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What would be an 'Appropriate' Sanitation Technology in Slum Areas? Experience from Kisumu, Kenya

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Abstract

Slum settlements are characterised by overcrowding, lack of/ insecure land tenure, and lack of basic services like water and sanitation facilities. One challenge in such settlements is identifying the most appropriate sanitation technology in the midst of these living conditions and variety of sanitation technologies. The aim of this study was to identify characteristics of an appropriate and feasible sanitation technology given the social, economic, cultural, and environmental conditions in the slums of Kisumu. Qualitative methods were used for data collection, mainly interviews with household heads and group discussions with residents, in Nyalenda, Bandani and Obunga slums. Thirty four interviews were conducted with household heads to identify and rank preferred sanitation technologies, and group discussions held with landlords and tenants, who had or did not have sanitation facilities. Four sanitation technologies were identified; pit latrines, eco san toilets, flush toilets, and pour flush toilets, and respondents showed preference for the pit latrine. Participatory discussions were then held, through which participants deliberated over the viability of the identified sanitation technologies, and further affirmed the preference for pit latrines. Reasons for, or against each of the identified technologies were given, and characteristics of an appropriate sanitation technology were inferred from these reasons. An appropriate sanitation technology would be one that, inter alia, is practical, has been tested and proven successful, is socially and culturally acceptable, is affordable, has economic benefits, can be shared and managed by a few households, and encourages relationships between landlords and tenants. These findings demonstrate the necessity of working with different stakeholders, including slum residents to determine the design and appropriateness of sanitation technologies in slums. A participatory approach enables identification of issues from residents, who are end users of the sanitation technologies, and policy makers could borrow a leaf from such in designing appropriate sanitation technologies.

Keywords: Pit Latrine, Sanitation, Appropriate Technology, Slums, Participatory, Kisumu

Introduction

Poor human waste disposal methods in slums demands the provision of sanitation facilities to curb the ill effects associated with this practice. Due to the interwoven nature of living conditions in slums, sanitation provision is complex. Insecure land tenure, overcrowding and dense settlements, lack of basic services such as water and uncertainty over an appropriate sanitation technology are some factors that influence sanitation provision. It is therefore important that these factors are taken into consideration when designing an appropriate sanitation technology for slum areas.

An appropriate sanitation technology should exhibit certain elements, including affordability to users, ability to use local resources and function in the local area, replicability, suitability for both male and female users, and ability to adapt to social cultural conditions of an area (D. D. Mara, 2003; Murphy, McBean, & Farahbakhsh, 2009). In other literature, the term ósustainable sanitation technologyô is used, which, should consider the costs and space available, should improve human health, should be technically feasible, and should ensure environmental sustainability in slums (A. Y. Katukiza et al., 2012; D. Mara, Drangert, Anh, & Tonderski, 2007) There are various types of sanitation technologies, ranging from simple pit latrines to flushable toilets. Some authors propose that simplified sewerage is the most appropriate in urban poor settings (Paterson, Mara, & Curtis, 2007), while others propose urine diversion dry toilets and bio gas toilets as the most appropriate (A. Katukiza & Ronteltap, 2010) in urban slums. Each slum settlement has different living conditions, and therefore requires a sanitation technology whose features have been designed specifically for the slum settlement.

Little has been done on the most appropriate and sustainable sanitation technology for urban slum settlements, a view re-iterated by Katukiza and colleagues (2012) and Letema et al (2014). This does not rule out the diversity of various technologies, but rather points to gaps in identification of the most feasible sanitation technology for specific urban slum settings. With the differences in living conditions in each slum settlement, it is apparent that a feasible technology in one slum may not be the most appropriate in another slum; pointing to the need to identify slum specific sanitation technologies. This study therefore sought to identify the characteristics of a sanitation technology that would be most appropriate in the slums of Kisumu in Kenya.

Materials and methods

Study area

Kisumu is the third largest city in Kenya and the main city in the western region of the country, which unfortunately, has half the population living in poverty (UN-Habitat, 2005). Population growth has led to growth of slum settlements, where sixty percent of the population live (UN-Habitat, 2008). The main slums are Manyatta A and B, Nyalenda A and B, Obunga and Bandani. A number of other settlements that are classified as slums also exist, these being Manyatta Arab, Kaloleni and Kibos. Over the years, several sanitation technologies have been used in the city, ranging from the bucket, to the use of septic tanks, and the sewer system. (S. Letema et al., 2014). Residents in slums however, mostly rely on pit latrines, because of lack of a sewer connection in the settlements. Some areas of the slums have high water tables, and usually experience flooding, which leads to collapsing of pit latrines (UN-Habitat, 2005). Approximately half of the population lacks sanitation facilities, and open defection is common (Karanja, 2010). Bio gas toilets and eco san facilities have recently been introduced in the slum settlements by Non-governmental organisations (S. Letema et al., 2014).

Methods

Qualitative methods (interviews and group discussions) were used to collect data from Nyalenda A, Nyalenda B, and Obunga slums. Due to different residence types in the slum areas, respondents were landlords, tenants and caretakers (point persons between landlords and tenants). Data on known and preferred sanitation technologies was first collected through household interviews with residents in the slums. Transect walks were taken through each slum settlement, and in the process, systematic selection of households was done by skipping at least two compounds (a group of households under one landlord). Respondents were household heads, who were willing to participate in the interview. Preference was given to landlords, and in their absence, tenants and/or caretakers were interviewed. Respondents were asked to mention and rank sanitation technologies in order of preference, while giving reasons for their choices. This process continued until no new information was forthcoming, by which time, a total of 34 interviews had been conducted.

After this exercise, the same sampling strategy was used to select respondents for focus group discussions. These were selected based on residence type and availability of a sanitation facility on the compounds they lived in, leading to eight categories of group discussion respondents. Each of these eight categories had a minimum of eight and maximum of 16 participants, and the discussions were held on separate days and times, and at a venue that was central to all participants. At the start of the discussions, participants were divided into smaller groups of four respondents for manageability. Just like in the household interviews, respondents were asked to mention sanitation technologies, and rank them from the most to the least preferred. This was done to validate the results from interviews. After this, all respondents were engaged in a common discussion, where they were tasked to rank the already identified technologies. This led to a rich discussion with participants giving reasons for or against selected sanitation technologies, and identifying the most feasible technologies in the slum settlements.

Data management and analysis

Data was recorded on audio recorders and later transferred to computers, after which it was transcribed and analysed. Ranking of sanitation technologies was summarised descriptively in SPSS, while the rest of qualitative data on reasons for or against technologies was coded and managed using Atlas.ti (vs 7).

Results

Results will be presented under two main headings: preference of identified sanitation technologies, and reasons for preference.

Preference of identified sanitation technologies

Four sanitation technologies were mentioned by respondents: these were pit latrine, eco san toilet, flush toilet connected to the sewer system, and the pour flush toilet. The pour flush toilet was defined as one that had a bowl instead of a drop hole, but which did not necessarily need to be connected to the sewer system. It required using water which would be poured directly into the bowl, instead of flushing from a cistern.

Pit latrines and flush toilets were ranked as the most preferred by 47% of respondents of household interviews, while the eco san toilet was ranked as the most preferred by only 6% of respondents. From respondents who ranked second most preferred technologies, 71% selected pit latrines and 21% selected flush toilets, with 8% selecting the eco san toilet.

From smaller group discussions, pit latrines were ranked as the most preferred technology by 48% of respondents, followed by flush toilets (32%) and eco san toilet (20%). The second most preferred option was still the pit latrine, selected by 43% of respondents, followed by flush, eco san and pour flush at 32%, 19% and 6% respectively.

In the participatory discussions, respondents of most categories reached a consensus that the pit latrine was the most feasible and preferred sanitation technology. This is shown in table (i).

Table i: Preferred sanitation technologies from participatory discussions

Category of respondents	Preferred technology	Second alternative	Third alternative
Tenants with resident landowners, and have a sanitation facility	Pit Latrine	Flush toilet	Eco san
Tenants with resident landowners, but lack a sanitation facility	Pit Latrine	Eco san	Flush Toilet
Tenants with absentee landowners, and have a sanitation facility	Pit Latrine	Flush toilet	Eco san
Tenants with absentee landowners, and lack a sanitation facility	Pit Latrine	Pour Flush	Eco San*
Resident landowners lacking a sanitation facility in their compounds, and have tenants	Pit Latrine	Flush toilet	Eco san
Resident landowners who have a sanitation facility; and have tenants	Pit Latrine	Eco san	Flush Toilet
Landowners lacking a sanitation facility	Eco san	Pit Latrine	Flush Toilet
Tenants living on compounds with caretakers, and have a sanitation facility	Pit Latrine	Eco san	Flush toilet

*The flush toilet was ranked as the fourth option

Reasons for preferences of sanitation technologies

Respondents gave various reasons for or against the mentioned sanitation technologies.

(a) Flush toilet/Sewer System

The flush toilet was preferred because respondents felt it was easier to clean, compared to the pit latrine; and again, it was more stylish. A number of respondents expressed the wish to have a flush toilet, but as a household sanitation facility.

"The flush toilet..... Because I only need to pull the handle after which the toilet will be clean"

On the other hand, because the slums lack a conventional sewer system and often experience water shortage, it was felt that the flush toilet was not feasible in the slums. Respondents also mentioned challenges of high costs of installation and management difficulties of the flush toilet as a shared facility.

"Some people may not know how to use the flush toilet....In cases of water shortage, someone for instance may want to keep on flushing....such practices will lead to breakages"

(b) Eco San

The Eco san toilet was popular among land owners, who had farming land, because manure could be used on their farms. They lived in flood prone areas, where pit latrines collapsed during the rainy season if not constructed properly. Other respondents also felt that eco san toilets looked ốbetterô in terms of design, and they were easier to empty compared to pit latrines. However, some respondents were not happy with the emptying process, as it was felt to be embarrassing. It did not favour residents who lived in areas that had a high population density where sanitation facilities were shared, because of difficulties in maintenance as shared facilities. Such areas also lacked farming lands, and users thought it meaningless to collect manure.

"Eco-san is easier to empty it, and we can use manure on the farms"

"Eco san looks nice and presentable"
"It will fill up very quickly because of many people sharing....... no one will be willing to empty it……then it will soon lead to conflicts over who needs to empty it"

(c) Pit latrines

Pit latrines were commonly used in the slums where they were shared by a number of households. Residents noted that they could be used even without a regular water supply, and compared to eco san toilets, they took longer to fill up, and were easier to manage as shared facilities. The disadvantages mentioned were the need for emptying, and collapsing during the rainy season. However, residents still preferred the pit latrine since they knew how to handle the challenges posed by pit latrines.
"The pit latrine is better because we can share……"
"Pit latrines can be used when we do not have water…"
"If dug deeply it [pit latrine] can take a longer time before it fills up"

(d) Pour flush toilet

Respondents felt that pour flush toilets looked better, almost close to flush toilets, and also similar to pit latrines since they did not depend on a regular water supply. They were also easier to manage as shared facilities compared to flush toilets.
"When we do not have water, we can pour water directly into the toilet"

Discussion

The pit latrine was preferred as the most feasible sanitation technology despite its shortcomings of collapsing during rainy seasons and emptying challenges. This preference may be due to the long experience in using pit latrines or/and lack of knowledge of other technologies. The long experience means that residents had learnt how to make do with the challenges posed by pit latrines. Slums in Uganda also faced similar challenges, and pit latrines were raised off the ground during construction as a way of dealing with flooding and high water tables. It is also premised that residents may have lacked knowledge of other technologies, hence the continued use of pit latrines (Isunju et al., 2013; Niwagaba, Ssemanda, Sande, & Kamara, 2008). Pit latrines are favoured in slum areas because they can be shared by many households who may not have space to construct individual pit latrines. Further, management responsibilities, especially cleaning can easily be shared among the users.

