system (Ramleelakhare and Mela, 2019).

f. Microfiltration and Ultrafiltration

Microfiltration and ultrafiltration systems effectively remove turbidity, metals such as iron, manganese, and arsenic, as well as protozoa like Cryptosporidium. Ultrafiltration systems remove viruses from the source water without additional treatment. The applications are replacements for small, older conventional treatment systems, lowering capital costs, operating costs, and improving performance (Malmrose, 2019).

g. Electrodialysis and Electrodialysis Reversal

Dissolved contaminants in the source water are removed using electrodialysis membranes, which are ion exchange membranes that use electrical current to separate the contaminants from the water. This operation is primarily used to desalt brackish water to remove silica, pathogens, and dissolved organics. Electrodialysis uses alternating pairs of cations and anion membranes positioned between two oppositely charged electrodes. When voltage is applied, the electrical current causes ions from the source water to migrate toward the oppositely charged electrodes (Malmrose, 2019).

3. AUTOMATION CONTROL SYSTEMS OF TREATMENT PLANT

Modern electronic devices such as water flow sensors can be used to overcome the basic limitations of an analog meter, such as less accuracy, human error while billing, etc. (Gouthaman and Srikanth, 2021). The available water billing system is tedious, time-consuming, and error-filled. An automatic system or control process is used to automatically run or control processes such as chemical processes, plants, and equipment. The automated system often uses a network to communicate with sensors, controllers, operator terminals, and actuators. In reality, automated processes are based on open standards as compared to a distributed control system, which is traditionally proprietary. However, programmable logic controllers (PLC) and human-machine interfaces (HMI) have gained popularity, making automated systems or processes more associated with them. An automated system uses computer-based technology (CBT) and software engineering to aid power plants, water purification plants, and industrial setups (Shritharanya and Lavanya, 2019). Automation has been developed out of the need for higher productivity, lower costs, and more precise manufacturing. Automation is also an answer to the reduction of problems such as operator fatigue, carelessness, and other human frailties (Megha *et al.*, 2022).

a. Automation Concepts and its Components Description

With the advancement of computer technologies, instrument control has become possible without human intervention. Carlton and Rafic (2019) designed a feedback control system that regulates the temperature of a process at a desired set point. The design used Lab View (LV) as the control software, consisting of a personal computer (PC)-based data acquisition unit that provides input and output interfaces between the PC and the sensor circuit and hardware. Obanda (2019) also developed a microprocessor-based system for successful monitoring and control of temperature, humidity, and light level in a green house. The developed system was based on the microprocessor; the hardware consists of a humidity sensor, a linear monolithic (Lm) 35 temperature sensor (which gives out an analog value on the change of temperature), two analogs to digital converters, a clock with reset circuitry, 7-segment displays, and A light-emitting diode (LED_S) is a semi-conductor device that emits infrared or visible light when charged with an electric current.

b. Micro-controllers

A microcontroller is used to control the overall system automatically, which reduces the design and control complexity. The microcontroller takes input from the sensor unit, which senses the water level through an inverter. After processing input variables, the resultant output determines the water pump action (on/off) with respect to the current status of the tank. There is a vast array of single-chip microcontrollers on the market that integrate quantities of both random-access memory (RAM) and read-only memory (ROM) on the same chip, along with basic peripherals including serial communication controllers, timers, and general input/output pins (Pranitavi and Joshi, 2019; Kumar, 2021). The other advantages of using such microcontroller-based systems are easy troubleshooting and maintenance.

c. Power Supply Unit

An automatic fire control system requires a direct current (DC) voltage source for its operation. The electricity supply from the national grid is alternating current (AC). An alternating current (AC) power supply usually uses a transformer to convert the voltage from the wall outlet (mains) to a lower voltage. If it is used to produce direct current (DC), a rectifier is used to convert alternating voltage to a pulsating direct voltage, followed by a filter, comprising one or more capacitors, resistors, and sometimes inductors, to filter out (smooth) most of the pulsation (Adejumobi, 2022). A direct current (DC) voltage is needed to power the complete hardware of the system. A regulated and low-rising DC voltage will be the appropriate voltage to power an automatic control system (Mitra and Roy, 2019).

d. Sensors

Proper monitoring with the help of sensors and automation is needed to ensure water sustainability. In many houses, there is wastage of water due to overflow in overhead tanks. An automatic water level controller can provide a solution to this problem. It provides ease in taking the meter readings, accuracy, and detection of faulty readings. Leakage control can be enhanced by incorporating sensors at the line connecting each and every house to detect leakage (Madihalli and Ittanajar, 2019).

