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The Use of ICT in Household's Water Leaks Detection and Control,Opportunities and Challenges:A Case of Iyunga Ward In Mbeya Region

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Abstract:- Water has always been an essential component in supporting many of the human body metabolic functions, is involved in digestions, controlling body temperature, excrete waste products, saliva creation, ensuring proper human brain functions, protecting body tissues, spinal cord and joints, preventing body from dehydration and supporting treatment of many infections comprising UTI and bladder infections.

In many households, water is wasted and sometime contaminated with water borne diseases due to post meter leakages. Tariffs set and approved by special utilities regulating bodies like EWURA in Tanzania are relatively high compared to the average income of many citizens which calls for devising effective measures of reducing amount of consumed water per household and ensures post meters water hygiene. In Tanzania many household's water leaks remain undetected for years and this is attributed by the fact that the sources of those leaks are in areas which are either not visible or rarely visited by owners. Water leaks are easy to fix when they are timely identified and located, and timely fix and correct household's water leaks can save household's water bills up to about 10 percent.

In this paper, assessment of both opportunities and challenges of using ICT in water leaks detection and control have been exhausted and the research has ended up with the design and development of a contextualized prototype that uses microcontroller to constantly monitor water flow for post meters leaks detection and control in households. Once leak has been detected the prototype automatically close flows, play buzzer and send GSM SMS's to pre-configure mobile number.

Quantitative research design approach was used when designing this research, a sample of Two Hundred Sixty Seven (267) respondents was visited using a Simple Random Sampling (SRS), structured questionnaires were used when collecting data and in presenting findings an IBM SPSS software was used to analyze data.

Keywords:- *Water leaks; Detection; Control; System; Smart home.*

ABBREVIATIONS AND ACRONYMS

Gph	Gallons per Hour
DAWASCO	Dar es Salaam Water Supply Company
KPa	kilopascal
GSM	Global System for Mobile Communications
SMS	Short Message Service
UML	Unified Modeling Language
SPSS	Statistical Package for the Social Sciences
ICT	Information and Communication Technology
EWURA	Energy and Water Utilities Regulatory Authority
HBS	Household Budget Survey
TZS	Tanzanian Shillings
UTI	Urinary Tract Infection
USB	Universal Serial Bus
MODEM	Modulation Demodulation
dB	Decibel
MUST	Mbeya University of Science and Technology

I. INTRODUCTION

Water has always been an essential component for supporting many of the human metabolic functions, water is involved in supporting digestions, controls body temperature, excrete waste products through urine, perspiration and defecation, saliva creation, proper functioning of the brain, protecting body tissues, spinal cord and joints, preventing body from dehydration and treating many other issues like UTI and bladder infections. In 2018/2019 The Tanzanian Energy and Water Utilities Regulatory Authority (EWURA) which was established by the EWURA Act Cap 414 approved a tariff of 1,663 Tanzania shillings per cubic meters of water for Dar es Salaam water consumers of which has assumed to be the country indicative tariff. The tariff approved by EWURA is relatively high compared to the average income of many Tanzanian citizens and strategies to control amount of water consumed per household cannot be disregarded as a means of avoiding excessive household's monthly budgets. This research has established cost for the water tariff to be represented by below linear regression equation:

$$f(x) = \beta_0 + \beta_1 X_1 + \beta_2 x_2 + \varepsilon$$

Where
$f(x)$ Is Water utility cost (Value of dependent variable)
β_0 Is a Constant
β_1 Is the coefficient of X_1
β_2 Is the coefficient of X_2
X_1, X_2 Are independent variables which are water leaked and water properly used.
ε Is the error term which signifies all variables omitted and collectively have effect to the model/equation.