Few residents had knowledge of eco san facilities, and fewer households used them. This observation is also raised by Letema (2012), who noted that most of the eco san facilities were not in optimum operation. Users gave a number of reasons for their dislike of the eco san toilets, most of which are socio-cultural, and others relating to challenges of operation and maintenance as shared facilities. In Uganda however, a high adoption of eco san toilets was noted, and this was attributed to a number of factors including availability of masons to construct the toilets, and a high level of awareness that had been created through mass media (Tumwebaze et al., 2011). Due to this, Katukiza and Rontelp (2010) commend it as the most appropriate technology. Resident of Kisumu lacked some of these factors, especially knowledge of eco san facilities and masons to construct the facilities. This points to some important prerequisites for an appropriate sanitation technology.

The flush toilet was preferred because it looked better, and was easier to manage as a household facility. Its limitations include economic considerations that ought to be considered in designing an appropriate sanitation technology. Such economic/financial limitations have also been noted in Accra (Nimoh & Poku, 2014), Uganda (Niwagaba et al., 2008) and Botswana (Bolaane & Ikgopoleng, 2011) as barriers to householdsô acquisition of flush toilets. High financial costs are limitations reiterated by Paterson and colleagues (2007) who propose that a simplified sewerage system, would be a better alternative. It is clear that residents in Kisumuôs slums were knowledgeable about the flush toilet, but were also aware of its limitations, hence the alternative of a pour flush toilet. Its preference may be attributed to the desire to have something better than the normal, and the normal in this case is the pit latrine. Limitations of a constant water supply in the slums have indirect financial implications on the operation of a flush toilet. In such slum settings where water is bought, the urban poor are unlikely to spend money to buy water that will be flushed down the toilet.

Each of the identified technologies presents strengths and weaknesses, and an appropriate sanitation technology for the slums would be one that incorporates the strengths of the identified technologies and minimizes the weaknesses.

- Due to lack of space in the settlements, it is not practical to have individual household sanitation facilities; calling for shared sanitation facilities. An appropriate sanitation technology would be one that can be shared by a few households.
- Sharing of sanitation facilities brings in the question of management, both in terms of cleaning and repair. An appropriate technology should be one whose users can manage, with less conflicts.
- It should be affordable by users, both in terms of installation, and operation and maintenance
- It should not be entirely sewer and/or water dependent. The lack of a sewer system and a constant water supply in the slums would limit its functionality
- It should be one that can be constructed by local masons, and this may be achieved by training the masons.
- It should have additional benefits apart from human waste disposal. The eco san for instance was lauded by farmers because of manure, and had the potential for business in manure.
- It should be acceptable both socially and culturally by users.
- It should not be limited by the environmental challenges of the area, especially high water table, flooding and loose soils.
- Users should find it easy to use.
- Proof of its efficiency in other similar slum settings would be an added advantage, though this needs not to be the major issue, as slums have different living conditions.
- The technologyôs appearance needs to be aesthetically appealing. This is the reason residents preferred some technologies because they looked presentable
- It should be flexible enough to encourage local relationships between landlords and tenants

Conclusion

This study used qualitative methods to identify the features of an appropriate sanitation technology for the slums of Kisumu. Through participatory discussions, users identified the pit latrine as the most feasible sanitation technology in the slums, due to the advantages it offered. Other sanitation technologies were mentioned, this being pour flush toilet, the eco san toilet, and the flush toilet connected to a sewer system. Each of these however, presented a number of strengths and weaknesses, which act as pointers to the characteristics of an appropriate sanitation technology. Thus an appropriate sanitation technology for the slums in Kisumu would be one that can be adopted in the environmental, technical, social and cultural conditions of the slums, has additional benefits, more so economic benefits, should be easy to use, allows sharing by a few households, can be easily managed as a shared facility, and should be affordable both in terms of installation and maintenance. Due to differences in living conditions, what has proven workable in one slum setting may not necessarily work perfectly in another slum. This study shows the need for different disciplines to work together to identify the most appropriate sanitation technology, with a participatory approach from the end users.

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References

Bolaane, B., & Ikgopoleng, H. (2011). Towards improved sanitation: Constraints and opportunities in accessing waterborne sewerage in major villages of Botswana. *Habitat International*, *35*(3), 486ï 493. doi:10.1016/j.habitatint.2011.01.001

Isunju, J. B., Etajak, S., Mwalwega, B., Kimwaga, R., Atekyereza, P., Bazeyo, W., & Ssempebwa, J. C. (2013). Financing of sanitation services in the slums of Kampala and Dar es Salaam. Health, 05(04), 783ï 791. doi:10.4236/health.2013.54104

Karanja, I. (2010). An enumeration and mapping of informal settlements in Kisumu, Kenya, implemented by their inhabitants. Environment and Urbanization, 22(1), 217ï 239. doi:10.1177/0956247809362642

Katukiza, A., & Ronteltap, M. (2010). Selection of sustainable sanitation technologies for urban slumsð A case of Bwaise III in Kampala, Uganda. Science of the Total Environment, 409(1), 52ï 62. doi:10.1016/j.scitotenv.2010.09.032

Katukiza, A. Y., Ronteltap, M., Niwagaba, C. B., Foppen, J. W. A., Kansiime, F., & Lens, P. N. L. (2012). Sustainable sanitation technology options for urban slums. Biotechnology Advances. doi:10.1016/j.biotechadv.2012.02.007

Letema, S. C. (2012). Assessing Sanitary Mixtures in East African Cities (p. 161). Wageningen Academic Pub.

Letema, S., van Vliet, B., & van Lier, J. B. (2014). Sanitation policy and spatial planning in urban East Africa: Diverging sanitation spaces and actor arrangements in Kampala and Kisumu. Cities, 36, 1ï 9. doi:10.1016/j.cities.2013.08.003

Mara, D. D. (2003). Water, sanitation and hygiene for the health of developing nations. *Public Health*, *117*(6), 452ï 6. doi:10.1016/S0033-3506(03)00143-4

Mara, D., Drangert, J., Anh, N., & Tonderski, A. (2007). Selection of sustainable sanitation arrangements. *Water Policy*, *9*, 305ï 318. doi:10.2166/wp.2007.009

Murphy, H. M., McBean, E. a., & Farahbakhsh, K. (2009). Appropriate technology ï A comprehensive approach for water and sanitation in the developing world. *Technology in Society*, *31*(2), 158ï 167. doi:10.1016/j.techsoc.2009.03.010

Nimoh, F., & Poku, K. (2014). Householdsô Latrine Preference and Financing Mechanisms in Peri-urban Ghana. *Journal of Economics and Sustainable Development*, *5*(16), 63ï 74. Retrieved from http://www.iiste.org/Journals/index.php/JEDS/article/view/15336

Niwagaba, C., Ssemanda, J., Sande, H., & Kamara, I. (2008). Social marketing for sanitation improvement in Kampala, Uganda. In *(Part 1-Oral Presentations) International Water Associations (IWA) Conference of the sanitation Challenge, New Sanitation Concepts and Models of Governance* (pp.

1ï 7). Wageningen. Retrieved from http://www.sswarsuganda.org/phocadownload/niwagaba et al social marketing - presented at conference on sanitation challenge netherlands may 2008.pdf

Paterson, C., Mara, D., & Curtis, T. (2007). Pro-poor sanitation technologies. *Geoforum*, *38*(5), 901ï 907. doi:10.1016/j.geoforum.2006.08.006

Tumwebaze, I. K., Orach, C. G., Nakayaga, J. K., Karamagi, C., Luethi, C., & Niwagaba, C. (2011). Ecological sanitation coverage and factors affecting its uptake in Kabale municipality, western Uganda. *International Journal of Environmental Health Research*, *21*(4), 294ï 305. doi:10.1080/09603123.2010.55003

UN-Habitat. (2005). *Situation Analysis of informal settlements in Kisumu*. Nairobi: UN-HABITAT.

UN-Habitat. (2008). *UN Habitat and the Kenya Slum Upgrading Programme strategy document. ... : United Nations Human Settlements Programme* (p.75). Nairobi: UN-HABITAT.

Factors affecting Functionality and Sustainability of Mechanized Elements of Water Supply Systems in Mbeere South Sub-County, Kenya

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Abstract

This paper focuses on the functionality and sustainability of mechanized elements of water supply systems. Kenya experiences water scarcity in many communities forcing many to walk long distances in search of water, especially during the dry periods. To mitigate against these water shortages, many non-governmental organizations (NGOôs) as well as other development agencies spend huge sums of money in developing water supply systems. Unfortunately, once these agencies funding period come to an end, the water supply systems start experiencing breakdowns and even in some cases total failure. The study evaluated the functionality and sustainability of mechanized elements of water supply systems in Mbeere South Sub-County with a particular focus in Makima and Mwea Divisions. It was undertaken through adoption of a cross sectional retrospective design while using stratified and systematic random sampling technique to obtain study sample. The target population was made up of people living in Makima and Mwea Divisions of Mbeere South Sub-County and the installed mechanized water systems. The functionality of mechanized elements of water supply systems varied across the study area but the study revealed that use of locally developed hand pumps and solar systems was more sustainable. Failure to adhere to the recommended schedule of maintenance, lack of spare parts and lack of enhanced training of artisans and caretakers in operation and maintenance of the water systemsô mechanized elements heavily contributed to non-functionality of the systems. The study recommends that the choice of technology for community water projects should be prioritized considering operation and maintenance cost and enhanced sensitization on the importance of communities in adhering to manufacturerôs recommended scheduled maintenance to boost the water supply systems sustainability.

Keywords: Functionality and sustainability, mechanized elements, water supply systems, choice of technology, community participation, spare-parts, maintenance.

Introduction

Although access to safe drinking water is a basic human right, it is estimated that about 1.1 billion people, or 18 per cent of the worldôs population, lack access to safe drinking water [1-3] and every year in developing countries an estimated 3 million people die prematurely from water-related diseases and the largest proportion of these deaths is infants and young children, followed by women from poor rural families [4] . The Government of Kenya (GoK) Vision 2030 emphasises on the central role that water plays in the performance of key sectors of the economy and the livelihoods of Kenyans under which the economic and social pillars of the Vision, improved access to safe water in both rural and urban areas, had been given prominence [5] to reduce by half the population with no access to safe water by 2015 [3]

Donors have strongly supported the development of rural water supply systems but in significantly a number of cases, the expected returns from the water projects are not fully realized because most of the commissioned water projects eventually become partially or fully inoperative [6 and 7]. The functionality and sustainability of these water supply systems is very low as manifested by many water supply projects which suffer partial or complete collapse soon after the donor help ends. Various factors have been identified as the main causes of this partial or complete failure and they include, lack of knowledge of the health benefits of improved water supplies, un affordable tariffs, lack of sensitivity by donors and the central government to the local customs and beliefs, the inability to operate and maintain water systems by the local population, as well as lack of community participation in the design and management of water resources [2 and 8]

Part of the study aims at bridging the knowledge gap by evaluating the functionality and sustainability of water projects in Makima and Mwea Divisions of Mbeere South Sub-County. To achieve this, one specific objective focused on identifying the factors affecting functionality and sustainability of mechanized elements of community water supply systems. The study used stratified and systematic random sampling technique to obtain the sample for the study and the study targeted mechanized water supply systems, artisans and committee members as the research population units. The sampled mechanized water systems were studied and tested to determine their conditions, capacity of pumping and history of maintenance.

Key study assumptions

The study assumed that all the water projects established in the past 10 years had been properly designed and installed with mechanical elements while taking into consideration the borehole characteristics and water demand. The success of the research depended on the cooperation, and willingness of the target community and accessibility of sampled sites. The study further assumed that: The beneficiary community members kept records of maintenance schedules and would be willing to give correct information on the water supply systems. The NGOs that participated in implementation of water projects in the area of focus within the stipulated duration were in existence and would provide the required information for the research and that the sampled water supply systems were accessible.

Research Design

The research design was a cross sectional retrospective study whereby both primary and secondary data collection methods were used. Tools used included questionnaires, pump performance forms, and writing materials. The questionnaires were administered to the artisan and committee members, pump position and parts observed while records of schedule maintenance, and pump user manual were used as secondary data. The data gathering was focused on mechanized water supply systems and the people involved in maintenance.