e. Billing Units

The billing meter shows how customers can manage their load by using a smart energy meter (SEM). It provides ease in taking the meter readings, accuracy, and detection of faulty readings. This enhances leakage control by incorporating sensors at the line connecting each and every house to detect leakage (Abdni et al., 2019; Akhar et al., 2022). Arduino-based Water Billing System developed for Domestic Purpose reads sensors to monitor water usage for houses or domestic purposes (Anita et al., 2021). The billing of the water usage can be done automatically, and the same will be sent to the user using the Short Message Service (SMS) facility. A smart water metering system is used to control the water supply in the house so that the wastage of water will be less (Mark et al., 2019; Zhuiykov, 2022).

4. MODELLING OF AUTOMATIC SOLAR POWERED CONTROL WATER DISTRIBUTION PLANT

The schematic diagrams of a proposed system and the life circle of the water distribution control system are shown in Figures 1 to 4, respectively. This study therefore develops an automatic control system to reduce the disadvantages of conventional systems by using programmable logic controllers (Hassaan and Thabel, 2020; Hegde and Adarsh, 2019). The model is designed to develop a drinking water purification and water distribution system using a PLC. The level of the storage tank is sensed, and the command is given by the PLC to the pump (Warm, 2021). Based on the decided time, the valve in a particular house will be operated. Most well-water treatment plants in use have their pumps electrically powered to get water from the well to the storage tank (reservoir). This method causes water wastage, increasing time consumption, effort, cost, and manual errors when the reservoir is full; pump overheating and, at times, burning when operating non-stop; high electric bills on current consumed; even leakages on the water distribution line cannot be detected; and the time of a water shortage is not known until the system runs out of water (Ebele and Oladipo, 2019). Therefore, water automatic control systems are all that is required for these problems to be eliminated. The solar source of power will reduce the cost of energy consumed, time, effort, and cost; manual errors and repetitive tasks can be completed faster to circumvent irregularities in the power supply (Ramprabu and Paramesh, 2019; Mukesh et al., 2019; Hart et al., 2020; Whittle et al., 2020).

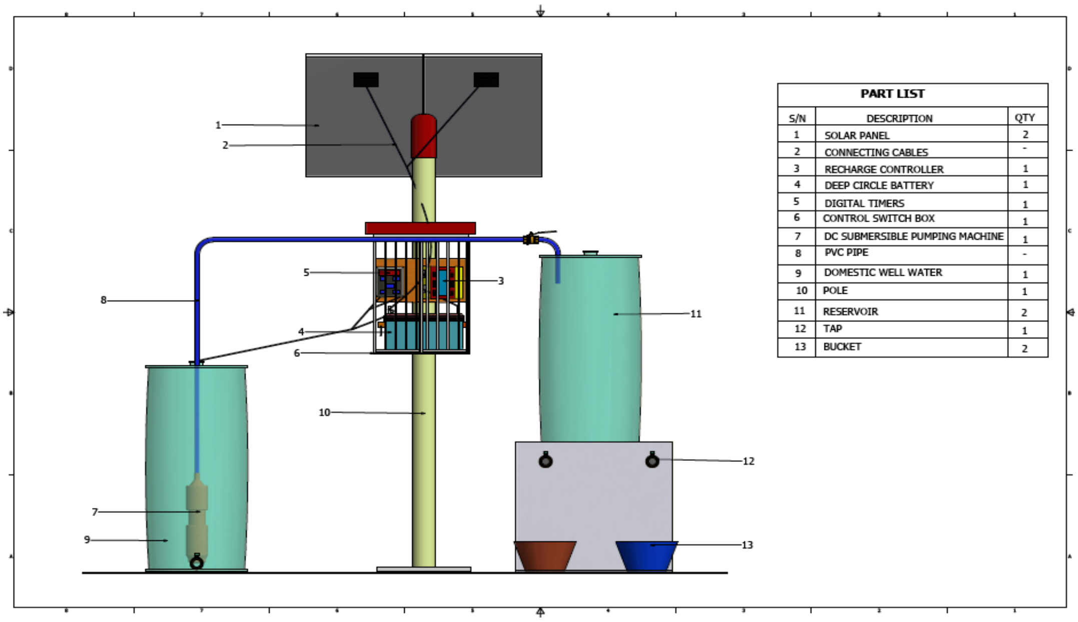

Figure 1: Prototype Water Distribution System Design (Using Micro-Processor Devices Treatment)