The 2017-18 HBS revealed that average consumption per household per month in Tanzania Mainland was TZS 416,927, the average household consumption expenditure was higher in Urban Areas (TZS 534,619) than in Rural Areas (TZS 361,956), and basic needs poverty was at 26.4 percent in the 2017-18 [1]. It has been identified that leaks from fittings, water pipes and plumbing fixtures are the leading origins of wasting water to both households and water utilities, typical home waste between 2,000 to 20,000 gallons of water per year following leaks. In Tanzania many household's water leaks remain undetected for years and this is attributed by the fact that the sources of those leaks are in areas which are either not visible or rarely visited by the household owner. Plumbing problems, worn toilet rubber parts, use of old bath or showers, damaged pipes and joints, water heaters, air conditioning units, sprinkler systems and washing machines are commonly hidden sources of household's water leaks. Collectively or individually, the leaks can easily waste thousands of gallons of water each year costing money to both the household and the water utility [2].

As the common practice small and medium sized leaks in household plumbing are generally ignored, substantially increases household water consumption [3]. Individually, leaks are insignificant, however, when summed together for a long period of time their impact on water loss is noticeable. Other nations and communities are putting forward initiatives of addressing water leaks problem, example European Union through their funded research have aspired to develop and introduce Information and Communication Technology (ICT) as enabling technology in managing water as a resource, affect end-users behavioral changes, increase conservation awareness to end-user, and avoid water losses through leak detection. Closer look of the existing global water leakage detection approaches, reveals that detection measures are more on larger diameter pipes in water supply distribution networks or transmission pipes and little on household's leakages. However, it has been estimated that the average household's leaks can accumulate up to 35 cubic meters of water waste per year [4]. Water is faced with the global scarcity crisis, so human consumed water supply systems must be of high precision with minimum wastage and properly monitored to avoid water borne diseases contamination. Leaks may introduce infections into the water distribution system under low pressure conditions [5]. Pressure in developing systems for water leaks control has more been to water authorities and less has been done in household's water leakage control management. However, it is estimated that post meter water leaks accounts to a maximum of 10% of total water produced for distributions, leaks are mainly found in the residential sector [6]. In Tanzania at June 10, 2011 MS Mlengu when addressing the public, agreed and confirmed that DAWASCO as the major water supply company in Tanzania was losing up to 45 per cent of water produced as a result of leaks, The company with the Tanzanian government interventions was mobilizing resources to start the project called 'non-revenue water', aimed at identifying areas where water is wasted as a result of leaks and propose promising resolutions.

In addition, it has been noted that Dar es Salaam, Tanzania's capital is losing out up to USD 1.7 million every month due to water leakages. The business capital is yet to address the issue as broken down pipes are to be replaced with better ones to reduce the leakage. The city is losing heavily to a humongous amount of revenue that could actually be used properly to establish better infrastructure and a solid economic ecosystem with their middle income status vision [7]. Other than wasting water, water leaks also causes the increase of moisture contents within the structure and enhance the growth of mold and other infestation, also over time, water leaks in the ground may result into a significant damage to the building's foundation. Damage of the building's foundation, growth of mold and other infestation could prove to be very expensive to solve [8].

Tanzania has set a target of reducing water leakages to 30 per cent in the year 2020 by implementing better measures such as replacement of water pipes and reducing errors with the measuring devices. With the current trend developing sophisticated devices though the use of ICT which are able to detect and automatically report both post and pre meters leakages is not an optional.

Reentry, development of water leakage detection system has gained popularity and many researchers are engaged and researching on designing and developing automatic leakage control systems, example Najwa Rosli et all (2018) proposed two staged conceptual framework which monitor water pressure within the water supply pipe and send leakage notification when pressure goes below 2.7 Kpa. The proposed conceptual framework assumes that when there are no leaks in the water supply system the pressure inside the supply system must be above 2.7 Kpa. The system proposed by Najwa et all (2018) was designed to be installed at home's underground pipes and immediately carry out necessary actions when leakage has been detected for the purpose of reducing water wasted and minimizing maintenance cost [9]. In addition; power to the mains water machine is cut off to remove the risks that may occur. Rain sensors when located under the laundry and dishwasher in the house are used to detect possible leaks and data is sent to the Arduino circuit board and an audible alarm is given in the direction of this data [10]. Chenning Wu et all (2019) mentioned that there are merits of low cost, removal of radiations hazards, high temporal resolutions and non-intrusive/non-invasive when there is a use of electrical resistance tomography modality on smart