Sample Size

The study focused on the sixty (60) mechanized community water supply systems that were spatially located in the study area with a population of 51,408 persons. They included boreholes fitted with hand pumps, submersible pumps generator sets, wind pumps, and solar pumps. 39 mechanized water supply systems were sampled from which 28 artisans and 100 committee members were administered with questionnaires. The 60 mechanized water supply systems were accessible to a total population of 51,408 persons. 50% of the target population is considered adequately representative of a large population and the confidence level was set at 95%. [6] to get a representative sample size of a 50% (25,704) population of the study area, equation 3.1 was used to calculate the desired sample size for a population greater than 10,000 thus n = 384 as demonstrated below;

$$n = \frac{z^2 pq}{d^2} \qquad \text{Equation 3.1}$$

Where:

n= the desired sample size (target population > 10,000)

z = the standard normal deviation at the required confidence level.

p = the proportion in the target population estimated to have the characteristics being considered.

q = 1- p,

d = level of statistical significance set

[7]

Artisans

The estimated population of two (2) artisans for each of the 39 mechanized water supply systems is 78 which is less than 10,000 hence the final sample (nf1) to be administered with questioners was determined using equation 3.2 as demonstrated.

$$n_f = \frac{n}{1 + \frac{n}{N}} \qquad \text{Equation 3.2}$$

Where:

n_f = the desired sample size (when the population is < 10,000) and artisans are represented by nf1

n = the desired sample size (when population is > 10,000)

N = the estimate of the population size

[7]Given n = 384 and N = 78, then by using equation 3.2, and n_{fi} is 65

$$n_{fl} = \frac{384}{1 + \frac{384}{78}}$$

$$\textit{Therefore} \qquad n_{fl} = 65$$

Committee Members

The estimated population of five (5) committee members for each of the 39 mechanized water supply systems is 195 which less than 10,000 hence the final sample (nf2) to be administered with questioners was determined using equation 3.2 as demonstrated.

Given n = 384 and N = 195, then by using equation 3.2:

$$n_{f2} = \frac{384}{1 + \frac{384}{195}}$$

$$n_{f2} = 130$$

Therefore:

$n_f = n_{f1} + n_{f2} = 65 + 130 = 195$

The values of nf1 (artisans sampled) and nf2 (Committee members sampled) were confirmed using a table for determining sample size from a given population.

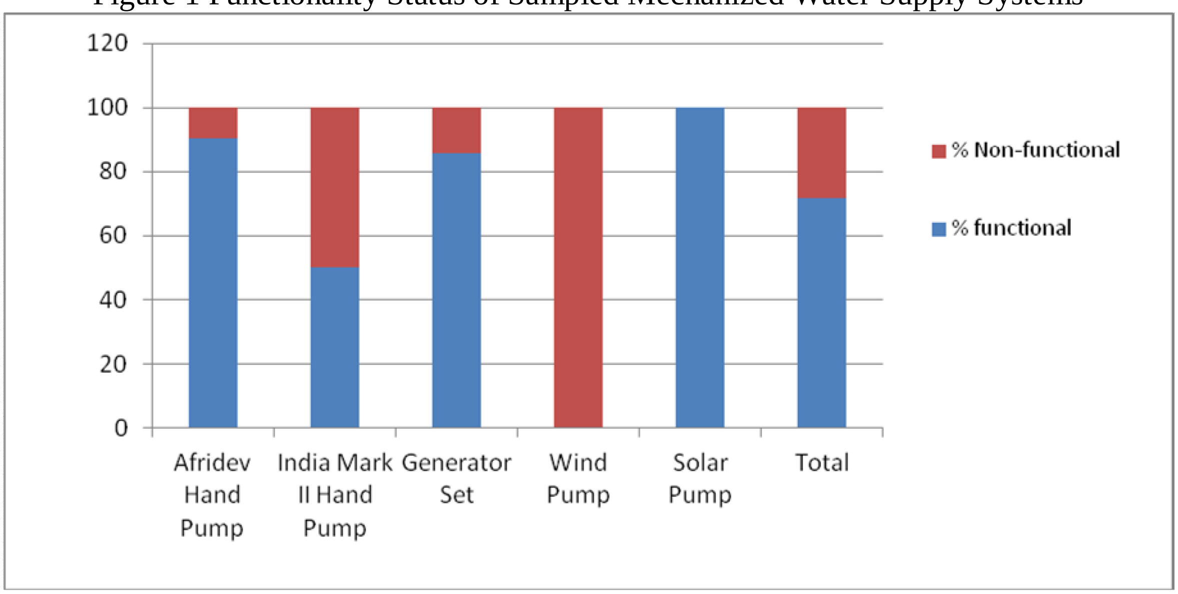
Data Analysis Methods

The questionnaires and pump performance forms were verified, coded and tallied according to the themes after which they were quantitatively and qualitatively analyzed by use of SPSS (Scientific Package for Social Sciences) through the use of tables and charts. Qualitative data refers to the information gathered in a narrative form through interviews, focus discussion groups and observations while the quantitative data refers to statistics generated through administration of questionnaires or use of structured interviews. The responses from the people who verbalized their reactions in open-ended questions in the questionnaires, Focus Discussion Groups, interview schedules, pump performance forms and observations were organized to form the qualitative analysis and answer the research questions of the study. The researcher gave much attention to the recurring responses that formed the themes of the study hence organized into various thematic aspects as outlined in the research objectives and questions.

Results and Discussions

Ideally, 65% (39) of all the mechanized water supply systems in the study area that were sampled were subjected to functionality evaluation criteria and the results are shown on Figure1. Out of all the sampled 39 mechanized water supply systems, 71.8% (28) were functional while 28.2% (11) were non functional.

Figure 1 Functionality Status of Sampled Mechanized Water Supply Systems



As per the manufacturerôs tested life span for the various mechanized elements found in use in the study area, the lowest lifespan was that of Afridev and India mark II hand pumps with each having 15 years and Wind pumps having the longest lifespan of 30 years. By the time of study, the majority of the water projects that represented 70.9% (91) respondents had been in existence for more than 10 years but had the mechanical elements replaced at least once.

Six types of mechanized water supply systems had been in use in the area of study within the last 10 years but the study showed 29.1% (38) of responders indicating that the boreholes had only existed for less than ten years, a duration far below the lowest lifespan of 15 years for a hand pump hence their sustainability not able to match the manufacturerǿs lifespan. For instance the records and minutes availed at Mbondoni Market indicated that the Mbondoni Market borehole had been in existence since the year 2002 but had changed pumps three times thus from India Mark II to Wind Pump then back to India Mark II.

Factors Affecting Functionality and Sustainability

A key cause of the non-functionality for all the six types of mechanized elements installed in the study area was failure to adhere to the manufactureǿs recommended maintenance standards. 40% (40) of respondents indicated that scheduled maintenance was practiced hence it could be concluded that 60% (60) were rarely doing the scheduled maintenance as recommended by the manufacturer of the mechanical element. In addition for India Mark II hand pumps, none of them had bobbins, plunger, rods or bush bearing changed as scheduled while for Wind pumps no respondent indicated as having changed the bearings, or belts as required. Majority of the caretakers admitted to falling short of manufacturersô recommended maintenance schedules

Any pumping technology chosen for installation for a mechanized water supply system require operation and maintenance hence the technology with high costs for repairs and purchase of spare parts is likely to defeat the ability of community management. Depending on the pump choice, repairs can either be frequent at minimal costs, or infrequent at higher costs, whichever is more suitable for the local situation. Moreover basic economics principles inform that if the cost of repair of a pump exceeds the financial capacity of the community benefiting from the pump, the pump may not be repaired [9]. All the wind pumps (costly to maintain) were broken down while solar systems which require minimal maintenance costs were all working and had been in place in the previous 2 years thus as per the study 100% of existing solar pumps were functional while 100% of the existing seven Wind pumps were dysfunctional.

A 100% (128) of respondents reported that the water projects that served them in the study area had broken down at one time or the other. The research also revealed that 91.4% (117) of the respondents had their pumps break down within the first 8 months of installation or after repair. The reported duration of time taken from installation or repair to first breakdown was mainly due to lack of carrying out scheduled maintenance.

The study found that there was a significant relationship between who identified and implemented a water project and the duration it took before breaking down. Those projects where the community was involved in identification and implementation were more likely to take longer before experiencing their first breakdown compared to those where the community was not involved in their identification and implementation. This result suggests that it is important to involve communities in the identification and implementation of projects in order to ensure sustainability of a project in terms of minimizing operation cost by ensuring proper use, repair and maintenance of the machines

Failure to Repair the Broken down Mechanical Elements

Once a project broke down, the time taken to repair it, ranged from less than a day to more than four months. Respondents reporting that projects were repaired within a day or less were, 46.9% (60) in less than a week, 19.5% (25) in less than one month and 11.7% (15) in less than two months. 14.1% (18) reported that projects were repaired after more than four Months.

Factors which contributed to non-functionality of the systems and delay in repair time included lack of spare parts, since most spare parts shops were far off, and lack of systemized spare parts acquisition. There was lack of a systemized way of dealing with the issues of spare parts and contribution sessions to raise money for spare parts were held when they encountered a breakdown. This meant that it was not possible for the water supply systems to be repaired as soon as they broke down since this method of raising money would require time.

Probably a more systemized method of collecting funds to buy spare parts for example by charging a small fee on water would ensure sustainability of water supply systems. Ideally, for a consistent water supply to occur, water committees had to be able to obtain spares the same day a fault occurred in order to facilitate rapid and effective repair of their water system [1]. Other factors affecting functionality included lack of adequate skills to carry out the required pump as caretakers and artisans were only trained on basic skills on operation and maintenance of the mechanized elements and lack of incentives to motivate the organizational management structure. This was mainly caused by lack or minimal payment for water hence artisans not motivated to repair hand pumps and other systems for free.

Conclusions and Recommendations

The poor performances of the water supply systems in the study area was caused by the lack of community participation in the identification and implementation of the projects and lack of adherence to manufacturersô recommended maintenance schedules. This approach of project execution led to the community not owning the projects and hence poor management of the mechanized water systems. The choice of technology to pump water and capacity to manage it plays a key role to either the non-functionality or functionality and sustainability of the installed system. Use of African Developed (Afridev) hand pumps and solar powered projects were functional and hence they are more. Lack of artisans and caretakers enhanced training in operation and maintenance of the mechanized elements was found to contribute to elements failure. The functionality and sustainability is also affected by the lack of a systemized way of dealing with spare parts and human resources needed for water supply systems maintenance which led to frequent breakdowns and prolonged delaying of water systems repair.

Recommendations

Community participation needs to be enhanced in all aspects of the water supply systems development including identification, implementation and maintenance to increase their efficiency. Choice of technology for community water projects should be prioritized considering operation and maintenance costs. The development agencies and community should prioritize installation of pumps which require minimal operation and maintenance costs. The study also recommends educating communities on the need to systemize spare parts acquisition and human resources required for water systemsô maintenance to boost the water supply systems sustainability. The study recommends further study to establish what needs to be changed to improve functionality and sustainability of Wind pumps and the effective ways of strengthening the institutional capacity of the government of Kenya department of Water and Irrigation to enable it to effectively manage rural water supply in Kenya.

References

[1] DFID, U.K. *Water Action Plan*. London: Department for International Development. (2004).