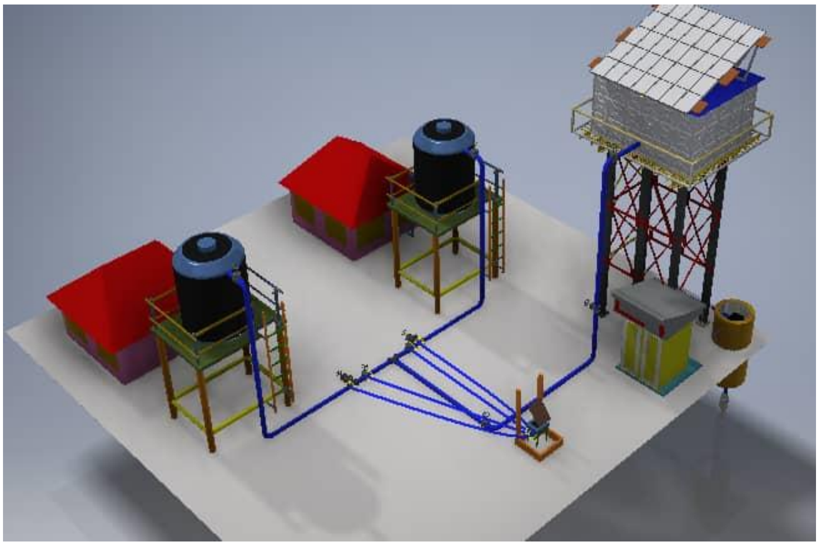

Figure 2: 3D Modeling of the Proposed Automatic Control System for Domestic Well-Water Treatment Plant and Distribution System.

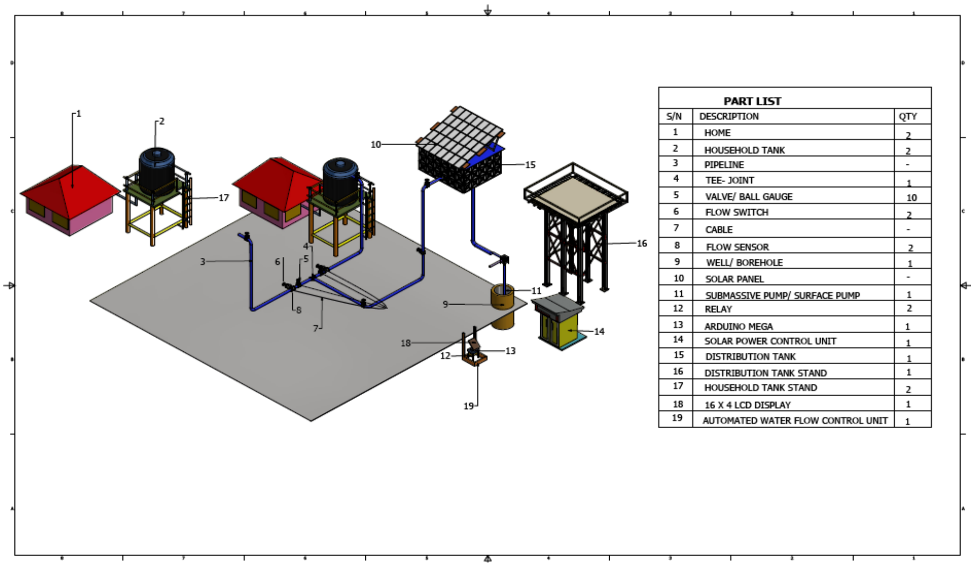

Figure 3: Framework of the Proposed Automatic Control System for Domestic Well-Water Distribution System.