wastewater metering, [11]. Above mentioned advantages in waste water metering have made electrical tomography an alternative technology in monitoring and analyzing s industrial flows. Through researching, this paper has acknowledged presence of various household's water leaks detectors and controllers in the market, among them Flo by Moen, Streamlabs, Flume, FLUID and FL-1000 are the leading five cutting edge leak detectors and controllers [12]. However neither tangible nor technological adoptions has been done in Tanzania for the tenacity of addressing household's post meter water leakage calamites.

Fig 1:- Water leaks effects, photo credits John Fowler

Fig 2: Leaking water pipe in Tanzania

In this paper, exploration of both opportunities and challenges of using ICT in water leaks detection and control has been exhausted and then design and development of a system prototype that uses microcontroller which constantly reads the data from flow rate sensors thereby constantly monitoring water flow in Tanzanian households was completed. The developed system compares the flow rate by calculating the difference in data from sensor and takes the necessary action. If the difference is greater than the set threshold, microcontroller signals the solenoid valve to close the valve and stops water flow, the system also sends alert SMS to the user. By doing so the system minimizes water wastage. This design helps in overcoming problems of early developed leak detectors which demands to be placed in areas with high water leaks probability, it is obvious that leaks are not always following set rules, they can happen anywhere within the household.

Following are the electronics components that have used when designing and develop household's water leakage detection and control system

- *Microcontroller (Arduino)*

The Arduino also termed as microcontroller is the open source and programmable device that is capable of running one program over and over again, Arduino are normally used when creating interactive electronic projects, they are capable of driving various electronic components including buzzer, GSM module, sensors, LEDs, motors and others. Arduino boards are equipped with sets of digital and analogue input/output (I/O) pins that may be interfaced to various expansion boards and other circuits. Arduino board designs use a variety of microprocessors and controllers and have communications interfaces such as Universal Serial Bus (USB) which is used for loading programs from the personal computers [13]. In this research this tool has been programmed to receive signal from water flow sensors and decides on when to close water valve, play buzzer or send an SMS

Fig 3:- Microcontroller

- *GSM Module*

Is an electronic end device (chip) that is normally used when establishing communication between a device or a computing device where it is embedded with a GSM enabled system. From working perspective GSM module functions in same way as MODEM. GSM modules are sometimes referred as the wireless MODEM. In this research this circuit has been used to send SMS's when water leakage has been detected.

Fig 4:- GSM Module

- *Water sensor*

This is an electronic device usually used to detect water presence. The device is able to provide timely water presence alert and triggers for appropriate measures to be incorporated for the purpose of either removing water or

controlling the situation. Practically water sensors are applied to notify on sprinkler system failures and other malfunctioning like damaged pipe, toile leaks, roof leakages, leaks on washing machine sewerage system failure and others. Having water sensors properly installed offers many advantages to home owners including that of insurance benefits [14]. In this research this device has been used to detect water leaks and send signal to the programmed microcontroller.

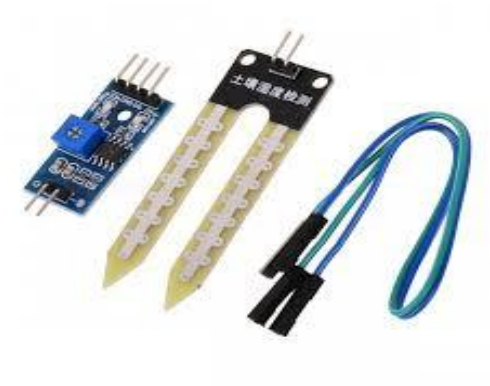

Fig 5:- Water leak sensor

➢ *Buzzer*

Is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Product size, voltage and sound output level are among the factors to be considered when selecting appropriate buzzer for the electronic project. Buzzers with sound levels ranging from 80dB to 105dB are commonly available on the market. In this research the buzzer has been used to provide an audio as an alert following detected water leaks.