[2] Engel, S., Iskandarani, M., and Useche, M. ó*Improved Water Supply in the Ghanian Volta Basin' Who Uses it and Who Participates in Community Decision-Making*. Washington: International Food Policy Research Institute. (2005).
[3] UN-Water Session *Gender, Water and Sanitation: A Policy Brief*. New York: UN Water Session (2006).
[4] UNESCO. *The United Nations World Water Development Report 3: Water in a Changing World*. Paris: UNESCO and Earthscan. (2009).
http://webworld.unesco.org/water/wwap/wwdr/wwdr3/pdf/WWDR3_Water_in_a_Changing_World.pdf
[5] ADB. *Small Towns and Rural Water Supply and Sanitation Project*. Abidjan: African Development Bank. (2009).
[6]Mzee, A. *The Role of Operation and Maintenance in Community Rural Water Supply Training.* Paper presented at the Rural Water Supply in Developing Countries Workshop, (1980).
[7]Whittingtona, D., Davisc, J., Prokopyd, L., Kristin Komivese, Thorstenf, R., Lukacsc, H., How well is the Demand-driven, Community Management Model for Rural Water Supply Systems Doing? Evidence from Bolivia, Peru and Ghana. *Water Policy 11*, 696-718. (2009).
[8] Garn, H. A. *Lessons from Large-Scale Rural Water and Sanitation Projects: Transition and Innovation*. Washington: UNDP-World Bank. (1997).
[9] MWR. Sessional Paper No. 1 of 1999 on National Policy on Water Resources. (1999).

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The Utility of Using Technology in Water Treatment Process

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Abstract

Automaton control is an essential tool to produce drinking water of necessary quantities on right time with high levels of efficiency in water production, energy and chemical materials consumption. The primary objective of this paper is to propose strategies for controlling the sucking pumps operation system to supply Bait-Elmal area in Khartoum State. The proposed system works as follows: Pumps are placed on floating lunch joined to Shambat Bridge. Then, the operation system of these pumps is controlled by Programmable Logic Controllers (PLCs) to suck water from the Blue Nile stream. Reservoir water level is controlled by programming the working and standby pumps using level sensors installed inside the water reservoir. Practically, a control system has been applied to control the pumps operation system. The water level in the reservoir is monitored and controlled by using two (high & low) level sensors connected to the sucking water pumps via PLCs. In summary, a complete control system has been successfully tested, where the sucking pumps are installed to supply Bait-Elmal water plant from the Blue Nile. The results obtained prove the reliability and applicability of the system with more advantages in this area or any similar drinking water plant.

Keywords: Control, Water treatment, Pump, PLCs, Sensors.

Introduction

Due to the increasing population and the demand of adequate hygiene drinkable water (Abdelmagid, 1986), it is necessary to apply automation control system in the water treatment processes to attain a desired system response (DORF, 2011). This paper models Bait-Elmal, a highly populated area in Khartoum State as supply station that depends on the White Nile water as the main water source (Ali, 2007). Basically, there are problems in the White Nile water. Water level instability together with the impurity content (e.g. the minimum turbidity in White Nile 55 NTU *, while in Blue Nile only 2 NTU) causes the use of excess purification materials that leads to higher production cost. Besides, this water type needs more time in sedimentation basin which affects the overall production (KSWC Central Lab., 2006).

To solve these problems, a control system using a PLCs to operates water sucking pumps form Blue Nile has been suggested to manage the production process and raise its efficiency to the best possible level without using excess chemical materials. Therefore, it is important that automated systems must work efficiently to get the maximum profit out of the production process. It will also ensure the safety of operating the plant and to prevent possible fatal accidents or even catastrophic disasters that might affect the environment (Gil, 2004). Potential unwanted incidents at the plant can be reduced by a safety automation system, as it can remarkably reduce the overall cost and possible human errors, too (Mandal, 2013). Thus, high reliability on automation system is mandatory for economic and safety reasons (Mikkor, 2004).

Proposed Modifications for Water Treatment Process

This section explains the existing operation system as well as suggests new techniques to promote operation performance, production efficiency and cost reduction. The new control techniques mainly focus on pumps operation and reservoir water level.

Sucking Pumps Operation

Operation of these pumps as shown in Fig.(1) is based on Delta/Star control circuit (starter) located at the bank, beside the pumps. The start/stop process is applied manually by pressing start/stop pushbuttons. These pumps generally operate at the voltage 415 V- 3 phases.

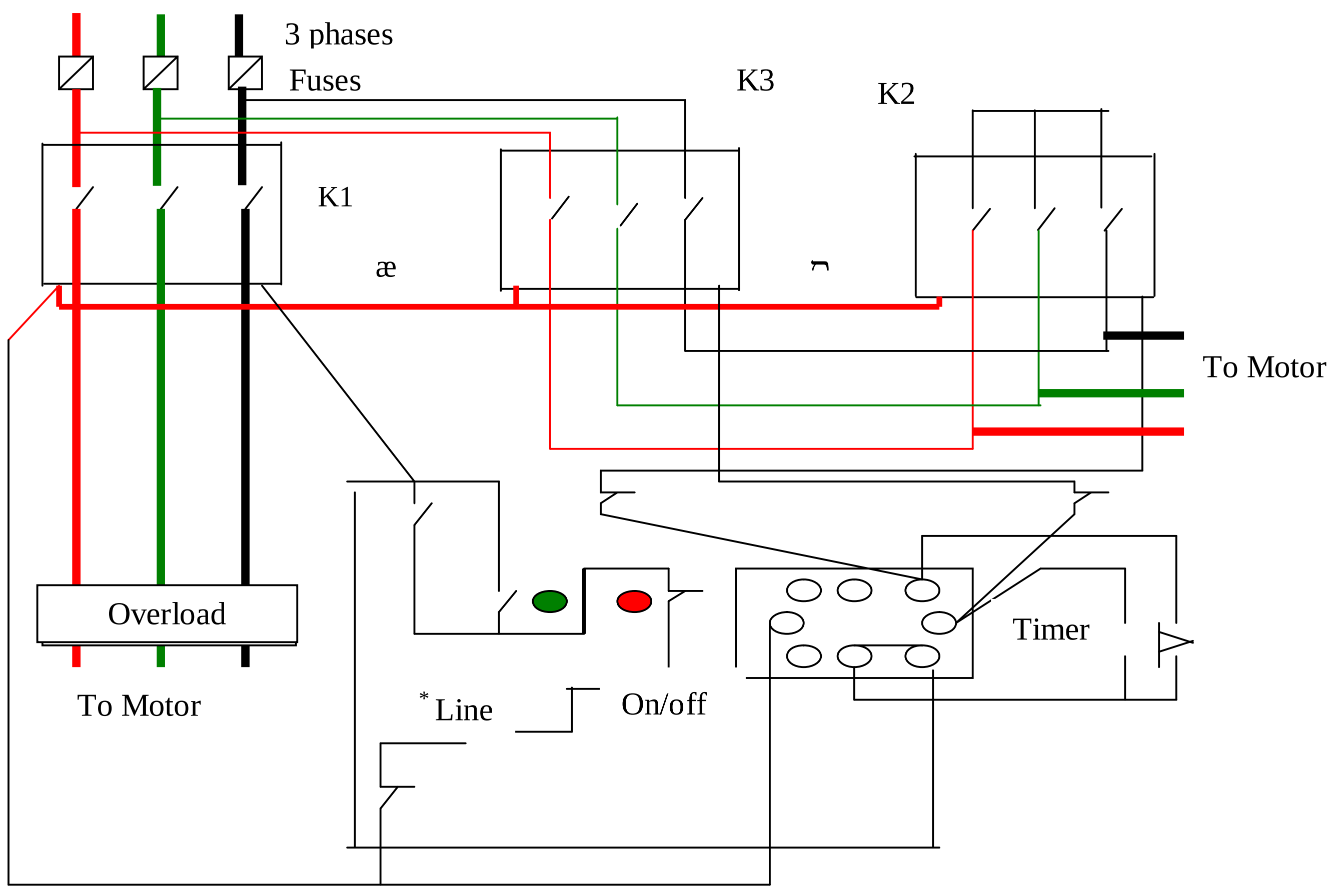


Fig. 1: Control circuit of the pump operation

*NTU = the standard turbidity measurement unit. * Line = PLCs to control the system connects via this Line.

The starting circuit consists of three contactors (K1, K2 and K3) with a timer control to mange the starting conditions of the pumps. K1 controls the main supply to the pump and protects the pump from overload and short circuit conditions. K2 works to initialize the pump operation at Start (Y) condition for a short time adjusted by a timer control system. Finally, K3 operates simultaneously when (K2) releases (by means of interlock) to inject full supply voltage to operate the pump at Delta (φ) condition (Ali, 2007).

Suggested Control for sucking pumps operation system

This paper aims to locate the water sucking pumps on floating lunch to suck water from Blue Nile stream. The water sucking pumps operation can be controlled by a computer and PLCs system, i.e. by replacing the manual control system (Jack, 2007). Water from all pumps is collected in the main pipe (collector) and then the water passes through Shambat Bridge to supply the plant at other bank.

Suggestions Control for Reservoir Water Level

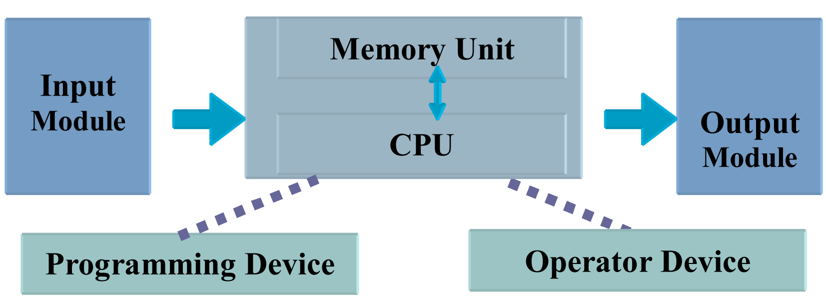
One important thing in water treatment process is how to maintain reservoir water level which changes according to the quantity of water consumption in the city and the quantity of filtered water during day hours (Ali, 2007). To maintain reservoir water level, the number of raw water operating pumps will be increased in case of level drop and be stopped in case of overflow; otherwise it will be constant. This process is executed by taking discrete readings from reservoir sensors and then a program can control the level.

PLCs System

PLCs is a special form of microprocessor-based controller that uses programmable memory to store instructions and implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes (Bryan, 2009). PLCs have been gaining popularity in industry because of the advantages they offer (Bolton, 2006): cost-effective for controlling complex systems, flexible and can be reapplied to control other systems quickly and easily, computational abilities allow more sophisticated control, holds troubleshooting aids that make programming easier and reduce time possesses reliable components which make these likely to operate for years without fail.

PLCs hardware

The most essential components are (Bolton, 2009): power supply, Central Processing Unit (CPU), and Input/Output (I/O) modules. Fig.(2) illustrates the major components.



Input module should be connected to a group of physical elements such as electric switches, sensors, thermometer, liquid level detectors and other sensors (IE 447 CIM, 2014). Input module receives analogue signals from these elements, transfers them to logic signal and finally forwards it to CPU for controlling the overall operation of the system (Tahvonen, 2006). Central Processing Unit (CPU) is a decision making center of PLCs. It receives and processes logic signal sent by input module, decides relevant action according to stored instruction, and issues control instructions to output module. The output module receives instructions from CPU and transfers it to either logic or analogue signals used to control a group of actuator devices (Bolton, 2006). A typical operator unit can help an operator to display information for various controllable processes and to enter or modify parameters. A programming device is a special device for writing and transferring programs to the PLC, e.g. a computer can be used for this purpose (Bradley, 2011).

PLC operation

Initially, when the PLC is turned on, it will check its own hardware and software for faults. If there is no problem, it will copy all the input data into the memory which is called ôInput Scanö. Using the input, the ladder logic program (LLP) is executed which is called logic scan (Lab-Volt Ltd, 2011). The outputs will be updated using the temporary data in the memory. This is called output scan. This process is typically repeated 10 to 100 times per second (Parr, 2003) as shown in Fig.(3).