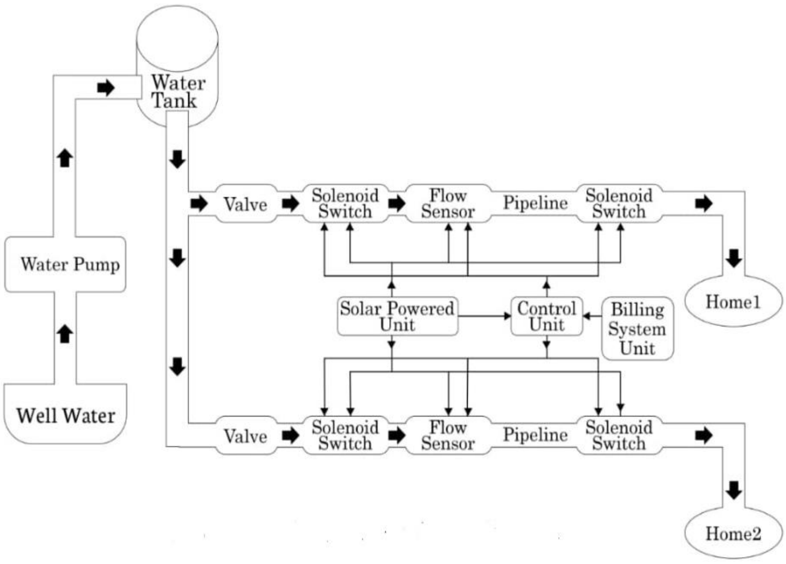

Figure 4: Circuit/Wiring Diagram of Domestic Well Water Distribution

5. CONCLUSION

The assessment of various water sources, treatments for quality assurance, and modeling of a solar-powered automatic control system for an effective domestic well-water distribution system have been analyzed. The outcomes showed the benefits and setbacks accompanying different technologies and methods adopted to treat and reduce the degree of impurities in water for human consumption. The study helps with higher production rates, control of water waste, less use of power due to solar energy, improved pump safety, reducing human error, and promoting purity of pumped well-water certainty due to less or no contamination by employing the proposed model. This is a rational way in which well-water treatment plant systems can reduce time, effort, cost, water leakage, and waste. Repetitive tasks can be completed faster. There will be high-quality results as each task is performed identically without human error. The electrical running cost and its irregularities will be cared for by solar energy. This review serves as the basis for proper planning to avoid failure and helps to control the parameters like solar-powered water tanks, valves, flow sensors, Arduinos, pipelines, and relays that consultants, engineers, and project managers will use to calculate the amount of domestic well water used in the system. The outcome will be economical by eliminating manpower inefficiencies and providing regular and dependable portable water to rural and urban areas. The proposed model will boost the technological innovation and self-reliance of Secure Digital (SD) card businesses, thereby creating job creation and employment.

REFERENCES

[1] Abdni, L.M., Izwan, A. and Moin. M. (2019). “Task Water Level Monitoring System using GSM Network”, IJCSII, vol. 2(3).

[2] Adejumobi, I.A. (2022). “Development of a multi-AC/DC Power Supply System for domestic and laboratory use”, International Journal of Research and Review in Applied Science, vol. 12: 126-132.

[3] Adelman, M.J. (2019). “Novel fluidic control system for stacked rapids sand filters” www.ascelibrary.org.

[4] Ahmad, T.J. and Hamzah, S.G. (2019). “Controlling and Monitoring of Automation of Water Supply System based on IOT with theft identification”, International Journal of Research, vol. 5(5).

[5] Akhar S., Paliam M., Sujara, B. and Shinde, D.C. (2022). “Smart Water Metering System”, IJARIFF ISSN 01-2395-4396, vol. 2(2).

[6] American Water Works Association, (AWWA), (2019). “Water Quality and Treatment: A handbook of Community water Supplies”, 5th Edition, McGraw-Hill Inc., New York.

[7] Amirtharajah, A. and Melia, C.R. (2019). “Coagulation Processes: Destabilization, Mixing and Flocculation, Water Quality and Treatment”, A handbook of Community Water Supplies, 4th Edition, American Water Works Association, McGraw-Hill Inc., New York, pg. 269-365.

[8] Anita, V.P., Poyanka, M.S., Solashe, D., Shruti, R. and Dagade, K.P. (2021). “Automatic Proportional Water Distribution in residential Buildings “, IJRTI, volume 2(5): 2456- 3315.

[9] Anselmo, C.S. and Alexandre, K.S. (2022). “Operational optimization of water distribution systems by using the spea multi objective genetic algorithm. The Free Library.

[10] Ayamal, A. and Mohammed, A. (2021). “A supervisory Control and Data Acquisition (SCADA) for Water Dumping Station of GATA”, The Islamic University Journal, vol.19: 303-321.

[11] Carlton, P. and Rafic, B. (2019). “Implementary PID Temperature Control using Labview”, Proceedings of ASEE. Gulf Southwest Annual Conference, Texas Tech University.

[12] Central for Public Health and Environmental Engineering Organization, CPHEEO, (2019). “Ministry of Housing and Urban Affairs. Manual on Water Supply and Treatment”, 3rd Edition, Standard book Company, New Delhi, 149.