Fig 6:- Buzzer

➢ *Flow rate sensor*

Is a device used for measuring the flow rate or quantity of a moving liquid or gas. Flow rate sensors are of two major classes which are differential and linear flow meters, on market various categories of the flow rate sensors are existing, among them turbine, electromagnetic, vortex, orifice-plate, venture nozzles, pilot tubes, thermal mass flow and laser doppler are the leading types of flow rate sensors. In this research flow rate has been used to determine the quantity of water flowing through the pipe and send appropriate signal to the programmable microcontroller when the rate surpasses set thresholds.

Fig 7:- Flow rate sensor

II. PROBLEM STATEMENT

Annually household's water wasted following leaks can accumulate to approximately 10,000 gallons, around ten percent of homes in United States of America waste about 90 gallons of water and even higher in a day following household's water leaks. Many of these leaks are easy to fix if they are timely identified and located, when leaks are timely fixed implicate to the massive water saving and consequently colossal financial saving. Timely fix and correct household's water leaks can save household's water bills up to about 10 percent [15]. Post meter leakage is leading type of leakage in households, which has a key consequences on water consumed per household. Damaged pipe joints, loose water connectors, intruding tree roots, corrosion, rapid temperature Changes are also notable cause of household water leaks. Though globally there are efforts on developing cutting edge leak detectors, Tanzania has lagged behind on adopting available technologies and reasons are open for researches and justification though cost and knowledge are preliminary leading.

This research is focused on developing cheap and contextualized structure that detects, reports and controls water leakages in Tanzanian households. With this system households water leaks are detected, controlled and householders are informed about interventions, allowing them to promptly put necessary initiatives for an early fix of the problem. By so doing households will be capable of properly utilizing water and reduce unnecessary cost.

III. RESEARCH SIGNIFICANCE

This research is signified by the design and development of a prototype that detects and control post meters water leaks, the detections and controls are automatically happening and once happened special buzzer will be played to notifying in proximity household. If the household's owner has not reacted to the played buzzer, the system ascends to the next level and send an SMS to a pre-configured mobile number and finally close the gate valve for further leaks preventions. By so doing the system helps

to detect and control leaks which implicate to saving precious water wastage, time and maintenance cost.

Water leakages detection and control system has emphasized on unaccounted for water reduction and conservation. In water utility industry, greatest economic loss occurs in the distribution networks. Unaccounted for water figures are high to 50 percent in North America for some water distribution systems recent surveys show [16].

IV. RESEARCH OBJECTIVES

Objectives of this research have been categorized into two focal fragments entitled main and specific objectives.

➢ *Main objective.*

To use ICT in Household's Water Leaks Detection and Control, Opportunities and Challenges: A Case of Iyunga Ward in Mbeya Region

➢ *Specific objectives*

- Identify challenges and opportunities of using ICT to detect and control household's water leaks.
- Design contextualized household's water leak detection and control circuit.
- Simulate designed household's water leak detection and control circuit.
- Interface microcontroller with other components.
- program the microcontroller
- Test the in household leak control and detection system.
- Write household leak control and detection system's documentations.

V. CHALLENGES OF USING ICT IN HOUSEHOLD'S LEAK CONTROL AND DETECTION OF WATER

The use of ICT in diversified range of applications in Tanzania is attributed by many challenges, lack of ICT literacy among Tanzania citizens, adopted technologies being unsustainable and rely on external supports, resistance from the community on using ICT, high cost of installing and maintain ICT systems and poor ICT supporting infrastructures including unreliable electricity, poor internet access and lack of mobile phone network coverage are among the key acknowledged challenges. Many of the listed challenges are replicable to all applications including the water leak detections and control.