Fig. 3: Scanning steps

Controlling System Development

Controlling of the Motor

Fig.(4) explains a motor starter (M) which is wired in series with a normally open (NO) momentary pushbutton (Start), a normally closed (NC) momentary pushbutton (Stop), and the normally closed (NC) overload relay (OL) (Jack, 2007). The NO start pushbutton is connected to the input 10.0 while the NC stop pushbutton is connected to input 10.1. The NC OL contact as part of motor starter is connected to input 10.2. The input (10.0 - 10.1 - 10.2) forms an AND circuit and controls the operation of output (Q0.0). The logic state of input bit 10.1 is logic 1 because of the (NC) stop pushbutton. The logic state of input bit 10.2 is logic 1 also because protective OL is NC. By A program a NO-contact Q0.0 is added to ladder logic which is in direct relation with output (Q0.0) and forms an OR circuit with input (10.0). Motor starter is connected to output Q0.0 at output module (Lab-Volt Ltd, 2011). When press the pushbutton, unit CPU receives logic 1 signal from input 10.0 at input module. This causes contact 10.0 at ladder logic to close. In this case, all contacts are on ladder logic 1 state, so the logic condition of output Q0.0 on the ladder logic is logic1.

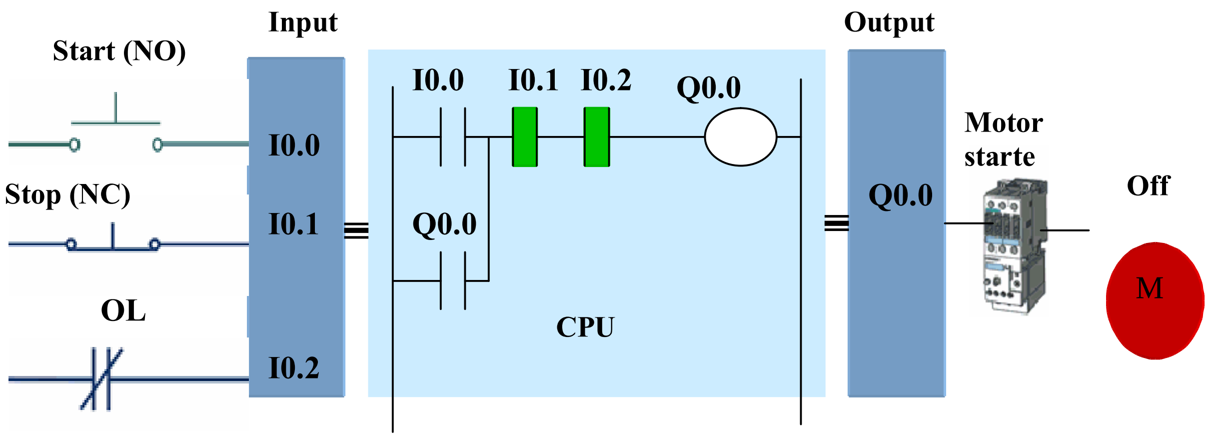


Fig. 4: Ladder diagram for motor start/stop

Controlling of the Reservoir Water Level

The reservoir contains purification water. This water is pumped to the city and the reservoir water level changes. To get level established, the reservoir is controlled by using two sensors connected to the sucking water pumps through PLCs system as shown in the Fig.(5)

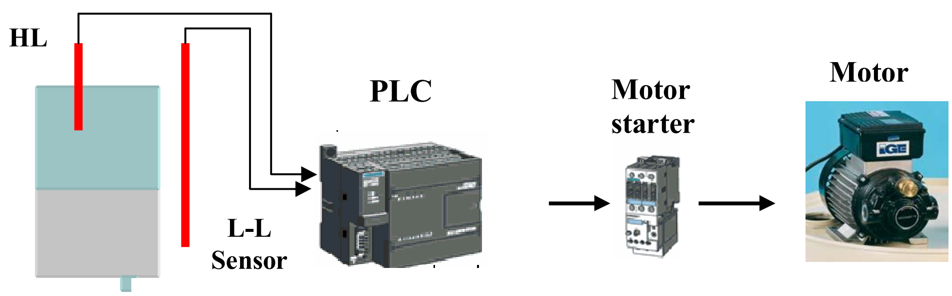


Fig. 5: Sensors connected to the raw water pump through a PLC

It is important to define the raw water sucking pumps which work throughout the day and the other ones which are programmed to operate as auxiliary pumps when the reservoir water level is low. The auxiliary pumps are required to operate (ON state) till the water level reaches the low level sensor; after that it stops. When the water level in the reservoir goes down the low level sensor, the auxiliary pump is required to operate again. For this reason, we need two inputs (sensors) and one output (pump). Usually, both the input level sensors are ‚normally closed level sensorsâ. When a sensor is not immersed in water, it will be at operation state and if the sensor is immersed in water, it will be at non operation position. A complete control cycle can be explained as follows:

(i) First scan process:

When the reservoir is empty, both sensors are at operation state (ON), as illustrated in Fig.(6), so the logic states of inputs (10.0&10.1) are logic 1 and due to this the state of output Q0.0 is true.

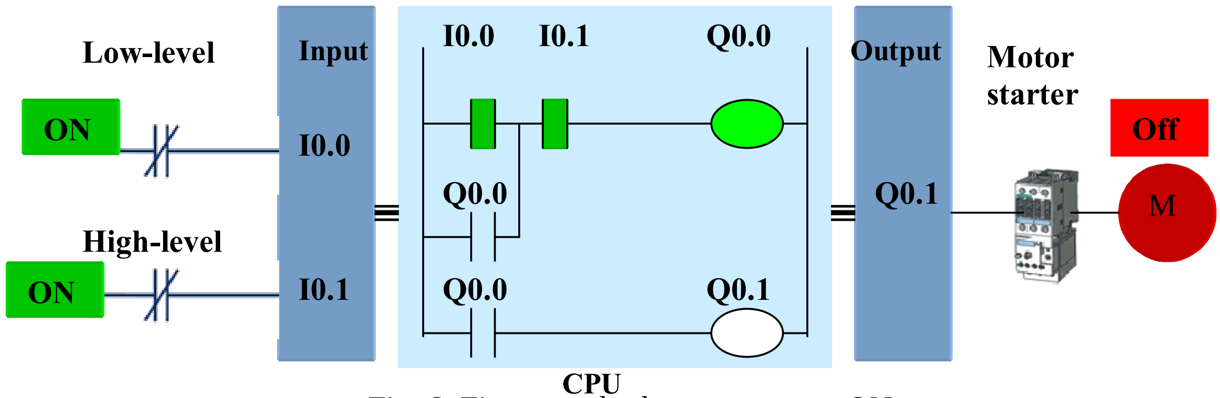


Fig. 6: First scan; both sensors are at ON state

(ii) Second scan process:

Input Q0.0 is activated at both ladder logic stages which lead to activate output Q0.1, so the pump starts operation to fill the reservoir. The scan process is repeated many times and the state of the inputs remains constant at the same state till the water immerses the low level sensor. At this point, low level sensor changes to OFF position and input 10.0 state changes to false condition without affecting the pump operation because the logic state of the route between the two vertical lines of the ladder logic is still true. This scan process is repeated many times and the pump continues filling the reservoir till the water immerses the higher level sensor, where high level sensor changes to OFF and then the logic state of input 10.1 becomes false. Consequently, there is no true state route between the two sides of ladder logic, so the logic state of output Q0.1 becomes false and the pump stops.

Results and Discussion

This section describes real implementation of the proposed control system. Initially, the main control circuit has been setup, where the PLCs (Schneider Electronic, 2014) have been interconnected with inputs (level sensors and pushbutton switches) and outputs (motor starter and lamp indicators). In this work ladder logic program has been written with Zeliosoft-v2 software, including all the steps for controlling the pumps operation as described in the previous section. The ladder logic program has been transferred to the PLCs via computer interface. Thus, different steps of water treatment process have been successfully tested under various settings and conditions.

Motor Operation Control Test

Fig.(7) demonstrates experimental tests of the controlling program for operating and stopping the pump. A (NO) Start pushbutton is wired to the first input (I1), a (NC) Stop pushbutton is wired to the second input (I2) and (NC) OL relay contacts (part of the motor starter) are connected to the third input (I3). First input (I1), second input (I2) and third input (I3) form an AND circuit and they are used to control NO programming function contacts on Network 1. I1 status bit is a logic 1 because the (NC) Stop Pushbutton is closed. I1 status bit is a logic 1 because the (NC) OL relay contacts are closed. Output Q1 is also programmed on Network 1. In addition, a NO set of contacts associated with Q1 is programmed on Network 1 to form OR circuit. A motor starter is connected to output Q1. When the Start pushbutton is pressed, the CPU receives a logic 1 from input I1which causes the I1 contact to close. All three inputs are now logic 1. The CPU sends a logic 1 to output Q1. The starter is energized and the motor starts.

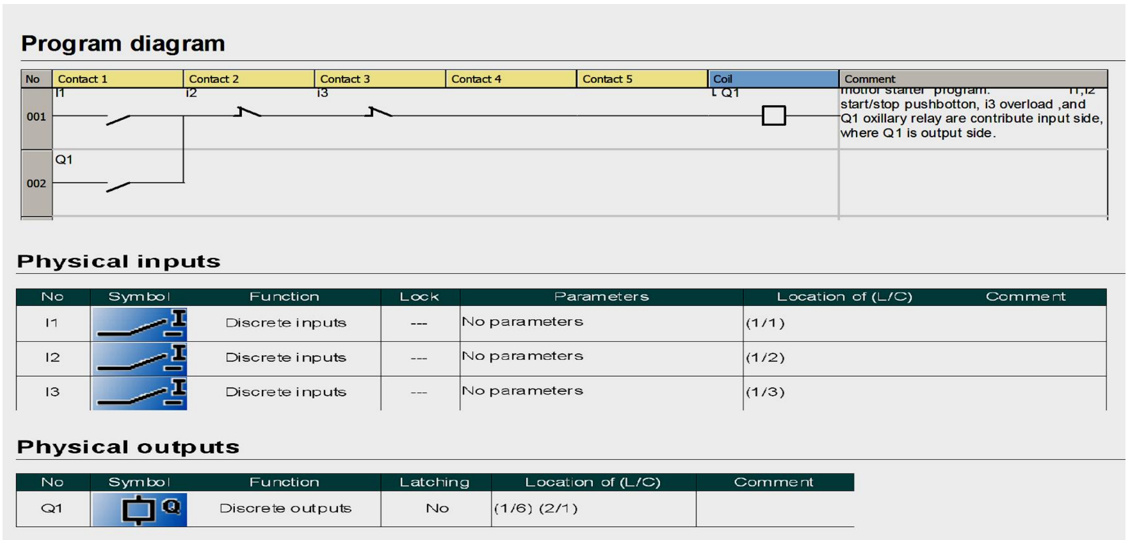
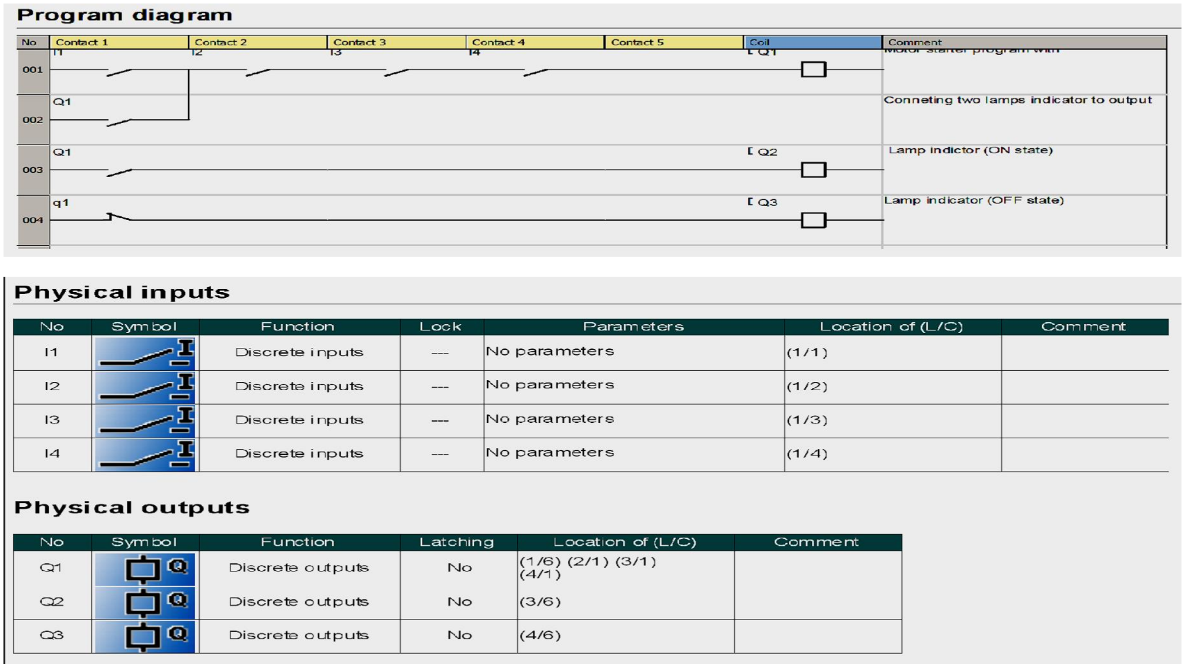