[13] Chatterjee, A.K. (2019). “Water Supply, Waste Disposal and Environmental Engineering”, 8th Edition, Khanna Publishers, Delhi. Pg. 188-254.

[14] Chick, H. (2019). “An Investigation of the Laws of Disinfesction” Journal of Hygiene, vol. 8: 92 DCNDW00964.

[15] Cleasby, J.L. (2019). "Filtration" Water Quality and Treatment: A Handbook of Community Water Supplies”, Fourth Edition, American Water Works Association, McGraw-Hill, Inc, New York, 455-560.

[16] Clifford, D.A. (2020). "Ion Exchange and Inorganic Adsorption." Water Quality and Treatment: A Handbook of Community Water Supplies, Fourth Edition, American Water Works Association, ed., McGraw-Hill, Inc., New York, 561-639.

[17] Dankoo, K.P. and John, M. (2019). "Towards sustainable water supply: Schematic development of big data collection using Internet of Things (IOT)", Proceeding Engineering, vol. 118 (Supplement): 489-497.

[18] Dhabadaounkar, S.M. (2019). "Jet Floccu-Clarifier: Appropriate technology for water treatment in India", J. Ind. Water Work Association 4(3) 149-159.

[19] Ebele, E.V. and Oladipo, O.F. (2019). "Microcontroller based automated water level control system", International Journal of Innovative Research in Computer and Communication Engineering, vol. 1(6): 1-6.

[20] Encarta, M. O. (2019). Water' Microsoft Student (DVD), Redmond, W. A.: Microsoft Corporation

[21] Engineering, vol. 2, 228-231.

[22] Eswaran, P. and Aswin, K. (2021). "Conceptual design and development of water metering system for multiple family residential buildings." International Journal of Advanced Computer Research, vol. 2(4).

[23] Gaikwad, S.A. (2021). "Water antitheft and quality monitoring system by using PLC and SCADA" International Journal of Electrical and Electronic Engineering Research, vol. 3, 355-364.

[24] Gouthaman, J., Bharathwajanprabhu, R. and Srikanth, A. (2021). "Automated Urban Drinking Water Supply Control and Water Theft Identification System", Proceeding of the IEEE Students' Technology Symposium 14-16. Kharagpur.

[25] Gritsenko, K.G. (2022). "Automated energy saving control of the pump station of water supply system", dis.kand.tech Sciences. Donetsk.

[26] Harring, W.A. (2020). "Economic losses of water disease outbreak", Journal of urban and spofford. Economics, vol. 25(4): 110-127.

[27] Hassaan, A. and Thabel, G. (2020). "Design and implementation of a pi controller for n automated building water supply system using PLC techniques", Journal of Theoretical and Applied Information Technology, vol. 5.

[28] Hegde, P. and Adarsh, H. (2019). "Automated Water flow Control System", National Conference on Product Design (NCPD 2019). International Journal of Soft Computing and Engineering 2.228-231.

[29] Jadhao, Y. (2022). "Computer aided hydraulic design of small capacity water treatment plant, UNIT", Nagpur. Test.net/thread-14331.html.

[30] Johnnalagadda, S.B., Nadupalli S. and Pare, B., (2019). "Water treatment and industrial bleaching: Scope of chlorinedioxide", J. Environ Res. Develop., vol. 9(2): 956-963.

[31] Kawamura, M.C. (2020). "Water Treatment principles and design", 3rd Edition, Wiley inc. USA. ISBN-13:9780470405390.

[32] Madihalli, D.B. and Ittancylar, S.S. (2019). "Smart Water Supply Management" IJETEE ISSN 2320-9569 Vol. 10 ISSN 9.

[33] Malmrose, P.M. (2019). "Residual Management Research Committee Subcommittee on Membrane Residual Management, "Committee Report: Residuals Management for Desalting Membranes", Journal AWWA, vol. 96(12):73.

[34] Mark, E.S., Michael, M.I., Maher, M. and Abdel, A. (2019). "Electronic Water Billing System" ESCS 17, ISBN-60132-455-3, CSREA Press.

[35] Meda, D. and Laxaman, T. (2022). "Computer aided design of a common effluent treatment plant (M.Tech. Thesis)", Institute of Technology and Science, Indore.

[36] Megha, M., Raykar, D.V., Parinti, V., Prechi, K.M. and Lovee, J. (2022). "Automated Water Billing with Detection and Control of Water Leakage using Flow Conservation", IJEDR, vol. 3(2).

[37] Mehta, K.P. and Patel, A.S. (2021). "Reverse Osmosis design with hydranautics design software for industrial waste water reuse", J. Environ. Res. Develop. 9(2): 421-430.