It has also been noted that lack of use of ICT supporting policies from government like Tanzania, lack of incentives and grants on ICT related projects, lack of ICT platforms standardizations, poor community awareness are also barriers to the use of ICT in many applications including that of household's water leak detection and control. Interoperability together with interconnectivity sensor network generic supporting infrastructure is also omitted to enable national interventions [17].

VI. OPPORTUNITIES OF USING ICT IN HOUSEHOLD'S WATER LEAK DETECTION AND CONTROL

The use of ICT in water leaks control and detection is embraced with a number of opportunities. Real time leaks monitoring enables early and timely detection of leaks and device alternatives to fix them, by doing so ICT helps in reducing water consumed per household, helps water supply companies to account for sources of non-revenue water, provides better ways of utilizing energy that is used when propelling water to a supply network, helps in reducing incurred on providing or getting water service, ICT also simply integrations to other sophisticated systems like that of Smart Sustainable Cities (SSC), protects environment and also provide better way of engaging public in water management are some of them [18].

VII. METHODOLOGY

Apart of reviewing various journal and other internet resources in finding what has been done on design and development of household's water leaks detection and control system, the paper also used a quantitative research design approach when designing this research, as mentioned in the title the case study of this research was Ikuti village at Mbeya city in Tanzania where a sample of Two Hundred Sixty Seven (267) respondents was chosen using a Simple Random Sampling (SRS), SRS was opted so as to grant respondents an equal likelihood of participating in this research and circumvent biasness, on data collection structured questionnaires were used and finally to scrutinize data and present findings IBM SPSS software was used.

VIII. MODELLING AND SYSTEM DESIGN

In this research the Object-Oriented approach with the assistance of Unified Modeling Language (UML) was used for elucidation users' interactions with the system, structure of the system as well as system's behavior. To converse system structure block diagram was used, in user interactions use case diagram was used and to communicate system's behavior a sequence diagram was used.

➢ *Use case*

To suitably demonstrate how a developed system interact with external actors use case diagrams are preferred, use cases diagrams are normally involved at the early stage of the design and especially on the requirement specification phase. The diagram below shows the use case diagram for the household's water leak detection and control system, the diagram shows how interactions with the external actors is happening for user interfaces creation.

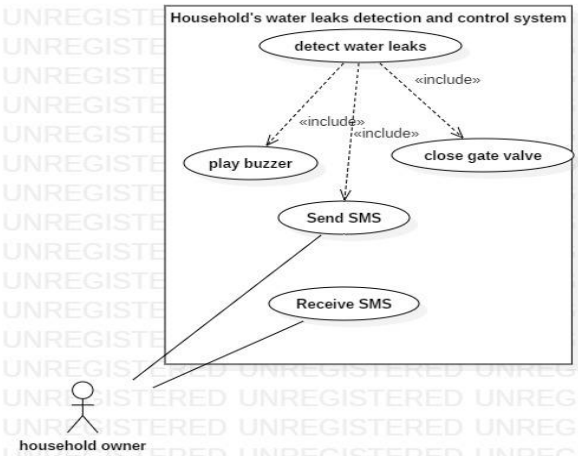

Fig 8:- Use case, household's water leaks detection and control system.

➢ *Sequence Diagram*

To represent interaction between system's objects in a sequential order a sequence diagram is routinely preferred. Sequence diagram also shows how interactions take place in a specified order. The diagram below explains the sequence diagram of household's water leaks detection and control system.