Fig. 7: Motor operation control

Fig.(8) includes indicator lights for RUN and STOP conditions. In this test, a RUN indicator light is connected to output Q2 and a STOP indicator light is connected to output Q3. It can be seen from the ladder logic that a (NO) output Q1 is connected on Network 2 to output Q2 and a (NC) Q1 contact is connected to output Q3 on Network 3. In a stopped condition, output Q1 is off. The (NO) Q1 contact on Network 2 is opened and the RUN indicator, connected to output Q2 light is OFF. The (NC) Q2 on Network 3 lights are closed and the STOP indicator light, connected to output Q3 is ON. When the PLC starts the motor, output Q1 is now a logic high (ON). The (NO) Q1 contacts on Network 2 now switch to a logic 1 (closed) and output Q2 turns the RUN indicator ON. The (NC) Q1 contacts on Network 3 switch to a logic 0 (open) and the STOP indicator light connected to output Q3 is now OFF.



No	Symbol	Function	Lock	Parameters	Location of (L/C)	Comment
I1		Discrete inputs	---	No parameters	(1/1)	
I2		Discrete inputs	---	No parameters	(1/2)	
I3		Discrete inputs	---	No parameters	(1/3)	
I4		Discrete inputs	---	No parameters	(1/4)	

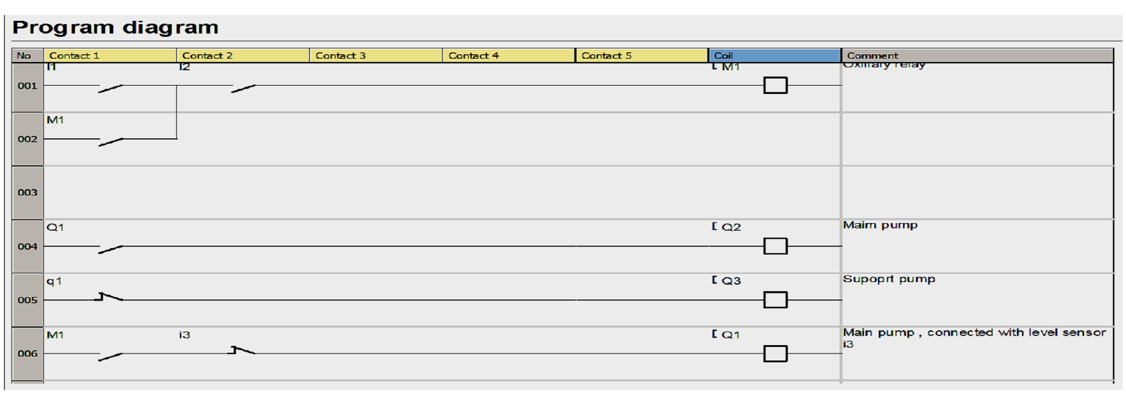
No	Symbol	Function	Latching	Location of (L/C)	Comment
Q1		Discrete outputs	No	(1/6) (2/1) (3/1) (4/1)	
Q2		Discrete outputs	No	(3/6)	
Q3		Discrete outputs	No	(4/6)	

Fig. 8: Motor operation control with two lamps indicator

Reservoir Water Level Control Test

This test has managed the connection of the raw water pumps to reservoir water level sensors through a PLCs unit that has monitored and controlled the water level in the reservoir.

In this test, the two level sensors (L-L and H-L) have been connected to the PLC as shown in Fig.(5). The results can be explained as follows: at step 1 neither of the sensors is immersed in water (indicates that the reservoir is empty), hence both support and main pumps are operated. At step 2 when the L-L is immersed in the water (i.e. water in the reservoir gets above the low level line), the support pump is stopped while the main pump is still operating. At step 3, when the two sensors are immersed in water (i.e. water in the reservoir gets above the high level line) both support and main pumps are stopped. At step 4, when only L-L is still immersing in the water (i.e. water level in the reservoir is in the middle of low level and high level) both support and main pumps are still stopped. Step 5 repeats step 1 (i.e. water level in the reservoir goes below the low level line). The above steps been repeated more than five times and they have given the same results. In addition to the stability of the system, it has been observed that the system is highly responsive.



Physical inputs

No	Symbol	Function	Lock	Parameters	Location of (L/C)	Comment
I1	I	Discrete inputs	---	No parameters	(1/1)	
I2	I	Discrete inputs	---	No parameters	(1/2)	
I3	I	Discrete inputs	---	No parameters	(6/2)	

Physical outputs

No	Symbol	Function	Latching	Location of (L/C)	Comment
Q1	Q	Discrete outputs	No	(4/1) (5/1) (6/6)	
Q2	Q	Discrete outputs	No	(4/6)	
Q3	Q	Discrete outputs	No	(5/6)	

Configurable functions

No	Symbol	Function	Lock	Latching	Parameters	Location of (L/C)	Comment
M1	M	Auxiliary relays	---	No	No parameters	(1/6) (2/1) (6/1)	

Fig. 9: Reservoir water level control

Conclusion

This paper addresses the problem of level instability together with impurity content of the White Nile water as a main supply of the plant. As an alternative solution, the suggestion is a pumps controlled system that has been fully developed on a PLCs system and Sensors. As a conclusion the proposed control system has been successfully tested, where the sucking pumps are installed to supply Bait-Elmal plant with a sufficient quality and quantity of Blue Nile water. So this paper is appropriate to fulfill those requirements of the drinking water process. The results obtained prove the reliability and applicability of the system with more advantages at Bait-Elmal as a typical drinking water plant.

References

Abdelmagid, E. M. (1986). *Water treatment & Health Engineering*, College of Civil Engineering University of Khartoum. Arabic version.

Ali, M. O. (2007), *Design and Implementation of an Automation Control System for Drinkable Water Plant*, Unpublished M.Sc. Dissertation, Faculty of Engineering and Technology, University of Gezira, Sudan.

Bolton,W. (2006), *Programmable logic controllers*, Newness, 4th edition.P:14-15.

Bolton,W. (2009), *Programmable logic controllers*, British library, 5th edition.P:9-10.

Bradley, A. (2011), *Basic PLC Programming*, Rockwell Automation, 2011.

Bryan L. A. and Bryan E. A. (1997), *Programmable Controllers*, Industrial Text Company, 2nd edition. p 17.

DORF, R. C. and Bishop, R. C. (2011), *Modern Control Systems*, Pearson International Edition. 11th edition. p 22.

Gil A. E. and Passino K. M. (2004), *Literature Review of Feedback Control for Drinking Water Purification*, Dept. of Electrical and Computer Engineering, The Ohio State University. Access in June 3014.

Jack, H. (2008), *Automating Manufacturing Systems With PLC*, Hugh Jack, Version 5.1.p 25, 121-128.

Khartoum State Water Corporation Central Lab., (2006) Periodic Reports. Sudan.

Lab-Volt Ltd, Staff, (2011), *Programable Logic Controller*, Canada. P: 25-36.

Mandal, R. and et al, (2013), õApplication of Programmable Logic Controller for Gases Monitoring in Underground Coal Minesö, ESTIJ, ISSN: 2250-3498, Vol.3
Mikkor, A. and Roosimölder, L.(2004), õProgramable Logic Controller in Process Automationö, in 4th International DAAAM Conference. Tallinn, Estonia. Access on June 2014.
Netto, R. and Aditya, B. (2013), õProgrammable Logic Controllersö, International Journal of Computer Applications (0975 ó 8887) Volume 77 ó No.11.
Parr, E.A. (2003), õProgrammable Controllersö, 3rd edition, Newness. P 36-37.
Tahvonen, T. (2006), õMethods and Tools for Simulation Assisted Process Automation Testingö HELSINKI, Univ. of Technology, Dept of Engineering, M.Sc Thesis.

Websites

IE 447 CIM Lecture Notes ó Chapter9 ó PLC ó 122. Accessed on august 2014
http://en.wikipedia.org/wiki/Control_unit. Accessed on sept. 2014.
http://processcontrol.analog.com/en/programmable-logic-controllers/segment/pcia.html.

SIEMENS - Basic of PLC- LEARN PLC WWW.PLCS.NET WWW.TKNE.NET. 2014
Schneider-Electronic, http://www.schneider-electric.com/products/ww/en/3900-pac-plc-other-controllers/
Acessed on May 2014.

Impact of rainfall variability on groundwater levels in Ruiru municipality, Kenya

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Abstract

Groundwater accounts for the largest fresh water resources in the world. However, there has been limited exploitation of this vital resource in many areas. In areas where groundwater resources have been exploited, there has been over-exploitation, pollution, wastage and mismanagement. About a third of Kenyaǒs population has no access to portable water. In Ruiru municipality, groundwater from boreholes is a major source of water supply contributing about 70% of the water demand. Rising population and industrial development has led to high water demand and increased water scarcity in the area. There is need to improve existing historic groundwater level data by investigating changes in seasonality of groundwater levels in order to evaluate its potential to meet increasing demand and sustainability as a source of fresh water. This was by assessing effect of rainfall variability on groundwater levels of boreholes in Ruiru. The study focussed on the Ruiru municipality where water demand and concentration of boreholes is high. Information on groundwater usage was collected using a structured questionnaire while current groundwater levels were measured using a dipper. Spatial location of the boreholes was established using GPS and mapped appropriately. Rainfall data was collected from Kenya Meteorological Department and the Water Resources Management Authority. The data was modeled using the linear regression model to show the relationship between rainfall and groundwater levels and analyzed using graphs. The study showed a weak correlation with a correlation coefficient of -0.4032 between rainfall amount and groundwater levels. The correlation was due to the fact that rainfall is not the only determinant for groundwater levels. Other factors such as land cover and rock formation determines infiltration. There was rainfall variability across seasons of the year which can be explained as the impact of climate change in the area that lead to extreme weather conditions such as prolonged droughts and floods. The results indicated a decline in groundwater levels during low rainfall since groundwater recharge depends mainly on rainfall. Moreover during dry season there was over exploitation of the ground water as other sources supplied less water. On the other hand there was rise in groundwater levels as rainfall amounts increased. A linear regression model was developed which can be used to predict future groundwater levels. It was concluded that groundwater exploitation should be controlled to avoid overdependence on groundwater resources and more trees to be planted to cap the increasing emissions from industrialization that lead to climate change.

Keywords: Rainfall variability, Groundwater levels, Ruiru Municipality, GPS

Introduction

Groundwater forms a larger portion of fresh water in the world. In the semi-arid regions of Asia and the Middle East, which include some of the major breadbaskets of the world, the ground water table is falling at an alarming rate. There is an urgent need to focus the attention of both professionals and policy makers on the problems of ground water depletion, which must be seen as the major threat to food security in the coming century. (Seckler, 2010). Water use has been growing at more than twice the rate of population increase in the last century and an increasing number of regions are chronically short of water. There are about 40 million people living in Kenya, of which about 17 million do not have access to clean water. For decades, water scarcity has been a major issue in Kenya, caused mainly by years of recurrent droughts, poor management of water supply, contamination of the available water, and a sharp increase in water demand resulting from relatively high population growth. The lack of sufficient rainfall affects the ability to acquire food and has led to eruptions of violence in Kenya. (Marshall, 2011).