[38] Metcalf, K. and Eddy, D. (2019). "Waste Water Engineering: Treatment, Disposal and Reused", 3rd Edition, Tata McGraw-Hill Publishing company Ltd. New Delhi. 604-705.

[39] Mitra, A. and Roy, A. (2019). "A high regulated low ripple DC Power Supply based on LC filter IGBT", International Journal of Power electronics and drive system, vol.3, 30-40.

[40] Motling, S., Dutta, A. and Mukharjee, S.N. (2020). "Application of adsorption process for treatment of landfill Leachate", J. Environ Res. Develop., 9(2): 365-370.

[41] Mukesh, A.P., Sukhumar, S. and Karthik, C. (2019). "PLC based Automatic Corporation Water Distribution System using Solar Energy", International Journal of Engineering Research and Technology" (IJERT), vol. 2, 3100-3105.

[42] Obanda, W.N. (2019). "Design and fabrication of an electric system for monitoring temperature light illuminance and humility in a greenhouse", MSc. (Physics), Thesis Kenyatta University.

[43] Pranitavi, V.K. and Joshi, M.S. (2019). "An IOT based Water Supply Monitoring and Controlling System with Theft Identification" IJIRSET, vol. 5(9).

[44] Ramleela, K.F. and Mela, E. (2019). "Automation of water distribution plant", International Journal of Research in Engineering and Advanced Technology, vol. 2, 1-6.

[45] Ramprabu J. and Paramesh (2019). "Embedded based real time monitoring and contamination Detection in drinking Water Distribution System" (IJETTCS), vol. 3(5), ISSN 2278-6856.

[46] Ravi, H., Bagade, R. (2020). "Arduino Based Water Billing System for Domestic Purpose", IJMTER, vol. 2(6), ISSN (Online): 23499745; ISSN (Print):2393-8161.

[47] Sagakhole, T.K. and More, A.P. (2021). "Automated Drinking Water Supply System and theft identification using Embedded technology", International Journal of Innovative Research in Computer and Communication Engineering, vol. 3, 1-6.

[48] Shahji, A. (2022). Performance evaluation of Kabbit Khedi Sewage treatment Plant and Computer aided design of USAB based STP, (M.Tech. Thesis)", Institute of Technology and Science, Indore.

[49] Sharath, V.C. (2021). "Smart aqua meter" Advances in Electronics, Computers and Communications (ICAECC), International Conference on IEEE.

[50] Shritharanya, J.P., Jagadesan, A. and Lavanya, A. (2019). "Theft identification and automated water supply system using embedded technology", IJAREEIE, vol. 2(8).

[51] Sokratis, K., Edo, A., Julie, A. and Mccann, W. (2022). "A testbed for monitoring and controlling smart water networks. In proceedings of the 1st ACM International Workshop on Cyber-Physical Systems for Smart Water Networks, Page 8.

[52] Sorokhaibam, L.G., Bhandari, V.M. and Ranade, V.V. (2019). "Industrial Wastewater Treatment-removal of acid from wastewater", J. Environ. Res. Develop 9(2): 956-963.

[53] Stuart, A., Raziyeh, F., Fayyaz, M. and David, B. (2022). "Reliability indicators for water distribution system design: Comparison", Journal of Water Resources Planning and Management, 140(2): 160-168.

[54] Varne, A.L. and Wagh, K. K. (2019). "Low-Cost treatment of sewage using root zone technology", J. Environ. Res. Develop., 9(2): 411-420.

[55] Vinothini, E. and Suganya, N. (2020). "Automated Water Distribution and Performance Monitoring System", International Journal of Engineering and Innovative Technology (IJEIT), vol. 3.

[56] Warm, G.I. (2021). "Hydraulic modelling of drinking water treatment plant operations", Coperniaus publications on behalf of the ft University of Technology, Netherlands.

[57] Whittle, A.J., Allen, M.P. and Iqbal, M. (2020). "Sensor networks for monitoring and control of water distribution system", The 6th International Conference on Structural Health Monitoring of Intelligent Infrastructure, Hong Kong. Journal of Wireless Mobile Networks, Ubiquitous Computing and Dependable Applications, Vol. 6, No. 1 Pp. 4-23.

[58] Zhuiykoy, S. (2022). "Solid State Sensors Monitoring Parameters of Water Quality for the next generation of wireless sensors networks", Sens Actuators B; Chem., vol. 161(1):1-20.