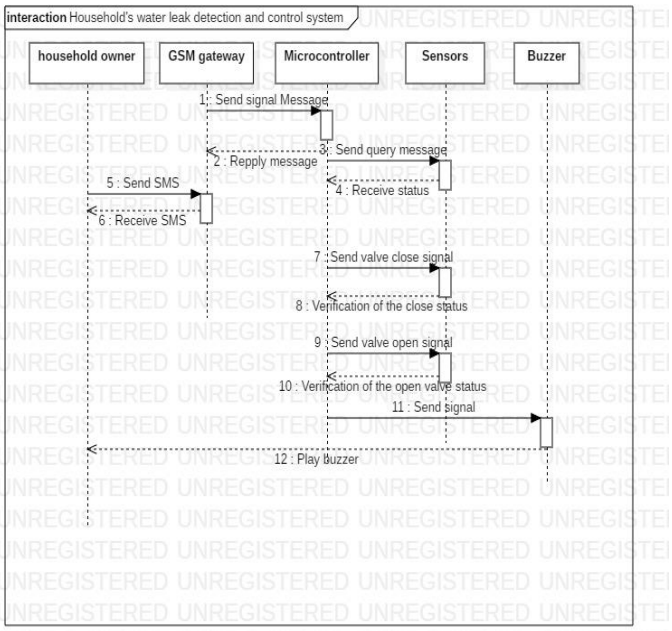

Fig 9:- Sequence diagram, household's water leaks detection and control system.

➢ *Block Diagram*

Block diagram is commonly used in engineering field as the specialized and higher level flowchart that amplify how things involved in a complex system harmonize. As a common practice block diagrams are used when design new systems or improving and describing existing system. Block diagram structure is used when providing higher-level synopsis of the system's major components, processes, and relationships. Below figure describes block diagram for the household's water detection and control system.

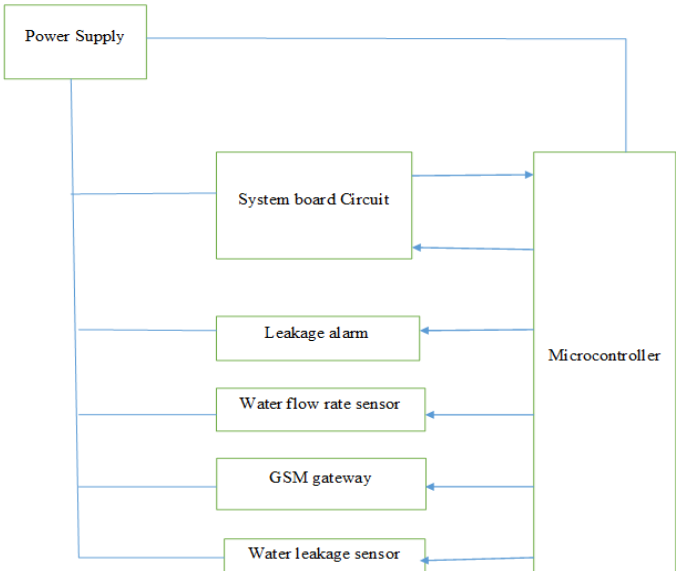

Fig 10:- Block diagram, household's water leaks detection and control system

➢ *The circuit design simulation and prototyping*

Simulation is the common act in complex designing. Any Logic Company in North America (2019) says efficiently and with the high level of safety simulation resolves many real-world complications. Simulations enables analysis of methods that are easily understood, communicated and verified. Modelling simulations offers cherished resolutions across several disciplines and industries via provisions of vibrant intuitions into complex systems. The screen shot below illustrate the system's development simulation stage with the assistance of Proteus software.

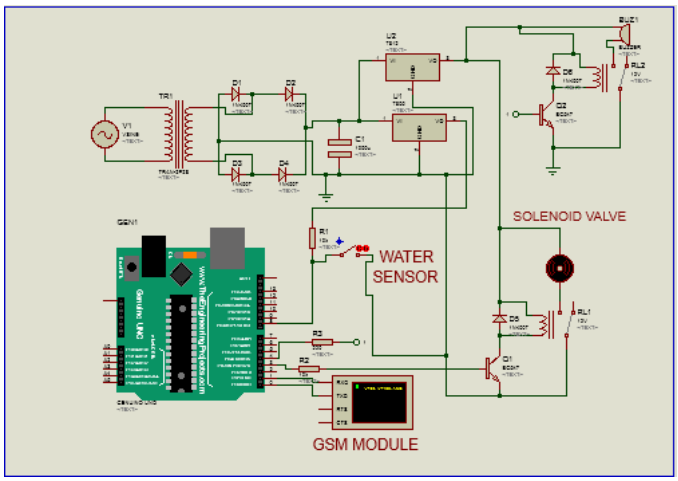

Fig 11:- Circuit simulation, household's water leaks detection and control system.