In many areas of Kenya, shortage of water has been amplified by the governmentôs lack of investment in water, especially in rural areas. Most of the urban poor in Kenya only have access to polluted water, which has caused cholera epidemics and multiple other diseases that affect health and livelihoods. Despite the critical shortage of clean water in Kenyaôs urban slums, there is also a large rural to urban discrepancy in access to clean water in Kenya. (Marshall, 2011). Slightly less than half of the rural population has access to water, as opposed to the urban population where 85 percent have access to safe water including a smaller portion of the urban poor in slums. Due to continued population growth, it has been estimated that by the year 2025, Kenyaôs per capita water availability will be 235 cubic meters per year, about two thirds less than the current 650 cubic meters. (World Bank, 2010).

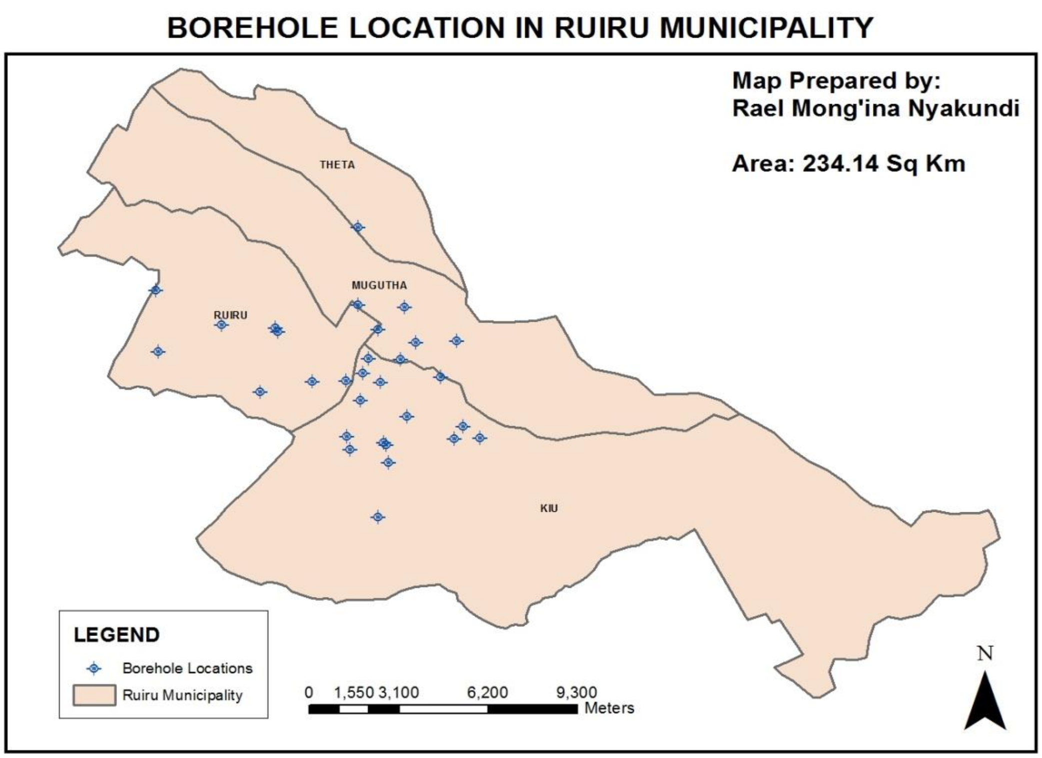

Fig 1: A map of boreholes studied

Groundwater plays major roles in Kenya today, as it contributes to water used in irrigation farming, domestic and industrial use hence helping in offsetting the supply deficit.There is increase in demand of the available water resources especially the groundwater resources which is the major source of water in Ruiru municipality. It is therefore necessary to study the impact of rainfall variability on groundwater resources in the municipality.

Table 1: Water Sources

Water source	**Production capacity m^3/day**	**Actual yield in m^3/day**	**Area of coverage**
Ruiru water supply	7000	700	25%
Boreholes(RUJWASCO)	360	240	10%
NWSC	400	100-150	5%
Community water projects (boreholes)	19890	2000	20%
Total ground water contribution to municipal water supply			**70.98%**

Source: RUJWASCO (2008)

Methodology

Secondary data of rainfall and groundwater levels of the monitoring borehole was obtained from Water Resources Management Authority (WRMA) and Meteorological department of Kenya office. The rainfall data and the groundwater levels were modeled using the linear regression model to show the relationship between groundwater levels and rainfall. The water level fluctuation was analyzed from the month of February to December. The groundwater data and the rainfall data assorted on monthly basis was analyzed and interpreted graphically to understand the dynamics of the groundwater level and rainfall. The data graphically analyzed data based on climate-change scenarios, enables changes in future annual groundwater-level minima to be modeled.

Presentation of Results

Table2: Groundwater Levels for Murera a monitoring borehole

2013				**2012**		
DATE	**WATER REST LEVEL (WRL) (m)**	**REDUCED WATER LEVEL (RWL) (m)**		**DATE**	**WATER REST LEVEL (WRL) (m)**	**REDUCED WATER LEVEL (RWL) (m)**
30/01/2013	26.6	0.4				
28/02/2013	27.32	-0.74		29/02/2012	27.4	
28/03/2013	27.34	-0.2		30/03/2012	27.4	0
30/04/2013	27	0.34		27/04/2012	27.3	0.1
29/05/2013	27.1	-0.1		31/05/2012	28	-0.7
02/06/2013	27.18	-0.08		29/06/2012	28.2	-0.2
24/07/2013	27.3	-0.12		31/07/2012	37.2	-9

22/08/2013	27.35	-0.05		31/08/2012	32.4	4.8
23/09/2013	27.4	-0.05		28/09/2012	37.3	-4.9
08/10/2013	27.5	-0.1		26/10/2012	36.6	0.7
03/12/2013	27.6	-0.1		30/11/2012	27.3	9.3
				31/12/2012	27	0.3

Table 3: Rainfall Data for Ruiru Municipality from 2009 to 2013

	2009	2010	2011	2012	2013
MONTHS	**RAINFALL (mm)**	**RAINFALL (mm)**	**RAINFALL (mm)**	**RAINFALL (mm)**	**RAINFALL (mm)**
JAN	50.4	147.3	5.4	0	36.3
FEB	69.9	135.3	54.7	20.7	0
MAR	38.2	244.4	94.7	0	265.1
APR	92.5	170.3	52.7	389	284.4
MAY	97.1	339.3	146.9	261.8	26.3
JUNE	92.3	27.5	33.3	27.8	24.5
JULY	5.6	7.2	5.4	32.4	0.5
AUG	3.5	16.4	23.9	51.8	37.4
SEP	3.7	0	83.6	41.4	49.9
OCT	168.1	61.5	187	114.6	8.2
NOV	100.9	153.7	267.1	159.4	90.1
DEC	113.9	66.2	124.6	303.7	115.6
TOTAL	766.1	1359.1	1079.3	1402.6	938.3

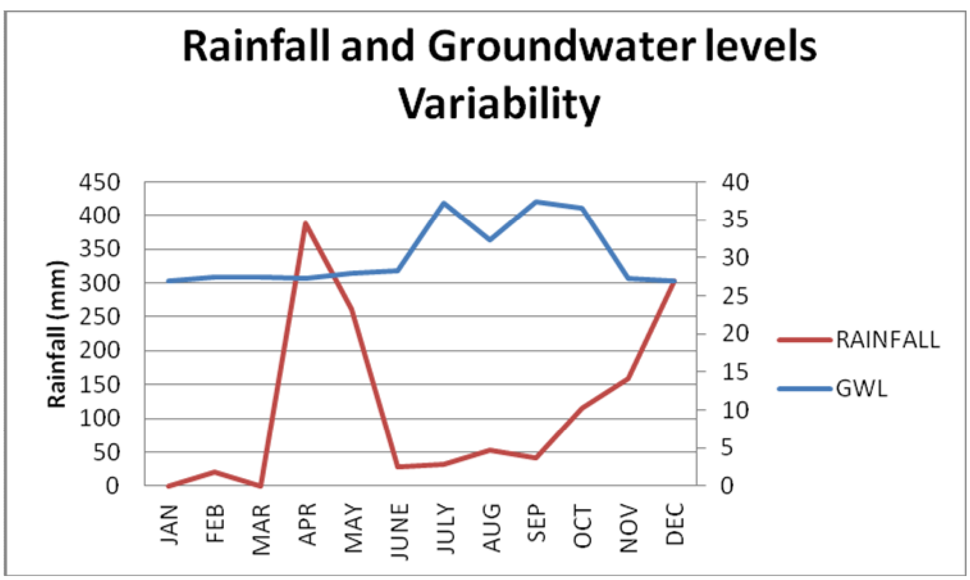

Fig 2: Rainfall and groundwater levels variability

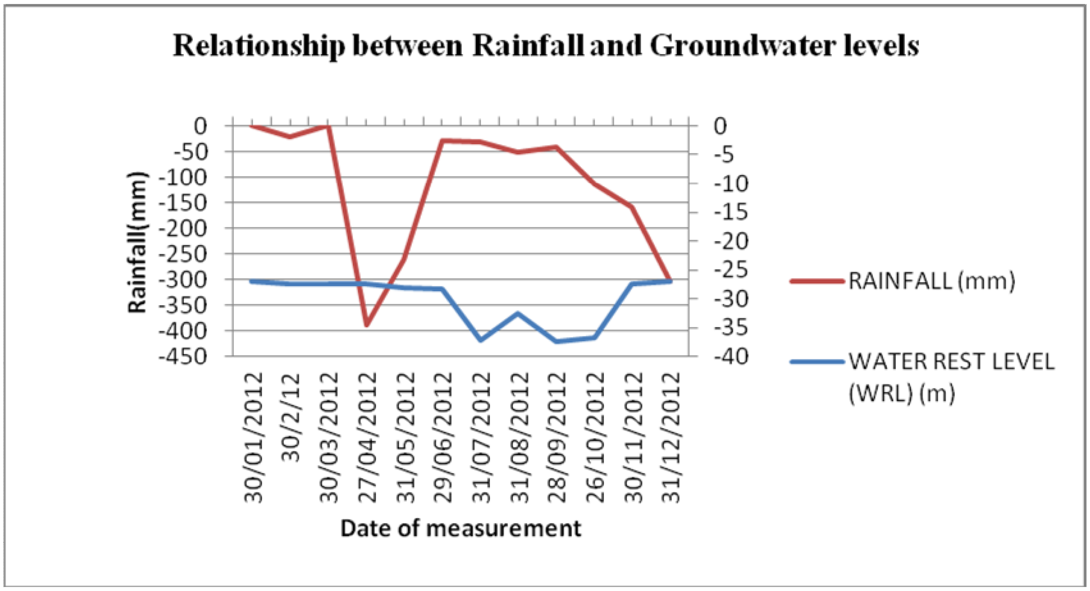

Fig 3: Scatter diagram of Groundwater Levels and Rainfall for the year 2012

Results Analysis and Discussions

There was rainfall variability across seasons of the year which can be explained as the impact of climate change in the area that lead to extreme weather conditions such as prolonged droughts and floods. The results indicated a decline in groundwater levels during low rainfall since groundwater recharge depends mainly on rainfall. Moreover during dry season there was over exploitation of the ground water as other sources supplied less water. On the other hand there was rise in groundwater levels due to infiltration as rainfall amounts increased.

The study showed that rainfall and groundwater levels were negatively correlated because water rest level was measured from the ground surface. This means that the distance from the ground surface to the surface of water in the borehole was the read figure. Thus as the groundwater level decreased the water rest level increased, hence explaining the negative correlation. The results showed that rainfall was not the only factor influencing groundwater levels. But rainfall did play a role to a certain extent. Other factors which might have influenced the groundwater levels include the land cover. Ruiru municipality is dominated by pavements as compared to vegetation. This lead to high runoff during the rain periods thus infiltration is low. Infiltration rate in the area could also be low because of the geologic formation, thus it took a lot of time for the rainfall to be reflected on the groundwater levels. Abstraction of water from the borehole also influenced the groundwater levels as it is a major source to compliment other water supply sources in the municipality.