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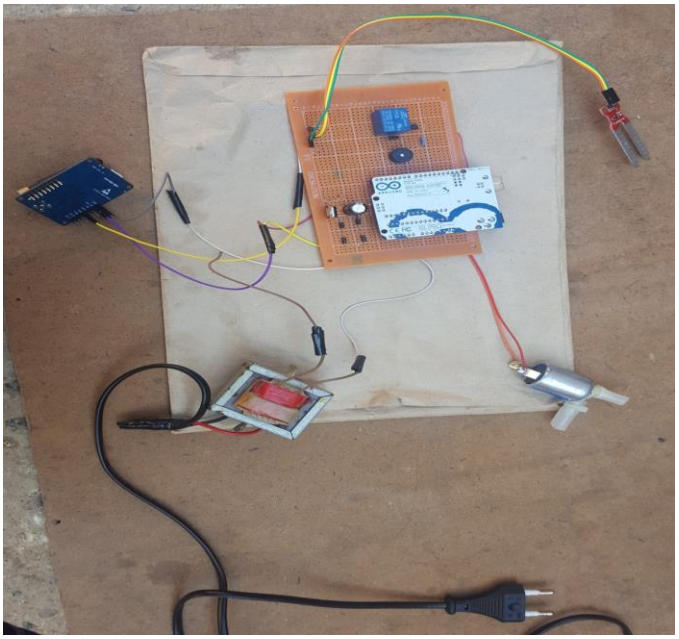

Fig 12:- Developed Prototype, household's water leaks detection and control system

IX. RESULTS AND DISCUSSION.

The research has ended with development of the system circuit comprising both flow rate sensor, water sensor, buzzer and solenoid valve serially connected in the water pipe. After design and development the system has been tested using numerous conditions of water flow. Through testing built prototype positive results were congregated. To operate the system water flow valve is initially kept open to allow water flows in water pipe. Periodically microcontroller gathers water flow rate data captured by the flow rate sensor. Microcontroller uses water leakage detection algorithm to make leakage detection.

X. CONCLUSION

Water that is aimed for household's consumptions needs special attention and treatments, following global statistics water meant for human's usage are facing global crisis of scarcity, thus sophisticated measures are mandatory to prevent water from being wasted. Various researchers have recommended proper use of water. Around 844 million people denied access to clean and safe water globally. Generations of various families and communities in Africa are locked in poverty following lack of easily accessible sources of water and clean water. Schools' dropouts are mounting among children and making a living has been a struggle for many parents [19]. Using this circuit the research can provide effective measures of monitoring water flows and detecting leaks in households.

Development of sophisticated devices like this are encourage for a proper utilizations of water and meet the set 2020 year Tanzanian vision of reducing water leakages to 30 percent.

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REFERENCES

[1] "Household Budget Survey 2017 - 2018 Key IndicatorsReport," National Bureau of Statistics, Ministry of Finance and Planning, Dodoma, 2019.

[2] AWE, "Alliance for Water Efficiency," Alliance for Water Efficiency, NFP., 2018. [Online]. Available: http://www.allianceforwaterefficiency.org/Household_Leaks.aspx. [Accessed 03 08 2019].

[3] T. Britton, G. Cole, R. Stewart and D. Wiskar, "Remote diagnosis of leakage in residential households," *Journal of Australian Water*, vol. 35, pp. 89-93, 2008.

[4] S. Seyoum, L. Alfonso, S. J. van Andel, W. Koole, A. Groenewegen and N. van de Giesen, "A Shazam-like household water leakage detection method," in *XVIII International Conference on Water Distribution Systems Analysis, WDSA2016*, Netherlands, 2016.