Conclusion

There was an impact of rainfall variability on groundwater levels. The rainfall variability caused by climate change, brought about extreme weather conditions such as prolonged droughts and flood in the area. Thus climate change should be mitigated to cap decline in groundwater especially during low rainfall periods. Ruiru municipality being dominated with pavement land cover, abstraction should be controlled to ensure that groundwater resources are managed properly to avoid depletion.

References

Allen, Diana M. (2010), *Historical trends and future projections of groundwater levels and recharge in coastal British Columbia, Canada*, SWIM21 - 21st Salt Water Intrusion Meeting, 21-26 June 2010, Azores, Portugal, pp. 267-270.

Butler, J. J., Gorelick, S. M. and Loheide ,S. P. (2008), *Estimation of groundwater consumption by phreatophytes using diurnal water table fluctuations: A saturated-unsaturated flow assessment*. *Water Resources Research.* Vol. 41(7)

Croley, T. E. and Luukkonen, C. L. (2003), Potential *effects of climate change on ground water in Lansing, Michigan*, Journal of the American Water Resources Association, Vol. 39 (1), pp. 149-163.

Crosbie, Russell S., McCallum, James L., Walker, Glen R. and Chiew, Francis H. S. (2010), *Modelling climate-change impacts on groundwater recharge in the Murray-Darling Basin, Australia*, Hydrogeology Journal, Vol. 18, pp. 1639ï 1656.

Dams, Jef, Salvadore, Elga and Batelaan, Okke (2010), *Predicting Impact of Climate Change on Groundwater Dependent Ecosystems*, 2nd International Interdisciplinary Conference on Predictions for Hydrology, Ecology and Water Resources Management: Changes and Hazards caused by Direct Human Interventions and Climate Change, 20-23 September 2010, Prague, Czech Republic.

Dragoni, W. and Sukhija, B. S. (2008), Climate *change and groundwater: a short review*, Geological Society, London, Special Publications 2008; v. 288; p. 1-12.

Holman, I. P. (2006), *Climate change impacts on groundwater recharge - uncertainty, shortcomings, and the way forward*?, Hydrogeology Journal, Vol. 14, pp. 637ï 647.

Hsu, Kuo-Chin, Wang, Chung-Ho, Cheu, Kuan-Chih, Chen, Chien-Tai and Ma, Kai-Wei (2007), *Climate-induced hydrological impacts on the groundwater system of the Pingtung Plain, Taiwan*, Vol. 15, Number 5, August 2007, pp. 903-913.

Jyrkama, Mikko I. and Sykes, Jon F. (2007), *The impact of climate change on spatially varying groundwater recharge in the grand river watershed (Ontario)*, Journal of Hydrology, Vol. 338, pp. 237ï 250.

Marshall, S. (2011). *The Water Crisis in Kenya:causes, effects and solutions*. Global Majority , 31-45.

McCallum, J. L., Crosbie, R. S., Walker, G. R. and Dawes, W. R. (2010), *Impacts of climate change on groundwater in Australia: a sensitivity analysis of recharge*, Hydrogeology Journal, Vol. 18, pp. 1625ï 1638.

Seckler, B. R. (05 August 2010). Water Scarcity in twenty first centuary. *Water Resources Development* , 29-42.

Woldeamlak, S. T., Batelaan, O. and De Smedt, F. (2007), *Effects of climate change on the groundwater system in the Grote-Nete catchment, Belgium*, Hydrogeology Journal, Vol. 15, Number 5, August 2007, pp. 891-901.

Field Measurement of Soil Moisture and Infiltration Rates along the Kenyan Coastal Region of Kilifi County

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Abstract

Infiltration rate is governed by the initial soil moisture on the ground surface, it is therefore important to measure the soil moisture content of the soils to enable determine how fast the water will infiltrate into the soil. Different methods can be used to measure the soil moisture content in the soils and the infiltration rates. Due to the importance of infiltration process and soil moisture content in the prediction of surface run off , hydraulic conductivity and ground water recharge, it is essential to understand this process and the factors affecting it to assist in determination of the state of the underground water in the coastal region. The study for field measurement of soil moisture and infiltration rates was carried out in the coastal region of Kenya during both the wet and the dry seasons so as to assess the rate of infiltration of storm water in the coastal region and how it affects underground water recharge. Double ring infiltrometer consisting of two concentric rings with inner and outer diameters were used to measure the infiltration rates in Kibarani and Sokoni areas. The soil meter was used to measure the soil moisture content around the boreholes and wells at different selected areas in Kilifi north and south. The dry season results indicated that, the soil moistures for the selected areas were lower that is ranging from 0.7%-11.2% compared to that for the wet season that ranged from 3%-31%. During the dry season the infiltration rate was high since the water took less time to infiltrate into the soil as compared to the wet season where the process was slow since the moisture content on the ground surface was higher.

Keywords: Soil moisture, infiltration rates, wells, boreholes, Kilifi County

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Assessment of Salinity in Boreholes and Wells in Kilifi County

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Abstract

Saltwater intrusion is the movement of salty water into freshwater aquifers. It occurs naturally in most coastal aquifers due to the hydraulic connection between ground water and sea water. Salt water has a higher mineral content than freshwater making it denser with a higher water pressure. As a result, water pushes inland beneath the freshwater. Certain human activities, especially groundwater pumping from coastal freshwater wells have increased saltwater intrusion in many coastal areas as extraction of water drops the level of fresh groundwater hence reducing its pressure and allowing salt water to flow further inland. Kilifi County lies within geographic coordinates of 3 ↵38â00 to 3 ↵40â00S latitudes and 39 ↵45â00 to 39 ↵51ô00E longitudes located at an elevation of 150 meters above the sea level. The county receives most of its water from Kilifi-Mariakani Water and Sewerage Company but the supplied water cannot meet the demand of Kilifi and neighbouring districts. This coupled with high population has led to an increase in demand of water resulting in overexploitation of groundwater which has become the major source of water. This study was aimed at assessing the salinity of ground water in the boreholes and wells within Kilifi County. Water samples from 9 boreholes and 11 wells within the hinterland areas and around the sea were collected in dry and wet season. The water samples were analysed for major anion (Chloride). Results showed that most hinterland samples had acceptable salinity levels as per NEMA standards (500) but two hinterland boreholes in Sokoni area exhibited very high values with 30442.5 and 20542.5 (dry season) and 12500 and 8020 (wet season). Higher values were also observed in areas closer to the sea such as Watamu with values of 11797.5,4587 (dry season) and 1925, 150 (wet season).

Keywords: Salt water intrusion, Salinity, Overexploitation, Groundwater, Kilifi County

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Assessment of Groundwater Levels in Kilifi County, Kenya

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Abstract

Groundwater represents a significant proportion of the Earthôs freshwater content. Estimates show that freshwater represents nearly 2.5 percent of the Earthôs total water content, of which 30 percent is groundwater. In many parts of developing countries like Kenyan coastal region (Kilifi county), groundwater is a major source of freshwater. Ground water levels are highly affected by seasonal changes in atmospheric conditions i.e. high temperatures and low amounts of rainfall during the dry season in kilifi county makes the ground water to lower while during rainy season it rises and some cases flooding occurs due to heavy rains and low temperatures. Kilifi County is located in the coastal area of Kenya and lies within geographic coordinates of 3↭38â00 to 3↭40â00S latitudes and 39↭45â00 to 39↭51ô 00E longitudes. It is located at an average elevation of approx. 100 meters above the sea level and it falls within a semi arid region frequently facing severe water scarcity especially during periods of prolonged drought. The assessment was done during the dry and wet season in the month of February and

Keywords: Wet and dry, Rest water levels, Boreholes, Wells, Groundwater.

Groundwater Quality Mapping Using GIS in Three Sub-Catchments in the Upper Athi River Basin, Kenya

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Abstract

Groundwater is an important natural resource used domestically by many people globally, especially in rural and peri-urban areas, but this resource cannot be sustainably used unless its quality is ascertained. The inadequate and lack of supply of potable water and sanitary services to inhabitants of the three Sub catchments in the Upper Athi River Basin has consequently compelled inhabitants to increasingly rely on groundwater as their only or supplementary source of water, however, groundwater in the area is under threat of pollution due to the utilization of on-site sanitation systems, mostly pit latrines which conflicts with Integrated Water Resources Management (IWRM) principles that advocate to preserve the integrity of vital ecosystems and maintain water quality and quantity, thus prompting this study: Groundwater Quality Mapping Using GIS in Three Sub-Catchments in the Upper Athi River Basin, Kenya. Spatial variations in ground water quality in the Thiririka, Thetha and Rwabura Sub Catchments located Kiambu County in the Upper Athi Catchment in Kenya were studied using geographic information system (GIS). Groundwater samples from 19 Boreholes and 17 Shallow Wells representing the entire Sub Catchment were sampled and analysed for selected physico chemical and microbial parameters. Standard methods were used for the analysis of groundwater samples in the laboratory. Results were compared to guideline values of the NEMA, USEPA and WHO to establish the potability of groundwater. pH ranged from 4.48 to 7.71 showing a mild acidic character. Conductivity ranged from 475 - 1320 µS/cm suggesting the groundwater are generally fresh. Hardness ranged from 215.18 to 307.79 mg/L, while the concentration of nitrates (0.29 - 71.0 mg/L) and turbidity (1 -380.9 NTU) in some of the samples exceeded the prescribed NEMA, USEPA and WHO standards of 10 mg/L and 5 NTU respectively. Ca2+, Mg2+, Na+, SO42- fell below the WHO guideline values for potability. The concentration of iron (3.05 - 12.89 mg/L) and manganese (0.42 - 12.7 mg/L) also exceeded the established standards of 0.3 mg/L and 0.4 mg/L causing aesthetic problems. 15 of the boreholes and all of the 17 shallow wells had faecal coliform contamination and did not conform to the NEMA, USEPA and WHO guideline value of 0 cfu/100 ml. The Inverse Distance Weighting Methodology in the 3D Analyst module of ArcGIS 9.3 was used to generate a thematic map for each of the tested parameters. The results obtained in this study and the spatial database established in GIS was helpful for monitoring ground water quality in the study area. Regular monitoring and awareness creation should be carried out by officials of NEMA and WRMA to sensitize the inhabitants about the status of groundwater in the Thiririka Sub Catchment

Keywords: Groundwater, Groundwater Quality, GIS

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Reduce Greenhouse Gases Emission by Flue Gas Treatment on an Energy Saving and Eco-Friendly Recovery System

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Abstract

The purpose behind this idea is to contribute in addressing climate change by minimizing Greenhouse Gases emission while sustaining and promoting energy efficiency. These suggested to be achieved by heat and gas recovering the Flue Gas in industrial plants. There have been researches conducted, solution presented and many approaches trying to minimize carbon footprint. Emission of Carbon Dioxide and Sulfur Dioxide has been a main concern among the greenhouse gases for they cause the most of the damage. Carbon Dioxide for instance has been recovered using algae to turn it into bio-fuel, this though to be the most promising approach so far and plenty of researches are taking place regarding this process. Theoretically speaking the system presented in this paper though to be more efficient, cost saving and environmental friendly. The outcome of doing heat recovery is saving energy by captioning the amount of heat wasted from the flue outlet by going through a secondary heat exchanger. While gas recovery comes next to produce LPG, Sulfuric Acid and Nitric Acid. The design suggested includes heat exchanger, separators, reactors and a blender to achieve optimum saving in materials, operation energy and complete elimination of flue gas outlet from the system.

Keywords Climate Change, Greenhouse Gases, Flue Gas, Sustainability, Liquefied Petroleum Gas, Energy Efficiency