[5] R. Puust, Z. Kapelan, D. Savic and T. Koppel, "A review of methods for leakage management in pipe networks," *Urban Water J*, vol. 7, pp. 25-45, 2000.

[6] T. C. Britton, K. O'Halloran and R. A. Stewart, "Smart metering: enabler for rapid and effective post meter leakage," *Journal of Cleaner Production*, vol. 54, pp. 166-176, 2013.

[7] J. Green, "The Exchange, Africa's Invetsment gateway," The Exchange, Africa's Invetsment gateway, 09 07 2018. [Online]. Available: https://theexchange.africa/water-leakages-costing-tanzania-1-7-million-monthly/. [Accessed 05 08 2019].

[8] LeakMasters, "Leak Masters," Leak Masters, 17 07 2019. [Online]. Available: http://www.leakmasters.net/blog/7-reasons-water-leak-detection-is-important/. [Accessed 06 08 2019].

[9] R. Najwa, A. A. Izzatdin and M. J. Nur Syakirah, "Home Underground Pipeline Leakage Alert System Based on Water Pressure," in *2018 IEEE Conference on Wireless Sensors (ICWiSe)*, Langkawi, Malaysia, 2018.

[10] S. DİKİCİ, R. UZUN and K. Erhan, "Versatile Home Design," *Journal of New Results in Engineering and Natural Science*, vol. 8, pp. 1-5, 2018.

[11] S. R. Aw, R. A. Rahim, M. H. Rahiman and R. Fazlul, "Electrical resistance tomography: A review of the application of conducting vessel walls," *Powder Technol*, vol. 254, pp. 256 - 264, 2014.

[12] . J. Basen, "Residential Tech Today," Residential Tech Today, 15 03 2019. [Online]. Available: https://restechtoday.com/guide-5-modern-leak-detectors/. [Accessed 06 08 2019].

[13] V. MACH, S. KOVÁŘ, J. VALOUCH and M. ADÁMEK, "Brushless DC Motor Control on Arduino Platform," *PRZEGLĄD ELEKTROTECHNICZNY, ISSN 0033-2097,*, vol. 94, pp. 105 -107, 2018.

[14] "Excite Home security," Mindspark Interactive Network, Inc, 2019. [Online]. Available: http://www.excite.com/content/home-security/sensor-detector/water-sensor. [Accessed 12 08 2019].

[15] U. S. E. P. Agency(EPA), "WaterSense," Water Sense, 14 03 2019. [Online]. Available: https://www.epa.gov/watersense/fix-leak-week. [Accessed 06 08 2019].

[16] G. W. Hennigar, "Water Leakage Control and Sonic Detection," *Canadian Water Resources Journal*, vol. 9, no. 3, pp. 51-57, 1984.

[17] G. Schimak, A. E. Rizzoli and K. Watson, "Sensors and the environmenteModelling & ICT challenges," *Environmental Modelling & Software*, Vols. 975 -976, no. 9, p. 25, 2010.

[18] M. Al Mahdi, "ICTs for Water Management," in *ITU Regional Workshop on "Prospects of Smart Water Management (SWM) in Arab Region"*, Khartoum-Sudan, 2017.

[19] WorldVision, "World Vision," World Vision, 01 03 2019. [Online]. Available: https://www.worldvision.org/clean-water-news-stories/global-water-crisis-facts. [Accessed 06 08 2019].

[20] J. Green, "The Exchange, Africa's Invetsment gateway," The Exchange, Africa's Invetsment gateway, 09 07 2018. [Online]. Available: https://theexchange.africa/water-leakages-costing-tanzania-1-7-million-monthly/. [Accessed 17 07 2019].

[21] WorlVision, "World Vision," World Vision, 1 03 2019. [Online]. Available: https://www.worldvision.org/clean-water-news-stories/global-water-crisis-facts. [Accessed 19 07 2019].